JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
ISSN: 2339-076X, Volume 2, Number 1 (October 2014): 211-218
DOI:10.15243/jdmlm.2014.021.211

Research Article

The use of biochar to reduce nitrogen and potassium leaching from soil cultivated with maize

Widowati[1*], Asnah[1], W.H. Utomo[2]

[1] Tribhuwana Tunggadewi University, Jl. Telaga Warna, Tlogomas, Malang 65144, Indonesia
[2] IRC-MEDMIND, Brawijaya University, Jl. Veteran, Malang 65145, Indonesia

[*] Corresponding author: widwidowati@gmail.com

Abstract: Nutrient leaching is often a problem especially in tropical areas with soil fertility constraints. This study aims to reveal the effect of biochars on leaching and uptake of nitrogen and potassium from degraded soils cultivated with maize. Each of three types of biochar originated from rice husk, wood, and coconut shell, was applied to the soil placed in PVC tube at four rates (0, 15, 30, and 45 t/ha). Maize was then planted in each pot. All pots received urea (135 kg N/ha), SP36 (36 kg P_2O_5/ha), and KCl (110 kg K_2O/ha). Twelve treatments (three biochars and four application rates) were arranged in a factorial randomized block design with three replicates. Results of the study showed interaction effects of biochar materials and biochar rates on nitrate leaching (except on day 1 to 30) and potassium, N uptake, and plant growth. On day 1-30, leaching of nitrate and potassium was reduced by biochar application. The lowest nitrate leaching was observed at rate of 45 t /ha of wood biochar, while application of 45 t coconut shell biochar / ha resulted in the highest K leaching. Beside, wood biochar resulted in a similar nitrate leaching with that of coconut shell biochar, but nitrate leaching increased with increasing rate of rice husk biochar on day 30-60. All biochar materials yielded similar potassium leaching at all rates. Application of 45 t rice husk biochar /ha resulted in the best maize growth.

***Key words**: biochar, degraded soil, leaching, and nutrient uptake*

Introduction

The amount of rainfall in the tropical climate can cause loss of nutrients through leaching. Water that can carry chemical fertilizer out from the rooting zone makes plants incapable utilizing nutrients provided by the fertilizers. The amount of nitrogen leached out from the rooting zone can be up to 80% (Lehmann et al., 2003). Nutrients in the soil can be leached down away from the plant-rooting zone of plants (Randall et al., 1997). This can rapidly occur in loamy soils (Renck and Lehmann, 2004). Intensive leaching of nutrients results in low soil pH, especially when this occurs in degraded soils.

Soil degradation severely limits soil fertility and crop production. Thus, low soil fertility will hinder the sustainability of agricultural systems. In addition, the length of flooded or saturated water conditions (drainage) is very important for the management of water and plant nutrients. Application of mulch, compost, and fertilizer improves soil fertility. However, under tropical conditions, organic matter is rapidly oxidized and added bases are rapidly leached (Tiessen et al., 1994). On the other hand, application of biochar has been proved to reduce nutrient leaching (Downie et al., 2009), and after incorporation into soil, biochar improves soil fertility (Lehmann et al., 2003; Steiner et al., 2007), increase the efficiency of N fertilizer (Widowati et al., 2012), and reduce the use of K fertilizers in Inseptisols (Widowati and Asnah, 2014). Biochar as a soil amendment is potential for improving crop yields and quality of degraded soils. Biochar generated from black carbon biomass has been shown to increase yields (Lehmann et al., 2003). However, information of their effects on nutrient leaching in clay loam soils is limited.

Biochar can be generated from various sources of biomass and pyrolysis conditions. Pyrolysis is a thermo chemical process in which biomass is converted to biochar through heating with limited oxygen supply. Biochar has different properties depending on raw materials and pyrolysis conditions used (Bonelli et al., 2010). According to Singh et al (2010), nutrients content of biochar is strongly influenced by the type of raw materials and pyrolysis conditions. According to Nguyen et al. (2004), biochar produced from various organic materials under different conditions will give different effects on soils. The amount of biochar added to the soil will influence the effectiveness of biochar in reducing soil N loss and improving plant growth. Plant response to biochar application has been reported to vary because of varying nature of biochar, depending on the biomass source and pyrolysis conditions (Major et al., 2009). Mineral contents of biochar generated from different raw materials also vary considerably (Yao et al., 2012). However, there is only limited study on the effect of biochar materials and rates on nutrient leaching and plant growth.

Biochar has been shown to reduce the loss of nutrients through leaching, thereby increasing the availability of nutrients, both in the laboratory (Singh et al., 2010) and in the glass house (Lehmann et al., 2003; Widowati et al., 2012). However, there is no information about the interaction between the material and the dose of biochar in reducing leaching of nutrients, especially N and K, as well as its influence on nutrient uptake and plant growth. It is thought that application of biochar will improve soil fertility and reduce nutrient leaching. Therefore, the purpose of this study was to elucidate the effect of various sources and doses of biochar on leaching of N and K from soil and uptake of N and K by maize.

Materials and Methods

A glasshouse experiment was conducted at Tunggadewi Tribhuwana University, Malang, Indonesia (7^o.48'. 50" S and 112^o.37'41" E). The daily temperature in the glasshouse varied from 16^o-36^{o}C with a relative humidity of about 43-86%, and light intensity of 365-1997 lux. Materials used for this study were soil, biochar and maize seeds.

Soil used for this study was an Alfisol of Jatikerto Village, Sumber Pucung District of Malang Regency. The soil has the following characteristics: 0.39% C content. pH 5.5, 0.08% total N; 0.68% organic matter, 6.35 mg/kg P (Bray 1), 0.43 mg /100g K, 0.54 mg100/g Na, 4.36 mg100/g Ca, 1.85 mg/100g Mg, 51% base saturation, 14 mg/100g CEC and clayey loam texture (21% sand, silt 47%, and 32% clay). The soil is located on a gently sloping land of 25% with an effective depth of <30 cm and has severely undergone water erosion for decades. Cassava and sugarcane are the dominant cultivated crops in the area.

Biochars used for this study were generated from rice husk, wood, coconut shells that were all collected from nearby soil sampling sites. The biochar was produced using pyrolysis at a temperature of 500 to 700 °C for 9 hours. All biochars produced were ground to pass through a 2 mm sieve for the analyses of their chemical compositions. The results of analysis are presented in Table 1.Treatments tested in this study consisted of three biochars (rice husk, wood, coconut shell) and four rates of application (0, 15, 30, 45 t / ha).

Table 1. Characteristics of biochars generated from three raw materials

Characteristics	Materials		
	Rice husk	Wood	Coconut shell
pH H_2O (1:2,5)	7.9	9.3	9.4
C organic (%)	20.93	71.47	60.07
N total (%)	0.71	0.81	0.95
P (%)	0.06	0.01	0.10
K (%)	0.14	0.36	0.71
Na (%)	2.24	0.43	3.82
Ca (%)	1.37	1.20	2.16
Mg (%)	0.06	0.06	0.10
KTK ($NH_4OAC1NpH_7$) (me/100 g)	17.47	4.98	16.41

Twelve treatments (three biochars and four application rates) were arranged in a randomized block design with three replicates. Dry ground (< 2mm) of each biochar was incorporated in 8 g of air-dried soil placed in a PVC tube (50 cm diameter and 14.4 cm length). Before pouring the soil-biochar mixture into the tube, 24 small marbles were placed over the bottom stem of each tube to facilitate water infiltration. A cap having pores of 3.0 mm (4 pore/cm^2) was fitted at the bottom of the tube and was connected with ahole. Water was then added to bring the soil water content to approximately 70% of the water holding capacity. A glass wool pad was placed on top of the soil-biochar mixture in the tube.

After 7 days of incubation, three seeds of maize (Pioneer 21 variety) were planted in each tube and thinned to one after 10 days. All tubes received basal fertilizers consisting of 135 kg N (urea) /ha, 35 kg/ P_2O_5 (SP36)/ha, and 110 g K_2O (KCl)/ha. Urea and KCl were supplied twice (1/3 of the rate on day 7 and 2/3 of the rate on week 4). SP36 was supplied at the planting time while no pesticides or herbicides were applied. After 14 days, all tubes were weekly leached with similar amount of water. Seven times of leaching process required as much as 12L of water. The amount of water used for leaching was increased in line with plant growth, i.e. 1 L at weeks 2-3, 1.5 L on week 4, 2 L on week 5-7, and 2.5 L on week 8. After leaching, the moisture content of the soil-sand mixture in the tube was brought back to the approximate water holding capacity. Each leaching process was started at 07.00 AM and leachate was collected at 15.00 pm. The leachates were analyzed for its nitrate and potassium concentrations.

Maize leaf area was measured with a leaf area meter, leaf area index was calculated from leaf area divided by spacing (80x25 cm), total plant dry weight, and levels of N and K in leaf samples were observed on day 60, while stem diameter and plant height were measured at 30 and 60 days. At harvest (62 days), aboveground biomass was collected by cutting at the base of maize stalks. The biomass was then oven dried at 60^oC for 72 hours, weighed and ground to pass through a 1 mm sieve for analyzes of nitrogen and potassium contents. The volume of water leached was calculated from the accumulation of water during the leaching process (day14-60). All data obtained were subjected to analysis of variance using SPSS version 13.0 software. Significant differences for the effect of material and biochar rates were analyzed using HSD test at P = 0.05.

Results and Discussion

Water, nitrate, and potassium leached

There was an interaction effect of biochar material and biochar rate on the volume of water leached (Table 2). The added water filled the soil pore spaces and the rest went down as the infiltration water and as the water leached out/drainage. Most of water retained by the soil was used for growing crops (Table 3). Of 12 liters of water supplied during the leaching process, the water drain collected ranged from 2.7 to 6.7L (Table 2). The greatest volume of water leached was observed for treatments without biochar. Application of coconut shell and rice husk biochar (45 t/ha) resulted in the lowest volume of water leached. This means that the water has been absorbed by the plant and / or retained by the soil so that the water leached was reduced. Water and nutrients absorbed by plants were used to establish the production of dry matter (Table 3).

Table 2. Effects of biochar materials and biochar application rates on leaching of nitrate and potassium.

Treatment	Nutrient Leached (mg/L)					Water Content after leaching at 30 days (%)	Cumulative Volume of water leached (mL)
	K^+			NO_3^-			
	1-30 days	30-60 days	1-60 days	30-60 days	1-60 days		
S0	1.47 a	5.14 b	6.60 a	0.15 a	1.06 bc	32.02 a	6.669 e
S15	1.43 a	6.26 b	7.69 a	0.47 ab	1.29 c	30.64 a	4.343 cd
S30	8.91 b	5.89 b	14.8 b	0.96 d	1.91 d	31.88 a	3.33 b
S45	8.33 b	6.62 bc	14.9 b	1.64 e	2.19 d	34.07 ab	2.803 a
K0	1.47 a	5.14 b	6.60 a	0.15 a	1.06 bc	32.02 a	6.669 e
K15	2.44 a	5.62 b	8.06 a	0.15 a	0.56 a	38.40 c	4.797 d
K30	7.82 b	3.55 ab	11.37 a	0.13 a	0.78 ab	40.61 c	4.385 ab
K45	15.35 cd	0.53 a	15.88 b	0.28 a	0.63 ab	55.43 d	3.950 c
T0	1.47 a	5.14 b	6.60 a	0.15 a	1.06 bc	32.02 a	6.669 e
T15	8.72 b	10.94 d	19.66 b	0.77 bcd	1.29 c	30.95 a	4.447 d
T30	14.52 c	10.54 cd	25.06 c	0.39 ab	0.81 abc	32.57 ab	3.110 ab
T45	16.47 d	12.31 c	28.79 c	0.90 cd	1.30 c	34.82 ab	2.760 a

*) Treatment: S = rice husk; K = wood; T = coconut shell, 0, 15, 30, 45 = rats of application (t/ha)

Treatments without biochar generated the lowest biomass production because there was not enough water to form plant material, as most of water was leached out from the soil. Data presented in Table 2 show that the more biochar was added the lower was the volume of water leached. Biochar reduced the volume of drainage water by twice.

The amounts of nitrate and potassium leached during maize growth on day1-30, 30-60, and 1-60 are presented in Table 2. There was no interaction effect of biochar material and biochar rate on nitrate leaching on day 1-30 after planting, but the interaction occurred on day 30-60 and 1-60 after planting. It was recorded that there was a similar pattern observed in potassium leaching. Hence, the higher biochar rate applied, the lower was the leaching of nitrate and potassium although the amounts of N and K in the soil increased (Table 2). At early maize growth (day1-30), the lowest nitrate leaching was observed for coconut shell treatments, and the highest was for rice husk treatments. Application of 45 t biochar/ha resulted in the lowest nitrate leaching. However, at the subsequent growth (day30-60), nitrate leaching increased twice with increasing rates of rice husk biochar. This seems to be related to the increase of N with increasing rate of biochar applied. Nitrogen from urea added to the soils was 6.4 g/pot in each treatment..

Table 3. Effects of biochar materials and biochar rates on plant height and N uptake after leaching.

Treatment	Plant Height (cm)	Stem Diameter (cm)		Leaf Area Index	Plant Biomass Dry Weight	N Uptake
	30 days	30 days	60 hst	(60days)	(g/ pot) 60 days	(g/plant)
S0	15.23 a	0.67 a	1.23 a	0.46 a	5.81 a	0.14a a
S15	27.97 cd	1.57 de	2.17 c	2.23 d	37.49 c	1.02 de
S30	26.77 c	1.50 de	2.37 d	2.45 de	41.08 c	1.10 e
S45	33.40 d	1.80 e	2.33 d	2.58 e	48.43 d	1.37 ef
K0	15.23 a	0.67 a	1.23 a	0.46 a	5.81 a	0.14 a
K15	20.07 ab	1.13 bc	1.83 b	1.60 d	23.37 b	0.57 b
K30	20.43 ab	1.10 bc	1.97 b	1.97 c	30.13 b	0.79 c
K45	16.33 a	0.90 ab	1.83 b	1.93 c	30.21 b	0.81 cd
K0	15.23 a	0.67 a	1.23 a	0.46 a	5.81 a	0.14 a
T15	25.13 bc	1.40 cd	2.13 c	1.97 c	29.77 b	0.77 bc
T30	27.83 cd	1.53 de	2.33 d	2.51 e	43.46 cd	1.22 ef
T45	27.50 cd	1.47 d	2.23 d	2.49 e	43.65 cd	1.23 ef

*) Treatment: S = rice husk; K = wood; T = coconut shell, 0, 15, 30, 45 = rats of application (t/ha)

The amount of N leached increased with increasing rates of rice husk biochar. This may be related to the relatively high N content of the rice husk (Table 1) which led to the high release of nitrate to be leached out from the system. In contrast, nitrate leaching did not increase with increasing rates of wood biochar on day 30-60. At a rate of 15t/ha, soil N ranged from 14.5 to 15.3 g /pot and N leached ranged from 0.5 to 1.3mg/L. At a rate of 30t/ha, soil N ranged from 17 to 18g/pot and N leached ranged from 0.8 to 1.9mg/L. At a rate of 45t/ha, soil N ranged from 18.8 to 20.9g/pot and N leached ranged from 0.6 to 2.2mg/L.

There was an interaction effect of biochar material and biochar rate on potassium leaching on day 1-30. The highest leaching of K on day 1-30 and day 30-60 were observed at treatments applied with 45 t coconut shell biochar/ha. This is related to the higher K content of coconut shell than that of other materials (Table 1). It is presumed that the amount of K taken up by plant was very small at early plant growth, yet the amount of available K in the soil was relatively high. Thus, most of K was leached from the system. On day 30-60, the lowest potassium leaching was observed for 45t wood biochar/ha treatment. The amount of K leached ranged from 7.7 to 25.5mg/L (rate of 15t/ha) of soil K 7.9 to 9.5g/pot; 14.8 to 19.3mg/L (rate of 30t/ha) of soil K 8.3 to 11.7g/pot; and 8.4 to 28.8mg/L (rate of 45t/ha) of soil K 8.7 to 13.8g/pot.

Treatments without biochar yielded the lowest growth that led to the loss of water through leaching and drainage (Table 2). Plant growth affected the volume of water leached. When the plants are still young with slow plant growth, there is only small amount of nutrients and water absorbed by the plant. During this stage, application of biochar reduced N leaching and increased K leaching. This occurred when the substantial amount N was taken up while the amount of K uptake was very small.

It is important to note that the amount of urea added at the early growth seemed to have met the needs of young plant under leaching conditions. Novak et al.(2009) reported that biochar derived from pecan shells was able to reduce nitrate leaching from the soil for more than 25 and 67days. Biochar has been found to improve nutrient retention, especially N in tropical soils that receive intensive rainfall (Lehmann et al., 2003; Steiner et al., 2007).

Although the amount of N in the biochar treated soil was substantial (14.5 to 20.9 /pot), there was only a small amount of N leached (Table 2). This is probably because of N contained in the biochar has not yet been released and dissolved during the leaching process. This was not the case with subsequent growth. At the beginning of the growth (30 days), biochar effectively reduced N leaching at high rates and biochar materials affected the amount of N leached. Rice husk biochar yielded the highest nitrate leaching while wood biochar yielded the lowest nitrate leaching.

On day 30-60, application of 45 t rice husk biochar/ha resulted in the highest N leaching, followed by 30 t rice husk biochar/ha. Cumulatively (1-60 days), application of 30t and 45 t rice husk biochar/ha resulted in substantial amount of N leaching. This was related to the amount of soil N generated from urea and biochar (14.53 to 20.95 g/pot). However, the amount of N taken up by the plant was also high to promote plant growth (Table 3). This indicates that the amount of N taken up by plants was higher than that leached. Two third rate of urea was applied on day 30-60 after planting.

Application of wood biochar did not increase nitrate leaching although the amount of available N in the soil increased with addition of biochar, except for rice husk biochar. Application of rice husk biochar at high rates resulted in high loss of nitrate. It is assumed that N in the husk biochar was released and dissolved during the leaching process.

At the beginning of plant growth, potassium loss increased with application of wood and coconut shell biochars at rates of 30 and45t/ha. The results are consistent with that reported by Lehmann et al. (2003) that application of biochar can increase the leaching of K, but not for Ca and Mg. Nutrients leaching increased during the first10-20 days after fertilizer application. Fertilization will cause intensive K leaching when biochar is applied to a Ferralsol. At subsequent growth (30-60 days), application of rice husk biochar did not increase K leaching. Application of wood biochar also did not increase K leaching, the use of high rate (45 t /ha) even reduced the loss of K. The amount of potassium leached from the soil applied with 30t biochar /ha did not differ from that applied with 200kg KCl/ha. Potassium is proven very mobile in the soil and up to 30% of K in the fertilized soil will rapidly being leached (Lehmann et al., 2003).

Maize growth and uptake of N and K under leaching conditions

There was an interaction effect of biochar material and biochar rate on plant height (at 30 days), andstem diameter, biomass production, leaf area index, and N uptake (at harvest). Biochar material and rate separately affected K uptake by maize. Maize grown on media without application of biochar produced the lowest plant growth, N uptake and K uptake. Application of 45 t rice husk biochar/ha resulted in better plant height, stem diameter, leaf area index, and biomass production compared to other treatments (Table 3). This is related to the highest uptake of N and K (Tables 3 and 4).

On day 30, application of 45 t wood biochar/ ha produced similar plant height to treatments without biochar application. At that age, the plants showed symptoms of P deficiency as indicated by the presence of purple colour in the leaves. It isassumed that during the initial growth of maize up to day 30, wood biochar did not demonstrate effectiveness in improving the condition of the soil as the high C/P ratio interfered with the uptake of P. However, after day 30-60, plant growth improved (Table 3) and no indication of P deficiency. Therefore, the level of K uptake increased with the increasing rates of biochar (Table 4).

In the first 30 days, all biochar added to soil improved maize growth, except for 45t wood biochar/ha. Application of 45t wood biochar/ha resulted in higher plant height than the treatment without biochar. Application of 45t/ha interfered with the uptake of nutrients compared to the rates of 15 and 30t/ha. This was indicated from the lowest plant height in early growth. Wood biochar used in this study contained the highest carbon but the lowest P (Table 1).

The higher the rate of wood biochar applied, the earlier was the occurrence of P deficiency. As observed on day 16, there was a purple leaf colour on wood biochar treatment of 45t/ha. This was similar to that of treatment without biochar. P deficiency symptom also appeared on wood biochar of 15 and 30t/ha on day 21. It is possible that after 21 days the increase in pH led to the increase of P availability. This was proven by the disappearance of purple colour on day 35 (Table 3).

Plant height, plant biomass, and leaf area index were lower at the 15 t/ha treatment than that of 30 and 45 t/ha treatments for any biochar materials. At the end of experiment, biochar application gave better growth than without biochar application. Application of 45 t rice husk biochar/ha yielded the best plant growth. This was because of the lowest N leaching on day 30 so N held in the soil was used to increase the uptake of N by maize (Table 3), and to improve plant growth (Table 2). The increase of soil water content after leaching (Table 4) kept soil moisture for the process of nutrient uptake (Table 3).

The improvement of plant growth by the application of biochar is because of the important role of biochar as a soil amendment that improves soil conditions. When biochar is used as a soil amendment material along with organic and inorganic fertilizers, various biochar have been reported to improve crop yields, crop productivity, and nutrients (Chan et al., 2008). In addition, biochar has a direct effect in the form of nutrient content (Table 1).

Although nutrients in the biochar and soil used for this study were low as the soil has been experiencing leaching process, the plant still up took nutrients, especially N and K to form biomass (Table 3). This occurs because of the ability of biochar to retain nutrients. Results of this study are consistent with that reported by Lehmann et al. (2003) that biochar may have a direct effect due to nutrient content and many indirect effects, including nutrient retention.

Soil water content

There was an interaction effect of biochar material and biochar rate on soil water content after leaching on day 30. Biochar materials and biochar rates separately affected soil water content before and after leaching on day 60 and before leaching on day 30 (Tables 2 and 4). Soil water contents before and after leaching are shown in Tables 2 and 4.

Table 4. The effect of biochar materials and biochar rates on plant height, K uptake, N leaching, and soil water content on day 1-30.

Treatments	Plant Height (cm) 60 days	K ptake (g /plant)	Nitrate Leached (mg/L) 30 days	Water Content (%) at 30 days before leaching	Water Content (%) at 60days before leaching	Water Content (%) at 60 days after leaching
Biochar rate (t/ha)						
0	38.30 a	0.11 a	0.91 c	22.71 c	38.96 a	23.30 a
15	77.23 b	0.65 b	0.59 b	18.71 b	43.74 b	17.24 b
30	85.21 c	0.89 c	0.57 b	17.40 a	50.44 c	17.18 c
45	88.64 c	1,02 d	0.43 a	16.16 a	54.94 c	16.02 c
Biochar materials						
S (rice husk)	73.38 a	0.56 a	9.68 c	17.37 a	46.03 b	17.23 a
K (wood)	66.77 b	0.72 b	6.04 a	20.33 c	49.80 c	20.08 c
T (coconut shell)	74.90 b	0.73 b	6.71 b	18.53 b	45.23 a	18.00 b

Treatments without biochar application showed the highest soil water content before leaching on day 30 and after leaching on day 60. The lowest soil water content was found before leaching on day 60 (Table 4). The highest soil water content was found in wood biochar treatments.

There was no difference in soil water content before and after leaching between rates 30 and 45t/ha on day 60 (Table 4). However, the application of 45t wood biochar/ha resulted in the highest soil water content after leaching on day 30 (Table 2). Water content after leaching increased with increasing rates of biochar (Table 2vand4). Application of biochar increased 54,78% water storage, while that without biochar application was 50.86%. As reported by Widowati and Asnah (2014) leaching of K from litter biochar affected the amount of water drained which tended to decrease with increasing rates of biochar. The use of biochar can improve soil porosity (Widowati et al., 2012; Steiner et al., 2007).

In this case, porosity is indicated by drainage pore. The lower the value of rapid drainage pores, the greater is the water holding capacity and available water content (Prima and Gunadi, 2010). Biochar is a very porous material having has a lower density than soil (Downie et al., 2009). According to Lehmann et al. (2003), biochar does not decrease water percolation and cause nutrient retention. Water retained by the soil was used for plant growth (Table 4). Soil water content before leaching varied according to plant growth. After leaching on day 30, the highest soil water content was the wood biochar treatment of 45t/ha (Table 4). This was related to the plant growth. Similarly, the lowest volume of water leached was observed for 45t wood biochar/ha treatment.

Conclusion

There was an interaction effect of biochar materials and biochar rates on leaching of nitrate (except on day 30) and potassium, N uptake, biomass production, leaf area index, plant height, and stem diameter. Nitrate leaching was reduced by application of biochar on day 1-30. The lowest nitrate leaching was at 45t wood biochar/ha treatment. Application of 45 t coconut shell biochar/ha resulted in the highest K leaching. On days 30-60, application of biochar materials (except for rice husk biochar) produced similar leaching of nitrate and potassium. The more rice husk biochar applied the more nitrate was leached.

Treatments without biochars yielded the lowest N and K uptake. The lowest K uptake was observed for application of wood biochar. Application of 45 t rice husk biochar/ha resulted in the highest biomass production, leaf area index, plant height, ands tem diameter. After leaching, the highest soil water content (55.43%) was observed for 45t wood biochar/ha treatment at 30days. On day 60, the highest soil moisture content (20.08%) was found at the wood biochar treatment. The volume of water leached decreased with increasing rates of biochar applied.

Acknowledgements

The authors thank the Directorate General of Higher Education, Ministry of Education and Culture for financial support through National Strategic Research Grant 2014.

Reference

Bonelli, P.R, Della Rocca, P.A., Cerrella, E.G. and Cukierman, A.L. 2010. Effect of pyrolysis temperature on composition, surface properties and thermal degradation rates of Brazil nut shells. *Bioresource Technology* 76: 15–22.

Chan, K.Y., Van Zwieten, L., Meszaros, I., Downie, A. and Joseph, S. 2008. Using poultry litter biochars as soil amendments. *Australian Journal of Soil Research* 46 (5): 437–444.

Downie, A., Crosky, A. and Munroe, P. 2009. Physical properties of biochar. In: Lehmann, J. and Joseph, S. (eds), *Biochar for Environmental Management. Science and Technology*. Earthscan: London, UK, p. 13–32.

Lehmann, J., de Silva, J.P.Jr., Steiner, C., Nehls, T., Zech, W. and Glaser, B. 2003. Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments. *Plant and Soil* 249: 343–357. Doi: 10.1023/ A: 1022833116184.

Major, J., Steinerm, C., Downiem, A. and Lehmann, J. 2009. Biochar effects on nutrient leaching. In: Lehmann, J. and Joseph, S. (eds), *Biochar for Environmental Management. Science and Technology*. Earthscan: London, UK, p. 271−287.

Nguyen, T.H., Brown, R.A. and Ball, W.P. 2004. An evaluation of thermal resistance as a measure of black carbon content in diesel soot, wood char, and sediment. *Organic Geochemistry* 35**:** 217–234. Doi: 10.1016/j.orggeochem.2003.09.005.

Novak, J.M., Busscher, W.J, Laird, D.L., Ahmedna, M., Watts, D.W. and Niandou, M.A. 2009. Impact of biochar on fertility of a southeastern Coastal Plain soil. *Soil Science* 174: 105-112.

Prima, L., and Gunadi, D.H. 2010. Utilization of biochar as a microbial carrier for stabilizer aggregate Ultisol of Parks Bogo-Lampung. *Menara Pekebunan* 78 (2): 52-60.

Randall, G.W., Huggins, D.R., Russell, M.P., Fuchs, D.J., Nelson, W.W. and Anderson, J.L. 1997. Nitrate losses through subsurface tile drainage in conservation reserve program, alfalfa, and row crop systems. *Journal of Environmental Quality* 26: 1240-1247. Doi: 10.2134 / jeq 1997. 0047242500 2600050007.

Renck, A. and Lehmann, J. 2004. Rapid water flow and transport of inorganic and organic nitrogen in a highly aggregated tropical soil. *Soil Science* 169: 330–341. Doi: 10.1097/01.ss.0000128016.00021.3d.

Singh, B.P., Hatton, B.J., Singh, B., Cowie, A.L. and Kathuria, A. 2010. Influence of biochars on nitrous oxide emission and nitrogen leaching from two contrasting soils. *Journal of Environmental Quality* 39: 1224–1235.

Steiner, C., Teixeira, W.G., Lehmann, J., Nehls, T., Vasconcelos de Macedo, J.L., Blum, W.E.H. and Zech, W. 2007. Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. *Plant and Soil* 291: 275-290.

Tiessen, H., Cuevas, E. and Chacon, P. 1994. The role of soil organic matter is sustaining soil fertility. *Nature*. 371: 587-615.

Widowati and Asnah. 2014. Biochars effect on potassium fertilizer and leaching potassium dosage for two corn-planting seasons. *Agrivita Journal Agriculture Sciences* 36 (1): 65-71.

Widowati, Utomo, W.H., Guritno, B. and Soehono, L.A. 2012. The Effect of biochar on the growth and N fertilizer requirement of maize (*Zea mays* L.) in green house experiment. *Journal of Agricultural Science.* 4: 255 – 262.

Yao, Y., Gao, B., Zhang, M., Inyang, M. and Zimmerman, A.R. 2012. Effect of biochar amendment on sorption and leaching of nitrate, ammonium, and phosphate in a sandy soil. *Chemosphere.* 89: 1467–1471.

.