Advances in Natural and Applied Sciences, 8(8) July 2014, Pages: 175-182

AENSI Journals

Advances in Natural and Applied Sciences

ISSN:1995-0772 EISSN: 1998-1090

Journal home page: www.aensiweb.com/ANAS


# The Use of Biochar Fortified Compost on Calcareous Soil of East Nusa Tenggara, Indonesia: 1. Evolution of organic matter and nitrogen on composting of farm yard manure (FYM) and Siam weed (C*hromolaena odorata* L.) biomass added with BIOCHAR as a bulking agent.

[1]M.S.M. Nur, [2]W.H. Utomo, [2]E. Handayanto, [3]W.H. Nugroho and [4]T. Islami

*[1]Nusa Cendana University, Kupang, East Nusa Tenggara 85001, Indonesia*
*[2]International Research Centre for the Management of Degraded and Mining Lands, University of Brawijaya, Malang 65145, Indonesia*
*[3]Faculty of Mathematic and Science, University of Brawijaya, Malang 65145, Indonesia*
*[4]Department of Agronomy, University of Brawijaya, Malang 65145, Indonesia*

A R T I C L E I N F O

*Article history:*
*Received 2 April 2014*
*Received in revised form*
*13 May 2014*
*Accepted 28 May 2014*
*Available online 27 June 2014*

*Keywords:*
*nutrient immobilization, organic amendment, sustainable crop production*

A B S T R A C T

An experiment was done to study the effect of biochar made from farm yard manure as a bulking agent on the evolution of organic matter and total nitrogen in composting farm yard manure and Siam weed (Chromolaena odorata L.) biomass. The treatments consist of 6 mixture of compost materials with biochar, i.e. : (i) pure FYM; (ii) FYM+biochar (3/1); (iii) FYM+biochar (1/1); (iv) pure Siam weed (C.odorata L.) biomass; (v) Siam weed+biochar (3/1); (vi) Siam weed+biochar (1/1). The experiment was set up in a Complete Randomized Design with 4 replications. The experimental results showed that the use of FYM biochar as a bulking agent in composting process reduced organic-C and total-N lost in both compost materials. The lost of organic-C and total-N in mix compost was influenced by the properties of the compost materials and the proportion of the biochar as the bulking agent. In addition of those two variables, the lost of total-N in mix compost was influenced by the initial of C/N ratio of the compost materials and the rate of decomposition. The addition of biochar into FYM and Siam weed based compost did not significantly (compared to pure FYM or pure Siam weed) influence the pH of the mature compost.



**To Cite This Article:** M.S.M. Nur, W.H. Utomo, E. Handayanto, W.H. Nugroho and T. Islami, The Use of Biochar Fortified Compost on Calcareous Soil of East Nusa Tenggara, Indonesia: 1. Evolution of organic matter and nitrogen on composting of farm yard manure (FYM) and Siam weed (Chromolaena odorata L. ) biomass added with BIOCHAR as a bulking agent.. **Adv. in Nat. Appl. Sci.,** *8(8): 175-182, 2014*

## INTRODUCTION

The importance of soil organic matter in improving and maintaining soil quality has been widely understood. Therefore, a proper soil organic management is an absolute prerequisite for obtaining sustainable crop production. The easiest way to improve and maintain soil organic matter is by adding the fresh organic materials. However, this practice had been known to have a lot of negative effects, such as plant nutrient immobilization, phytotoxic (Butler *et al*., 2001), and environmental pollution (Adhikari *et al*., 2009). To minimize this negative effect, the common technology used is by composting the fresh material before it is applied to the soil. Composting is biological processes which could reduced the bulk volume of the fresh materials, increase plant nutrient content, relatively stable, kills pathogen, and make easier for transporting the materials (Westerman and Bucido, 2005).

According to Adhikari *et al.* (2009) composting would increase the safety of waste cycle, reduce glass house gas emission, and avoid environmental pollution. However, during composting processes there will be a loss of nitrogen due to ammonium volatilization (Martin dan Dewes, 1992; Zhang *et al*., 1997). In addition, especially in humid tropic condition, when applied in a soil compost material is rapidly decomposed which causes this practice is un-practical and expensive for small farmers (Masulili *et al.*, 2010), and the emission of nitrogen gass will increase the rate of global warming (Lehmann *et al.*, 2007). To overcome the problem of rapid decomposition of compost in the soil, some researches had suggested using the more recalcitrant organic

**Corresponding Author:** W.H. Utomo, International Research Centre for the Management of Degraded and Mining Lands (IRC-MEDMIND), Soil Science Building, University of Brawijaya. Jl. Veteran, Malang 65145, Indonesia.
Tel: +62341553623 E-mail: wanihadi@ub.ac.id

materials called "biochar" (Lehmann *et al*., 2002). The success story of biochar application for improvement of soil properties had been shown by many workers (Chan *et al.*, 2007; Liang *et al.*, 2006; Rondon *et al.*, 2007). The increase of crop yield due to biochar application had been reported by many researchers, such Yamato *et al.* (2006) for cowpea; Tagoe *et al.* (2008) for soybean; Asai *et al.* (2006) for upland rice; Islami *et al.* (2011) for cassava, and Sukartono *et al.* (2011) for maize. Unlike the conventional manure or compost, the crop yield increase due to biochar application could be maintain without addition of biochar in the next cropping seasons (Sukartono *et al.*, 2011; Islami *et al.*, 2013).

Martin and Dewes (1992) showed that nitrogen losses during composting processes was related to the C/N ration of the compost materials. They showed that the high nitrogen losses occurred on the low C/N ratio material. Biochar is a result of combustion of organic materials in no or very low oxygen supply. This material has a high organic carbon and low nitrogen content. Therefore, it is suggested that the addition of biochar in composting processes will reduce nitrogen losses. The increase of compost quality with addition of biochar during composting processes had been shown by Dias *et al*., (2009). They showed that the organic carbon in the poultry manure-biochar mix compost was characterised by a high polymerization degree of the humic-like substances. Furthermore, they showed that addition of biochar in composting poultry manure decreased the loss of nitrogen in mature compost.

The work described here aimed to study the effect of addition farm yard manure (FYM) biochar in composting FYM and Siam weed (*Chromolaena odorata* L.) on evolution of organic carbon and total nitrogen. The work as also studied the properties of the mature compost.

## MATERIALS AND METHODS

Farm yard manure used in this experiment was collected from cattle farmers' cage in Kupang, East Nusa Tenggara, Indonesia. The manure was air dried to water content of about 15% (w/w), cleaned from stone, gravel, plastics and plant twigs, then crushed to a size of less than 5 cm. Siam weed biomass was obtained from farmers field, it was cut to a size of less than 5 cm, and then air dried to a water content of about 15% (w/w). Biochar was made from FYM with the simple method of Sukartono *et al*. (2011b)). The properties of the FYM, Siam weed, and FYM biochar were presented in Table 1.

**Table 1:** The properties of FYM, Siam weed and biochar used in the experiment.

| Organic materials | pH | Organic-C | Total-N | P | K | Ca | Mg | C:N | CEC |
|---|---|---|---|---|---|---|---|---|---|
| | | ...................................%........................................... | | | | | | | cmol kg$^{-1}$ |
| Farm yard manure (FYM) | 7.8 | 25,6 | 1,52 | 0,19 | 0,71 | 0,67 | 0,64 | 16,8 | 12,46 |
| Siam weed | 6,9 | 48,4 | 2,09 | 0,53 | 1,54 | 1,58 | 0,59 | 23,2 | 15,96 |
| Biochar | 8.7 | 28,6 | 0,78 | 0,21 | 0,82 | 0,79 | 0,76 | 36,7 | 18.83 |

CEC: cation exchange capacity

Composting experiment was done in Composting house of Nusa Cendana University, East Nusa Tenggara, Indonesia (10$^o$ 9' 21" S dan 123$^o$ 40' 16" E). The experimental treatments were: (i) 100% FYM (pure FYM); (ii) 75% FYM + 25% biochar (FYM+biochar: 3/1); (iii) 50% FYM+ 50% biochar (FYM+biochar: 1/1); (iv) 100% Siam weed (pure Siam weed); (v) 75% Siam weed+ 25% biochar (Siam weed+biochar:3/1) and 50% Siam weed + 50% biochar (Siam weed+biochar:1/1). Composting was done by put in about 150 kg of compost materials (air dry weight) in a plastic box of 60 cm x 60 cm x 70 cm for 120 days. During composting processes the compost was manually turnover for every 7 days. The humidity during composting was maintained at about 60%, temperature (at a depth of about 20 cm) during composting processes was recorded daily.

The compost sample was taken at days: 0, 3, 7, 15, 60 dand120 for laboratory analysis. Five samples ( were taken from each box, mixed and taken of about 0.5 kg, then this composite samples were air dried, grinded and passed through a 1.0 mm diameter sieve for further analysis.

The pH of the compost was determined in $H_20$ solution 1:1, measured with pH-meter (Jenway 3305); ash content analysis was carried out with the method of Dias *et al.* (2009); soil organic carbon was determined with the Walkley and Black method (Soil Survey Laboratory Staff, 1992), and total-N with the Kjeldahl method (Bremner and Mulvaney, 1982). To determine cation exchange capacity (CEC) the sample was extracted with CH3COONH4 (I N; pH 7.0) and the base concentration measured with AAS (Shimatzu *AA* 6800, Shimatzu Corp., Kyoto, Japan). Phosphorus content was extracted with wet oxidation with $HNO_3$ dan $HClO_4$ (Association Official Agriculture Chemists, 2002) and the concentration of P was measured with spectrometer (Vitatron Scientific Instruments Dieren, the Netherlands).

The change in organic matter was calculated with the first order kinetic equation as done by Paul and Clark (1989), i.e.:

$$A_t = A_o e^{-kt} \quad (1)$$

In which $A_t$ is the organic-C in the compost (%) at the time t (in days), and k is the constant of decomposition rate

The loss of total nitrogen was calculated similar to that of Paredes *et al.* (2000) technique, i.e.:

Loss of total-N (%) = $100-100[(X_1N_2)/(X_2N_1)]$ (2)

Here $X_1$ and $X_2$ are the initial and final ash content respectively; and $N_1$ and $N_2$ are the initial and final total nitrogen content respectively.

The changes in total nitrogen content were calculated with the first order kinetic equation of Paredes *et al*. (2000), i.e.:

Loss of total-N= Nt (%) = $A(1-e^{-kt})$ (3)

In which A is the maximum decomposed total-N (%), k is the constant rate of nitrogen loss, and t is composting time (in days).

The calculation of organic-C changes was done with Excel for windows program, and the calculation of total–N changes was done with SPSS version 16.00 for Windows program. Analysis of variance (ANOVA) was performed for pH and C:N ratio data, and if there were a significant differences the Duncan Multiple Range test at 5% probability was done.

## RESULTS AND DISCUSSION

*Temperature changes:*

The temperature changes during composting processes presented in Figure 1 followed a general trend in organic matter decomposition (Hsu and Lo, 1999; Dias *et al*., 2010). The initial mesophilic phase occurred for less than 24 hours and then followed by thermophilic phase which occurred for 11 to 25 days, after which the temperature decreases and it was relatively constant close to air temperature at 60 days after incubation.

Looking the results given in Figure 1a and 1b, it can be concluded that FYM compost base had a shorter thermophilic phase (11 days) compared to that of Siam weed compost base. This is a reasonable phenomenon because FYM has a lower C/N ratio compared to Siam weed (Table 1), and therefore it would be easier to be decomposed. Furthermore, the result in Figures 1a and 1b show that during decomposition, FYM compost base had a lower maximum temperature ($61^0$ C) compared to Siam weed compost base ($66^0$ C). To ensure that the compost really mature, although the temperature already constant at 60 days, the composting processes was continued till 120 days.

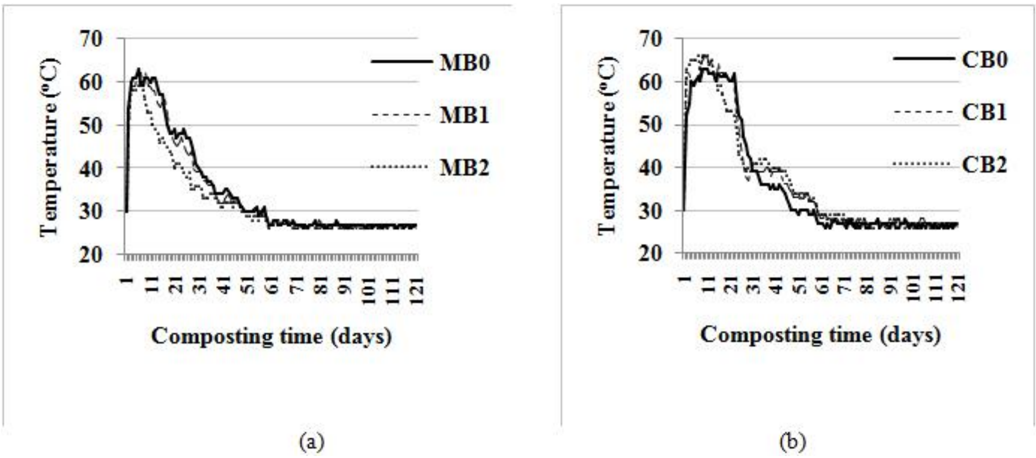


**Fig. 1:** Temperature changes during composting processes of different compost materials. (MB0: pure FYM; MB1: FYM + biochar 3/1; MB2: FYM + biochar 1/1;CBO: pure Siam weed; CB1: Siam weed + biochar 3/1; CB 2: Siam weed + biochar 1/1).

The results in Figure 1a and 1b show that addition biochar into compost materials had different effects on the composting processes. For FYM based compost (Figure 1a) addition biochar shortened the thermophilic phase and lowered the maximum temperature of composting processes. If there was no biochar addition (pure FYM compost treatment), the thermophilic phase occurred for 17 days with maximum temperature of $63^o$ C, whereas in a mix of 50% compost and 50% biochar ( Compost + biochar 1/1), the thermophilic processes decreased to 11 days with maximum temperature of 59% C. It seems that the addition of organic carbon from biochar decreased microbial activity, and hence slows down the decomposition processes. A different phenomenon was observed for the compost made from Siam weed (Figure 1b). Similar to the compost made from FYM, a mix of biochar with Siam weed shortened the thermophilic phase from 26 days (pure Siam weed compost) to 23 days (a mix of Siam weed + biochar). However, the maximum temperature of composting processes increase from 63$^o$ C (pure Siam weed compost) to 66$^o$ C (a mix of Siam weed + biochar). It seems that the addition of biochar decreased the porosity of the compost material so that slow down the release of the heat generated during the composting processes, which in turn would resulted in a higher temperature.

*The change of compost pH:*

The initial of compost pH was influenced by the pH of the materials and the proportion of the biochar added (Table 2). The initial pH of compost made from FYM was higher (7.8) compared to that of made from Siam weed (6.9). Addition of biochar in compost materials increased pH of the two compost materials. Furthermore, increasing biochar proportion would further increase compost pH. For the compost made from FYM, for example, the pH of pure FYM was 7.8, increased to 8.0 in if the compost was mixed with biochar (3/1), and further increased to 8.4 if the proportion of biochar was increased to 1/1.

The increase of compost pH with addition biochar is reasonable because biochar has a higher pH compared to both FYM and Siam weed compost materials (see Table 1). Indeed, the increase of biochar proportion would make a further pH increase.

Table 2. pH change during composting processes of different compost materials

| Compost materials | pH (at ….. days of composting time) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 3 | 7 | 15 | 30 | 60 | 120 |
| Pure FYM | 7.8 b A | 7.9 b A | 8.3 cd B | 8.5 cd B | 8.6 a B | 8.0 a AB | 7.6 a A |
| FYM + Biochar 3/1 | 8.0 b AB | 8.0 b AB | 8.3 cd B | 8.7 cd C | 8.5 a CD | 8.0 a AB | 7.6 a A |
| FYM + biochar 1/1 | 8.4 c B | 8.4 c B | 8.6 d B | 8.7 d B | 8.4 a B | 7.9 a A | 7.7 a A |
| Pure Siam weed | 6.9 a A | 6.8 a A | 7.2 a AB | 7.3 a B | 8.3 a D | 7.7 a C | 7.4 a BC |
| Siam weed + biochar 3/1 | 7.0 a A | 7.0 a A | 7.7 b BC | 7.8 a BC | 8.2 a D | 7.9 a CD | 7.5 a B |
| Siam weed + biochar 1/1 | 7.7 b AB | 7.6 b AB | 8.0 bc C | 8.2 bc C | 8.3 a C | 7.9 a B | 7.4 a A |

Means followed by the same letters (small letter for the same column, and capital letter for the same rows) are not significantly different (p=0.05)

The results in Table 2 show that during the first 30 days of composting processes, the pH increased with increasing of composting time, and then decreased steadily until the end of composting processes (120 days). Different from the initial composting processes, the pH of the mature compost was not significantly different. The increase of pH in the initial phase of composting processes was probably due to the decomposition and demineralization of organic acid and protein into inorganic anion such as $NH_4$+ and OH- (Paredes *et al.*, 2000; Sanchez-Monedero *et al*., 2001). The decrease of compost pH after 30 days of composting processes was thougt caused by the production of acid (especially humic and fulvic acid) with the change of the fresh materials to the compost (Dias *et al.*, 2009).

*Evolution of organic matter content:*

The experimental result presented in Figure 2a and b shows that the organic carbon content of FYM based compost was lower than that of Siam weed based compost. Furthermore, addition of biochar into compost materials decreased the rate of decomposition and demineralization rate of organic matter content in the compost materials.

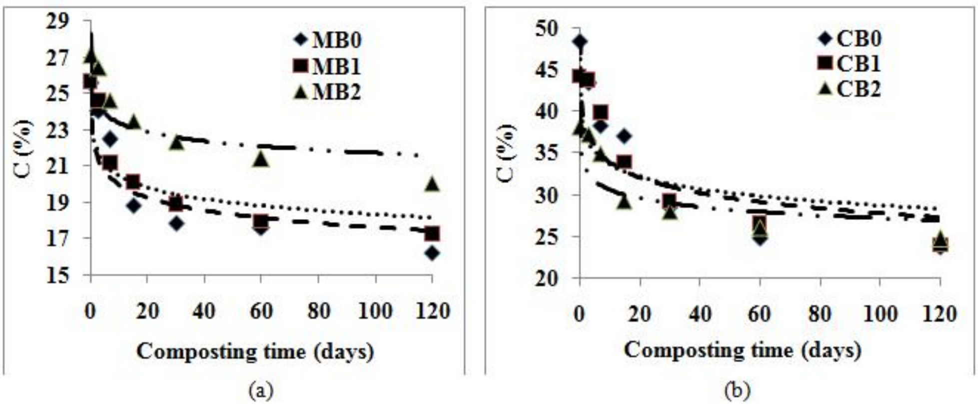


**Fig. 2:** The change of organic matter content during composting processes of different compost materials (MB0: pure FYM; MB1: FYM + biochar 3/1; MB2: FYM + biochar 1/1; CBO: pure Siam weed; CB1: Siam weed + biochar 3/1; CB 2: Siam weed + biochar 1/1).

The decrease of organic carbon with composting time followed the first order kinetic equation (eq. 1), with the resulted k constant value for FYM pure FYM, FYM + biochar (3/1) and FYM + biochar (1/1) were -1.42, -1.29 and -1.01 respectively, and that for Siam weed compost were: - 3.73, -3.01, and -2.09 for pure Siam weed, Siam weed + biochar (3/1) and Siam weed + biochar (1/1) respectively (see equations 4 - 9).

MB0: $C = -1.42\ln(t) + 23.58$ (4)
$R^2 = 0.87$

MB1: $C = -1.29\ln(t) + 23.72$ (5)
$R^2 = 0.89$

(MB2) $C = -1.01\ln(t) + 25.92$ (6)
$R^2 = 0.86$

CB0: $C = -3.73\ln(t) + 43.30$ (7)
$R^2 = 0.88$

CB1: $C = -3.10\ln(t) + 41.45$ (8)
$R^2 = 0.79$

CB2: $C = -2.09\ln(t) + 35.92$ (9)
$R^2 = 0.82$

The decrease of k value of with addition (and increase of the proportion) of biochar in the compost materials indicated that the rate of organic matter decrease in biochar enrichment compost went slower than that in no biochar added compost. This was reasonable because, as had been suggested by previous workers, organic carbon in biochar is more resistant to be decomposed (Lehmannn *et al.* 2006).

*Loss of nitrogen:*

The rate of nitrogen loss during the composting processes is presented in Figure 3, and the total nitrogen loss in Figure 4. The results in Figure 3a and 3b show that the rate of nitrogen loss from FYM based compost was lower compared to that of Siam weed based compost , and biochar addition decreased the rate of total nitrogen loss.

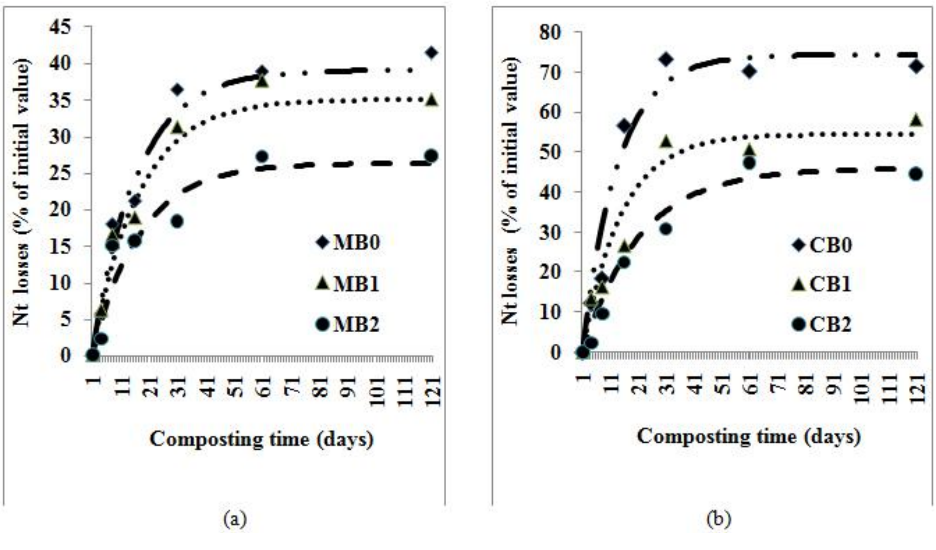


**Fig. 3:** The loss of total nitrogen content during composting processes of different compost materials (MB0: pure FYM; MB1: FYM + biochar 3/1; MB2: FYM + biochar 1/1; CBO: pure Siam weed; CB1: Siam weed + biochar 3/1; CB 2: Siam weed + biochar 1/1)

The loss of nitrogen during composting processes indicated that there was nitrogen immobilization due to the decomposition and demineralization of organic nitrogen compound (such as protein, amino acid) into in-organic nitrogen. The cumulative nitrogen loss with composting time was calculated with the first order kinetic equation (eq. 3) as done by Paredes *et al*. (2000), and the resulted equations were (see also Fig. 3)

MB0: $N_t$-loss = 39,1(1-$e^{-0,064t}$) (10)
$R^2$ = 0,95

MB1: $N_t$-loss = 35,0(1-$e^{-0,061t}$) (11)
$R^2$ = 0,97

MB2: $N_t$-loss = 32,1(1-$e^{-0,053t}$) (12)
$R^2$ = 0,94

CB0: $N_t$-loss = 74,1(1-$e^{-0,079t}$) (13)
$R^2$ = 0,96

CB1: $N_t$-loss = 54,5(1-$e^{-0,072t}$) (14)
$R^2$ = 0,94

CB2: $N_t$-loss = 45,7(1-$e^{-0,049t}$) (15)
$R^2$ = 0,97

The rate of nitrogen loss calculated with equation (10 -15) show that the rate of nitrogen loss from pure FYM compost was 0.064%/day, and addition 50% biochar (FYM + biochar 1/1 treatment) decreased the rate of nitrogen loss to 0.053%/day. The rate of nitrogen loss from pure Siam weed compost was 0.079%/day and addition of 50% biochar (Siam weed + biochar 1/1) decreased the rate of nitrogen loss to 0.049%/day.

In line with the rate of nitrogen loss The calculation of total nitrogen loss presented in Figure 4 show that total nitrogen loss from pure FYM compost was 39.1%. Addition of 25% biochar into FYM (FYM+biochar 3/1) decreased the total nitrogen loss to 35.5%, and further increase in biochar proportion (FYM+biochar 1/1) decreased the total nitrogen loss to 32.2%. The same phenomena was observed in Siam weed based compost material.

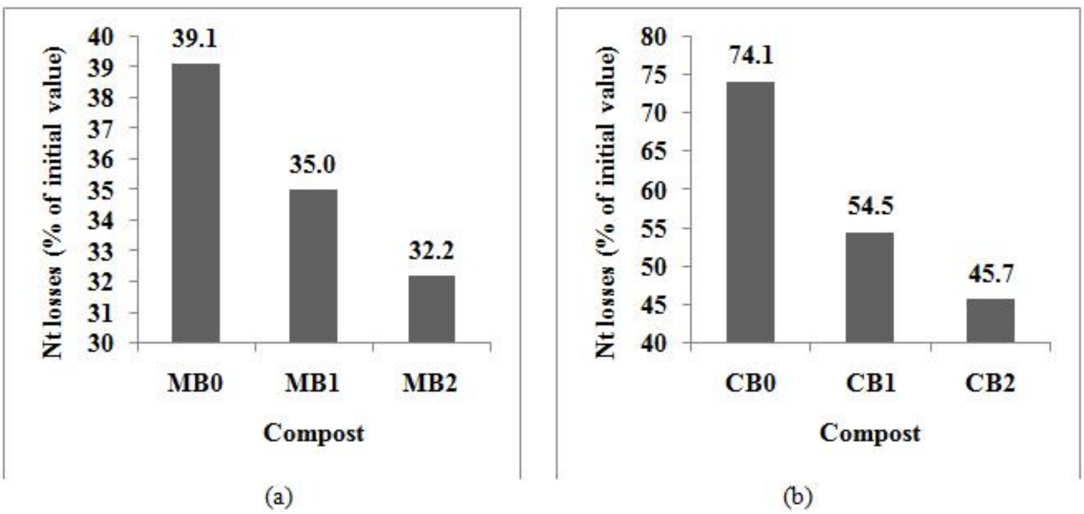


**Fig. 4:** The effect of biochar addition on total nitrogen loss from FYM based and Siam weed based compost materials. (MB0: pure FYM; MB1: FYM + biochar 3/1; MB2: FYM + biochar 1/1; CBO: pure Siam weed; CB1: Siam weed + biochar 3/1; CB 2: Siam weed + biochar 1/1).

The decrease of nitrogen loss with biochar addition, especially in the Siam weed based compost was thought that biochar addition decreased aeration of the compost so that reduced the loss of nitrogen in the form of

$NH_3$. In addition, in line with Tiquia and Tam (2000) experimental result, it seems the loss of nitrogen during composting processes was also influence by the initial C/N ratio of the compost materials. The increase initial C/N ratio of the compost material would decrease the nitrogen losses. Addition of biochar into FYM based compost, for example, increased C/N ratio from 16.8:1 (pureFYM) to 24.9:1 (FYM+biochar 1/1). The same phenomena were observed in Siam based compost material.

*Conclusion:*

The addition of biochar as bulking agent for composting FYM and Siam weed decreased the loss of organic C and total nitrogen. The loss of organic carbon and total nitrogen from pure FYM were 36.5% and 39.1% decreased to 26.0% and 32.2% with addition of 50% biochar (FYM + biochar 1/1 treatment). For Siam weed based compost, the loss of organic carbon and total nitrogen were 50.7% and 74.1% (pure Siam weed compost) decreased to 32.5% and 45.7% for Siam weed + biochar 1/1 treatment. Addition biochar increased the initial pH, but did not significantly the pH of mature compost.

## ACKNOWLEDGMENTS

This article is a part of dissertation of the first author at the School of Post Graduate Study, University of Brawijaya, Malang, Indonesia. Thank to Directorate of Higher education for her financial support, and to PPIKID Team of University of Brawijaya for their help in article preparation.

## REFERENCES

Adhikari, B.K., S. Barrington, J. Martinez and S. King, 2009. Effectiveness of three bulking agents for food waste composting. Waste Management, 29: 197-203.

Asai, H., B.K. Samson, H.M. Stephan, K. Songyikhangsuthor, K. Homma, Y. Kiyono, Y. Inoue, Shiraiwa, T. and T. Horie, 2009. Biochar amendment techniques for upland rice production in Northern Laos 1. Soil physical properties, leaf SPAD and grain yield. Field Crops Research, 111: 81–84.

Association Official Agriculture Chemists, 2002. Official methods of analysis of AOAC International. Volume I. P. 2.5-2.37. In Horwitz W. (Ed.). Agricultural Chemicals, Contaminants, Drugs. 17$^{th}$ ed. AOAC International, Maryland, USA.

Bremner, J.M. and C.S. Mulvaney, 1982. Nitrogen-total. In Methods of Soil Analysis, Part 2. Page, A.L., Miller, R.H. and Keeney, D.R. (Eds.). American Society of Agronomy and Soil Science Society of America Inc., Madison, Wisconsin, USA, pp: 595-624.

Butler, T.A., L.J. Sikora, P.M. Steinhilber and L.W. Douglass, 2001. Compos age and sample storage effects on maturity indicators of biosolids compost. J. Environtmental Quality, 30: 2141-2148.

Chan, K.Y., L. Van Zwieten, I. Mescaros, A. Downie and S. Joseph, 2007. Agronomic values of green waste biochars as a soil amandements. Australian Journal of Soil Research, 45: 629-634.

Dias, B.O., C.A. Silva, F.S. Higashikawa, A. Roig and M.A. Sanchez-Monedero, 2010. Use of biochar as bulking agent for the composting of poultry manure: Effect on organic matter degradation and humification. Bioresource Technology, 101: 1239-1246.

Islami, T., B. Guritno, N. Basuki and A. Suryanto, 2011. Biochar for sustaining productivity of cassava based cropping system in the degraded lands of East Java, Indonesia. J. Tropical Agriculture, 49: 40-46.

Islami, T., S. Kurniawan and W.H. Utomo, 2013. Yield Stability of cassava (*Manihot esculenta* Crantz) planted in intercropping system after 3 years of biochar application. American-Eurasian Journal of Sustainable Agriculture, 7: 306-312.

Lehmannn, J., J.P. da Silpa, C. Steiner, T. Nehls, W. Zechs and B. Glaser, 2002. Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: Fertilizer, manure and charcoal amendments. Plant Soil, 249: 343–357.

Lehmannn, J., J. Gaunt and M. Rondon, 2006. Biochar sequestration in terrestrial ecosystem. A review. Mitigation and Adaptation Strategies for Global Change, 11: 403-427.

Liang, B., J. Lehmannn, D. Kinyangi, J. Grossman, B. O'Neill, J.O. Skjemstad, J. Thies, F.J. Luizao, J. Peterson and E.G. Neves, 2006. Black carbon increases cation exchange capacity in soils. Soil Science Society of American Journal, 70: 1719-1730.

Martin, O. and T. Dewes, 1992. Loss of nitrogen compounds during composting of animal wastes. Bioresource Technology, 42: 103-111.

Masulili, A., W.H. Utomo, and Syekhfani, 2010. Rice husk biochar for rice based cropping system in acid soil, 1. The characteristics of rice husk biochar and its influence on the properties of acid sulfate soils and rice growth in West Kalimantan, Indonesia. J. Agricultural Science (Canada), 3: 25-33.

Paredes, C., A. Roig, M.P. Bernal, M.A. Sanchez-Monedero and J. Cegarra, 2000. Evolution of organic matter and nitrogen during co-composting of olive mill wastewater with solid organic wastes. Biol Fertil Soils, 32: 222-227.

Paul, E.A. and F.E. Clark, 1989. Soil Microbiology and Biochemistry. Academic press, Inc. New York USA.

Rondon, M.A., J. Lehmannn, J. Ramirez and M. Hurtado, 2007. Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with bio-char additions. Biology and Fertility of Soils, 43: 699 -708.

Sánchez-Monedero, M.A., A. Roig, C. Martínez-Pardo, J. Cegarra and C. Paredes, 1996. A microanalysis method for determining total organic carbon in extracts of humic substances. Relationships between total organic carbon and oxidable carbon. Bioresource Technology, 57: 291–295.

Soil Survey Laboratory Staff, 1992. Soil survey laboratory methods manual. Soil Survey Investigation Report 42. Ver. 2. U.S. Dep. Agric., U.S. Gov. Printing Off. Washington, D.C.

Sukartono., W.H. Utomo, Z. Kusuma and W.H. Nugroho, 2011a. Soil fertility status, nutrient uptake, and maize (*Zea mays* L.) yield following biochar and cattle manure application on sandy soils of Lombok, Indonesia. J. Tropical Agriculture, 49: 47-52.

Sukartono., W.H. Utomo, W.H. Nugroho and Z. Kusuma, 2011b. Simple biochar production generated from cattle dung and coconut shell. J. Basis. Appl. Sci. Res., 1: 1680-1685.

Tagoe, S.O., T. Takatsugu Horiuchi and T. Matsui, 2008. Effects of carbonized and dried chicken manures on the growth, yield, and N content of soybean. Plant Soil, 306: 211–220.

Tiquia, S.M. and N.F.Y. Tam, 2000. Fate of nitrogen during composting of chicken litter. Environmental Pollution, 110: 535-541.

Westerman, P.W. and J.R. Bicudo, 2005. Management consideration for organic waste use in agriculture. Bioresource Technology, 96: 215-221.

Yamato, M., Y. Okimori, I.F. Wibowo, S. Anshori and M. Ogawa, 2006. Effects of the application of charred bark of *Acacia mangium o*n the yield of maize, cowpea and peanut, and soil chemical properties in South Sumatra, Indonesia. Journal Soil Science and Plant Nutrition, 52: 489–495.