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SOIL PROPERTIES AND GROWTH PERFORMANCE OF RIZE (*Oryza sativa* L.) GROWN IN A FLY-ASH AMENDED SOIL

Bambang J. Priatmadi[1], Akhmad R. Saidy[2], and Meldia Septiana[3]

[1]Department of Soil, Faculty of Agriculture, Lambung Mangkurat University. Jalan A. Yani Km 6 Simpang Empat Banjarbaru, South Kalimantan, Indonesia. Tel./Fax. 0511-4 4773112/4782899, [2]email address: asaidy@unlam.ac.id

ABSTRACT

Fly-ash (FA) is largely alkaline in nature and contains many essential elements for plant growth along with toxic metals. Therefore, fly-ash is potential to be applied as soil ameliorate that may improve soil properties and plant growth. In this experiment we studied the changes in chemical properties and rice production of acid sulphate soils amended with fly ash. Six different amounts of FA, viz. 0 (100% soil), 5, 10, 20, 40 and 75 tones FA ha^{-1} were added homogenously to 6 kg of soils in pots of PVC and then chemical properties of acid sulphate soils were observed after a 3-week of incubation. Subsequent of the observation of soil properties, rice was planted onto the pots. Results of study showed that fly-ash application improved soil pH and exchangeable Ca. However, the availability of nitrogen of acid sulphate soils decreased significantly with fly-ash application. The experiment also showed that fly-ash application to soils improved rice growth (height plant, number of tillers, dried-weight root and dried-weight shoot) and rice production. Application 20 tones FA ha^{-1} resulted in higher rice production than the application 0, 5 and 10 tones FA ha^{-1}, and increasing subsequent the amount of FA application did not significantly increase the rice production. Results of this study demonstrate that low-level fly-ash application resulted in the improvements of soil chemical properties and rice production.

Key words: fly-ash application; soil ameliorant; heavy metals; sub-optimal low land

INTRODUCTION

Main problem in rice cultivation in acid sulphate soils is low productivity. Data from the Department of Agriculture, South Kalimantan (2007) showed that rice production in acid sulphate soils ranged from 3.14 to 4.30 tonnes per hectare. One of the factors limiting the growth of rice in acid sulphate soils is low soil pH. The observations in the province of South Kalimantan showed that the pH (H_2O) of the acid sulphate soils ranged between 3.96 and 4.88 (Saidy et al., 2005). Low soil pH results in low availability of soil phosphorus, calcium, magnesium, potassium and sodium (Bohn et al., 2001), and this condition eventually result in unhealthy plant growth. Improvements soil properties can be done by adding ameliorant material into the soil to increase soil pH and simultaneously improve the content of some nutrients such as Na, Ca, K and Mg.

Fly ash (FA), a coal combustion residue, is an amorphous ferroalumino silicate with a matrix very similar to soil. Elemental composition of FA (both nutrient and toxic elements) varies due to types and sources of used coal (Comberato et al., 1997). Addition of FA to soil may improve the physico-chemical properties as well as nutritional quality of the soil and the extent of change depends on soil and FA properties. In view of the high cost of disposal and environmental management, utilization of FA in agricultural sector could be a viable option. Its use in agriculture was initially due to its liming potential and the presence of essential nutrients, which promoted plant growth and also alleviated the nutrient deficiency in soils (Mittra et al., 2005).

The disposal of fly-ash (FA) from coal-fired power stations causes significant economic and environmental problems. Dumped FA may adversely affect the environment by mobilization of its hazardous constituents and thus contaminate the surface and ground waters, soils and vegetation. Fly-ash is largely alkaline in nature and contains many essential elements like Si, S, B, Ca, Mg, Fe, Cu, Zn, Mn and P. Therefore, FA may be applied to soils as soil amendment to improve soil properties and thereby enhance plant growth and productivity. However, there is a lack of evidence the use of fly-ash as soil amendment. In this study, we examined the effect of fly-ash application on changes in chemical properties and rice production on acid sulphate soils.

MATERIALS AND METHODS

Experimental Sites

Fly-ash used for the experiment was collected from the Asam-asam Steam Power Plant, South Kalimantan Province, Indonesia while soils for mixing with FA were obtained from the Desa Tinggirian II Luar, Kecamatan Tamban, Kabupaten Barito Kuala, South Kalimantan. Selected properties of acid sulphate soils used for this study are presented in Table 1.

Greenhouse Experiment

Six levels of amendments of FA, viz. 0 (100% soil), 5, 10, 20, 40 and 75 tones FA ha^{-1} were added homogenously to 6 kg of soils in pots of PVC and then incubated for 3 weeks. After 3 weeks soils in the pots were sub-sampled and analyzed for pH, exchangeable bases (Na, K, Ca dan Mg), mineral nitrogen, and available P. The usual farm practice of transplantation of 20-30 days old seedlings, grown in a separate seedbed, was done at three seedlings per pot. Rice plants were kept in natural conditions and irrigated with tap water to maintain water-logged conditions and avoiding leakage of water from pots. All the growth and yield attributing characters were studied after the harvesting period of 120 days. Plant height (cm) was measured by a metric scale and number of tillers was counted manually. After this, plant parts were partitioned into roots, leaves, straw and grains and then were washed with double distilled water. Root biomass (g pot^{-1}), straw weight (g pot^{-1}) and total grain weight (g pot^{-1}) were determined on oven-dried at 60 ^{o}C basis.

Table 1. Selected physical and chemical properties of acid sulphate soils used for the study

Texture	
- Sand (%)	24.23
- Silt (%)	39.21
- Clay (%)	36.56
Bulk density (g cm^{-3})	0.55
pH (H_2O)	3.98
pH (KCl 1 N)	3.67
Organic C (g C kg^{-1} soil)	27.67
Total nitrogen (g N kg^{-1} soil)	1.42
Exchangeable bases (cmol kg^{-1} soil)	
- Na	0.13
- K	0.09
- Ca	4.51
- Mg	0.14
CEC (cmol kg^{-1} soil)	29.24
Total Al (mg kg-1)	1245.80
Total Fe (mg kg-1)	4916.17
Total Mn (mg kg-1)	175.65

Data Analysis

The ANOVA procedure of GenStat 11th Edition (Payne, 2008) was used to determine the effect of treatment on changes in the chemical properties and plant growth and production. In the case of significance in ANOVAs, means were compared by the Least Significant Difference (LSD) multiple comparison procedure at P<0.05.

RESULTS AND DISCUSSION

Changes in Soil Properties

Results of analysis of variance showed that soil pH, mineral nitrogen content and the concentration of exchangeable Ca were significantly affected by the addition of fly-ash. In contrast, fly-ash application to acid sulphate soils did not change the content of exchangeable Na, K and Mg, and available P.

Soil reaction (soil pH) in the soil without fly-ash application was 5.08, increased to 5.31–5.48 with the application fly-ash 5–40 tonnes ha^{-1} (Figure 1). The soil pH reached to 5.62 with when the amount of fly-ash application was increased to75 tonnes ha^{-1} (Figure 1). However, the soil pH at 75 tonnes ha^{-1} of fly-ash application was not significantly different to those at 20 dan 40 tonnes of fly-ash aplication (Figure 1).

Increased soil pH occurs because fly-ash containing CaO and MgO, which reacted with H^+ ions to neutralize soil acidity. The greater the amount of fly-ash application, the greater the amount of CaO and MgO are given into the soils, thus the greater the change in soil pH. Kishor et al. (2009) reported that the neutralization capacity of fly-ash ranged from 0.01 to 3.74 meq per gram H_3O^+. Increasing the pH of the soil in paddy soils treated with fly-ash was also reported in several other studies (Clark et al., 2001; Hyup et al., 2006; Swain et al., 2007; Sajwan et al., 2007).

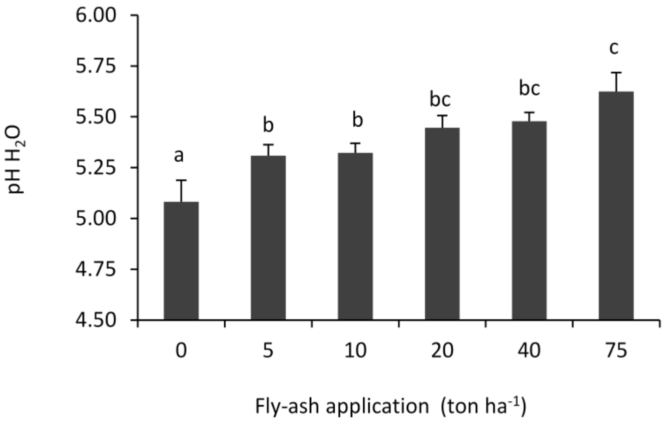

Figure 1. Effect of fly-ash application on soil pH. The vertical bars represent standard deviation (n=5). Similar letters above columns indicate no statistical difference between the treatments based on the LSD test at *P* <0.05.

Figure 2 reveals that the fly-ash application of 20 tonnes ha^{-1} yielded exchangeable Ca that is not different from the soil without fly-ash application. However, when the amount of fly-ash application increased to 40 and 75 tonnes ha^{-1}, the concentration of exchangeable doubled than the soils without fly-ash application (control), which only reached to 15 cmol kg^{-1}. Effect of fly-ash on the exchangeable Ca is due to the higher content CaO than the other cations (Na, K and Mg) of fly-ash, so that when fly-ash is added to soil, it will increase the availability of Ca in soils. This is consistent with the study of Kishor et al. (2009) who reported that exchangeable Ca is the most dominant cation in soils with fly-ash application

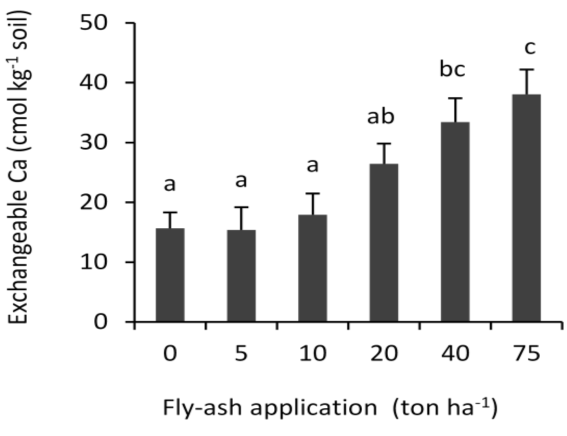

Figure 2. Effect of fly-ash application on exchangeable Ca. The vertical bars represent standard deviation (n=5). Similar letters above columns indicate no statistical difference between the treatments based on the LSD test at *P* <0.05.

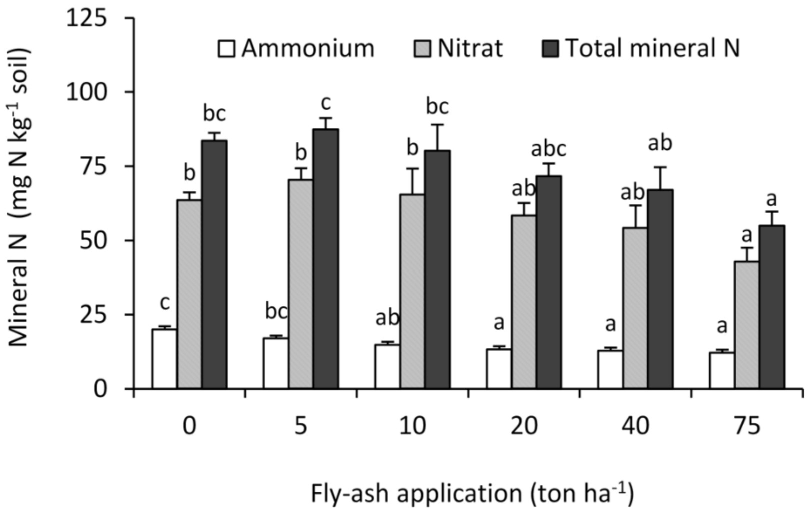

Figure 3. Effect of fly-ash application on inorganic nitrogen. The vertical bars represent standard deviation (n=5). Similar letters above columns indicate no statistical difference between the treatments based on the LSD test at *P* <0.05.

Concentration of ammonium and nitrate decreased with an increase in the amount of fly-ash application. Concentration of ammonium in the soil decreased from 20.03 mg N kg^{-1} to 12.15 mg N kg^{-1} soil and concentration of nitrate decreased from 63.61 mg N kg^{-1} soil to 42.83 mg N kg^{-1} soil with fly-ash application (Figure 3). These combinations resulted in reduction in total mineral nitrogen from 83.64 mg N kg^{-1} soil to 54.98 mg N kg^{-1} soil with the application of fly-ash (Figure 3). Decline in the mineral nitrogen with fly-ash application is due to increased gaseous N losses through denitrification process with increasing the amount of fly-ash application.

Growth Performance of Rice

Results of variance analysis showed that fly-ash application influenced significantly the growth and production of rice. Fly-ash application of 5 and 10 tonnes ha^{-1} improved plant height from 78 cm to 92-94 cm. However, when the amount of fly-ash application increased to 20-75 tonnes ha^{-1}, plant height did not show significant increases with subsequent increasing the amount of fly-ash application (Figure 4). Similar results were obtained for the number of tiller variable. Without the fly-ash application, the average number of tillers reached only 3 plants per pot. Number of tillers plants increased significantly to 7 plants per pot with the fly-ash application at the rate 5-10 tonnes ha^{-1} (Figure 4).

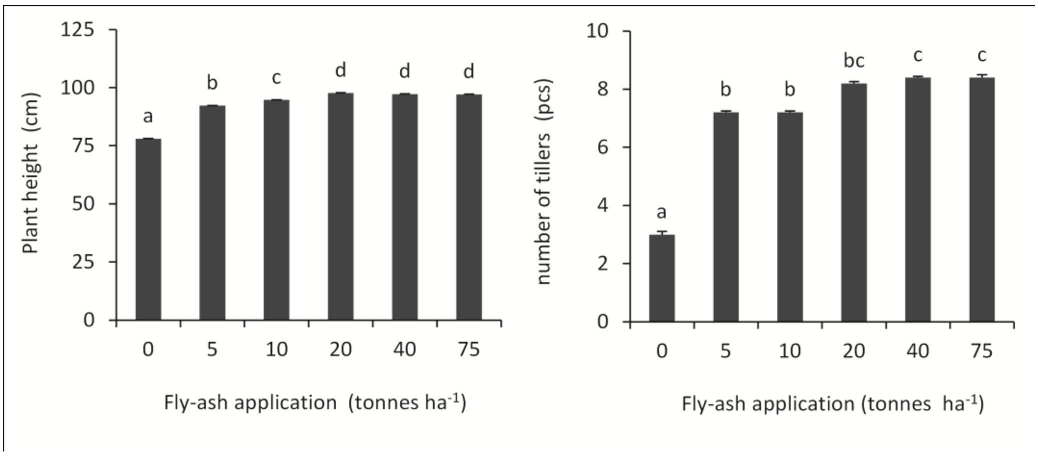

Figure 4. Effect of fly-ash application in plant height (left) and number of tillers (right). The vertical bars represent standard deviation (n=5). Similar letters above

columns indicate no statistical difference between the treatments based on the LSD test at P <0.05.

Root dry weight of rice plants with fly-ash applications up to the level of 20 tonnes ha^{-1} is no different from that without fly-ash application, which is in the range of 1.5 to 3.5 grams per pot (Figure 5). However, when the amount of fly-ash application increased to 40 and 75 tonnes ha^{-1}, root dry weight of rice plants increased to 5 grams per pot (Figure 5). In contrast to the root dry weight, stems dry weight of rice with the treatment of 5-20 tonnes ha^{-1} fly-ash application increased to 9-13 grams per pot from 3 grams per pot at the treatment of without fly-ash application (Figure 5). The highest root dry weight of plants was observed in the treatment of 40 and 75 tonnes ha^{-1} fly-ash application (Figure 5).

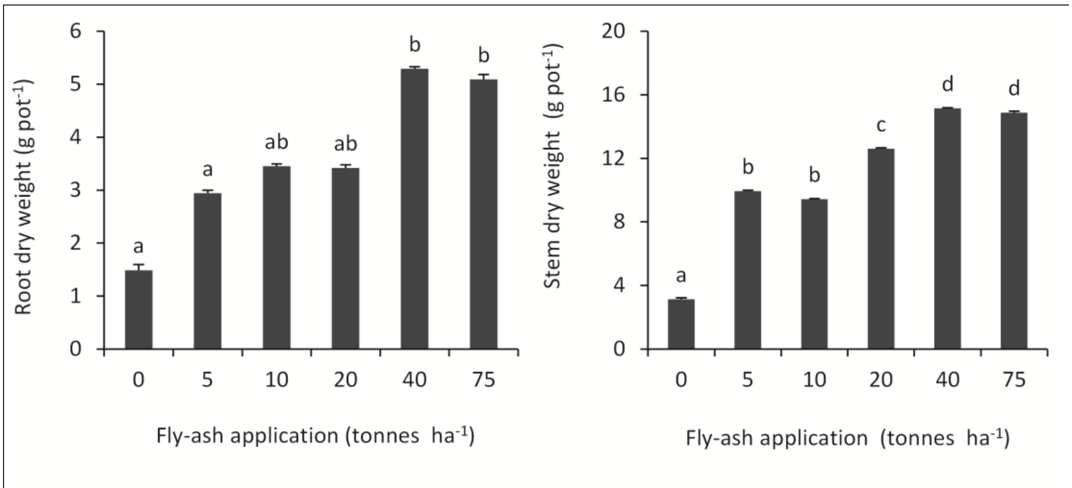

Figure 5. Effect of fly-ash application on root dry weight (left) and stem dry weight (right). The vertical bars represent standard deviation (n=5). Similar letters above columns indicate no statistical difference between the treatments based on the LSD test at P <0.05.

Figure 6. Effect of fly-ash application on rice production. The vertical bars represent standard deviation (n=5). Similar letters above columns indicate no statistical difference between the treatments based on the LSD test at P <0.05.

Rice production also increased by fly-ash application. Grain dry weight of rice without fly-ash application is 3.5 grams of pot^{-1}, increased more than 200% (11.4 g pot^{-1}) with 5 tonnes ha^{-1} of fly-ash application. When the amount of fly-ash application increased to 20 tonnes ha^{-1}, grain dry weight increased by 280% (13.4 g pot^{-1}). Moreover, there is an increase by 300% in the grain dry-weight (14.5 g pot-1) with 75 tonnes ha^{-1} of fly-ash application (Figure 5).

Increases in the growth and production of rice were attributed to increasing the amount of nitrogen, phosphorus and potassium absorbed by rice. Nitrogen uptake by rice in the treatment of without fly-ash application was 84.39 mg N pot^{-1}, increased by 16-38% with 5-75 tonnes ha^{-1} of fly-ash application. Phosphorus and potassium uptake by rice increased by 6-70% and 17-128%, respectively, with the similar amount of fly-ash application (data not shown).

Increase in nutrient uptake followed by increase in the growth and production of rice may due to changes in the characteristics of the soil with the application of fly-ash. The addition of fly-ash to soils accelerate the process of mineralization of organic matter (Khan and Khan, 1996), thus increasing the availability of nitrogen. Lee et al. (2007) in the study of changes in the availability of P in soils with 120 tonnes ha^{-1} of fly-ash application in South Korea reported that the increase in P in the soils due to the increase in the pH of the soil, increasing the amount of silicate and the additional P from coal ash. In this study, we also observed increases in soil pH from 4.43 at the treatment without fly-ash application to pH 5.22-5.41 with the fly-ash application. Study conducted by Swain et al. (2007) also showed that the fly-ash application increases the uptake of N, P and K by 106-149%.

CONCLUSION

Observations on soil chemical properties after fly-ash application showed that the addition of the fly-ash can increase the soil pH, in which increased the amount of fly-ash application to the soil will be followed by increases in soil pH. This result implies that the fly-ash is potential to be used as an alternative lime for soil improvement properties to increase biomass production. Results of the study demonstrated that among the exchangeable cations observed, only exchangeable Ca increased significantly with fly-ash application, indicating that fly-ash can be used as a source of Ca for improvement of soil properties. The application of fly-ash also increases the growth and yield of rice.

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