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Research Article

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

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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°.48'. 50" S and 112°.37'41" E). The daily temperature in the glasshouse varied from 16°-36°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 $60^{o}C$ 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.

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Research Article

Application of drip irrigation technology for producing fruit of Salak 'Gula Pasir' (*Salacca zalacca* var. Gula Pasir) off season on dry land

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Abstract: Naturally, Salak Gula Pasir (*Salacca zalacca* var. Gula Pasir) is flowering every three months or four times a year, but only one or two flowering seasons that the flowers can develop into fruit. The condition causes Salak Gula Pasir is available in the market in a short period (only 2-3 months) i.e. at the time of harvest (on-season) from December to February. This seasonal nature of Salak Gula Pasir occurs because Salak Gula Pasir is planted on dry land where irrigation depends only on rainfall, and drought occurs when water is shortage so that the plant internal water content is low that causes a high failure development rate of flower to become fruit (fruit-set failure). This study was aimed to overcome the fruit-set failure by providing drip irrigation. Two treatments (with drip irrigation and without drip irrigation/control) with sixteen replicates were tested at Salak Gula Pasir production centre (at Sibetan village, Bebandem District, of Karangasem Regency, Bali) at two harvest seasons, i.e. Gadu (July) and Sela II (October). The results showed that the plant provided with drip irrigation significantly yielded fruit-set percentage higher that that without drip irrigation, both in Gadu and Sela II seasons. The percentages of fruit-set in Gadu and Sela II seasons provided with drip irrigation were 75.30% and 93.13%, respectively, while those without drip irrigation were only 59.94% and 61.67%, respectively. The increase of fruit-set observed for drip irrigation treatment associated with the increase of leaf chlorophyll content, relative water content (RWC) of leaves, and leaf N, P, and K contents. The increase of fruit-set led to higher number of fruits and fruit weight per plant under drip irrigation than that without drip irrigation. Based on the results of this study, drip irrigation can be applied to produce Salak Gula Pasir planted out of season on dry land.

***Keywords**: drip irrigation, dry land, fruit-set, off-season, Salak Gula Pasir,*

Introduction

Salak Gula Pasir is one of superior tropical fruits native to Indonesia preferred by the community that has been released by the Minister of Agriculture of the Republic of Indonesia through Kepmentan No. 584 / Kpts / TP.240 / 7/1994. The superiorities of Salak Gula Pasir are as follows: sweet fruit flavour even at young age, no sour taste, no sandy taste, and the flesh fruit is thick and not attached to the seed. These salak fruit characteristics are considered ideal to meet the demands of salak commodity markets, both for domestic and export markets (Bank Indonesia, 2004).

Until today, the availability of Salak Gula Pasir fruit in the market is seasonal. In the harvest season (on-season) the availability of Salak Gula Pasir fruit is very abundant, but the selling price is low, only between Rp. 8,000 to Rp. 10,000 / kg. On the other hand, there is no Salak Gula Pasir fruit available during off-season, if it is available; the selling price reaches Rp. 35,000 to Rp. 45,000/kg (personal communication with farmers and fruit sellers, 2013). The situation is not favourable in terms of agribusiness because of the abundant production is only at harvest time (December-February) and the time supply is very short, only 2-3 months. This short supply condition of the fruit is due to its short shelf life of Salak Gula Pasir fruit, only 7-10 days at room temperature storage (Arisusanti, 2013). With the short time supply and the short shelf life of the fruit, the bargaining position of farmers in the marketing system of Salak Gula Pasir fruit is very weak which forcing farmers to immediately sell their crop products with low prices to avoid fruit rotting and wasting. Therefore, efforts to produce Salak Gula Pasir fruit out of season are needed to enable the supply-demand balance throughout the year to improve farmer's income.

The potential success for producing Salak Gula Pasir fruit out of season is large. Rai et al. (2010a) reported that naturally. Salak Gula Pasir is flowering once every three months or four times a year, i.e. in January (Raya flowering season), April (Sela I flowering season), July (Gadu flowering season), and October (Sela II flowering season). Of the four flowering seasons, harvesting or productions of good fruit only once a year at harvest Raya (December-February). At the three other flowering seasons (Sela I, Sela II, and Gadu) the flowers fail to produce fruit, or it is called fruit-set failure. Even if there are farmers who are capable to manage the flowers to become fruit, the percentage was very small, and hence, the amount of harvested fruits was very small too.

The failure of flower development into fruit of Salak Gula Pasir was caused by environmental factors (external) and plant physiological factors (internal) that were not supportive (Rai et al. (2010b). The external factors, i.e. low rainfall and rainy days caused low leaf Relative Water Content (RWC) that interfere with the metabolism process, while the physiological factor was lack of photosynthate in the flower which was shown by low sucrose, total sugar, and reduced sugar contents in the flower.

The low leaf RWC which caused the failure of fruit-set was indicated by a significant positive correlation between the percentage of fruit-set with leaf RWC (r = 0.99 *). The low leaf RWC was because Salak Gula Pasir of Karangasem is cultivated on dry land where farmers do not provide irrigation water but only relies on water rainfall. It was also found that the leaf RWC was positively correlated with leaf chlorophyll content (r = 0.89 **), flower sucrose (r = 86 *), flower total sugar (r = 0.93 **), and flower reduced sugar (r = 0.88 **).

Results of the above studies indicate that the low internal moisture content in the Salak Gula Pasir decreased chlorophyll content and photosynthesis yields allocated to the flower. Some other fruit researchers, such as Hanke et al. (2010) on avocado, Balta et al., (2007) on apricot, and Luis et al. (1995) on citrus also reported the important role of internal water in determining the success of the development of flowers into fruit. This study was conducted to elucidate the success of fruit-set on Salak Gula Pasir due to the effect of drip irrigation to produce fruit out of season.

Materials and Methods

A field experiment was conducted at the Salak Gula Pasir farm belonging to farmers of Sibetan Village, Bebandem District of Karangasem Regency from May to October 2013. Treatments tested for this study were drip irrigation (I) and without drip irrigation (TI).with sixteen replicates that resulting in thirty three plants

Plant samples were selected from one farmer. The selected plant samples were in one plot with uniform trees and similar maintenance history. For plant samples treated with drip irrigation, water in a tank was dripped to each tree with a pump machine. Pipes were set encircling the stem of plants at a distance of 20 cm. Pipes that wrapped around the stems of plants were drilled into small holes by the number four per tree, and the holes were fitted with water dropper nozzles. Droplets of water out through nozzles were arranged in such a way that the water content of the soil in the plant roots throughout the day was always in a field capacity condition. Variables observed included leaf RWC, fruit-set percentage, leaf chlorophyll content, fruit number and weight of fruit per plant, weight per fruit, and leaf N, P and K contents. All variables were observed in two seasons, i.e. Gadu (July) and Sela II (October), except for the leaf N, P and K contents that were measured only at Sela II season.

Results and Discussion

The results showed the percentage of fruit-set on a plant supplied with drip irrigation (I) was significantly higher that without drip irrigation (TI), both Gadu and Sela II seasons. Data presented in Table 1 show that the percentage of fruit-set in Gadu and Sela II for plants supplied with drip irrigation were 75.30% and 93.13%, respectively, while those without drip irrigation were only 59.94% and 61.67% respectively. This indicates that drip irrigation treatment increased the ability of the plant to prevent the failure of fruit-set so the percentage of fruit-set increased. Plant water content plays an important role in determining the success of the development of flowers into fruit. This is consistent with the results of a study reported by Kowalska (2008) on sunflower plant and Chauhan et al. (2006) on apple plant.

Increased ability of the plants to cope with the failure of fruit-set was associated with the increase of leaf relative water content (RWC). Data presented in Table 1 show that the leaf RWC of plants treated with drip irrigation was significantly higher than that without drip irrigation, both in Gadu and Sela II seasons. The leaf RWC values in Gadu and Sela II season for plants treated with drip irrigation were 74.56% and 77.76% respectively, while those without drip irrigation were 63.84% and 71.32% respectively.

The high leaf RWC value in drip irrigation treatment showed that application of drip irrigation increased the water content of the plant tissue that positively affected physiological processes as indicated by the increased chlorophyll formation and ability of plant to uptake nutrients. The chlorophyll content of leaves in drip irrigation treatment was significantly higher than that without the drip irrigation, both in Gadu and Sela II seasons. In Gadu season, leaf chlorophyll content in plants treated with drip irrigation was 87.27 SPAD, while that without drip irrigation was 80.85 SPAD.

Table 1. Differences in the effect of drip irrigation (I) and without drip irrigation (TI) on a variety of variables observed on the season and Sela Gadu II

No	Observed variables	Gadu Season		Sela Season II	
		I	TI	I	TI
1	Number of flower bunches per plant	6.125 a	5.625 a	4.63 a	4.56 a
2	Number of fruit bunches per plant	4.56 a	3.56 a	4.19 a	3.19 b
3	Percentage of fruit set (%)	75.30 a	59.94 b	93.13 a	61.67 b
4	Leaf RWC (%)	74.56 a	63.84 b	77.76 a	71.32 b
5	Leaf chlorophyll content (SPAD)	87.27 a	80.85 b	77.20 a	65.64 b
6	Number of fruits per plant	4.82 (24.50) a	3.70 (15.25) a	2.43 (6.38) a	2.05 (5.75) a
7	Weight of fruit per plant (g)	15.48 (287.51) a	13.53 (215.56) a	7.89 (94.08) a	4.66 (50.89) a
8	Weight per fruit (g)	3.42 (12.48) a	3.94 (18.81) a	2.89 (9.87) a	1.71 (3.15) a
9	N content (%)			1.8488 a	1.8088 a
10	P content (%)			0.2588 a	0.2350 a
11	K content (%)			0.8813 a	0.7363 b

Remarks: - The numbers are followed by the same letter in the same lane in each season indicates not significant at the 5% level T test. - In a variable number of fruits per plant, fruit weight per plant and weight per fruit, the figures show the results of the transformation confined to $\sqrt{x + 1}$, while the figure in front of the parentheses is the number of observations.

Similarly, in Sela II season the chlorophyll content of leaves at drip irrigation treatment was 77.20 SPAD, while at the control treatment was only 65.64 SPAD. In addition, application of drip irrigation significantly increased the leaf K, N and P contents although the differences were statistically not significant. Leaf N, P and K contents at drip irrigation treatment were 1.8488%, 0.2588% and 0.8813%, respectively, while those at the control treatment were only 1.8088%, 0.2350% and 0.7363%, respectively. These conditions favour the increased formation of chlorophyll in the leaves as indicated by the higher chlorophyll content in plants receiving drip irrigation significantly than that in plants without drip irrigation.

The increase in leaf RWC, leaf chlorophyll content, and plant nutrient uptake improved metabolic processes in plants receiving drip irrigation, which in turn increased the percentage of fruit-set. This caused the number of harvested fruit per plant, fruit weight per plant and weight per fruit in plants receiving drip irrigation treatments tended to be higher than without drip irrigation, in both Gadu and Sela II seasons.

For fruit crops, a relatively long dry period is needed to initiate flower, then after flower is initiated and induced, it needs sufficient water so that the flowers can grow and produce fruit (Hempel et al., 2000; Pidkowich et al., 1999; Bernier et al., 1985; Kinet et al., 1985). A similar result was obtained by Ogaya and Penuelas (2007) that Oak Mediterranean plants treated with 15%reduced soil moisture of field capacity caused the fruit-set percentage dropped 30%.

Several studies have shown that fruit-set failure is caused by unfavorable growing environmental factors such as inadequacy of water (Robinson et al., 2000, Balta et al., 2007), nutrients (Saleem et al., 2005), and carbohydrate content (Luis et al., 1995; Ruan, 1993) that hinder the process of plant physiology.

Conclusion

Drip irrigation can be applied to produce Salak Gula Pasir fruits out of season planted on dry land. Under drip irrigation, the percentage of fruit-set in Gadu and Sela II seasons were 75.30% and 93.13% respectively, while that without drip irrigation were 59.94% and 61.67%, respectively. The high percentage of fruit-set can produce fruit out of season.

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Research Article

Utilization of maize cob biochar and rice husk charcoal as soil amendments for improving acid soil fertility and productivity

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Abstract The decline in soil fertility in agricultural land is a major problem that causes a decrease in the production of food crops. One of the causes of the decline in soil fertility is declining soil pH that caused the decline in the availability of nutrients in the soil. This study aimed to assess the influence of alternative liming materials derived from maize cob biochar and rice husk charcoal compared to conventional lime to improve soil pH, soil nutrient availability and maize production. The experiment used a factorial complete randomized design which consisting of two factors. The first factor is the type of soil amendment which consists of three levels (calcite lime, rice husk charcoal and cob maize biochar). The second factor is the application rates of the soil amendment consisted of three levels (3, 6 and 9 t/ha) and one control treatment (without soil amendment). The results of this study showed that the application of various soil amendment increased soil pH, which the pH increase of the lime application was relatively more stable over time compared to biochar and husk charcoal. The average of the soil pH increased for each soil amendment by 23% (lime), 20% (rice husk charcoal) and 23% (biochar) as compared with control. The increase in soil pH can increase the availability of soil N, P and K. The greatest influence of soil pH on nutrient availability was shown by the relationship between soil pH and K nutrient availability with $R^2 = 0.712$, while for the N by $R^2 = 0.462$ and for the P by $R^2 = 0.245$. The relationship between the availability of N and maize yield showed a linear equation. While the relationship between the availability of P and K with the maize yield showed a quadratic equation. The highest maize yield was found in the application of biochar and rice husk charcoal with a dose of 6-9 t/ha. The results of this study suggested that biochar and husk charcoal could be used as an alternative liming material in improving acid soil fertility and productivity.

Keywords: *calcite lime, maize cob biochar, soil pH, nutrient availability, acid soil, maize yield*

Introduction

In acid soil, nutrient availability becomes a major problem that causes decrease in crop productivity. Nutrient availability is closely related to soil pH. At low pH decreased availability of macronutrients cause deficiency of nutrients for plants. Therefore, soil acidity is often a critical issue in soil fertility, especially in tropical soils, because most crops are not tolerant to low soil pH. Soil acidity can be caused by the climatic conditions such as high rainfall and temperatures resulting in alkaline mineral weathering rapidly and accompanied leaching of bases cations. The soil acidification is also due to the application of acidic nitrogen fertilizer, N transformation (Nitrification) that produces H^+ ions, and the release process of H^+ ions into the soil of various reactions in the soil (Havlin et al., 2005; Tabitha et al., 2008).

The influence of soil acidification can be classified into three categories, namely: (1) the availability of nutrients, (2) toxic nutrients, and (3) the soil structure. Availability of essential nutrients for plant growth is affected by soil pH. In acid soils, nutrient deficiencies and toxicities (Al, Mn, and H) becomes a major problem. Plants Growth, especially root growth in acid soils is limited due to the toxicity of Al^{3+}, Mn^{2+}, and H^+. The degree of toxicity depends on the level of concentration and the dissolved Al and soil pH (Okalebo, 2009). The high concentration of Al^{3+}, Fe^{3+}, and H^{+} in acid soil causes soil pH <5.5, high P fixation, and low organic matter content and activity of microorganisms (Fernández and Hoeft, 2012). The development of food crops in acid soil of dry land requires a great effort to recover the soil in order to the plants can produce optimally. According to Tarigan (2009), the plants will grow and produce optimally if planted in qualified growing medium especially environmental factors as climatic factors and soil properties such as soil pH, nutrient availability, CEC etc. One of the efforts to improve the soil fertility is the use of various soil amendment are easily available and are able to survive long in the soil or have the long-term effect and resistant to attack by microorganisms so that the process of decomposition is slow (Nurida and Rachman, 2010).

The soil amendments widely used farmers to increase soil pH is dolomite and calcite lime. Liming not only increase the pH, base saturation, exchangeable calcium and magnesium, but also increase soil microbial activity, improve the status of soil organic matter and improve soil nutrient availability (Johnson et al*.,* 1995).

The limestone material is relatively expensive and limited supply. To overcome it, recently have began to develop the use of agricultural wastes biochar (charcoal) as alternative soil amendment, because the waste is readily available and abundant supply and manufacture process is easier and cheaper than limestone. Maize biomass waste is one of the largest agricultural waste after the timber and rice waste. The maize biomass waste is usually used for animal feed and compost derived from stems and leaves of maize (Agustina, 2004). While many maize cobs are used as fuel, Rohaeni et al. (2005) reported that the potential of fresh maize straw waste is equal to 12.19 t/ha and maize cob by 1 t/ha. By considering the high C content of maize cobs (43.42%), waste of maize cob biomass has a great potential to be produced as charcoal (biochar) (Lachke, 2002).

Some research about applications of biochar as a soil amendment on degraded soil showed that application of biochar 23.2 t/ha increased the plant biomass by 189% that grown on degraded Oxisols (Major et al., 2010). Biochar can enhance the nutrient availability in the soil (Glaser et al., 2002; Lehmann et al., 2003; Rondon et al., 2007; Steiner et al., 2008). It is caused by the biochar can reduce nutrient leaching in soil (Schahczenski, 2010).

Increased nutrient availability in the soil due to the application of biochar can improve the productivity of degraded soil (Sinclair et al., 2010)

Based on the above information is necessary to study aimed to assess the effect of alternative liming materials in form of maize cob biochar and husk charcoal compared to conventional lime to improve soil pH, soil nutrient availability and maize production. This study is expected to provide information to farmers having problems with acidic soil that affected low nutrient availability in the soil.

Materials and Methods

Study Site and Soil Characteristics

This study is a pot experiment conducted at the field agriculture of Merjosari village in June-August 2013 with an altitude of 505 m above sea level, the average temperature of 20°-28°C and rainfall is 1750 mm/year. Soil samples used for this study were collected from the sugarcane monoculture land of more than 20 years with the type of soil is an Inceptisol. Soil samples were air dried and sieved to pass through a 2 mm sieve. The soil is well drained with the following characteristics; pH (H_20) 4.29, 1.85% organic C by Walkley and Black method; 0.13% total Kjeldahl N; 4.40 mg/kg P (Bray II), cation exchange capacity 17.22 me /100 g soil, and 14.1% sand, 85.5% silt and 0.4% clay.

Biochar and charcoal preparation

Maize cob biochar was made at the bioenergy laboratory of Tunggadewi Tribhuwana University. The biochar was made by pirolysis process (burning without oxygen). Maize cobs were put in a reactor to a slow burning process (carbonation) at a temperature of 300-400°C for about six hours with the absence of oxygen. After the combustion, cool charcoal was taken from the combustion reactor, then crushed and sieved using a 100 mesh sieve size. Husk charcoal was obtained from the farm shop. It was then crushed and sieved using a 100 mesh sieve size. The characteristics of husk charcoal and maize cob biochar are presented in the Table 1

Experimental procedures

Dry, ground (< 2 mm) of each of three soil amendments (b1 = calcite lime, b2 = husk charcoal, and b3 = maize cob biochar) with three application rates for each (d1 = 3 t/ha, d2 = 6 t/ha, and d3 = 9 t/ ha) was incorporated into 10 kg of soil in a 25-cm diameter plastic pot. A treatment receiving no added soil amendment was also included. The ten treatments (nine combinations of types and levels of soil amendment application, and one control soil alone without application of soil amendment) were replicated three times and arranged in a factorial randomized block design. One week after soil amendment application, two pre-germinated seeds of sweet maize, Bonanza variety, were planted in each pot at 5 cm depth, and thinned to one plant after 1 week. The experiment was conducted for 87 days. Water was supplied daily to each pot in order to keep the moisture content of the soil at the approximate water holding capacity.

Table 1. Some chemical properties of soil amendments

Soil Amendments	pH (H_2O)	Nutrient content (%)						C (%)	CEC me/100 g	Water content (%)
		N	P	K	Ca	Mg	Na			
Husk Charcoal	8.75	0.14	0.15	0.31	0.28	0.32	1.35	6.24	7.24	7.46
Maize cob biochar	8.85	0	0.12	0.22	0.46	0.42	1.44	18.73	18.52	5.42

Statistical Analysis

The collected data was statistically analyzed using analysis of variance (F-Test) at level ($P \leq 0.05$) and differences in each treatment were adjudged by Tukey test ($P \leq 0.05$) using Minitab Version 14.12. Dunnett test at 5% level was used to compare all treatments with control. The relationship between soil nutrient availability with crop yield was determined with regression and correlation analyses. For statistical analysis of data, Microsoft Excel was employed.

Results and Discussion

Soil pH

The results of this study showed that the treatments with application of soil amendments had higher soil pH compared with control (Figure 1). The average increase in soil pH of three kinds of soil amendment of calcite lime, rice husk, and biochar respectively were 23%, 20% and 23%. This indicates that the calcite lime and biochar has the same effectiveness in improving soil pH.

Increase of soil pH due to the application of these soil amendments was caused by the materials such as calcite lime, husk charcoal, and maize cob biochar having high base saturation and pH. If the basic compound is added (e.g. $CaCO_3$), H^+ will be neutralized. With the addition of a continuous base hydrolyzed Al^{3+} will produce H^+. In this way, the hydrolyzed Al^{3+} will buffer pH increase of solution. Soil pH will not rise until sufficient amount of basic compound is added to reduce soluble Al^{3+}. Finally, Al $(OH)_3$ will precipitate at pH 6.5, and the amount Al^{3+} in solution will be decrease and soil pH will increase (Plaster, 2004).

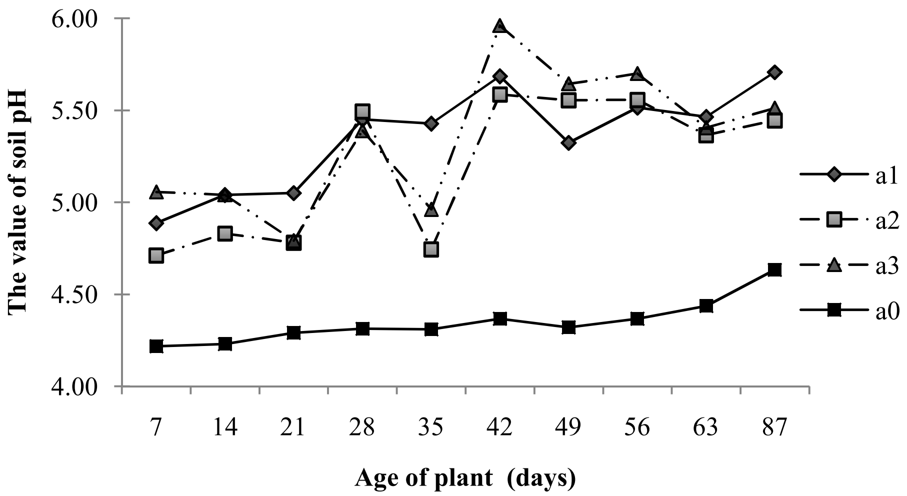

Figure 1. Soil pH of three soil amendments (a1=calcite lime, a2= husk charcoal and a3= maize cob biochar) at various plants age

Changes in soil pH during growth of sweet maize fluctuated since two weeks after application of soil amendment (sweet maize age of 7 days) until the sweet maize age of 87 days. The highest increase in soil pH occurred at the age of 42 days. Application of calcite lime (a1) caused an increase in the soil pH is relatively stable, compared with soil amendment derived from organic matter (a2, a3) (Figure 1).

Organic matters have variable charges. Functional group of organic matters can be positively and negatively charge depending on soil pH. Therefore, the ability to adsorb cations can also change, depending on the charge of soil complex (Havlin et al*.,* 2005). Sumarwoto (2004) reported that liming increased soil pH from 4.20 to 5.99, increased the availability of Ca and Mg, CEC, and decreased exchangeable Al 19.99 me/100g soil. Similarly, rice husk charcoal has high pH between 8.5 to 9 so it can be used to increase the pH of acid soils. The high soil pH gives the advantages because weeds and bacteria do not like the high pH. The use of rice husk charcoal as an organic fertilizer has a double advantage because it does not only supplying nutrients but also as soil amendment to improve soil properties. The results of this study showed that application of maize cob biochar was also able to increase the pH of acid soils equal to application of calcite lime. Masulili et al. (2010) reported that application rice husk biochar on acid sulfate soil increased the soil pH. The increase in soil pH occurred because the amount of exchangeable Al^{3+} decreased. Glaser et al*.* (2002) reported that the addition of soil amendment derived from organic matter in to the acid soil might have a positive effect that increase soil CEC and decrease toxicity of heavy metals present in the soil. This happens because the organic matters increase the soil negative charges derived from the carboxyl compounds, thereby reducing the solubility of heavy metals in the soil solution (Havlin et al., 2005; Shamshuddin et al., 2004). Hunt et al. (2010) pointed out that biochar is an organic material that is resistant to decomposition process. Therefore, biochar can survive for a long time in the soil. In addition, biochar also affects productivity through improved physical, chemical and biological soil properties (Chan et al., 2007). It has been widely reported that the use of biochar can increase soil pH and CEC (Liang et al., 2006; Yamato et al*.,* 2006).

Nutrient Availability

Results of analysis of variance showed that the interaction of soil amendment and doses significantly affected the availability of soil N, P and K. Application of 6-9 t maize cob biochar /ha gave the highest soil N and K contents, while the highest soil P content was found on treatment using 9 t rice husk charcoal /ha. All treatments were significantly different from control except for the soil N content with application of 3 t calcite lime /ha (Table 2).

Table 2. The Average of total soil N content, available P, and exchangeable K in the treatments of various soil amendments (a) and dose of application (d).

Treatment	Total soil N (%)	Available P (mg/kg)	Exchangeable K (me/100 g soil)
a_0d_0 (control)	0.10	20.010	0.147
a_1d_1	0.105^{ns} a	21.757^{*} a	0.200^{*} a
a_1d_2	0.108^{*} a	23.083^{*} a	0.217^{*} a
a_1d_3	0.123^{*} b	24.667^{*} b	0.257^{*} ab
a_2d_1	0.128^{*} bc	26.050^{*} b	0.250^{*} ab
a_2d_2	0.133^{*} c	29.433^{*} c	0.273^{*} bc
a_2d_3	0.141^{*} d	33.477^{*} d	0.287^{*} bc
a_3d_1	0.143^{*} d	21.873^{*} a	0.233^{*} a
a_3d_2	0.152^{*} e	22.107^{*} a	0.297^{*} bc
a_3d_3	0.156^{*} e	24.690^{*} b	0.327^{*} c
LSD 5%	0.005	1.759	0.057
Dunnet 5 %	0.004	1.560	0.050

Means followed by the same letters at each column are not significantly different (P=0.05)
ns = not significant at Dunnet test 5 % * = significant at Dunnet test 5 %

The results of this study showed that the application of biochar improved nutrient availability in the soil. Biochar does not only increase soil pH but also hold nutrients in the soil directly through the negative charge on the surface area of the charcoal.

The negative charge can act as a buffer so that the application of biochar can improve the use efficiency of N fertilizer (Chan et al., 2007). Thus, rice husk charcoal and biochar can serve as soil conditioners that can retain nutrients, so reducing the loss of nutrients due to leaching processes in the soil. Biochar derived from crop residues can also act as a nutrient source.

The relationship between soil pH and soil nutrient availability

Soil nutrient availability is affected by several factors such as total nutrient supply, soil moisture and aeration, soil temperature, and soil physical and chemical properties. One of the soil chemical properties influencing soil nutrient availability is soil pH. According to Siringoringo and Siregar (2011), the increase in the pH of acid soils can increase availability of nutrients for plant growth. Figure 2 shows the relationship between the pH of the soil with nutrient availability due to the application of three kinds of soil amendment. In general, the relationship between soil pH and soil nutrient availability follows a linear pattern. This means that the higher the pH of the soil, the higher is the availability of soil nutrients. The pattern of this relationship occurs because the increase in pH due to application of soil amendment has not reached a pH of 6.5, so the availability of nutrients is continuously expanding. The largest amount of essential nutrients is available in the range of pH between 5.2 and 6.5. Above and below this range, most nutrients are strongly bound by soil particles such as Fe and Mn oxides and they become unavailable to plants (Plaster, 2004). The greatest effect of soil pH on nutrient availability was indicated by the relationship between soil pH and soil K content (Figure 2). The availability of potassium (K) including base cations will increase with increasing pH of the soil. Brady and Weil (2004) stated that largest increase of soil K occurred at pH 6.5, whereas the optimum N availability occurred at pH 5.5.

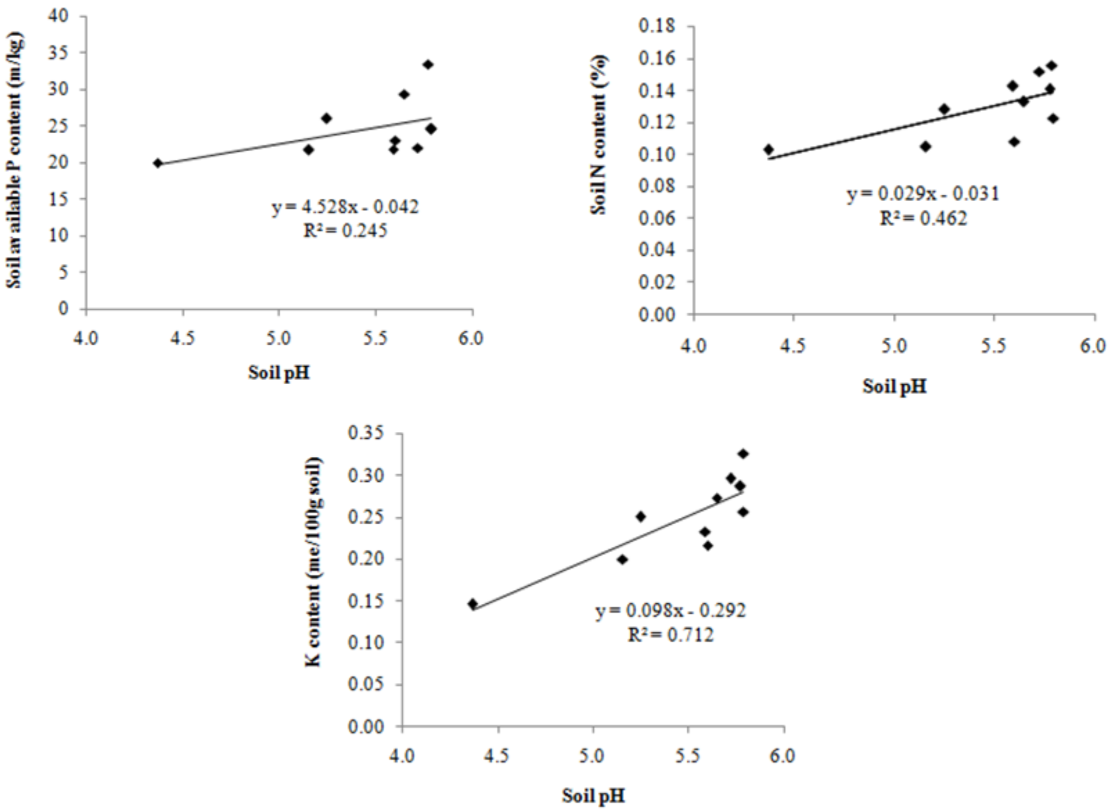

Figure 2. Relationship between soil pH and availability of soil nutrients.

Effect of soil pH on soil P content was not significant and provide a low R^2 value (R^2 = 0.245). This is because the increase in soil pH that was caused by the application of soil amendment only reached pH 5.5, where at the pH value; P availability was still relatively low due to the high availability micronutrients resulting in P fixation by Al, Mn and Fe. Optimum nutrient availability for plants is in the range of pH 5.0 - 7.5, but each plant has a specified optimum pH range. If the soil pH is above or below this range, the amount of nutrients will be imbalanced. The availability of essential nutrients is too high at a low pH such as Al and Mn, may be toxic for the plants, but if the nutrient availability is too low can causes nutrient deficiency in plants (Fernández and Hoeft, 2012). Thus, the pH value of the soil can be used as an indicator of soil chemical fertility, because it can reflect the availability of nutrients in the soil.

Maize Yields

The results of this study showed that the application soil amendments application significantly affected the yields of sweet maize. When compared with the control, the average increase of yield was 30% for all treatments. The high yields of sweet maize cobs between 59.5-63.1 g/plant was found in the rice husk charcoal and maize cob biochar treatment at a dose of 6-9 t/ha (Figure 3).

The positive impact of biochar applications include: retain nutrients in the soil, increasing the cation exchange capacity and soil pH, decreasing the absorption of soil toxic materials, improve soil structure, increase nutrient use efficiency, water holding capacity, reduce emissions of CO_2 and other greenhouse gases (CH_4, N_2O), and increase the population of beneficial soil microbes (Krishnakumar et al., 2013). Siringoringo and Siregar (2011) reported that biochar is able to hold nutrients in the soil directly through the negative charge on the surface area of the charcoal. With the increase in soil pH and soil nutrient availability due to the soil amendment application, the plants will be able to produce optimally, because the plant-growing medium can provide better conditions.

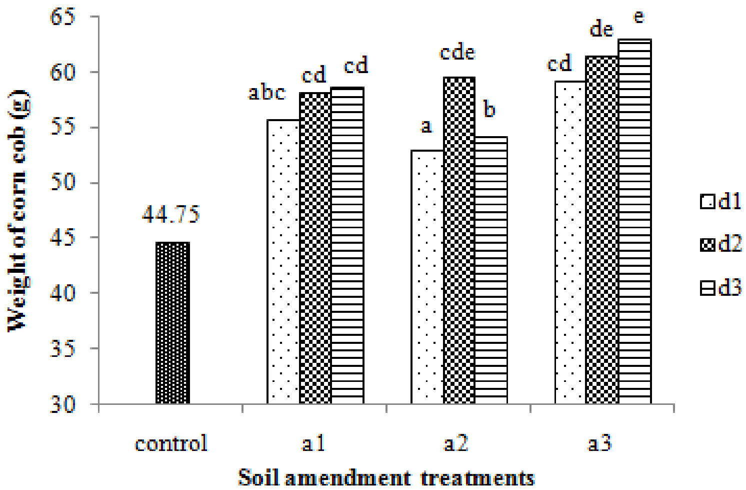

Figure 3. Effect of the soil amendment and dose of application doses on weight of maize cob (LSD 5% = 3.99)

The relationship between the nutrient availability and sweet maize yield

Compared to the control, application of calcite lime, rice husk charcoal, and maize cob biochar increased N availability by 9%, 30%, and 46%, P availability by 16%, 48%, and 14%, and K availability by 53% , 84%, and 94%, respectively. The increased nutrient availability was followed by the increase in yield of sweet maize. The relationship between soil N content and maize cob yield followed a linear pattern. It means that the higher N content of the soil, the higher is the weight of maize cobs, while the relationship between P and K content and maize cob yield followed a quadratic pattern (Figure 4). Based on the regression equation relationship between soil P and K with maize cob yields, the soil content of P and K gave a maximum maize cob yields was at soil P content by 27.2 mg/kg and soil K content by 12.27 me/100 g soil. Plants obtain nutrients and water from the soil through the roots system. However, increased soil nutrient availability does not always increase crop yields because there are many factors affecting the growth and activity of plant roots to absorb nutrients that can limit the uptake of plant nutrients. Understanding of other factors that cause nutrient deficiency in plants is important to avoid excess nutrients due to fertilizer application.

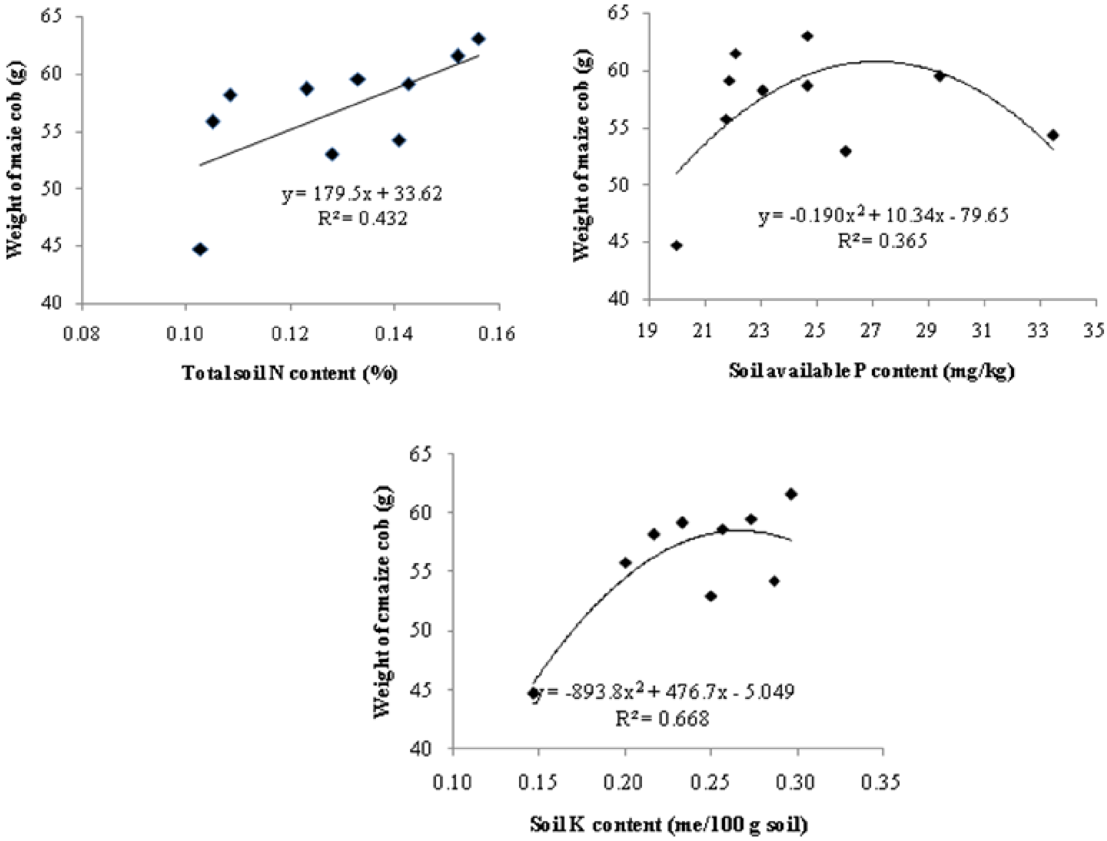

Figure 4. Relationship between availability of soil nutrients and yield of maize cob.

Conclusions

Application of various soil amendments on acid soils can improve soil fertility due to the increase in soil pH, which in turn increases nutrient availability in the soil. The increase of soil pH due to the application of biochar is able to be equally the beneficial effects caused by liming. The average of the increase in the soil pH for each soil amendment treatment was 23% (calcite lime), 20% (rice husk charcoal), and 23% (maize cob biochar) as compared to controls. The increase in soil pH increased the availability of N, P and K. The relationship between the N availability and maize cob yield followed a linear equation, while the relationship between the availability of P and K with the maize cobs yield followed a quadratic equation. The highest sweet maize cobs yield was found in the application of biochar and rice husk charcoal with a dose of 6-9 t/ha. The results of this study suggested that biochar and rice husk charcoals could be used as alternative lime materials for acid soils to improve soil fertility and productivity.

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Research Article

Food security and vulnerability modeling of East Java Province based on Geographically Weighted Ordinal Logistic Regression Semiparametric (GWOLRS) model

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Abstract. Modeling of food security based on the characteristics of the area will be affected by the geographical location which means that geographical location will affect the region's potential. Therefore, we need a method of statistical modeling that takes into account the geographical location or the location factor observations. In this case, the research variables could be global means that the location affects the response variables significantly; when some of the predictor variables are global and the other variables are local, then Geographically Weighted Ordinal Logistic Regression Semiparametric (GWOLRS) could be used to analyze the data. The data used is the resilience and food insecurity data in 2011 in East Java Province. The result showed that three predictor variables that influenced by the location are the percentage of poor (%), rice production per district (tons) and life expectancy (%). Those three predictor variables are local because they have significant influence in some districts/cities but had no significant effect in other districts/cities, while other two variables that are clean water and good quality road length (km) are assumed global because it is not a significant factor for the whole districts/towns in East Java .

Keywords *: East Java , food security, GWOLRS*

Introduction

The need for food is a basic human need is most essential and must be met by the state and society. Law No. 7 of 1996 on Food, defines food security as food for the fulfillment of the condition of each household, which is reflected in the availability of sufficient food, both quantity and quality, safe, equitable, and affordable. Understanding of the food security include macro aspects, namely the availability of sufficient food and at the same micro aspects, namely the requirement for food every household to live a healthy and active life. At the national level, food security is defined as the ability of a nation to ensure that all its inhabitants obtain sufficient food, decent quality, safe, and based on the utilization and optimization based on the diversity of local resources.

The problem of food security is an issue that is not being resolved. Multidimensional problem that is faced by the sub-systems of production, distribution sub-systems, sub-system of consumption. Under the identification map Food Security and Vulnerability Assessment 2009 (Food Security and Vulnerability Atlas / FSVA 2009) conducted by the Food Security Council (DKP) looks 100 districts identified food insecurity, the 94 districts of which are outside of Java. Only six districts on Java identified food insecurity which consists of one county located in Banten, and five districts in the province of East Java regency of Sampang Sumenep, Pamekasan, Bangkalan and Probolinggo. It is interesting to recall studied East Java is one of the provinces with the second highest GDP after Jakarta and is one of the national granaries because it has the second largest rice production in West Java, but there are still food insecure areas. Modeling on food security is built based on the characteristics of the area that would be affected by the geographical location among regions. This is due to differences in geographic location that would affect the potential possessed by a local. Therefore, a method of statistical modeling is needed that take into account to the geographical location or the location factor observations. Such a statistical method that is developed to explain the relationship between the response variable and predictor variables that depend on the geographic area is Geographically Weighted Regression (GWR) (Fotheringham, Brundson and Charlton, 2002). When the response variable is categorical in ordinal scale, the method used is Geographically Weighted Ordinal Logistic Regression (GWOLR). In reality, not all of predictor variables in the model have the effect of spatially GWR. Several influential predictor variables are globally, while others can maintain the spatial effect. Then the model developed is Geographically Weighted Ordinal Logistic Regression Semiparametric (GWOLRS)

Nakaya et al. (2005) explained that GWOLRS is one of the model that consider the geographical factors as predictor variables in ordinal variable and there are parameters that are influenced by location (varying coefficient) and other parameters that are not affected by location (fixed coefficient). In GWOLRS models, the response variable Y is predicted by calculating the odds of each category *a* where the calculation involves the regression coefficients $\beta_g(u_i,v_i)$ that depend on the location and γ_m regression coefficients that is constant. GWOLRS models for the i-th location is as follows

$$logit\,[P(Y_i \le a|x_i)] = \alpha_a\,(u_i,v_i) + x_i^{*T}\beta^*(u_i,v_i) + x_i^{**T}\gamma$$

where $a = 1,2,\ldots,A-1$, and u_i, v_i is *latitude* and *longitude* for the i-th location.

Based on equation above, the cumulative odds for a category *a* is:

$$P(Y_i \le a|x_i) = \frac{\exp\,[\alpha_a\,(u_i,v_i) + x_i^{*T}\beta^*(u_i,v_i) + x_i^{**T}\gamma]}{1+\exp\,[\alpha_a\,(u_i,v_i) + x_i^{*T}\beta^*(u_i,v_i) + x_i^{**T}\gamma]}$$

Based on ordinal logistic regression parameter estimation, the estimation of parameters of GWOLR can also be performed using Weighted Maximum Likelihood Estimator (MLE) (Hosmer and Lemeshow, 2000).

The function of the weighting is to give the results of estimation of different parameters at different locations. Euclidean distance (d_{ij}) between the location of the i-th and j-th location be calculated by using following equation (Leung, et al., 2000):

$$d_{ij} = \sqrt{(u_i - u_j)^2 + (v_i - v_j)^2}$$

Fixed Bisquare Kernel weighting function can be expressed as follows (Chasco, et al., 2007):

$$W_j(u_i,v_i) = \left[1 - \left(\frac{d_{ij}}{h}\right)^2\right]^2 \text{ for } d_{ij} \le h$$

$$W_j(u_i,v_i) = 0 \text{ for } d_{ij} \le h$$

Food security has nothing to do with food insecurity. Food insecurity means food insufficiency in a condition experienced by a region, community or household at a specific time to meet the physiological needs for growth and public health (Ariningsih and Rahman, 2008). Hence, discussing food security and food insecurity is discussing anything that causes food needs that are fulfilled or not.

Bogale and Shimelis (2009) have analyzed and did mitigation of food insecurity in Indonesia. Food insecurity is not just a question of food availability; this is shown from the amount of energy and protein availability nationally that has exceeded the recommended levels, but there are still problems arising with malnutrition and starvation. Access to food is as important as the availability of food itself. One of the elements in the distribution of food access is the visibility of the transportation infrastructure, warehousing, market, and most importantly, people's purchasing power. It should also be encouraged about food diversification, as there is stagnation in rice production and decreasing of farmland.

Material and Methods

The data used in this study is secondary collected in Susenas (National Socioeconomic Survey) module three annually consumption in 2011 and other secondary data collected by BPS (Central Bureau of Statistics). The area is the province of East Java that includes 38 counties and cities. Food security indicators used are the percentage of poor (X1) , the production of rice (X2), life expectancy (X3), clean water (X4), the long road of good quality and moderate (X5) with variable Y (0 = hold, 1 = prone, 2 = less, 3 = vulnerable).

Steps GWORLS modeling

1. Determine predictor variables that are global and local variables
2. Calculate the weighting matrix $W(u_i,v_i)$ using weighting function Fixed Bisquare Kernel ,which is the euclidean distance between the insert Regency/City and optimum bandwidth for the whole District/City obtained from the method of Cross Validation (CV) .

3. Perform parameter estimation using Maximum Likelihood Estimation (MLE) and the weighted significance testing GWOLRS model parameters $(\beta^*(u_i, v_i)$ and $\gamma)$ stimulant and partial.
4. Form the model for the case GWOLRS Food Security in East Java in 2011 and interpretation of the model formed .
5. Do the assumption of non multicollinearity and spatial heterogeneity.

Results and Discussion

There was no multicolinearity among the predictor variables as VIF statistic that was more than 10, so it could be continued to build such a logistic regression model. Besides, there was spatial heterogeneity in the data so that GWOLRS should be used. The next step, based on the testing parameters simultaneously that obtained the test statistic greater than the critical value (19.152 > 12.01), it can be concluded that food security indicators that are local (influenced by the location) and global (not influenced by location factors) jointly affect food insecurity in East Java in 2011. Among 37 regions, let us see the analysis result of parameter estimation and the test statistic of Batu as a sample in Table 1.

Table 1. Analysis result of GWOLRS for Batu City

Para-meters	Estima-tion	*Standard Error*	Wald test
α_1	-22.6417	14.5169	-1.5597
α_2	-18.1568	14.0062	-1.2963
β_1	-0.1726	0.1009	-1.7101*
β_2	0.4218	0.1032	2.6487*
β_3	0.3818	0.1821	2.0966*
γ_1	-0.0473	0.0530	-0.8918
γ_2	0.0010	0.0006	1.5754

GWOLRS model for food insecurity in Batu were:

$$logit\,[P(Y_i \le 1|x_i)] = -22.6417 - 0.1726X_1 + 0.4218X_2 + 0.3818X_3$$
$$logit\,[P(Y_i \le 2|x_i)] = -18.1568 - 0.1726X_1 + 0.4218X_2 + 0.3818X_3$$

The three-predictor variables that were local or influenced by the location, i.e. the percentage of poor in East Java Province (%), rice production per district (tons) and life expectancy (%). The third predictor variable was local because it had a significant influence in some districts/cities but had no significant effect to the another districts / cities to, while the other two predictor variables, those are clean water and good quality road length (km) are assumed to be global or not affected by location because it is not a significant factor for the whole district/town in East Java.

Table 2 Odd Ratio GWOLRS Model for Batu City

Parameter	Prediction Value	*Odd Ratio*
β_1	-0.1726	0.8415
β_2	0.4218	1
β_3	0.3818	1.4649

Value of the odd ratio that was less than 1 for a variable percentage of the poverty level (%) indicated that the lower the percentage of the poverty level (%) in Batu then classified categories tendency Batu City, District / City resistant food would be lower. The odd ratio value of more than 1 for rice production variables and life expectancy indicated that higher rice production and life expectancy then the tendency Batu City, Batu City classified food secure higher category.

Food security indicators that significantly based models in Batu GWOLRS not necessarily have a significant effect in the District / City another. Based on the results of testing the model parameters partially GWOLRS then produced two groups of districts / cities in East Java is based on similarity of predictor variables or indicators of food security is a significant effect on food insecurity in 2011. Table 3 is a grouping table regency / city in East Java by significant predictor variables in each region.

Table 3. Grouping regencies based on Variables significant predictor's variables

Regency	Significant Variables
Ponorogo,Trenggalek, Tulungagung, Blitar, Kediri, Malang, Lumajang, Jember, Banyuwangi, Bondowoso, Situbondo, Probolinggo,Pasuruan, Sidoarjo,Mojokerto, Jombang, Nganjuk, Madiun, Ngawi, Bojonegoro, Tuban, Lamongan, Gresik, Bangkalan,Sampang, Pamekasan,Sumenep, Kediri City,Blitar City, Malang City, Pasuruan City, Mojokerto City, Madiun City, Surabaya City, Batu City,	X_1, X_2 , X_3
Pacitan, Magetan	X_2 , X_3

Based on the map of resilience and vulnerability in East Java province in 2011, the analysis results of model predictions by GWOLRS in East Java in 2011 showed that there were 19 districts should be grouped as experiencing food susceptibility. Those districts were Ponorogo, Trenggalek, Tulungagung, Blitar, Malang, Jember, Banyuwangi, Pasuruan, Sidoarjo, Mojokerto, Jombang, Nganjuk, Magetan, Ngawi, Bojonegoro, Lamongan, Gresik, Blitar, and Mojokerto. For the 18 counties that grouped as less food are Pacitan, Kediri, Lumajang, Bondowoso, Situbondo, Probolinggo, Madison, Tuban, Bangkalan, Pamekasan, Sumenep Kediri City, Malang City, Probolinggo City, Pasuruan City, Madiun City, Surabaya City, and Batu City. Only Sampang area that could be defined as a region in food insecurity.

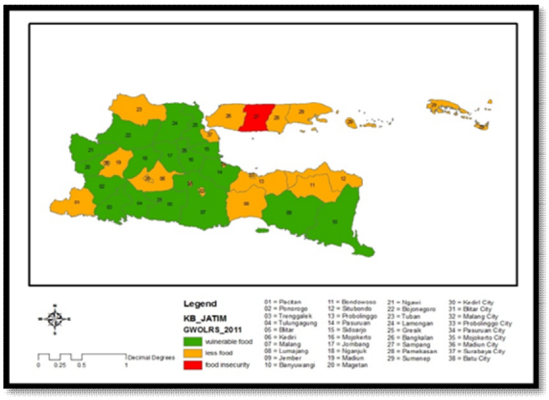

Figure 1. The map of food insufficiency

Predictions for each category of food insecurity regencies / cities in East Java based methods GWOLRS obtained by calculating the odds of each category of food insecurity in each district / city and define the category with the greatest opportunities. The food insecurity classification based GWOLRS models is presented in Table 4.

Table 4. The classification of Food Insecurity in East Java

Actual	**Prediction**			**Classification accuracy**
	1	**2**	**3**	
1	12	5	0	70.58%
2	7	11	0	61.11%
3	0	2	1	33.33%
Total				**63.16%**

APER values were obtained based on the classification table is equal to 34.84%. This value indicates that the percentage of samples incorrectly classified by the model is equal to 34.84% GWOLRS or in other words the exact percentage of samples classified by the model GWOLRS amounted to 63.16%. Testing the assumption of non-multicollinearity yielded the decision that there was no multicollinearity in the data because the VIF value for each predictor variable-value was below 10. Therefore, that data can be modeled using logistic regression models. Testing spatial heterogeneity resulted to the decision that there is diversity in each spatial data, so the data can be modeled using the model GWOLRS.

Conclusion

In 2011, there were three predictor variables that were influenced by the location: the percentage of poor in East Java Province (%), rice production per district (tons) and life expectancy (%). The other two predictor variables, e.i. clean water and good quality road length (km) were assumed to be global or not affected by location because it was not a significant factor for the whole District / town in East Java. The GWORLS model yielded high accuracy (63.16%) in the classification on food insecurity. It is still needed a further research to determine other indicators of food insecurity classification and food insecurity map in East Java province.

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Research Article

Mitigation of land degradation at Juana Watershed, Central Java

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Abstract: Land degradation became more and more widespread, especially in areas with a dense population and dependence on agriculture is high enough. Land degradation can be approximated by the susceptibility of land to erosion. This study aims to identify existing land degradation in the Juana watershed, Central Java. The method used is the analysis of the typology of the watershed. This method is based on the interaction between landforms and land cover. The results showed that the degradation of land in the watershed very heavy scattered in the upstream areas in the territory of the Kudus and Pati regency. While severe land degradation are also scattered in Kudus, Pati, and Blora regency. Almost all of these degraded areas are used for dry land farming. By knowing the rate of spread of land degradation, the authority having jurisdiction in this district offices on issues related to land degradation can plan the actions necessary to resolve or mitigate land degradation in each region so that a major disaster will not happen or the impact can be minimized.

Keywords: *land degradation, typology, Juana watershed*

Introduction

Widespread land degradation along with the growth of population incomes who depend on agriculture. An estimated 500 million people are subsistence farming in these marginal areas (Craswell et al. 1998). Higher population growth causes the land to more intensive processing that will eventually lead to problems of erosion, sedimentation and the formation of critical lands. Juana Watershed including one critical Watershed in Central Java. This watershed includes several districts in the northern part of Central Java. Treatment requires both the upstream-downstream integration, inter-sector and inter-district government. One of the problems in the watershed Juana is land degradation. In addition to causing declining land productivity, land degradation is also causing other environmental impacts such as flooding and drought.

The initial phase of a watershed management planning is the problem identification. The result of problem identification in a watershed can be used as one input for watershed planning by all stake holder in the watershed (Pramono et al. 2011). One of the problems encountered in the management of the watershed is land degradation. Land degradation can be estimated by the identification of susceptibility of land to erosion. The vulnerability of this area can be seen from the interaction between landforms and land cover (Paimin et al., 2012). Landform mountains with closure crops would be vulnerable to erosion, contrary to the plain landform forest land cover will not be susceptible to erosion.

Mitigation of land degradation should be done to reduce severe the environmental impact. The land should be covered by permanent vegetation, because the vegetation can protect soil surface from splash and sheet erosion through three layer such as canopy, litter, and soil pores, therefore runoff can be maintained (Pereira, 1989 in Asdak, 1995). In fact most of the degraded land cannot be planted by only permanent trees because the farmers need cash crops for daily lives. This paper aims to mitigate land degradation in the watershed Juana using watershed typology analysis.

Materials and Method

Research site locate in Juana watershed that covers an area of Pati, Kudus, Blora, Grobogan, and Jepara districts, Central Java Province. Materials used for this study were (1) The maps (hard copy and digital) scale 1: 50.000 - 1: 250,000, among others Indonesian Topographic maps, soil, geology, land use, RePPProT, (2). Landsat 2008, (3) Materials for printing maps and GIS data processing, (4) Blank survey field checks. Equipment used for this study were (1) Stationery, (2) GPS, meter, Abney level, (3) GIS Unit, and (4) Camera. Data analysis is directed according to the typology diagram watershed. Vulnerability of land obtained from the interaction between landforms and land cover. Each landform and land cover were scored. Form of swamp land were given a score of 1, whereas mountainous land forms were scored 5. Forest land cover were given a score of 1, while the closure of dry land were given a score of 5. Score the interaction between landforms and land cover can be seen in Table 1.

Table 1. Scale Vulnerability / Sensitivity Against Land Degradation.

Landform*	**Land cover**					
	Brsckish water, Fresh water, Building (1)	**Protected Forest, Conservation Forest (1)**	**Production forest, Estate Plantation, (2)**	**Paddy filed, grass, Shrubs (3)**	**Settlement (4)**	**Dry field, rocky soil (5)**
Marshes, Beach (1)	1	1	1	1	1	1
Alluvial palins, alluvial valley (2)	1	1.5	1.5	2	2	2.5
Plains (3)	1	2	2.5	3	3.5	4
Alluivial fan, and Lahar, Terrace (4)	1	2.5	3	3.5	4	4.5
Mountains and hills (5)	1	3	3.5	4	4.5	5

Results and Discussion

Biophysical Condition

Geographically Juana watershed in the position coordinates between 110 ° 49 '10 "- 111 ° 12' 57" East Longitude and between 6 ° 36 '48" - 6 ° 59' 29" South Latitude Juana watershed administratively includes five (5) districts namely Pati regency 97672.8 ha (74.91%), Kudus 28356.17 ha (21.75%), Blora 3411.96 ha (2.62%), Grobogan 941.71 ha (0.72 %), and the district of Jepara 8:59 ha (0.007%). The administration map of Juwana watershed is presented in Figure 1.

Slope steepness

Slope steepness of Juana watershed is dominated by flat areas with a form region that has a slope of 0-8%. This includes ± 75% of the watershed area of Juana. Areas with gentle slopes (8-15%) cover ± 10.38% region, rather steep slope (15-25%) covers an area of 7.9%, a steep slope (25-40%) covers 3.9% of the territory and the rest with a steep slope (> 40%) covers2.76% wide area. It can be said that 13.36% of the watershed area Juana is on a rather steep slope conditions up to very steep. This field slope rate affects the speed and erosive power of overland flow. In detail the condition of the slope basin Juana is presented in Table 1 and the distribution of slope in the watershed as shown in Figure 2.

Table 1. Slope class of Juana watershed

Class	Slope (%)	Area (ha)	(%)
I	0 - 8	97975.57	74.99
II	8 - 15	13567.59	10.38
III	15 - 25	10340.66	7.92
IV	25 - 40	5157.52	3.95
V	> 40	3608.11	2.76
	Total	130391.38	100.00

Soil Types

The type of soil in Juana watershed include Alluvial, Grumusol, Latosol, Litosol and the Mediterranean. The most dominating soil type is the type of Alluvial (58.25% of the territory). Alluvial soil types derived from alluvium parent material has a moderate to high fertility, it distributed in the river alluvial plain, coastal alluvial plains and basins. alluvial soil types are generally classified in the sub-group entisols with physiographic regions formed on flood plains. materials sediment carried by the river then deposited and accumulated in this area. Then followed by the type of clay texture latosol having up to blocky and crumb structure covers an area of 22.41%. in more detail the area of each soil type in the basin Juana presented in Table 2 and Soil Map in the watershed can be seen in Figure 3.

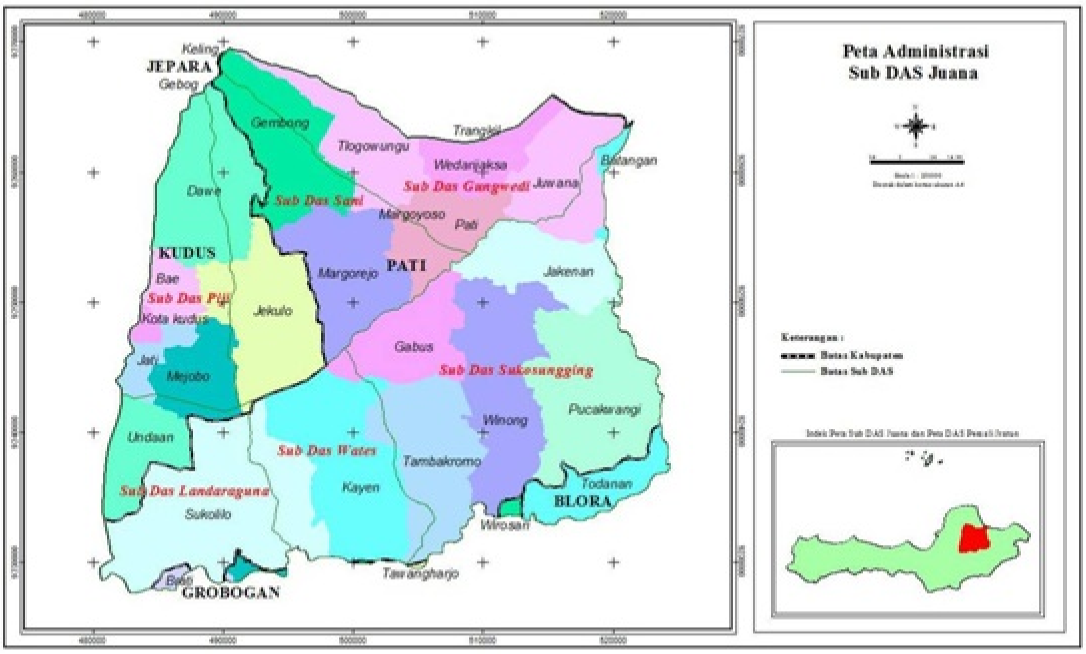

Figure 1. Administration Map of Juwana Watershed

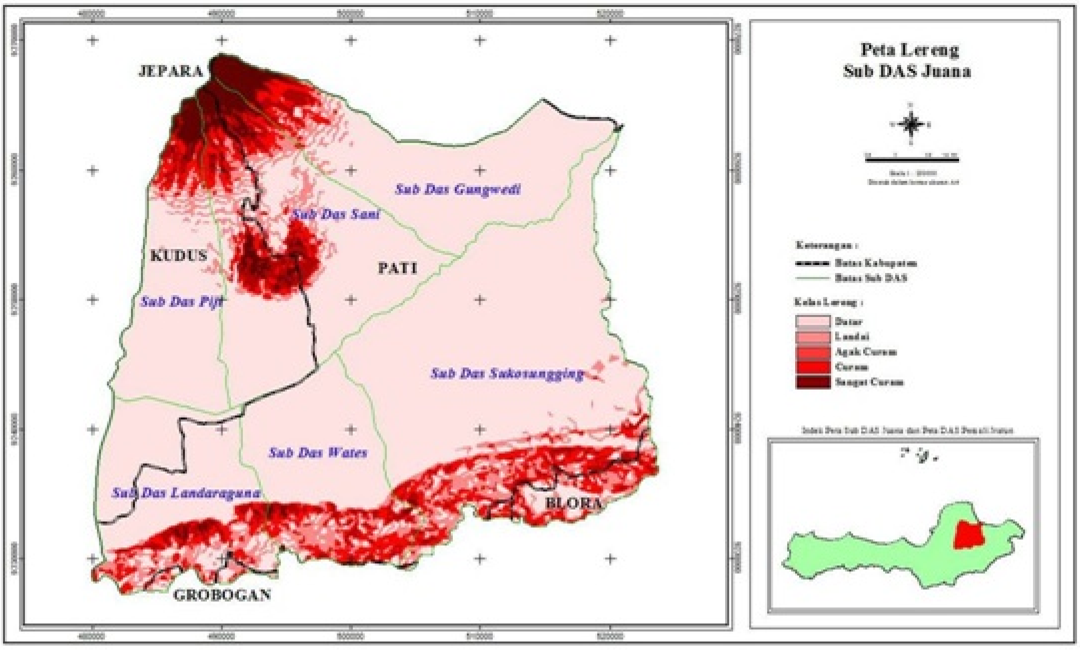

Figure 2. Slope Map of Juana Watershed

Table 2.The area of soil type in Juana watershed

Soil Type	Area (ha)	(%)
Aluvial	76097.32	58.25
Grumusol	2522.63	1.93
Latosol	29276.89	22.41
Litosol	11595.45	8.88
Mediteran	11146.11	8.53
Total	130391.38	100.00

Source: BPDAS Pemali Jratun, 2006.

Geology

Based on the analysis of geological map, the type of rock in the basin Juana include alluvium, rock containing leusit, Miocene limestone facies, Miocene sedimentary facies, sedimentary facies Pliocene, Pleistocene volcanic facies and reservoir / lake. The extent of each type of rock Juana basin is presented in Table 3 whereas Geological Map of the watershed as shown in Figure 4.

Rainfall

The rainfall data obtained from observed existing stations in Juana watershed. The rainfall in this region ranges from 823 mm / year up to 3,341 mm / year with an average of 2.522 mm / yr, the number of rainy days ranged between 87 days / year to 146 days / year. The highest rainfall usually occurs between October to April.

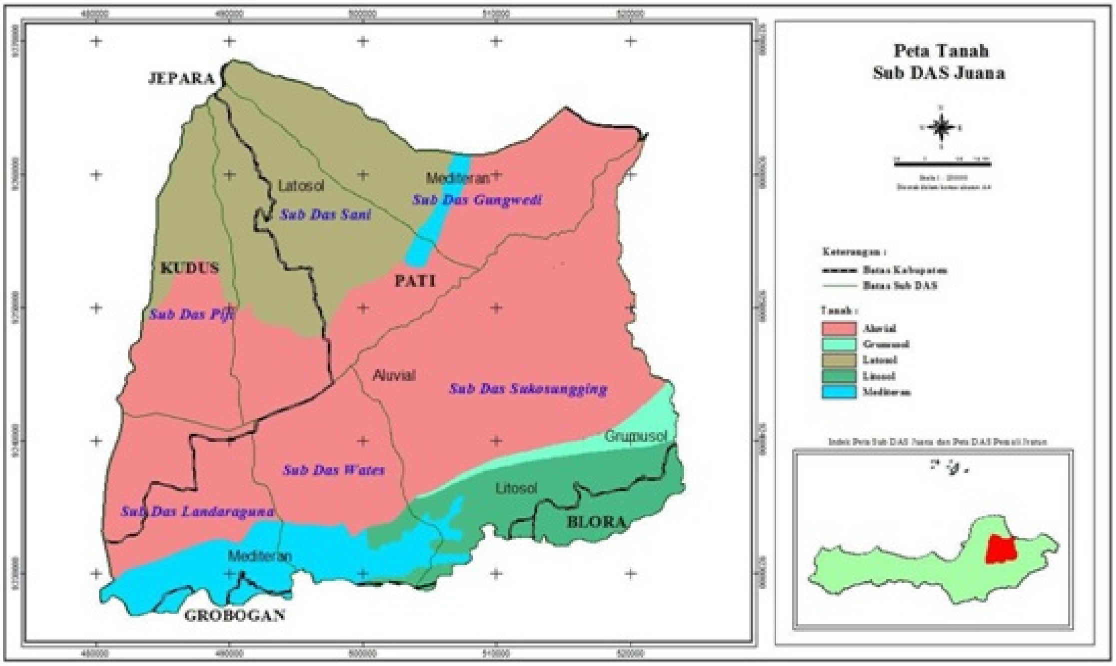

Figure 3. Soil Map of Juana Watershed

Table 3. Rock Types of Juana Watershed

Rock Types	Area (ha)	(%)
Aluvium	67194.41	51.44
Rock containing leusit	36034.18	27.58
Miocene limestone facies	11850.96	9.07
Mioses sedimentary facies	6409.32	4.91
Pliocene sedimentary facies	6324.41	4.84
Plistocen volcanic facies	2656.48	2.03
Total	130391.38	100.00

Source : BP DAS Pemali Jratun, 2006.

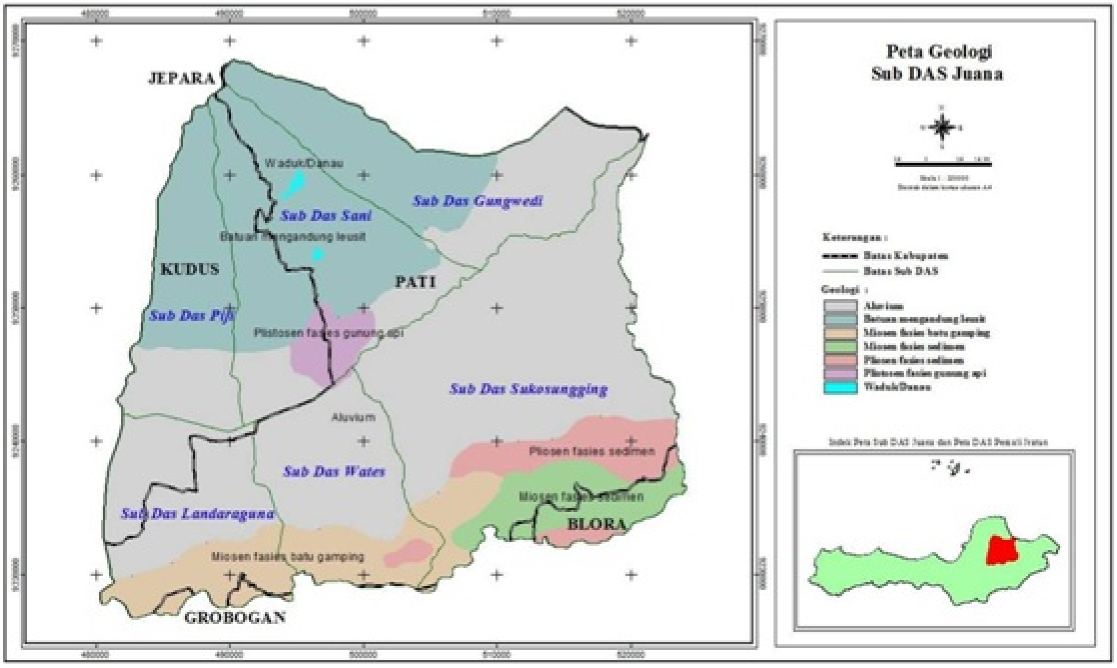

Figure 4. Geological Map of Juana Watershed

Mitigation of Degraded Land at Juana Watershed

Land system

The division of the land system describes the shape, description of the parent material, rock type, soil type, slope, annual rainfall, wet months and dry months. Under the system of land, divided into 10 watershed Attack land system are: KHY (Kahayan), MKS (Napier), BRN (Bogoran), LTG (Loud), KJP (Kajapah), HBU (Hiliboru), KLG (Necklace), BMS (Masung hill), BOM (Bombong), BRI (Bonto Sapiri), and WDK (Reservoir). Land in the watershed system deployment Attack can be seen in Figure 5.

Land Cover

Types of land cover in the watershed varies from Paddy Field, Rainfed rice fields, dry land, Estate Plantations, Forests, Settlements, Salting, grassland, scrub and others. The most extensive land cover in the watershed is use for irrigated rice field which covers 45.41% of the territory, then the use of land to dry land covers an area of 13.94%. land use such as forests covering an area of 1.22%. in more detail the area of each land use in the watershed presented in Table 5 and the distribution of the land cover as shown in Figure 6

Table 5. Land Cover in Juana Watershed

Land cover	Area (ha)	(%)
Forest	1597.44	1.22
Estate Plantation	15239.90	11.68
Dry land	18186.62	13.94
Irrigated Rice	59252.45	45.41
Rainfed	10928.31	8.38
Grass	1022.20	0.78
Settlement	17485.58	13.40
Building	39.90	0.03
Dam	3170.13	2.43
Salting	30.55	0.02
Fresh water	318.75	0.24
Bush	3080.15	2.36
Total	130391.38	100.00

Sources: BP DAS Pemali Jratun, 2006.

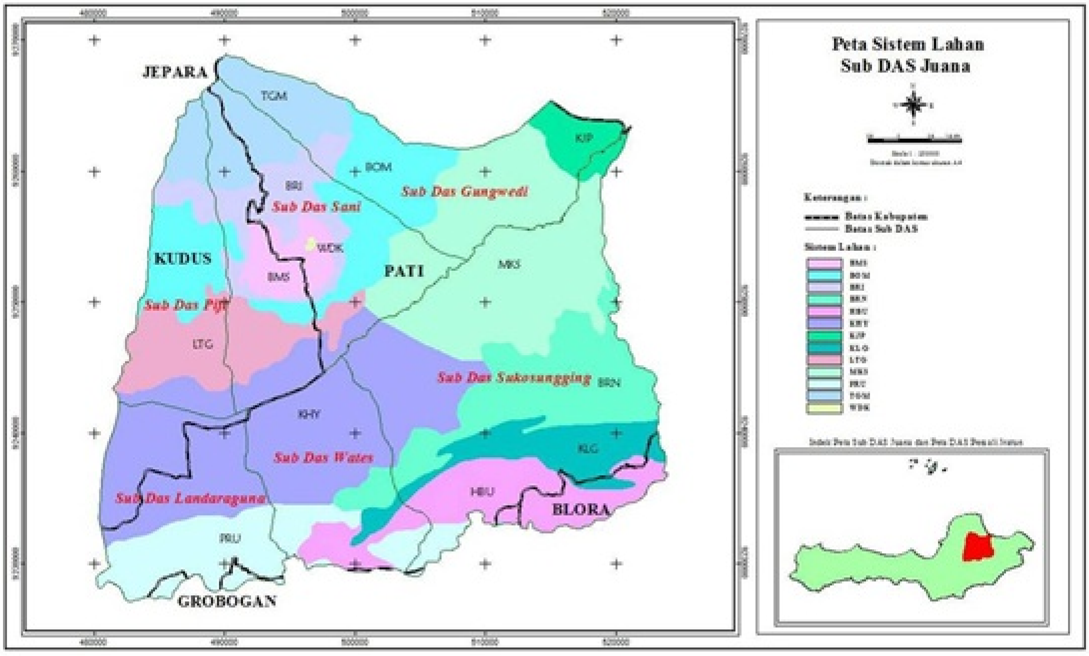

Figure 5. Land System Map of Juana Watershed

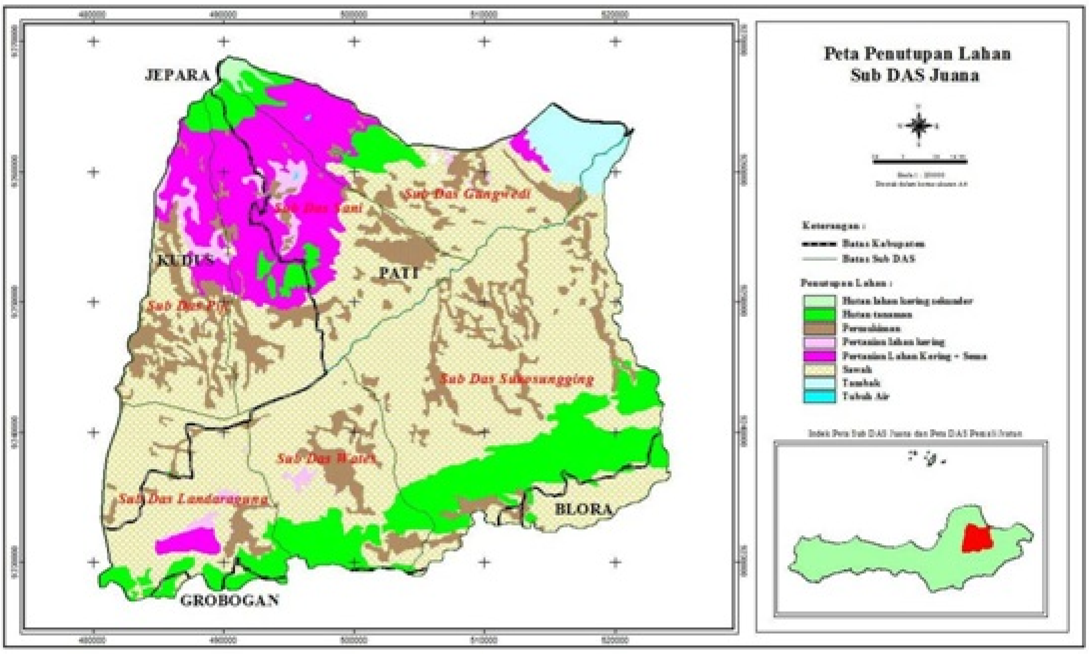

Figure 6. Land cover map of Juana watershed

Land Susceptibility

One of the factors that cause degradation of natural resources in the Juana watershed is a land utility. Optimal land productivity and sustainable land use will be achieved when adapted to the ability of carrying capacity. Most of the degraded land in Juana watershed occurred in the upper part where the slope is steep (25 – 40 %) and the land was utilized for dry land agriculture. Consequently, soil erosion will severe and the land will be unfertile. The most degraded land took place in Kudus and Pati regency. Furthermore, degraded land also occurred in Grobogan dan Blora regency but it less severe than in Pati and Kudus regency as shown in Figure 7.

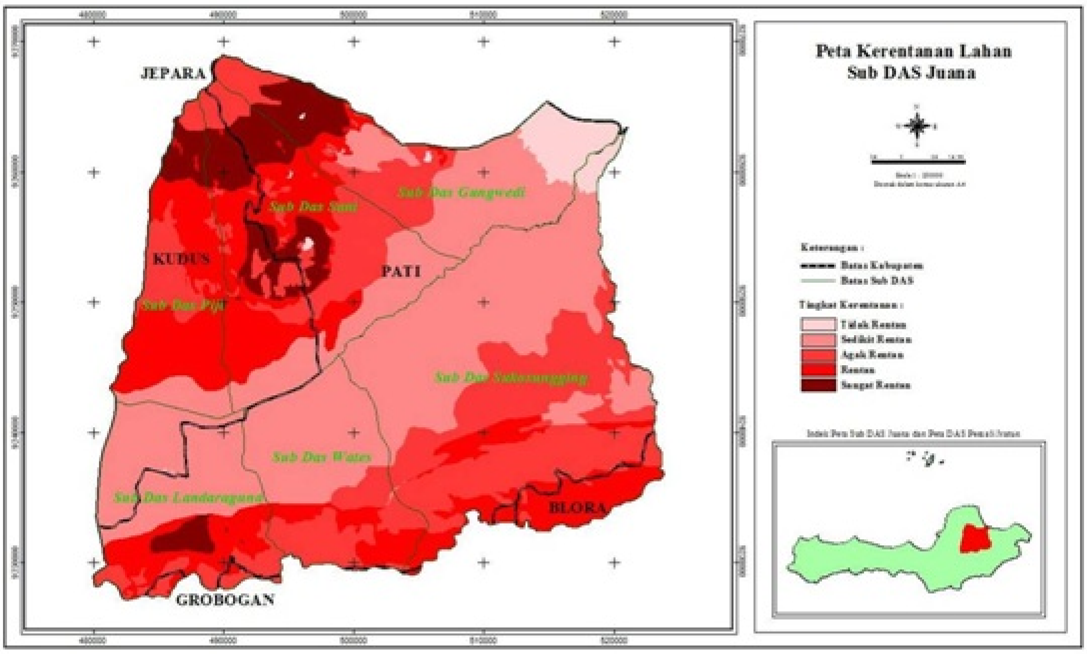

Figure 7. Land Susceptibility Map of Juana Watershed

Based on Figure 7, the local government of Kudus and Pati district should pay attention on their heavy degraded land. They have to collaborate to solve the problem because the heavy degraded areas are located in their administrative border. One of alternative solution is introducing agroforestry system where the land is cultivated mixing between tree and cash crops. Alwi et al. (2011) mentioned that plantation of cocoa, orange, pepper, bananas, and maize can reduce soil erosion and surface runoff in South East Sulawesi. The farmer and local government should determine the most suitable tree and cash crops in their land. Some soil conservation measure should be applied in certain areas where slope steepness is high. Although district of Blora and Grobogan have small contribution area in Juana watershed, they should rehabilitate their degraded land because the impact will influence in lower part of the watershed.

Conclusions and Recommendations

1. Land degradation in the watershed Juana is heavily spread into the upstream area of the Kudus and Pati Districts. Almost all of these degraded areas are used for dry land farming.
2. The impact of degraded land is not only on the land itself, but is also on the lower part of the watershed. Therefore, watershed analysis unit is the most appropriate technique for the mitigation of land degradation.
3. Handling of degraded lands can be started from a very vulnerable land in each district.
4. By knowing the rate of spread of land degradation is the authority having jurisdiction in this district offices on issues related to land degradation can quickly plan the actions necessary to resolve or mitigate land degradation in each region so that no greater disaster will occur.

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Research Article

Growth and yield of wheat (*Triticum aestivum*) adapted to lowland Lombok Island as an alternative food crop for dryland

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Abstract: Wheat is not currently grown as a commercial crop in Indonesia, however since the consumption of wheat in Indonesia is steadily increasing and alternative of dry season crops are required for farming system diversification, wheat becomes an important crop to be adapted in dry land areas of Indonesia, one of them is dry land area of Lombok Island. The aims of this experiment is to adapt and screen wheat varieties including national and introduced Australian varieties in lowland Lombok Island. In future, wheat is expected to be an alternative crop for degraded lands. The experimental method used to evaluate growth and yield of 10 wheat varieties to look at the adaptability on the lowland of 200 m asl (Pringgarata) and on higher land of 400 m asl (Aik Bukak). The results showed that at a lower altitude (Pringgarata), wheat growth is slower than in Aik Bukak, which can be caused by the temperature at 200 m asl has exceeded the tolerance limit for grain growth (supra optimal temperature). Wheat can give good yields on 400 m asl, but the yield is decreased at 200 m asl (average 1.68 t/ha vs 0.82 t/ha). This low yield is mainly due to sterility indicated by the low number of grain/spikelet (<2 grain/spikelet). There is genetic variation of wheat crop responses adapted to the lowlands. Nias, Dewata, Mace and Estoc give good yields (> 2 t/ha), higher than other varieties .

Keywords: *adaptation, dryland, Lombok Island, lowland, wheat*

Introduction

Wheat (*Triticum aestivum*) is a sub-tropical cereal commonly grown at latitudes 25 ° N / LS to 50 ° N / LS, but the cultivation of wheat to the tropics has been started up to latitude 15 ° N / S (Music and Porter, 1990). In Indonesia, wheat consumption has increased rapidly lately that wheat imports in 2012 reached 7.4 million tons (Siregar, 2012). The development of instant noodles, bread and snacks are very fast, especially for the urban areas encouraged flour consumption in Indonesia is high. To meet the needs of those made with wheat flour brought from wheat producing countries, such as Australia. Given the high number of the population, consumption increase of wheat flour and the advice of the government and needed to promote the diversification of sources of carbohydrates. Therefore, it is necessary to dig the potential of the wheat crop in Indonesia, including wheat crop adaptation efforts in areas that are potential for development, such as on the Island of Lombok.

Lombok Island (8.5ºS, 116ºE) has good potential areas for the development of wheat plants (Gusmayanti et al., 2006). Although most of the area is rain-fed, but wheat can adapt well on dry land where rice cannot well survive. Lombok island topography varies with the edges around the lowland islands and highlands in the north-central part of the Mt. Rinjani as the highest peak. Wheat plants can be used as an option to enrich the diversity of food crops on less irrigated land and is expected as an alternative crop in degraded lands. Previous experiments conducted in 2010 and 2011 showed that the Australian wheat crop could produce well with a yield of about 3 t / ha when planted at an altitude of about 1000 m above sea level (Zubaidi et al., 2011). Efforts of extending through the expansion of the wheat planting area to lower ground needs to be done, considering the plateau should be more suitable for the cultivation of wheat is an area that has long been used for the cultivation of vegetables and other horticultural crops. For that also needs to be tested wheat varieties suitable lowland. This study was aimed to select wheat varieties that are adapted to agroecology of Lombok in order to develop optimum wheat production. This study is expected to set the location of the minimum altitude for planting wheat with adequate results and the selection of appropriate varieties.

Materials and Methods

Determination of the locations used in this study is based on the altitude from the sea level: ± 200 m above sea level (Pringgarata, District Pringgarata Central Lombok) and ≥400 m above sea level (Aik Bukak, Batukliang District of North Central Lombok). Two wheat varieties from Indonesia (Nias and Bali) and eight wheat varieties from Australia (Axe, Gladius, Correl, Estoc, Espada, Mace, Scout and Cobra) were used for this study of each site. All wheat varieties from Australia used for this study were the spring types that do not require a cold treatment (vernalisation) for flowering. Each wheat variety was grown on a 1.5x4 m plot. Seeds were planted in five rows with 30 cm distance between rows. In each plot, 1000 seeds were planted or 250 seeds per row. The ten treatments (two wheat varieties from Indonesia, and eight wheat varieties from Australia) were arranged in a randomized block design with three replicates. Tillage was done by plowing and harrowing twice and then leveled the experimental blocks that consisting of 30 experimental plots at each experimental location. Planting was done on July 2, 2013 in Pringgarata and July 4, 2013 in Aik Bukak. Plant maintenance included fertilization, weed control and pest control, but disease control was not conducted. Plant harvest was conducted when 80% of the population of plants in experimental plots reached harvest criteria that are characterized by physiological ripe panicles, yellowish stems and leaves, and yellow and hard grains.

Observations were made on growth phase, number of leaves, leaf growth rate and phylochron, plant height, number of total tiller, number of productive tillers, flowering date, harvest date, number of panicles, number of spikelet per panicle, number of seeds, number of seeds per spikelet, weight 1000 grains, grain weight per m^2, yield, harvest index, and vulnerability index (susceptibility index). Growth phase was measured using Zadoks scale (Zadoks et al, 1974), while number of leaves was measured using Haun scale (Haun, 1973). Harvest index was calculated by comparing the results of economic crops (beans) with biological results (stover dry weight). Susceptibility index indicates the amount of yield loss caused by non-ideal environment (e.g. altitude) of a genotype relatively compared with all genotypes tested at the same stress index (Fischer and Maurer, 1978).

The experiment was conducted at two independent that are not related with one to another, then the data at each site were analyzed separately. Data were analyzed using Statistical Package GENSTAT (VSN International Ltd. United Kingdom). Least Significant Difference test was performed to differentiate the average varieties. Comparison of plant responses between the two experiments was shown by calculating the average of varieties and standard error of means.

Results and Discussion

The growth and development of plants

The growth of wheat leaves in Pringgarata was slower than that in Aik Bukak. On average, 0.15 parts of leaves grew daily in Pringgarata, while in Aik Bukak the leaves only grew 0.16 parts daily. Time required to grow one leaf (phylochron) in Pringgarata was 6.6 (± 0.11) days, while that in Aik Bukak was 6.2 (± 0.11) days. All varieties planted in Pringgarata tended to grow slower than that planted in Aik Bukak. This slow leaf growth might indicate the presence of high temperature stress (Midmore et al., 1984). However, the number of leaves in the two sites was not significantly different (Table 1). In general, wheat growth is driven by an increase in ambient temperature (Slafer and Rawson, 1994b). The temperatures in Pringgarata seem already beyond the limit of tolerance adaptation of wheat varieties studied. This made the growth became slower (Summerfield et al., 1991).

Growth of plant height in Aik Bukak and Pringgarata did not differ. The difference in growth occurring between varieties indicated that genetic factors were more influential than environmental factors. There were no differences in the growth of the wheat crop and Pringgarata and Aik Bukak, except for varieties with slow growth (Scout, Cobra and Estoc). The growth of plants in Pringgarata was slower than in Aik Bukak (Figure 1). The growth of wheat crop in Mataram at lower elevations (± 10 m above sea level) is even slower than Pringgarata (Anugrahwati and Zubaidi, 2012). The growth of each of the varieties in Pringgarata showed a similar trend with that in Aik Bukak. This indicates that varieties with the development phase of rapid growth in Aik Bukak also showed rapid growth in Pringgarata, except that the varieties with slow growth in Aik Bukak became slower in Pringgarata. In the second week, plant development at the seed growth phase was almost similar (Zadoks Scale / SZ dozen).

Table 1. Number of leaves, leaf growth and Phylochron at Pringgarata (PR) and Aik Bukak (AB) of ten varieties of wheat.

Variety	**Number of Leaves**		**Leaf Growth (leaf/day)**		**Phylochron (day/leaf)**	
	AB	**PR**	**AB**	**PR**	**AB**	**PR**
Axe	6.3	6.2	0.188	0.174	5.3	5.7
Nias	7.3	7.4	0.157	0.152	6.4	6.6
Gladius	7.2	7.0	0.153	0.149	6.5	6.7
Mace	7.4	7.2	0.156	0.146	6.4	6.8
Cobra	7.1	7.3	0.153	0.142	6.5	7.0
Correll	7.7	7.3	0.163	0.147	6.1	6.8
Dewata	7.4	7.4	0.158	0.153	6.3	6.5
Espada	7.3	7.2	0.156	0.149	6.4	6.7
Scout	7.8	7.4	0.162	0.152	6.2	6.6
Estoc	7.6	7.6	0.161	0.156	6.2	6.4
Mean	7.3	7.2	0.161	0.152	6.2	6.6
SEM	0.13	0.12	0.0032	0.0027	0.11	0.11

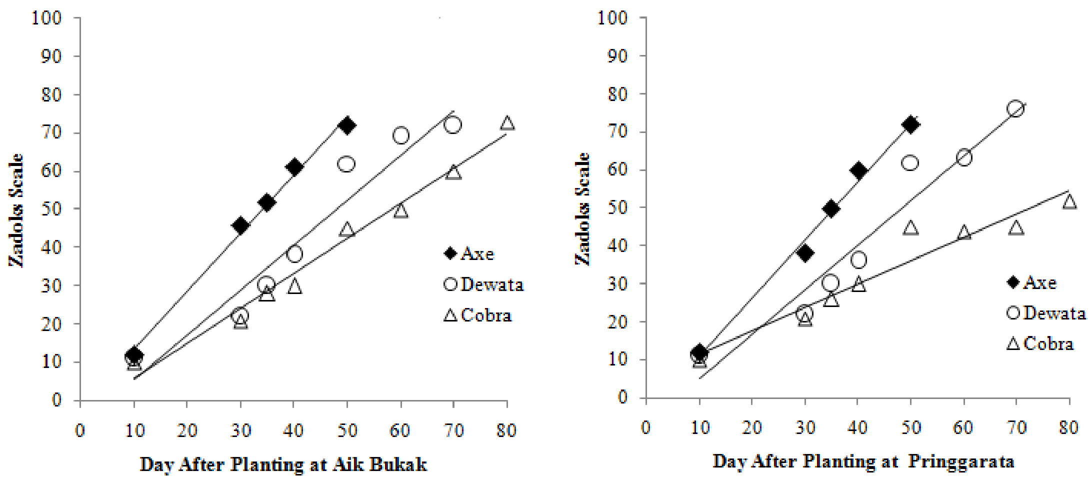

Figure 1. The rate of development of wheat plants (in the Zadoks scale) in Aik Bukak (400 m above sea level) and Pringgarata (200 m above sea level). The trend line for Axe (♦), Dewata (○) and Cobra (Δ) are shown to represent the speed of growth. Cobra line slope that is flatter than Aik Pringgarata Bukak indicating that the speed of development in Pringgarata Cobra was slower. There was no difference for the Axe and the Dewata.

At 28 days, the development of Axe variety exceeded the development of other varieties, when the Axe variety reached the phase of stem elongation (SZ 30s), either in Aik Bukak or in Pringgarata, while other varieties were still in the phase of seedling growth (tillering / SZ 20s). At six weeks, the development of plants varied according to the speed of their development. The ten varieties can be grouped into 3 groups, i.e. rapid (Axe and Nias), medium (Gladius, Mace, Espada, Dewata, Correll), and slow (Scout, Cobra, Estoc). It should be noted that although Cobra variety is characterized to have rapid to moderate growth (short to mid-season), in this study Cobra variety showed slow development growth. This indicates the existence of genetic variation in response of plants to high temperature stress in Lombok. Summerfield et al. (1991) suggested that the growth of wheat plants when grown in areas with temperatures above the tolerance threshold (supra-optimal temperature) would show a decrease in growth rate. This was also found in long-lived varieties (Cobra and Scout).

Phenology

Phenology is an important character in the adaptation of plants to environmental changes that may occur naturally or is conditioned on the particular environment. Phenology is associated with phases of growth (development), flowering, and harvest. The three main characters that affect plant responses to the environment are vernalization, photoperiod, and the need for the vegetative phase (Earlyness or Basic Vegetative Phase / BVP) (Kosner and Pankova, 1998; Slafer and Rawson, 1994; Snape et al., 2001).

In this study, there was no difference in days of flowering between Pringgarata and Aik Bukak except for the varieties having the slow rate of development, i.e. Estoc, Scout and Cobra, that were flowering about 5 days slower than in Aik Pringgarata Bukak (Table 2). There were significant differences between varieties. Axe and Nias are wheat varieties having rapid flowering age, whereas Estoc, Scout and Cobra are varieties with slow flowering age, and other varieties are between them.

Table 2. Age of flowering, harvesting and grain filling period of wheat crop at Pringgarata (PR) and Aik Bukak (AB)

Variety	**Age of Flowering (day)**		**Age of Harvesting (day)**		**Grain Filling Period (day)**	
	AB	**PR**	**AB**	**PR**	**AB**	**PR**
Axe	42	42	77	78	35	36
Nias	45	44	77	78	32	34
Gladius	56	59	92	91	36	32
Mace	63	68	92	91	29	23
Cobra	67	72	110	108	43	36
Correll	57	59	92	91	35	32
Dewata	51	51	92	91	41	40
Espada	57	61	92	91	35	30
Scout	70	75	110	108	40	33
Estoc	63	68	110	108	47	40
Mean	57	60	94	94	37	34
SEM	2.9	3.6	3.9	3.6	1.7	1.6

Despite the difference in age of flowering in some varieties, grain-filling period of varieties tested also showed no difference in the two sites, and the grain-filling period was not correlated with the yield.

Yield and yield components

All overall wheat varieties grown in Aik Bukak yielded higher than those grown Pringgarata, i.e. 1.68 t / ha in Aik Bukak and 0.82 t / ha in Pringgarata. The higher yield in Aik Bukak was supported by all the yield components observed, such as number of stems (tillers), stover dry weight, number of seeds, number of seeds / spikelet, weight and individual seed as well as Harvest Index. Although wheat varieties planted in Pringgarata generally had longer panicles, as shown the high number of spikelet per panicle, but they could not support high yield (Table 3). This was due to the low number of seeds / spikelet.

The introduced Estoc variety was able to produce almost similar to the National variety of Dewata with the highest yield was in Aik Bukak

(2.17 t / ha). The yield performed by Estoc in this experiment was quite high and similar to its origin, Australia. The high yield of Estoc in Aik Bukak was a combination of two components, i.e. the high number of seeds / m^2 and the high number of seeds / spikelet. Dewata is a wheat variety with the longest panicle or has the highest number of spikelet per panicle. This character supports the Dewata to produce high yield. Nias, Gladius and Mace also produced quite good yield which was close to the yield of the Dewata. Although Axe had many tillers and panicles, this variety did not produce a good yield. This was probably because Axe has short panicles and low number of grains / spikelet (Table 4). Wheat grain yields in Pringgarata were lower than in Aik Bukak. However, Estoc also had the highest yield in Pringgarata (1.42 t / ha) (Table 4). The highest number of seeds produced and the high number of seeds in a spikelet (2.1 grains / spikelet) supported the high yield of Estoc. The lowest yield observed for Axe (0.35 t / ha) was because Axe had short panicles (7.8 spikelet / panicle) and the low success of seed formation (0.9 seeds / spikelet) (Table 4).

Wheat yields in this study were quite good at Aik Bukak (400 m above sea level) was 1.68 t / ha (ranging from 0.9 to 2.17 t / ha) and low in Pringgarata (200 m above sea level), 0.83 t / ha (ranging from 0:35 to 1:42 t / ha). For comparison, Zubaidi et al (2011) reported the yield of 1 t / ha for wheat planted at below 200 m above sea level and about 2 t / ha for that planted at about 500 m above sea level. Handoko (2007) also reported that the yield of 2 t / ha could be obtained from the crops planted at an elevation of 500 m above sea level. As the low areas plains have high temperature, the low yields at 200 m above sea level is because the temperature of above tolerance limits growth and production of wheat (Summerfield et al. 1991).

Table 3. Comparison of yield and yield components at Pringgarata (PR) and Aik Bukak (AB), Values in parentheses indicate the Standard Error of Means

Location	Yield (t/ha)	Number of Tillers	Biomass (g/m^2)	Spikelet/ panicle	Number of Seeds	Seed /spikelet	Yield Index	Weight of 1000 seeds (g)
PR	0.83 (±0.085)	254.0 (±18.82)	369.4 (±26.28)	12.8 (±0.97)	3988 (±428)	1.5 (±0.1)	33.2 (±2.43)	31.4 (±1.27)
AB	1.68 (±0.083)	340.0 (±15.44)	500.3 (±23.36)	10.8 (±0.41)	5780 (±336)	1.9 (±0.08)	39.56 (±1.45)	34.6 (±1.04)

Data presented in Table 5 show evidence that there was genetic variation of plant response to high temperature stress. Calculation of Susceptibility Index (S) (Fischer and Maurer, 1978) indicated that Nias, Dewata, Mace, and Estoc had a value of $0.5 < S < 1$, which means those varieties have medium degree of adaptation to the stress conditions, while other varieties are the varieties that could not adapt well or less adaptable.

In line with that indicated by the value of S, Nias, Dewata, Mace and Estoc varieties had a percentage of yield decrease in Pringgarata ranged from 30-40% compared to Aik Bukak, and that for other varieties was greater than 50%.

The low yield in Pringgarata compared to Aik Bukak could be caused by a failure in pollination because of high temperature stress. It is assumed that the lower plane has a higher temperature range than the area on higher land, which means that Pringgarata has an average temperature that is higher than Aik Bukak, and thus the failure probability of pollination in Pringgarata is higher than Aik Bukak. This was indicated by the lower number of seeds formed on a spikelet in Pringgarata than in Aik Bukak (1.5 vs. 1.9 seeds / spikelet). The low number of seeds / spikelet in this experiment (<2.0 seeds / spikelet) indicates the low quality of pollination in both locations. The occurrence of sterility is a phenomenon observed by many wheat researchers at high temperature stress (Saini and Aspinall, 1982; Wheeler et al., 1996, Tashiro and Wardlaw, 1990). It was also evidenced that the yield was strongly influenced by the number of seeds / spikelet ($r = 0.64$ / Aik Bukak, and $r = 0.86$ / Pringgarata, $n = 53$, $P = 0.05$ level). Other yield components that affected wheat yields in this study were the dry biomass, number of spikelet per panicle, number of seeds, number of seeds / spikelet and Harvest Index. The significant correlation with the yield shows the importance of these yield components. Hence, the plant growth phases that determine the growth of these components should be of concern.

Table 4. Average yield and yield components of ten wheat varieties tested in Aik Bukak (altitude 400 m above sea level) and Pringgarata (altitude 200 m dpl)

Variety	Yield (t/ha)		Number of Tillers		Biomass (g/m^2)		Spikelet/ panicle		Number of Seeds		Seed / spikelet		Yield Index		Weight of 1000 seeds (g)	
	AB	**PR**	**AB**	**PR**	**AB**	**PR**	**AB**	**PR**	**AB**	**PR**	**AB**	**PR**	**AB**	**PR**	**AB**	**PR**
Axe	0.91	0.35	405	126.5	361.3	220.8	10.3	7.8	5311	1747	1.6	0.9	43.51	24.8	29.9	30.1
Nias	1.86	1.20	356	217.7	565.6	442.5	11.2	14.6	7567	6240	2.3	1.9	44.58	42.0	33.0	29.0
Gladius	1.85	0.75	407	236.0	582.4	241.0	9.1	11.2	6494	2687	1.9	1.5	44.25	38.7	39.4	32.7
Mace	1.89	1.12	322	231.0	532.9	286.8	12.7	11.7	6482	3767	1.8	1.7	45.66	42.7	37.7	30.5
Cobra	1.06	0.24	233	169.8	321.8	257.6	11.0	10.9	3523	1261	1.7	1.3	29.12	14.4	27.1	29.4
Correll	1.29	0.66	364	330.8	507.9	372.9	7.7	10.8	3059	2819	1.3	1.0	28.57	28.3	41.7	38.7
Dewata	2.13	1.12	265	252.0	605.7	553.9	13.7	15.1	6804	5831	2.0	1.8	41.36	38.5	36.6	36.2
Espada	1.74	0.69	369	313.0	558.6	373.7	11.6	20.0	5677	4303	1.7	1.2	40.32	40.8	39.9	32.9
Scout	1.89	0.79	293	246.0	484.1	437.6	11.0	16.1	5491	3897	2.0	1.4	36.13	29.4	32.7	32.0
Estoc	2.17	1.42	384	417.4	482.8	507.3	9.7	9.9	7387	7332	2.2	2.1	42.09	32.5	27.4	22.6
Mean	1.68	0.83	340	254.0	500.3	369.4	10.8	12.8	5780	3988	1.9	1.5	39.56	33.2	34.6	31.4
LSD	0.213	0.318	ns	72.83	ns	133.48	3.17	ns	2366.7	1927.1	ns	0.59	10.39	ns	5.36	ns

Table 5. Comparison of yield Pringgarata done to Aik Bukak Vulnerability to stress index and percent decrease

Variety	Yield (t/ha)		S Value	% Decrease
	AB	PR		
Axe	0.91	0.35	1.2	61.5
Nias	1.86	1.20	0.7	35.5
Gladius	1.87	0.71	1.2	62.0
Mace	1.92	1.09	0.8	43.2
Cobra	1.06	0.24	1.5	77.4
Correll	1.29	0.62	1.0	51.9
Dewata	2.13	1.12	0.9	47.4
Espada	1.74	0.69	1.2	60.3
Scout	1.89	0.75	1.2	60.3
Estoc	2.17	1.42	0.7	34.6

Conclusion

There was a genetic variation in wheat varieties response if they were adapted to the lowland areas. Growth and yield of wheat in high area (400 m above sea level), was better than at 200 m above sea level. Growth at areas having high temperature exceeding the limit of tolerance (supra-optimal), were slowed down. When grown at high temperature, wheat (in this case Cobra variety) underwent changing of the nature of the growth from medium (mid-season) to slow (late). Varieties with medium growth rate (mid-season variety), i.e. Nias, Dewata, Estoc and Mace produced higher yield (> 2 t / ha) that yield of other varieties. Environmental conditions that affect the success of pollination / fertilization should be considered to obtain a better yield with high number of seeds / spikelet.

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Research Article

Application of organic matter to enhance phytoremediation of mercury contaminated soils using local plant species: a case study on small-scale gold mining locations in Banyuwangi of East Java

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Abstract: The discharge of small-scale gold mine tailing to agricultural lands at Pesanggaran village of Banyuwangi Regency caused soil degradation as indicated by reduced crop production. This soil degradation is mainly due to the toxicity of mercury contained in the tailing. The purpose of this study was to explore the potential of three local plant species, i.e. *Lindernia crustacea*, *Digitaria radicosa*, and *Cyperus kyllingia* for phytoremediation of agricultural land contaminated gold mine waste containing mercury, and its influence on the growth of maize. Six treatments (three plant species, and two levels of organic matter application) were arranged in a randomized block design with three replicates. Maize was grown on soil after phytoremediation for 8 weeks. The results showed that among the three plant species tested, *Cyperus kyllingia* was the potential candidate plant species for phytoremediation of soil contaminated with gold mine tailing containing mercury because of its ability to accumulate mercury from 32.06 to 73.90 mg / kg of soil in 60 days. Phytoremediation of mercury contaminated soil using *Cyperus kyllingia* using increased maize yield by 126% compared to that the biomass yield of maize grown on soil without phytoremediation. Induce phytoremediation needs to be carried out to accelerate the process of remediation of mercury contaminated soils.

Keywords: *indigenous plant species, mercury contaminated soil organic matter, phytoremediation*

Introduction

Gold mining sector in Indonesia consists of a large-scale gold mining, gold mining medium scale and small-scale gold mining (ASGM). Pesanggaran Village, District tile, Banyuwangi regency is one of ASGM locations in East Java that has been operating illegally since 2009. Miners generally using mercury amalgamation method because it is considered an efficient method and requires only a small investment. However, in addition to the assumption of the efficiency of mercury amalgamation, the ability of mercury to bind the gold from gold ore is highly dependent on particle size and geochemistry of gold (Viega et al., 2006). A study conducted at ASGM locations in the Philippines reported that gold obtained from the mercury amalgamation method is only 10% (Hylander et al., 2007). In addition, there is always mercury lost to the environment through the disposal of wastewater from amalgamation treatment processes.

At Pesanggaran Village, Genteng District of Banyuwangi Regency, the discharge of gold amalgamation waste to agricultural land gave a negative impact on maize production. Chlorosis is a major symptom of mercury toxicity in plants. As reported by head of Pesanggaran Village, illegal gold mining activities in the village reduced maize production by 70%. According to Fitter and Hay (2004), metal ions react specifically with enzymes, which in turn interfere with the metabolic processes in plants. Therefore, remediation technologies are needed for reclamation and remediation of soil contaminated with metals, including mercury (Wuana and Okieimen, 2011).

The last few years, concern about the use of plants for remediation environments contaminated with heavy metal is increasing. The technology known as phytoremediation can be used as a cheaper alternative than the physical method (Fasani, 2012). From various phytoremediation techniques, most attention has been focused phytoextraction of metals. In this method, the plants absorb heavy metals from soil contaminated with heavy metals. Harvesting and disposal of plant biomass also means cleaning up metal elements from soil (Banuelos et al., 2011; Pedron et al., 2011). Muddarisna et al. (2013) reported that *Digitaria radicosa*, *Cyperus kyllingia*, and *Lindernia crustacea* potential are potential for use in phytoextraction mercury because these plant species efficiently absorb and transport mercury from the roots to the shoots. Hidayati et al. (2009) reported several species of plants at ASGM locations in West Java that are able to accumulate mercury up to 20 mg/kg, i.e. *Lindernia crustacea*, *Digitaria radicosa*, and *Cyperus kyllingia*. Accumulator plants and the availability of metals in the soil for the plant uptake determine the success of phytoextraction (Lin et al., 2010).

Hg discharged to soils is generally retained by the soil through absorption on sulphide, clay particles and organic matter (Evans, 1989). The form of Hg is not soluble, so it is relatively not mobile in the soil. Mercury has a strong affinity with thiol groups, especially sulphide and bisulphide complexes (Morel et al., 1998). In addition, humic compounds that make up 50% of soil organic matter contain functional groups containing S in large enough quantities (Wallschlager et al., 1998a). Humic compounds that are composed of humic acid and fulvic acid are Hg chelate (Wallschlager et al., 1996). Therefore, Hg humic-fulvic acid complexes are mobile in the soil (Wallschlager et al., 1998b). Humic-fulvic acid has been shown to stimulate the availability of Hg in soil and uptake by organisms Hg (Hinton, 2002).

Based on the above findings, application of organic matter into small-scale gold processing waste containing mercury are expected to enhance the solubility of mercury that can be absorbed by the metal accumulator plants. The purpose of this study was to examine the study the effects of organic matter application on phytoremediation of soils contaminated with small-scale gold mine tailings using *Lindernia crustacea*, *Digitaria radicosa*, and *Cyperus kylingia*, and its effect on the growth and biomass production of maize.

Materials and Methods

A pot experiment was conducted in October 2011 to November 2012 in the glasshouse of the Faculty of Agriculture, Brawijaya University. Materials used in this study were (1) plant species, *Lindernia crustacea*, *Digitaria radicosa*, and *Cyperus kyllingia*, (2) waste of gold mining process with mercury amalgamation (hereafter referred to as amalgamation tailing), (3) topsoil (0-30 cm) that is not contaminated with amalgamation tailing containing mercury, and (4) maize seeds of NK33 variety. Seeds of three plant species (*Lindernia crustacea*, *Digitaria radicosa*, and *Cyperus kyllingia*), amalgamation tailing and uncontaminated soil were all obtained from the ASGM locations at Pasanggaran Village, Genteng District of Banyuwangi Regency.

Samples of soil and tailing were air dried for two weeks, then sieved to pass through a 2 mm sieve for analyses of pH (1:2.5 water suspension), and N, P_2O_5, organic C, Hg contents. The results of the analysis were as follows: (a) uncontaminated soil: pH 6.27, organic C 0.65%, 0.16% P_2O_5, and 0.67% total N, (b) amalgamation tailing: pH 7.02, organic C 0%, P_2O_5 0:06%, 0.22% total N, and 190.03 mg Hg / kg. The Hg concentration was measured by Cold Vapor Atomic Absorption Mercury analyzer. Samples of soil and amalgamation tailing were mixed with the proportion of 80% soil + 20% tailing. Seeds of each *Lindernia crustacea*, *Digitaria radicosa*, and *Cyperus kyllingia* that had been germinated for two weeks were then planted on 5 kg of the soil-tailing mixture, each of which was supplied with 10 t organic matter / ha, and without the addition of organic matter. Six treatments (three plant species and two doses of organic matter), were arranged in a randomized block design with three replications.

Organic matter used for this experiment was compost produced by Composting Unit of the Faculty of Agriculture, Brawijaya University. During the experiment, water was supplied every day to maintain a sufficient supply of water for plant growth. After 60 days, the plants were harvested and analyzed Hg concentrations in the plant biomass (shoots and roots) and soil-tailing mixture in the pot. The ability of plants to transport mercury from roots to shoots was evaluated by using the Translocation Factor (TF) (Yoon et al., 2006; Sarawet and Rai, 2007; Zacchiini et al., 2008). TF is the ratio of metal concentration in the plant shoot with metal concentrations in plant roots. Plants with TF values> 1 could potentially be used to phytoextraction, whereas plants with TF values <1 could potentially be used to phytostabilization (Yoon et al., 2006). Phytoremediation efficiency was expressed by RF (remediation factor), which is the metal uptake in the plant shoot compared with the amount of metallic elements in the soil (Sun et al., 2009).

The results of the statistical analysis were used as the basis for selecting the best plant species (highest Hg accumulation), for phytoremediation of mercury contaminated soils. The remaining soil-tailing mixture in the pot (post-phytoremediation), was then used for growing maize for 60 days. For comparison, one control treatment was included for each plant species. The control treatment was the soil-tailing mixture without phytoremediation treatment. Each pot was supplied basic fertilizers equivalent of 100kg N / ha, 50kg P / ha and 50kg K / ha. At the time of harvest (60 days), plant height and dry weight of maize shoot and roots were measured. Statistical analysis was performed using the F test (analysis of variance) with a significance level of 5% to determine the effect of treatment on the observation of parameters followed by Least Significant Difference at 5% significance level.

Results and Discussion

Pant biomass

The results of the evaluation of three herbaceous plant species showed that the three species were tolerant to soil contaminated with amalgamation tailing containing mercury (Figure 1). This indicates that the growth of the plants for 60 days did not show symptoms of toxicity and damage to plant morphology. Shoot and root dry weight of all plants without the addition of organic matter showed no significant differences. In the treatment of organic matter addition, addition dry weight was achieved by *C. kyllingia* that was significantly higher than *L. curstacea* and *D.radicosa*, while the shoot dry weights of *L. crustacea* and *D. radicosa* were not significantly different. However, the addition of organic matter did not significantly affect root dry weight of three of herbaceous plant species.

A type or plant species that can be classified as a heavy metal accumulator must meet the criteria in addition to survival in the conditions of the soil medium with high concentration of heavy metals, the rate of uptake and translocation of metals in plant tissues and, biomass yield should also high (Rascio and Navari-Izzo, 2011). Figure 1 shows that at the age of 60 days, *C. kyllingia* had the highest potential to produce biomass, followed by *D. radicosa* and *L. crustacea*. In terms of biomass production, Cyperus kyllingia can be expressed as best candidate species for phytoremediation of soil contaminated gold amalgamation tailing containing mercury.

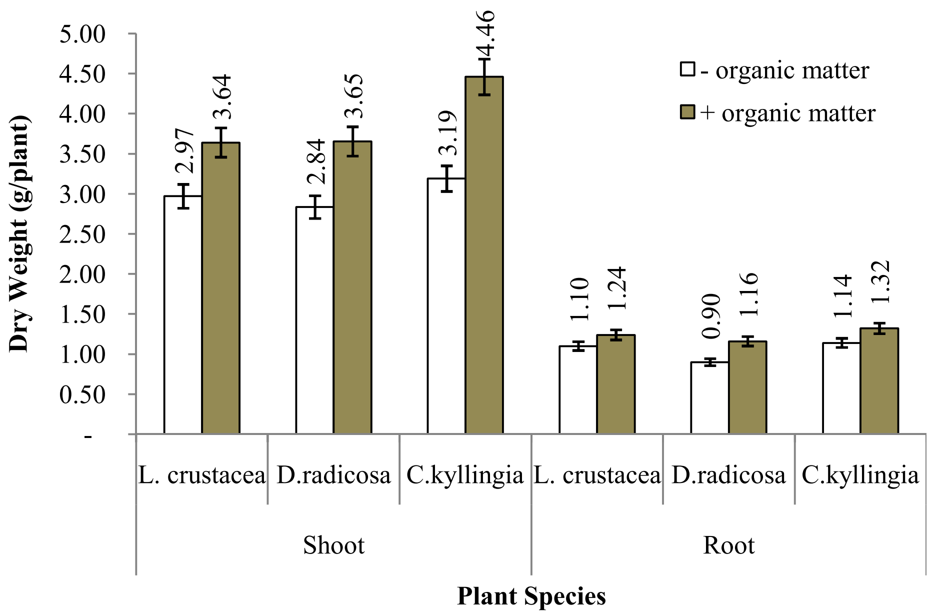

Figure 1. Biomass dry weight of *L.crustacea, D.radicosa* and *C.kyllingia* grown on soil contaminated with amalgamation tailing for 60 days, with and without addition of organic matter

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Accumulation of mercury in plants

The highest Hg concentration was found in *C. kyllingia* followed by *L. crustacea* and *D. radicosa*, either with or without the addition of organic matter. The addition of organic matter to the planting medium did not significantly increase the concentration of Hg in the plant roots, but significantly increased the concentrations of Hg in the shoots, especially for *C. kyllingia*. Plants develop some effective mechanisms in order tolerant to high concentrations of metals in the soil (Nagajyoti et al., 2010). Accumulator plants do not prevent the entry of metal into the root element, but develop specific mechanisms to detoxify the metal element inside the cell to bioaccumulation of metal elements (Fasani, 2012). The accumulation of heavy metal elements in plant species reflects the high metal concentrations in the rhizosphere. By nature, plants can accumulate metallic elements that exceed the tolerance threshold of 1% (Zn, Mn), 0.1% (Ni, Co, Cr, Pb and Al), 0.01% (by Cd and Se), 0.001% (Hg) or 0.0001% (Au) of the dry weight of the plant without showing symptoms of toxicity (Navari-Izzo and Rascio, 2011).

Calculation of the concentration of Hg and comparison of Hg concentration ratio in each plant species presented in Figure 2 show the differences in the ability of plants to accumulate Hg. The highest accumulation of Hg was observed for *C. kyllingia* followed by *L. crustacea* and *D. radicosa*. The highest Hg concentration in the roots was also found in *C. kyllingia* followed by *L.crustacea* and *D.radicosa*. High biomass production affected the accumulation of Hg. The addition of organic matter to the planting medium significantly increased Hg accumulation in the plant shoots and roots. Without the addition of organic matter, the accumulation of Hg in the shoots of the three plant species at 60 days ranged from 14.43 mg / kg (*L.crustacea*) to 32.06 mg / kg (*C.kyllingia*). This value was significantly lower than that of treatments with the addition of organic matter that ranged from 37.69 mg / kg (*L. Crustace*) to 73.90 mg / kg (*C. kyllingia*) (Figure 2). This value exceeded the threshold concentration of 10 mg Hg / kg dry weight of plants (Pedron et al., 2011).

According to Nagajyoti et al. (2010), there is a relationship between the levels of heavy metal contamination in soils with uptake by plants. Accumulation of metal elements occurs because there is a tendency to form a heavy metal compound complex with inorganic compounds found in the body of organisms (Selin, 2009). The addition of organic matter to the planting medium also significantly affected the accumulation of mercury in the roots that ranged from 33.87 mg / kg (*L. crustacea*) to 43.18 mg / kg (*C. kyllingia*) (Figure 2). In the treatments without addition of organic matter, the accumulation of Hg in roots ranged from 22.73 mg / kg (*L. crustacea*) to 28.07 mg / kg (*C kyllingia*) (Figure 2).

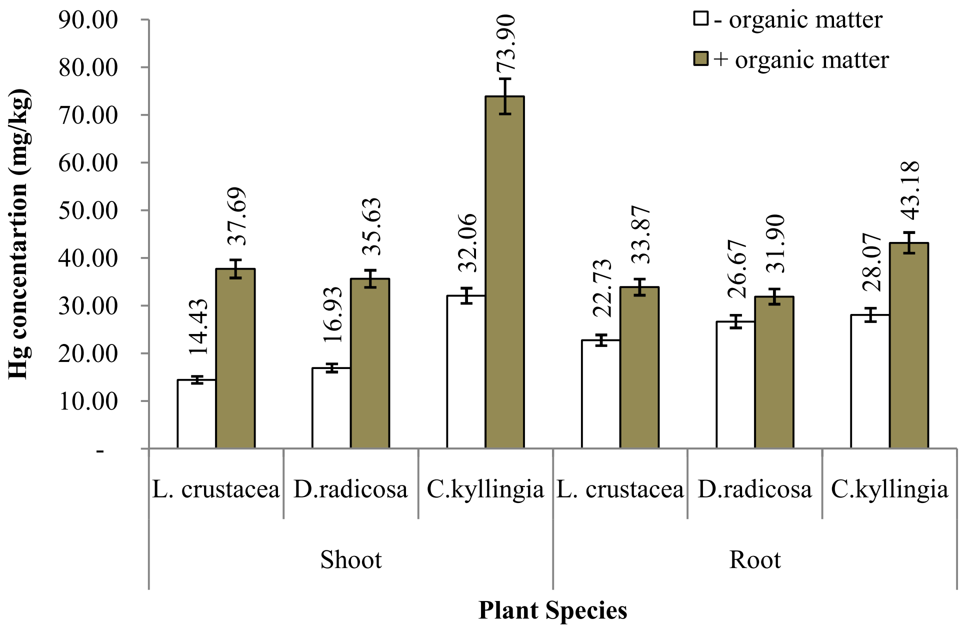

Figure 2. Concentration of Hg in the shoots and roots of *L. curstacea, D. radicosa* and *C. kyllingia* grown on soil contaminated with amalgamation tailing for 60 days, with and without addition of organic matter

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The addition of organic material in an average increased accumulation of Hg in the shoots and roots of the plants by 132% and 41%, compared to the media without the addition of organic matter. This is thought to occur because of the role of humic compounds in the organic matter (Wallschlager et al., 1998a). Humic compounds that composed of humic acid and fulvic acid chelate are Hg chelates (Wallschlager et al., 1996). Therefore, Hg humic-fulvic acids complex is mobile in the soil (Wallschlager et al., 1998b). Humic-fulvic acid has been shown to stimulate the availability of Hg in soil and uptake of Hg by organisms (Hinton, 2002).

The ability of plants to move metal elements from the root of the shoot can be measured by the value of TF (Translocation Factor), which is defined as the ratio of metal concentration in the shoot with metal concentrations in roots (Yoon et al., 2006). A plant species having a TF value of <1 is less suitable for phytoextraction (Fitz and Wenzel 2002). TF values> 1 indicate the effectiveness of moving the metal elements from the plant roots to the shoot (Zhang et al., 2002, Fayiga and Ma 2006). Results of this study showed that value of TF or the ratio of the concentration of Hg in the shoots and the roots of the addition of organic matter treatment resulted in were > 1 (Figure 3). However, the treatment with no organic material, the value of TF three plant species were all <1. This suggests that the addition of organic matter changes the role of the plant formerly as phytostabilizators (TF value of <1) to plant metal phytoextractor plants (TF values> 1) that is able to move Hg from the roots to the shoot.

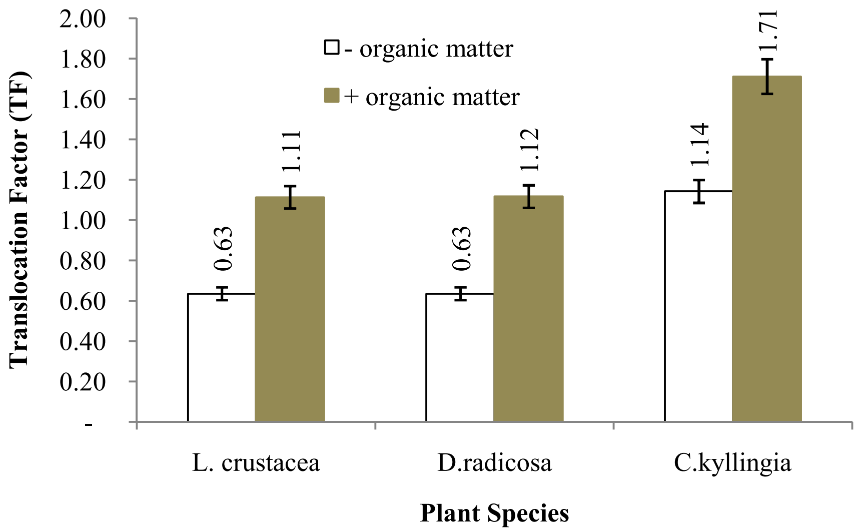

Figure 3. Translocation Factor (TF)

The highest TF value was found in *C. kyllingia* with or without the addition of organic matter (Figure 3). The differences in RF values on three plant species showed differences in the effectiveness of each plant species in the transport of mercury from the shoot to the root system as a place of accumulation (Selin, 2009). This difference is also thought to be related to the modification of plant growth under conditions of heavy metal was seized as a result of the absence of certain amino acids in plants (Ashraf et al., 2011). The efficiency of Hg phytoremediation of *C. kyllingia* Hg was higher than *D. radicosa* and *L.crustacea*, while the efficiency of phytoremediation of *D. radicosa* and *L. crustacea* were not significantly different (Figure 4). Application of organic matter significantly improved the efficiency of Hg phytoremediation by three plant species tested, with the highest increase was achieved by *C. kyllingia*.

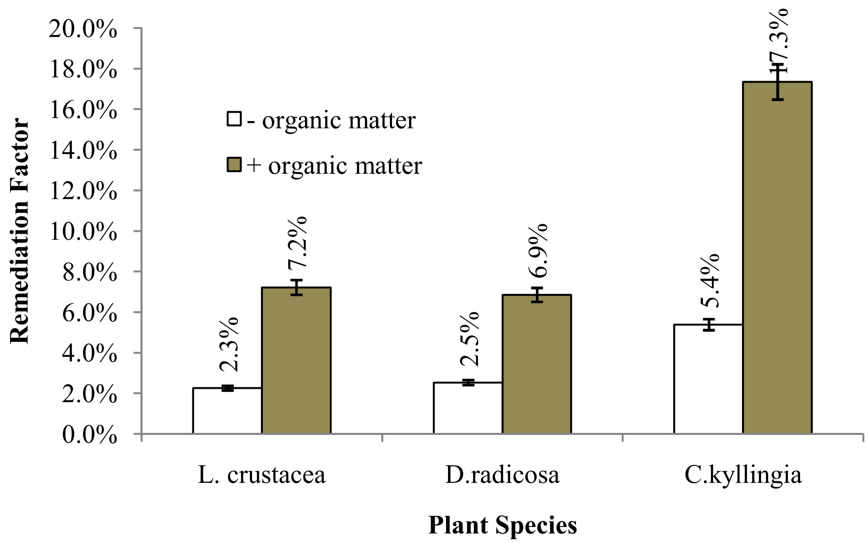

Figure 4. Phytoremediation efficiency of Hg by *L.crustacea*, *D. radicosa,* dan *C.kyllingia* grown on soil contaminated with amalgamation tailing for 60 days, with and without addition of organic matter

Growth of maize on post-phytoremediation soil

At the time of harvest (60 days), maize plant height ranged from 33.58 cm (control, without phytoremediation) to 116.10 cm (post-phytoremediation using *C.kyllingia*) in the planting medium without application of organic matter (Figure 5). At the growing media with application of organic matter, plant height varied from 36.29 cm (control) up to 158.31cm (post-phytoremediation using *C.kyllingia*) (Figure 5). Overall, compared with controls, the average height of maize plants grown in the media that had been remediated with three plant species without application of organic matter increased 151%, while the treatment with the application of organic materials the plant height increased by 230% .

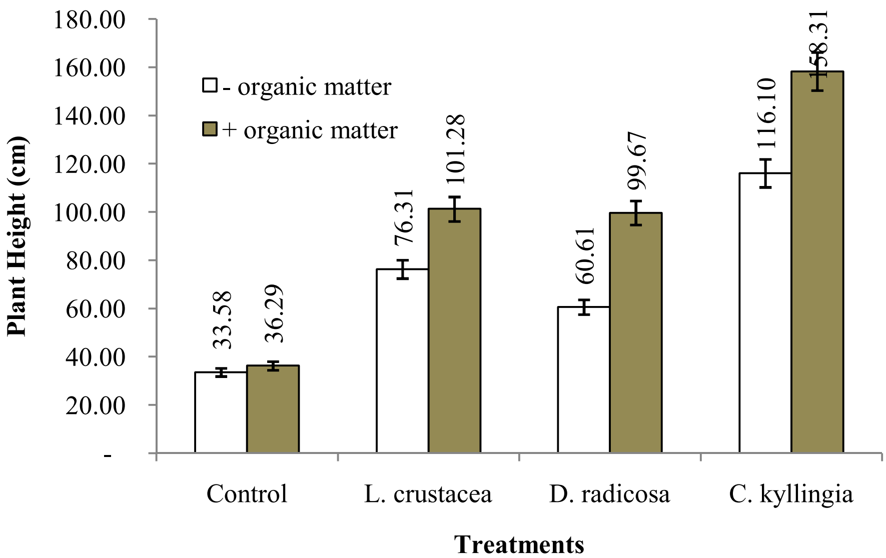

Figure 5. Maize plant height at 60 days on post-phytoremediation of soil contaminated with amalgamation tailing containing mercury.

Maize shoot dry weight also increased (compared to control) after soil phytoremediation by three species of herbaceous plants. Consistent with the ability of *C. kyllingia* in accumulating the highest Hg, the highest increase in dry weight of maize shoot was also observed for *C.kyllingia* treatment (Figure 6).The average dry weight biomass (shoot) of maize grown on previously growing media previously remediated with three herbaceous plant species without application of organic matter increased 65%, while that of grown on media previously remediated with three herbaceous plant species with application of organic matter increased 102%. The lower growth and biomass of maize grown on post-phytoremediation media without application of organic matter compared to the application of organic matter treatment, was related to the reduction in mercury content in the media due to uptake by the three accumulator plant species in the phytoremediation activities.

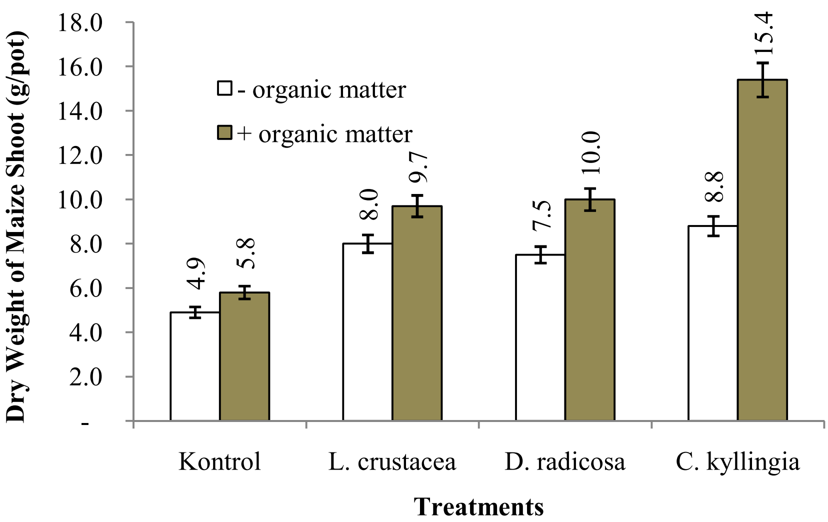

Figure 6. Dry weight of maize shoots at 60 hari on post-phytoremediation of soil contaminated with amalgamation tailing containing mercury.

Mercury remaining in the planting medium without application of organic matter was higher than the mercury remaining in the planting medium with the application of organic matter, thus inhibiting plant growth. In the plants, mercury is toxic and cause damage to enzymes, polynucleotide, nutrients transportation system, and destroy integrity of the cell membrane (Nagajyoti et al., 2010). Extension of the root is often used as a first indication of Hg toxicity (Moldovan et al., 2013). Symptoms of mercury toxicity in general are stunted growth of roots and seeds, and inhibition of photosynthesis which in turn reduces crop production. In addition, mercury accumulated in root tissue can inhibit K uptake by plants (Hooda, 2010). Mercury absorbed by the roots can cause some enzymes become inactive due to the inclusion of mercury in the form of sulfihidril peroxide through formation of reactive oxygen compounds, such as superoxide (O_2), hydroxyl radicals (OH-) and hydrogen peroxide (H_2O_2) (Chen and Yang, 2012) .

Conclusion

Digitaria radicosa, *Cyperus kylingia* and *Lindernia crustacea* are potential herbaceous plant species that van be used for phytoremediation of soil contaminated with gold amalgamation tailing containing mercury. The ability of the plant roots to transport Hg to the plant shoot was in the following order, *Cyperus kyllingia*> *Lindernia crustacea*> *Digitaria radicosa*. Application of organic matter in soil contaminated gold amalgamation tailing containing mercury increased the concentration of Hg and Hg uptake by plants accumulator. Phytoremediation of soil contaminated with gold amalgamation tailing containing mercury amalgamation increased growth and yield of maize.

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Research Article

Effects of humic acid-based buffer + cation on chemical characteristics of saline soils and maize growth

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Abstract: Humic acid is believed to maintain the stability of the soil reaction, adsorption / fixation / chelate of cation, thereby increasing the availability of water and plant nutrients. On the other hand, the dynamics of saline soil cation is strongly influenced by the change of seasons that disrupt water and plant nutrients uptake. This experiment was aimed to examine the characteristics of the humic acid from compost, coal, and peat and its function in the adsorption of K^+ and NH_4^+ cations, thus increasing the availability of nutrients and ~~of~~ maize growth. Eighteen treatments consisted of three humic acid sources (compost, peat and coal), two cation additives (K^+ and $NH4^+$), and three doses of humic acid-based buffer (10, 20, and 30 g / 3kg), were arranged in a factorial completely randomized with three replicates. The treatments were evaluated against changes in pH, electric conductivity (EC), cation exchange capacity (CEC), chlorophyll content, plant dry weight and plant height. The results showed that the addition of K^+ and $NH4^+$ affected pH, CEC, K^+, $NH4^+$, and water content of the buffer. Application of humic acid-based buffer significantly decreased soil pH from > 7 to about 6.3, decreased soil EC to 0.9 mS / cm, and increased exchangeable Na from 0.40 to 0.56 me / 100g soil, Ca from 15.57 to 20.21 me/100 g soil, Mg from 1.76 to 6.52 me/100 g soil, and K from 0.05-0.51 me / 100g soil. Plant growth (plant height, chlorophyll content, leaf area, and stem weight) at 35 days after planting increased with increasing dose of humic acid. The dose of 2.0g peat humic acid + NH_4^+ / 3 kg of soil or 30g peat humic acid + K^+ / 3 kg of oil gave the best results of maize growth.

Keywords: *compost, cations, humic acids, maize, saline soil*

Introduction

Humic substances play an important role in soil fertility and plant nutrition (Tan, 1998; Spark, 2003; Pettit, 2011). Humic acid is a derivative product of decomposed organic material that is soluble in alkali but insoluble in acid (Mikkelsen, 2005; Pena-Méndez et al., 2005). A typical humic acid molecule polymer structure may consist of six carbon aromatic ring of the basis of di- or tri-hydroxyl phenols linked by -O-, -NH-, -N-, - S-, and contain group-OH and quinone (O- C_6H_4-O-) (Tan, 1998). Humic acid is a cyclic organic compound having high molecular weight, long-chain, and active carboxyl group (-COOH) and phenolic (-OH), which are ampoter, binding of cations/anions at certain pH conditions (pH dependent charge) (Stevenson, 1994; Bohn et al., 2001; Pena-Méndez et al., 2005; Khaled and Fawy, 2011). Carboxylate of some carboxyl group is released below pH 6 leaving a negative charge on the functional group: R-COOH = R-COO- + H^+ (Pettit, 2011). Dissociation of H+ from amide (= NH) also can increase the negative charge. Protonated groups such as R-$OH_2^+$and R-NH_3can produce a positive charge, but the overall humus is negatively charged.

Extraction of humic acid with NaOH or KOH causes the negative charge of humic acid is saturated with Na or K, so that the ions are easily exchanged. NaOH or KOH saturation increases the pH up to11, encouraging all acids at the level of maximum solubility and stabilizing hydrocolloid in suspension. Humic acid levels in compost, manure, straw, and other are relatively low (<1%), while that in coal deposits "Leonardite" is relatively very high (~ 15%) (Humintech, 2012). Mindari et al. (2013) obtained 2.6%, 4.6% and 7.6% humic acid extracted from compost, coal and peat with 0.5 N NaOH and deposition to pH 2, respectively. Goff (1982), Lebo et al. (1997), Anaya-Onala (2009), and Chen et al. (2009) obtained humic acid at least 60-80% and has a high solubility. They extracted humic acid in alkaline conditions (pH 9-12), and precipitated at pH 0.5-2.9, temperature of 100°C - 200°C, pressure of 5-200 psi, and time of 0.5 - 2 hours.

Nur Hasinah et al. (2008) reported that reduction of the duration of the extraction time from 24 hours to 12 hours gave a similar character humic acid. Humic acids can be characterized from the ratio of the value of E4 / E6, which is the value of absorbance at 465 nm (E4) and at 665 nm (E6). Kononova (1966) and Chen et al. (1977) believed that the ratio of E4/ E6 is associated with the degree of condensation of aromatic carbon lattice. Weak ratio values indicate weak condensation of high levels of humic aromatic components, while strong ratio indicates the proportion of higher aliphatic structure. The ratio value of E4 / E6 is primarily governed by the size of the molecule or molecular weight or particle, which is correlated with the concentration of free radicals with O, C, CO_2H and total acidity (Chen et al., 1977), but it does not depend on the concentration of humic acid or fulvic. The structure of humic acids have E4 / E6 ratio that ranges from 4.1 to 4.8 (Orlov et al., 1975) and from 3.3 to 5.0 (Pansu and Gautheyrou, 2006).

The ability humic acid to adsorb cations follows the liotrophic sequence, i.e., $Al^{3+} = (H^+) > Fe^{3+} > Fe^{2+} > Ca^{2+} > Mg^{2+} > K^+ = NH_4^+ > Na^+$ (Tan, 1998). Sorption of NH_4^+ is similar to Na^+(Nursyamsi et al., 2009). Sorption and maximum buffering capacity of the $NH_4^+$and Na+ are relatively different. Application of NH_4^+ significantly increased exchangeable K in Cromic Endoaquert and Typic Endoaquert. Cation adsorption by humic acid occurs through the exchange of cations in solution or that adsorbed by clay-humic. The cations are easily absorbed by the roots, increasing the transfer of micronutrients to the plant circulatory system and then change the balance of K:Na:Ca:Mg (Sharma and Kappler, 2011). Adsorption of cations or metals by humic acid can be through (a) direct adsorption (Ca^{2+} that release PO_4^{3-}), (b) complexation of Cu^{2+}or outer-sphere interactions for hydrated Mg^{2+}(c) serving as a cation bridge (outer sphere complex) through direct or indirect chelation, and (d) interaction with Ca^{2+}- humic acid aggregates or with amine groups (Sharma and Kappler, 2011). Clay or humic materials have a strong affinity to weak acids containing phenolic hydroxyl, carboxyl group, or aminosulfonyl. Alkaline cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) are primary detained by simple cation exchange with COOH groups (RCOONa, RCOOK) (Zhang et al., 2013).

Food and Agriculture Organization (2005) reported that salt affects plant growth mainly through: (a) poisoning due to absorption of excessive salt constituent elements (Na), (b) decreased uptake of water, and (c) decreased uptake of essential elements (K). Maize (*Zea mays* L.) is the second staple food after rice, but the growth of maize is very susceptible to salinity, with tolerance levels of 1.5 - 2 mS / cm (Ayers and Wescot, 1976; Goudarzi and Pakniyat, 2008; Mindari et al., 2011). Maize plant is more tolerant to water shortages, lack of nitrogen and high temperature than the soil salinity. Turan et al. (2011) found that concentrations of 45 and 60 mM NaCl had a negative impact on the dry weight and uptake of N, P, K, Ca, Mg, Fe, Cu, Zn and Mn by maize.

Application of humic acid has been identified to reduce the soil salinity and improve nutrient uptake by plant (Çelik et al., 2010; Paksoy et al., 2010; Khaled and Fawy, 2011; Turan et al., 2011), increase plant physiology and biochemistry, and crop productivity (Canellas and Olivares, 2014). Variation of humic acid dose amongst researchers is determined by the source of organic matter, humic acid extraction techniques, and cationic additives, as well as the nutrients studied. Dose of humic acid and N of 1.5 to 2 g/kg, 0- 150 mg P/kg, and 0-300 mg K/kg have been reported to reduce soil salinity (60 mM NaCl or 40% $CaCO_3$) and increase N uptake by wheat (Çelik et al., 2010).

Application of 4 g humic acid / kg to saline soil also improved N uptake by maize (Khaled and Fawy, 2011). Mindari et al. (2013) have reported application of 1.5-2.0 g humic acid / kg and 150 mg NPK / kg to saline soil that increased rice straw weight and number rice seedlings at 35 days after planting. Turan et al. (2011) reported that uptake of N and P do not need additional humic acid, but the uptake of Mg and Mn need application of 1 g humic acid /kg, and Cu uptake need application of 2 g humic acid /kg for maize grown in saline soils. Value of K^+ / Na^+ ratio in leaves can be used to determine indicators of plant susceptibility (Goudarzi and Pakniyat, 2008).

Based on the above findings, this study was aimed to elucidate the characteristics of the humic-based buffer of various organic materials (humic acid + K^+ or NH_4^+) on the chemical properties of saline soil and maize growth. The characteristics of humic acids were used to determine their potential in the cation exchange, to control cation equilibrium in saline soil dominated by Na or Ca. Addition of K^+ or NH_4^+ is expected to decrease exchangeable Na so it does not toxic to plant and increase nutrient uptake and plant growth.

Materials and Methods

The experiment was conducted from April 2013 to July 2013 in the glasshouse and laboratory of Land Resources, Faculty of Agriculture, Universitas Pembangunan Nasional "Veteran", East Java, and in the laboratory of Soil Science Department, Brawijaya University.

Experiment 1: Formulation and characterization of humic acid-based buffer

Humic acid-based buffer was prepared from a mixture of humic acid with K^+ or NH_4^+ cation. Humic acids were extracted from compost, coal and peat with 0.5 N NaOH solution (1:10) through 24-hour agitation and precipitation with 6N HCl up to pH 2 in accordance with the method of Stevenson (1994). The extracted humic acid was purified by adding a mixture of HCl and HF (2:1 by volume) which were then forwarded with water up to 3 times by centrifugation or settling in the separator tube. Humic acid precipitate was heated at 40^{o}C to obtain concentrated humic acid.

Organic-C content of the humic acid was determined using the method of Walkey and Black. The percentage of humic acid was calculated by gravimetric method at a temperature of 100^{o}C. The value of E4 and E6 were analyzed by diluting humic acid with 0.05 N $NaHCO_3$ (1 mL of humic acid: 10 mL), and then each of which was analyzed at a wavelength of 465 and665 nm using a Spectro Pharo 100. Ratio of E4 / E6 was obtained by dividing the value of E4 with E6 (Kononova, 1966; Chen et al., 1977). The value E4 / E6 ratio of less than 5 shows the character of humic acid, while that of more than >5 is fulvic acid (Tan, 2003). CEC value of the humic acid was analyzed by saturation 1N NH_4OAc at pH 7. Results of the analysis of the three different humic acid materials are presented in Table 1.

Buffer was formulated from a mixture of humic acid, 30-40% compost, 40-50%, 10-20% clay and 10-20%cations. The mixture was processed to become grains or granules in a pan granulator. At first, compost and clay were evenly mixed and then fed to the pan granulator before the granulation machine was started. Once the materials were evenly mixed, the concentrated humid acid was diluted and sprayed into the mixture until the materials formed a uniform grain with diameter of about 2 mm.

Table 1. Characteristics of humic acid materials

Sources of Humic Acid	Origin	Organic-C (%)	Humic Acid-C (%)	Humic Acid (%)	Ratio E4/E6	CEC (me/100g)
Compost	Gunung Anyar, Surabaya	25.15	16. 39	2.60	3.71	80.72
Coal	Bukit Asam	34.80	23.87	4.60	2.37	104.09
Peat (0-10 cm)	Kotawaringin Hilir Village, Central Kalimantan	46.32	22.61	7.60	2.92	116.83

The granules were then removed from the pan granulator, air-dried, sieved to pass through a 1-2 mm sieve, and water content of the granule was made around 10-20%. Large granules was returned to the pan granulator and smoothed again for granulation process. Addition of KH_2PO4 and NH_4SO_4 to the buffer was directed to increase the CEC to meet the standard of soil amendment according to Permentan (2011). Humic acid-based buffer was analyzed for C-organic content, CEC, pH, K^+, NH_4^+, and water content. The C organic content and CEC were analyzed according to the previous methods in organic materials that have been oven dried at 70°C as proposed by Pansu and Gautheyrou (2006). CEC was analyzed by saturation 1N Ammonium Acetate. pH and EC values were analyzed in pasta humic acid 1:1.

Experiment 2: Effect of buffer on soil chemical characteristics and growth of maize

The experiment was arranged according to a factorial completely randomized design where factor 1 was three types of humic acid source (compost, peat, and coal), factor 2 was two types of cation (K^+ and NH_4^+), and factor 3 was dose of buffer (10, 20, and 30g / 3kg soil). Each treatment was repeated three times. Soil used for this experiment was top soils (0-20 cm depth) collected from Gununganyar Village of Surabaya to represent saline soils. Soil samples were air dried and sieved to pass through a 2 mm sieve for chemical analyses. The soil has the following characteristic: slow to moderate permeability (2.2-25.5 mL / h), clay texture (60-62% clay), pH 7.5-7.55, EC 1.77-1.83 mS /cm, exchangeable Ca 19.4-20.4 me/100g, exchangeable Mg 4.3-3.8 me/100g, exchangeable K 2.6-2.73, exchangeable Na 0.9-0.8 me/100g, CEC48.22-52.95 me/100g, and 1.58-2.46% organic C.

Three kilograms of dried soil were mixed with the appropriate treatment and placed in a plastic pot. Ten grams of NPK fertilizer were evenly mixed into the soil. Water with salinity of less than 1 mS / cm was added to the soil to approximate field capacity and incubated for two weeks at room temperature. After incubation of two weeks, 50 g of soil subsample was collected from each pot, air-dried and sieved to pass through 0.5 mm sieve for analyses of pH, EC, and exchangeable bases. Two pre-germinated maize seeds were planted in each pot and thinned to one seedling after one week. Maize was grown for 35 days.

Data analysis

The data obtained were subjected to analysis variance followed by 5% and 1% last significance different test. The statistical analysis was performed using Excel. Regression and correlation treatment of the results were used to assess the buffer dose optimization

Results and Discussion

Buffer characteristics

There was a positive correlation between humic acid content and organic-C content, and CEC, but negative correlation to E4/E6 ratio. The values of E4 / E6 ratio of humic acids from various types of materials were less than 5 (Table 1). This was slightly different from that previously expressed by Tan (2003), who obtained the ratio E4 / E6 of soil humic acid extracts of about 4-5. Humic acid-based buffer from the mixture of humic acids, clay and cations (K^+ and NH_4^+), was intended as a soil conditioner for saline soil to stabilize pH and to balance cations in order to improve soil nutrient availability, plant growth and production. The characteristics of humic acid-based buffer from a variety of organic materials enriched with cations are presented in Table 2. Organomineral buffer complexes were various with different substrate. Association of humic acid and clay mineral form colloidal complexes of humic acid-clay and humic acid-silt aggregate (Petit, 2011). The addition of K^+ decreased the amount of $NH_4^+$and conversely the addition of NH_4^+decreased soil K^+ exchange. The addition of NH_4^+ increased buffer CEC higher than the addition of K^+, because the colloid prefers to absorb NH_4^+ than K^+ (Nursyamsi et al., 2009). Peat humic acid-based buffer had slightly higher CEC than others. This is consistent with the characteristics of peat containing higher organic-C, humic acid, CEC, and smaller E4 / E6 ratio than others.

Table 2. Chemical characteristics of buffer after addition of cations in mixture of humic acid, compost, clay and mineral

Humic acid + cations	pH 1:2.5	Organic-C (%)	CEC (me/100g)	Exch K^+ (me/100g)	NH_4^+ (mg/kg)	Water content (%)
Humic $acid_{Peat}$	6.3	8.17	42.80	4.50	2443.92	12
Humic $acid_{Peat}$ + K^+	4.9	9.44	67.53	6.33	1105.32	59
Humic $acid_{Peat}$ +NH_4^+	8.0	10.17	65.40	4.13	14791.45	62
Humic $acid_{Compost}$	6.8	7.43	59.58	3.19	367.20	64
Humic $acid_{Compost}$ + K^+	5.9	3.93	58.43	9.42	160.71	61
Humic $acid_{Compost}$ +NH_4^+	8.1	10.35	156.48	2.75	10129.52	65
Humic $acid_{Coal}$	6.5	9.65	52.58	4.15	150.40	63
Humic $acid_{Coal}$ + K^+	5.8	8.92	61.32	6.98	48.24	60
Humic $acid_{Coal}$ +NH_4^+	8.0	10.30	56.31	4.51	13017.70	64

The addition of cations did not significantly change water content and organic C content of the materials. Overall, the addiction of humic acid changed pH from > 7 to about 6.3, EC soil was about 0.9 mS / cm, exchangeable Ca, Mg, Na and K decreased from 15.57 to 20,21, from 1.76 to

6.52, from 0.40 to 0.56 and from 0.05 to 0.51 me / 100g soil, respectively.

Effects of buffer on chemical characteristics of saline soil

Application of humic acid + cations significantly affected soil cation exchange (Ca, Mg, K, Na) and soil pH, but not for EC and organic-C (Table 3). The three types of humic acid material affected the value of exchangeable Na and K but did not significantly affect exchangeable Ca and Mg. Although the dose and type of humic acid only partially affected soil cations, there was a strong interaction between them on all the cations evaluated.

Dose of buffer + cations up to 30 g / 3kg (10 g / kg, equivalent to 3 g of humic acid / kg soil) applied at 2 weeks after incubation increased the average C-organic content of more than 20% and CEC of 80 -156 me /100g. Dose of treatment of 20g humic acid with K^+ or NH_4^+ / 3kg increased the exchangeable K, Ca and Mg, as well as decreased the exchangeable Na better than the other treatments (Table 5). This condition is similar to that found by Çelik et al. (2010), Paksoy et al. (2010), Khaled and Fawy (2011) and Turan et al. (2011), where application of humic acid reduced the soil salinity that was detected from the decrease of Na.

Humic acids extracted from compost, peat and coal were abundant sources of organic materials having variations of humic acids content, organic-C content, and CEC. Highly oxidized organic matter such as coal, in which parts of its chemical structure are oxidized, will create site adsorption to bind micronutrients, microflora, and the molecules. According to Tan (2003) and Miklesen (2005), positive ions bound to oxidized site adsorption provide space for the entry of negatively charged molecules which causes them to absorb micronutrients.

Decomposed organic matters (peat and compost) that were saturated with NaOH or KOH caused the site was oxidized to molecules saturated with Na or K, which was ready to be exchanged with all ions in the soil. Saturation NaOH on decomposed or oxidized organic material increased the pH up to 11, leading to maximum acid solubilization and stabilizing of hydrocolloid in suspension. Formulation of humic acid-based buffer was designed to meet the quality requirements of organic soil amendment according to Permentan (2011), i.e. minimum organic-C content is 15%, pH is 4-9, and water content is 15-25%. The characteristics of inorganic soil amendment are as follows: minimum CEC is 60 cmol/kg, maximum moisture content is 10%, and minimum fineness of 50-60 mesh is 90%. The results obtained from buffer formulation showed that the characteristics approached the quality requirements of organic soil amendment with the addition of K^+ and NH_4^+. The addition of K^+ (KH_2PO_4) in a mixture of humic acid, compost and clay increased CEC, exchangeable K^+, but reduced exchangeable NH_4^+, and exchangeable Na^+. This reduction was because of K^+ replaced them on the surface of colloid adsorption so the proportion of K increased. Because the three ions have similar valence, their exchange ability are determined by the affinity of the cations (Tan, 2003). In line with the increasing charge, addition of cations also increased CEC. The ability of K^+ to exchange H^+ potential of missel was greater than NH_4^+, this has made solution to become more acid. The pH values of 4.9-5.9 were lower than the original pH buffer of 6.3-6.5.

The content of buffer-NH_4^+ increased 3-8 times after addition of NH_4^+ and decreased 2-4 times after addition of K^+. As adsorption of K^+ and NH_4^+ follows a similar liotrophic (Tan, 1998), the ability to remove both cations is also similar. The difference in the results obtained was probably because of other ions in the KH_2PO_4 and NH_4SO_4 used. The addition of NH_4^+ increased CEC higher than that of K^+. This condition occurred because of NH_4^+ is easier or more preferable adsorbed to the colloid surface than K^+ (Nursyamsi et al., 2009).

The high amount of NH_4^+or K^+ adsorbed by colloid determines the amount of nutrient supply to the plant. Because of the ability of colloid to absorb NH_4^+ or K^+ is similar, addition of one of the ions will exchange the others in the same amount. The higher the dose of humic acid increased the CEC value. This was because of the increase of cations at the mineral surface and between minerals. Colloids do not only adsorbed ions, but also absorbed water, so that increase water reserves. Humic acid absorbs more than absorbents used to date (Pena-Méndez et al., 2005). This was evident that the absorption ability of the humic acid-based buffer to water was high, around 50-60%, yet during buffer formulation process the water added was only 20%. Soil reaction greatly affects the availability of nutrients to plants.

Under neutral soil pH, nutrients are available in considerable amounts. However, if the soil pH is more than 8.0, nitrogen, iron, manganese, boron, copper, and zinc will be less available to plants (Tan, 1998).

Table 3. ANOVA of humic acid –based buffer on chemical characteristics of saline soil

Source of Variation	F Calculated							F table	
	exch. Ca	exch.Mg	exch.Na	exch.K	pH	EC	Organic-C	0.05	0.01
Replicate	1.33ns	0.94ns	1.56ns	1.14ns	0.52ns	0.69ns	2.85ns	2.92	6.96
Factor A (dose)	0.15ns	0.51ns	3.59*	3.49ns	12.31*	1.58ns	0.10ns	2.92	6.96
Factor B (humic acid type)	1.11ns	0.61ns	2.62**	7.26**	1.04ns	0.85ns	2.66ns	2.92	6.96
A x B	1.09ns	1.61ns	0.79ns	1.48*	0.46ns	1.32ns	3.35*	2.13	3.75
Additive (K^+, NH_4^+)	23.23**	30.72*	3.15ns	23.31**	3.33ns	0.004ns	10.04*	6.31	31.82
Type x Additive	1353.96**	40.19**	187.68**	29.10**	23.90**	0.60ns	1.21ns	1.8595	2.8965

Remarks: ns not significance, * significance at 5% level, ** significance at 1% level

Saline intrusion on soil causes (a) fixation or absorption of other nutrients in the soil by the compounds and silica carbonate or oxide Fe, Ca, and Mg, and (b) disturbance in the balance of Ca^{2+}, Mg^{2+}, Na^+, and K^+ in the soil, and further strengthen the aggregate stability (Mikklesen, 2005; Khaled and Wafy, 2011). Humic acid can increase aggregate stability (Pena-Méndez et al., 2005) which leads to improvement of physical properties of saline soils. The addition of buffer reduced the soil pH from > 7 to about 6.3. This was presumably because of the release of H^+ from humic acid because the cation exchange with Na^+, K^+, Ca^{2+} or Mg^{2+} which made the pH of the solution slightly acid. The ability of K^+ to exchange with potential-H of missel was greater than NH_4^+. This has made solution become more acid. The decline of soil pH was thought to affect the solubility of Fe^{3+}, $H_2PO_4^-$ and NO_3^- fixed by minerals into plant available forms (Mikkelsen, 2005).

Effects of buffer on plant growth

Application of humic acid-based buffer and K^+ or NH_4^+ significantly affected chlorophyll content, biomass dry weight, plant height and leaf area of maize at 35 days after planting (Table 4). The different types of humic acid significantly affected the chlorophyll content and plant height, but did not affect biomass dry weight and leaf area. Application of humic acid-based buffer and NH_4^+ at 20g/3 kg increased chlorophyll content, biomass dry weight, plant height and leaf area greater than the other treatments (Table 5). In order to obtain a better yield, humic acid-based and K^+ should be applied at a dose of up to 30g /3kg, that is equivalent to 3g humic acid/kg as a buffer was made of 30% humic acid, although the results were lower when compared with the addition of NH_4^+. This value was in the range of dose from 1-4 g/kg (Khaled and Wafy, 2011), but higher than 2 g/kg (Turan et al., 2011; Celik et al., 2010). Differences in the results of this study with previous studies reported by other researchers are determined by the sources of humic acid, soil texture and nutrients added. Previous researcher added Zn in humic acid-clay colloid to improve plant growth.

Petrus et al. (2010) reported that addition of humin to humic acid-NK increased maize dry matter and nutrient efficiency. Application of humic substance to soil makes the soil becomes more susceptible to interact with bioinoculants, as humic substances can modify the structure / activity of the microbial community in the rhizosphere compartment, and increase plant physiology, biochemistry, and productivity (Canellas and Olivares, 2014)

Table 4 ANOVA of humic acid –based buffer on the growth of maize growth at 35 days

Source of Variation	F Calculated				F table	
	Chlorophyll	Dry Weight	Plant Height	Leaf area	0.05	0.01
Replicate	0.01ns	0,08ns	0.57ns	0.33ns	2.92	6.96
Factor A (dose)	51.32**	48.51**	22.91**	14.88**	2.92	6.96
Factor B (humic acid type)	95.97**	0.98ns	4.33*	0.04ns	2.92	6.96
A x B	6.88**	0.77ns	1.07ns	1.97ns	2.13	3.75
Additive (K^+, NH_4^+)	17.61**	24.61**	6.97*	1.46ns	6.31	31.82
Type x Additive	156.61**	305.02**	1.016,64**	323.54**	1.8595	2.8965

Remarks: ns not significance, * significance at 5% level, ** significance at 1% level

Table 5. Effects of humic acid-based buffer and cations on soil chemical properties and maize growth.

Additive Cations	Dose (g/3kg)	exch.Na	exch.K	exch.Ca (me/100g)	exch.M	pH	Dry Weight (g/plant)	Chlorophyll	Plant Height (cm)	Leaf area (cm^2)
K^+	10	0.56c	0.48c	15.57a	5.16c	7.39a	86.11b	0.56a	150.82a	403.02a
	20	0.54c	0.34b	17.41b	6.52e	7.58b	93.67c	0.80a	154.06b	403.98a
	30	0.40a	0.41b	15.76a	5.82d	7.67c	112.44e	1.14b	158.92c	471.09c
NH_4^+	10	0.45a	0.05a	20.21c	1.82a	7.41a	47.78a	0.34a	163.02d	408.38b
	20	0.46ab	0.51c	19.80c	2.54b	7.38a	487.22f	2.23c	179.24f	474.12d
	30	0.42a	0.08a	20.13c	1.76a	7.41a	105.44d	0.69a	177.96e	530.53e
LSD 5%		0.04	0.06	0.59	0.59	0.09	0.59	0.59	0.59	0.59

Remarks: numbers in one column followed by same letter are not significantly different at 5% level

Plant will grow optimally if all nutrients needed are available. The need of nitrogen is greater than phosphorus and potassium. Addition of NH_4^+ is expected to increase maize growth better than the addition of K^+, as N plays a role in the formation of chlorophyll. Chlorophyll is crucial to plant photosynthetic. The high release of humic acid-H^+ affected the adsorption of cation added. The addition of K^+ or NH_4^+ improved soil exchangeable of Na and Ca, as well as increased their availability in the soil for plants.

The higher concentrations of humic acid-based buffer was added, the greater amount availability of K^+ or NH_4^+ for plant uptake. These conditions increased the process of photosynthesis that promoted growth of plant organs, i.e. weight of biomass (Figure 1), the amount of chlorophyll (Figure 2), and the plant height (Figure 3). The improvement of those plant organs was determined by the interaction of different sources of humic acid, various cations, and doses applied. Addition of K^+ in the humic acid will increase the proportion of K in the sorption colloid so that the equilibrium of cations shifted toward increasing ratios of K/Na and K/Mg (Goudarzi and Pakniyat, 2008). The increase of K/Na value will reduce constraints of Na uptake by plants. Provision of K will increase ion transport in the process of assimilation of sugars and carbohydrates which further increases the plant height, leaf area, and biomass.

Although the addition of K increased crop yields, the biomass dry weight of the plant was lower than that with the addition of NH_4^+. Ammonium (NH_4^+) is one of mayor nutrients for plant uptake and it is required more than K^+, so that the availability of N determines the development of plant organs. The formation of plant leaf chlorophyll will help the process of photosynthesis with the availability of CO_2, water and sunlight into carbohydrates. These nutrients are available in abundance in the air and in the soil. The addition of humic acid also indirectly increase the reserves of H_2O in the soil because of its ability to absorb water becomes high (Pena-Méndez et al., 2005).

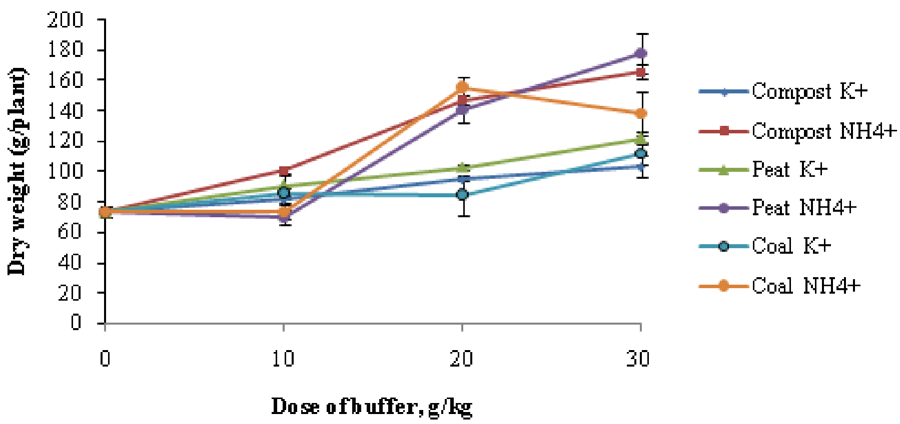

Figure 1. Dry weight of maize at 35 days after planting under various doses of humic acid and cations

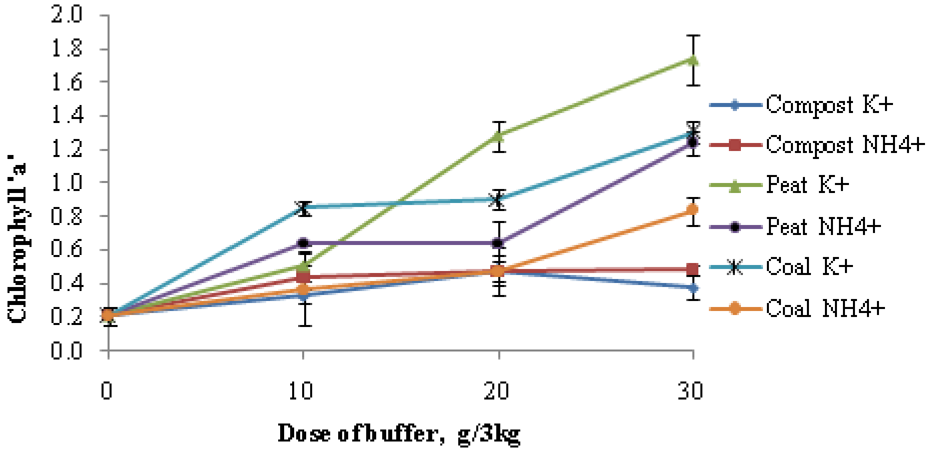

Figure 2. Chlorophyll ‘a’ of maize at 35 days after planting under various doses of humic acid and cations

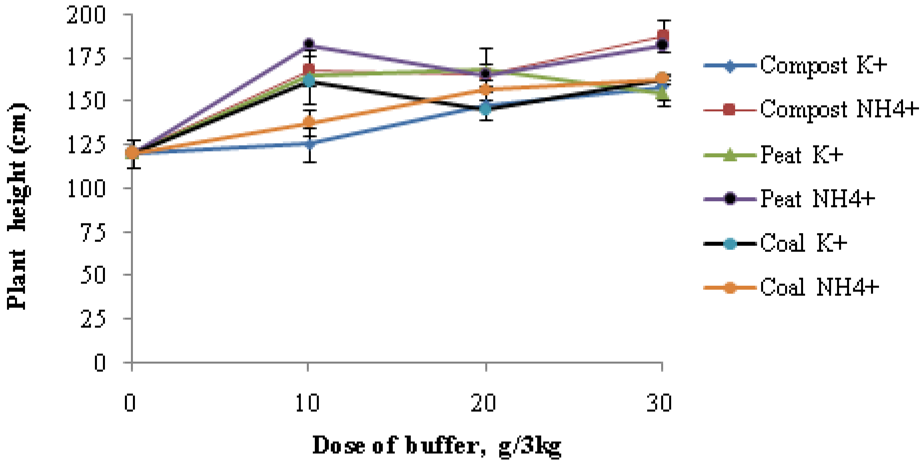

Figure 3. Plant height of maize of maize at 35 days after planting under various doses of humic acid and cations

In line with the increasing dose of buffers, the chlorophyll content of leaves increased. Total leaf chlorophyll in the treatment of peat + NH_4^+ was higher than the other buffer additions. This was thought to be the high capability of peat humic acid to exchange cations that led to maximum nutrient uptake by the plant (Figure 1). As shown in Figure 1, application of buffer up to 30g/3kg linearly increased maize growth. This indicates that additional dose is needed to achieve optimum results. The addition of NH_4^+ increased biomass dry weight and plant height, but did not increase chlorophyll. This condition occurred because of the part–of NH_4^+ exchanged to NH_3 form in alkaline soil, so that the availability of N reduced. The decrease of N resulted in the reduction of chlorophyll formation. On the contrary, the addition of K^+ increased available Mg (Table 5) and inhibited other cations, which led to the increase of chlorophyll content. There was a strong correlation of biomass dry weight at 35 days after planting with leaf chlorophyll and exchangeable Ca and inversely correlated to soil pH and soil EC (Table 6). This indicates that the maize growth was limited by soil reaction, soil salinity, and nutrient availability. The strongest correlation between chlorophyll content and biomass dry weight 35 days after planting was probably due to the important role of chlorophyll in photosynthesis that generate energy for plant organ development.

Table 6. Correlation of the biomass dry weight with soil chemical characteristics of and plant growth

	Chlorophyll (%)	Exch.Ca (me/100g)	Soil pH	Soil EC (mS/cm)	Organic-C (%)
Biomass dry weight (g/plant)	0.876700216	0.64612	-0.62737751	-0.58332144	0.243036103

Conclusion

Humic acid-based buffer made of a mixture of humic acid extract, compost, clay and cations of K^+ or NH_4^+ with a proportion of 30-40%, 40-50%, and 10-20%, 10%, respectively, had CEC of 60-156 me/100g, organic C-organic content of 20-30%, pH of about 6.0, black in colour, and slow water soluble. Application of buffer up to 30g/3kg of soil significantly increased the exchange cations, biomass dry weight, plant height, chlorophyll, and leaf area. There was interaction between the dose and the type of humic acid in affecting soil cation exchange and plant growth. The best treatment combination was 20 g peat humic acid + NH_4^+ or 30 g peat humic acid + K^+ per 3 kg of saline soil.

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