Available online at:
http://journal.unila.ac.id/index.php/tropicalsoil
DOI: 10.5400/jts.2013.18.2.99

Changes of Soil Chemical Properties during Rice Straw Decomposition in Different Types of Acid Sulphate Soils

Anna Hairani* and Ani Susilawati**

*Indonesian Swampland Agriculture Research Institute. Jl. Kebun Karet. Loktabat Utara. Banjarbaru. Indonesia, e-mail: *hairani_anna@yahoo.com; **ani.nbl@gmail.com*

Received 26 November 2012 / accepted 8 May 2013

ABSTRACT

Organic residues often exhibit different physico-chemical properties and affect the soil ecosystem in different ways. Hence, the study of their impact on soil is essential to benefit from their potential as amendments and to avoid adverse environmental effects. It is required to study the role of rice straw in the changes of soil properties during decomposition processes in the rice field. The research was conducted on potential acid sulphate soil (PASS) and actual acid sulphate soil (AASS) in the glass house. Soil pH, Fe^{2+}, organic-Fe, total N and available P were observed at 2, 4, 6 and 8 weeks after planting (WAP). The results showed that rice straw application : (1) decreased soil pH of PASS and increase soil pH of AASS; (2) tended to increase Fe^{2+} both in PASS and AASS; (3) stimulated the organic-Fe concentration that was higher than in PASS; (4) had no different effect in total N and decreased P concentration in the both of soil during observation. P concentration on PASS was lower than on AASS.

Keywords: Decomposition, rice straw, soil chemical properties, soil type

INTRODUCTION

Most of acid sulphate soils are found in the tidal swamp. Originally, it is unfertile soil for rice cultivation. In the tidal swamp, farmers have been using rice straw as an ameliorant technology to improve their rice field. Evidently, it is sustainable and environmental friendly technology. The application of green manure from rice straw increased rice production on acid sulphate soil (Indrayati and Jumberi 2002). Local farmer in Kalimantan always applicate the rice straw to the their rice field to maintain soil fertility, none of anorganic fertiliizer and lime were applicated to the their rice field. The rice straw was composted in naturally with flooded condition.

Many researches were conducted to study the role of organic matter as a economical and environmental friendly technology for agriculture development. The results showed that organic matter has a complicated and specific role to the soil properties and plant growth. Reddy and DeLaune (2008) and De-Campos *et al.* (2009) stated that the different in soil redox reaction was determined by organic matter quality and quantity. Most of researchers have reported that the rice straws contain N, P, K, Ca and organic acid, its application in to the soil increases nutrient concentration and decreases toxic element concentration through chelate reaction with organic acid (Dobermann and Fairhurst 2000). However, these results are contradicted with the studies that conducted by Kongchum (2005) and Fahmi. (2010). Their results indicated that the rice straw application had adverse effect on the rice growth, rice straw application increased Fe^{2+} concentration and decreased P availability in the soil solution. In addition, Reddy and DeLaune (2008) stated that organic matter promoted increasing of redox reaction in the soils, highest concentration of Fe^{2+} was found in the soil with higher decomposable organic matter content.

Organic residues often exhibit different physico-chemical properties and impact on soil ecosystem in different ways. Hence, the study of their impacts on soil are essential to benefit from their potential as soil amendments and to avoid adverse effects to environment. It is required to study the role of rice straw in the changes of soil properties during decomposition processes in the rice field. Organic matter decomposition was largely controlling the soil quality and productivity and its affect to the soil chemical properties (Cayuela *et al.* 2009).

The present work was aimed to study the changes of soil chemical properties during rice straw domposition processes on the two type of acid sulphate soils.

MATERIALS AND METHODS

Study Site and Design

The research was conducted in a glass house consisting of two factors using a completely randomized design with three replications. The first factor was soil type: potential acid sulphate soil (PASS) and actual acid sulphate soil (AASS). The second factor was height of flooding water: 1 cm and 4 cm from above the soil surface.

Soil and Rice Straw Used

The soil used in the experiments was sampled (0–20 cm) from potential and actual acid sulphate soils. The soils were air dried and sieved (< 2 mm) and rice straw was cutted into small pieces (about 5 cm in size) to homogenize their particle size before application. Twenty four kg of air drying soil and 60 gr of rice straw were placed into a plastic pot. Sufficient amount of rain water was added into each pot so that the water level was 3 cm above the soil surface. Two weeks later, water was drained to leach acidity and toxic elements of soils due to pyrite oxidation during air drying soil.

Experimental Procedures

Rice seedlings (aged 21 days) were planted in the pot, sufficient amount of water was added into the pots according to each treatment. Throughout the duration of the experiment, aquadest was regularly added into each pot in order to maintain the water level. Three days after planting, 2.36 g of SP-36 and 1.18 g of urea as well as KCl were applied as basal fertilizers (equal to 100 kg urea ha^{-1}, 200 kg SP-36 ha^{-1} and 100 kg KCl ha^{-1}). Soil sampling was conducted at 2, 4, 6 and 8 weeks after planting (WAP). Soil pH, Fe^{2+}, organic-Fe, available-P and total-N in soil were analyzed by methods outlined in Balai Penelitian Tanah (2005).

Table 1. Soil and rice straw properties used in the experiment.

Properties	Soil		Rice straw
	PASS	AASS	
pH	4.44	3.60	-
Total N	0.20	0.15	-
P-Bray 1	24.19	38.96	-
Initial C/N	-	-	77.9
Final C/N	25.31	24.51	-

PASS= potential acid sulphate soil; AASS = actual acid sulphate soil.

Data Collection and Analysis

The first factor of soil type were statistically significant on the observed parameters. Data were analyzed by the Analysis of Variance (ANOVA) method and presented in a scatter form were statistically significant. While, the second factor of height of water flooding was not.

RESULTS AND DISCUSSION

Soil pH

Two weeks after planting (2 WAP), application of rice straw decreased soil pH of PASS but increased soil pH of AASS (Figure 1). It indicates that hidrogen (H) ion was released from the initial decomposition processes of rice straw. Similiar results were reported by Kongchum (2005) and Fahmi *et al.* (2009), that the average of soil pH decreased after rice straw application. In addition. The different patterns of PASS pH and AASS pH are considered to be related to their buffering capacity. Rukshana *et al*. (2010) stated that the initial soil pH determined by the changes of soil pH and soil buffering capacity.

Rice straw application led to differences in responses pattern of changes in soil pH between PASS and AASS (Figure 1), it indicated the difference in reduction ability of PASS and AASS, Reddy and DeLaune (2008) stated that the changes of soil pH due to redox reaction are determined by

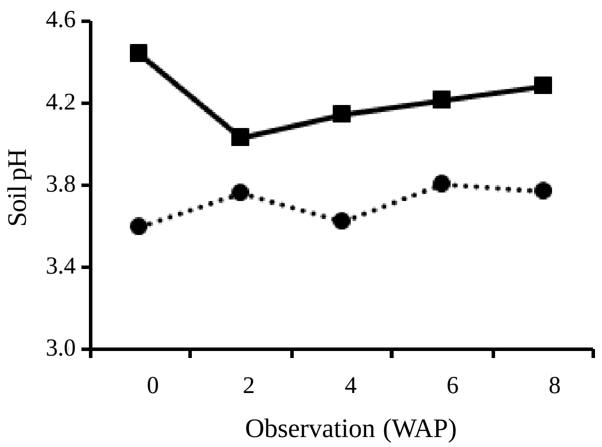

Figure 1. Dynamics of soil pH due to rice straw application on the potential acid sulphate soils (—■—) and actual acid sulphate soils (···●···).

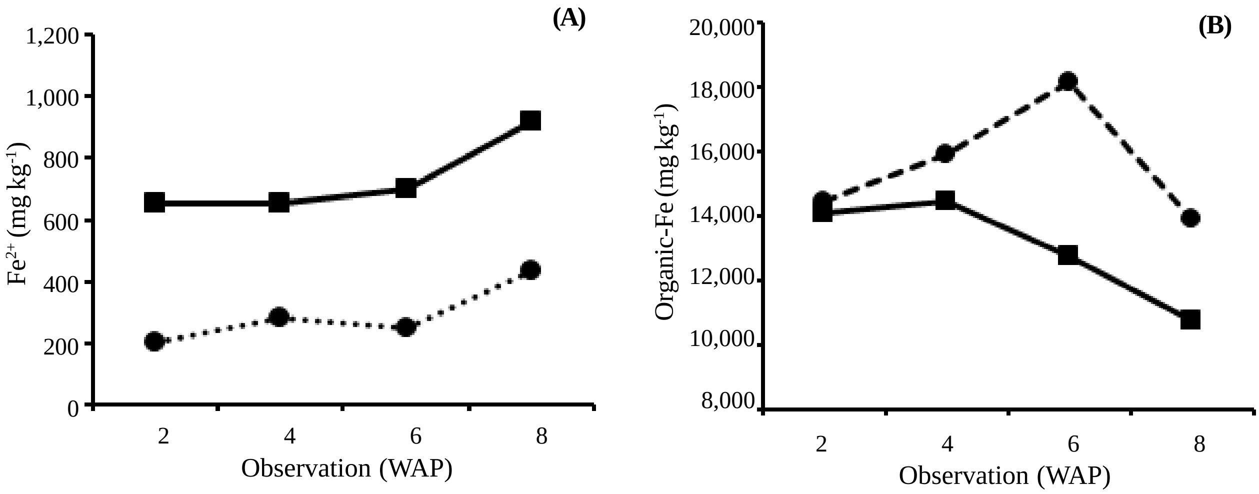

Figure 2. Dynamics of Fe^{2+} concentration (A) and organic-Fe (B) due to rice straw application on the potential acid sulphate soils (—■—) and actual acid sulphate soils (···●···).

Fe mineral in soil. This arguement is proved with data of Fe^{2+} concentration in PASS compared to Fe^{2+} concentration in AASS (Figure 2).

Iron Concentration in Soils

Based on the observation on 2 to 8 WAP, Fe^{2+} concentrations in the PASS and AASS are likely to increase (Figure 2A), this condition indicated that soil flooding and rice straw application stimulated Fe^{3+} reduction in the soil. On 6 WAP, rice straw application increased Fe^{2+} concentrations in the PASS and reduced Fe^{2+} concentrations in the AASS. The different in Fe concentrations pattern may be related to mineralization of organic-Fe (Figure 2B). In addition, AASS which was used in this experiment was affected by the agricultural activities, which caused the soils more ploughing and higher surface area. So, more reactive sites can be provided for Fe^{3+} reduction, resulting in the higher total Fe reduction rates than the other soils (Liu *et al.* 2010). Pedologically, AAS is older than PASS, Dent (1986) stated that an old acid sulphate soil, which contains most iron is in of well-crystallised geothite and haematite. Morris (2011) stated that crystalline Fe is more difficult to be reducted compared to Fe-hidroxide.

The increasing of Fe concentration at 8 WAP was caused by mineralization of organic-Fe not by Fe^{3+} reduction. This was proved by 2 evidences: (1) the decreasing of organic-Fe at 8 WAP (Figure 2B), the equlibrium system of Fe in soil solution was largelly controlled by mineralization of organic-Fe (Olomu *et al.* 1973) and (2) soil pH did not increase at the 8 WAP (Figure 1).

The organic-Fe concentration in AASS was higher than in PASS (Figure 2B), it may be related to lower pH of AASS than PASS. This condition stimulated the organic-Fe complexes formation. The solubility of Fe-oxide increases with decreasing pH (Lindsay 1979), leading to a trend that lower pH favors complexation and precipitation of Fe with organic matter (Wagai and Mayer 2007). The reducing concentration of organic-Fe at the 6 and 8 WAP on PASS and 8 WAP on AASS may be caused by mineralization of organic-Fe due to the increase of Fe^{2+} concentrations as shown in the Figure 2A.

Total Nitrogen and Available Phosphorus in Soils

There is no different on total N content in the both of soil during observation (Figure 3), low organic matter quality might caused this condition. Fresh straw that was applied in has C/N value as 77.9. Havlin *et al.* (2005) stated that the organic matter with high C/N value applied to the soil, soil N will be immobilized. Compared at 0 WAP, total N in the soil solution of PASS and AASS at 4 and 6 WAP tended to increase. This condition may be ccaused by aplication of urea as basal fertilizer at the 3 days after planting. Whereas, decreased of total N at 6 ad 8 WAP in the soil solution might be related to volatization processes of N and N uptake by rice. Flooding led to strong changes in soil due to a switch from aerobic to anaerobic conditions, favoured the reduction of NO_3 to NH_4^+. Subsequently, N may loss through volatization as NH_3 or N_2O (Reddy and DeLaune 2008; Banach *et al.* 2009).

Although P fertilizer was applied 3 days after planting, the application of low quality organic matter decreased P concentration in the soil solution, especially for AASS (Figure 4). Decreasing of P in soil solution during the experiment can be explained with three reasons (1) immobilization was occurred

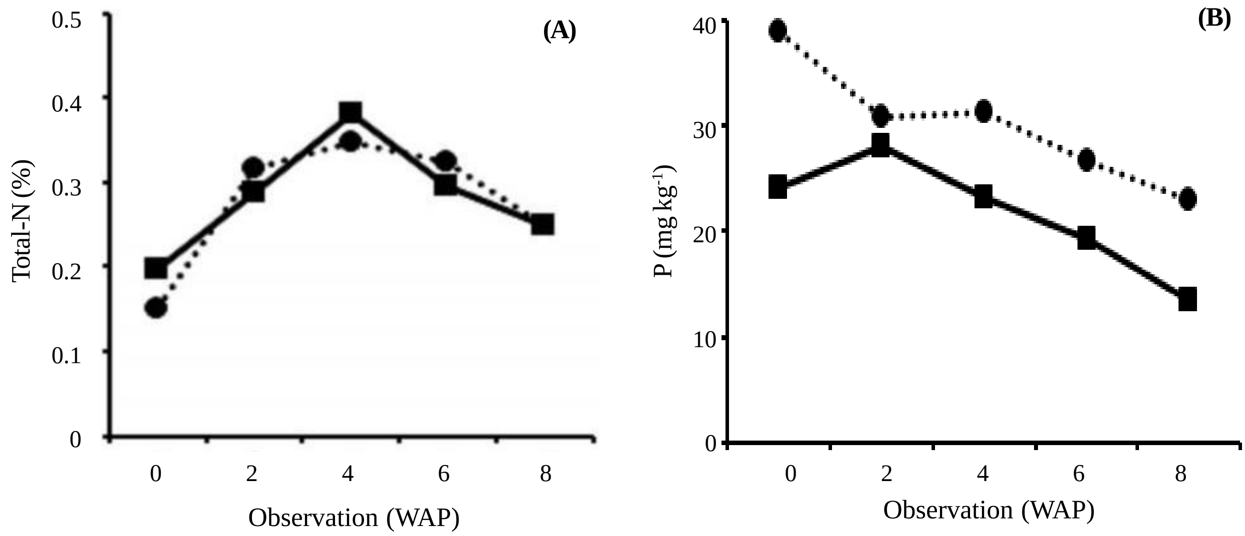

Figure 3. Dynamics of total N (A) and available P (B) due to rice straw application on the potential acid sulphate soil (—■—) and actual acid sulphate soil (···●···).

due to low quality of organic matter applied. Application of rice straw with high C/N value led to P immobilization (Fahmi *et al.* 2009), (2) most of applied P into the soil was fixed by iron in the soil solution, and (3) the occurence of P uptake by rice plant.

Concentration of P on PASS was lower than on AASS (Figure 3), this condition was related to higher Fe^{2+} concentration in AASS than PASS (Figure 2). Phosphate dissolution was correlated with Fe^{3+} reduction (Morris 2011). However soil pH of PASS was higher than AASS, available P in AASS was higher than PASS (Figure 3), this fact showed that increasing availabilty of P in low soil pH was controlled by Fe in large concentration. Liang *et al.* (2010) found that the release of P significantly increased in the low pH, more P was released on pH range of 1.6 to 3.4 than pH 4.6. Lindsay (1979) demonstrated that Al/Fe-oxide was more dissolved in pH < 4, therefore, ortho-P which is fixed will be released to the soil solution as shown in the equations:

$AlPO_4\ 2\ H_2O + 3\ H \longrightarrow Al^{3+} + H + H_2PO_4 + 2\ H_2O$

$FePO_4\ 2\ H_2O + 3\ H \qquad Fe^{3+} + H + H_2PO_4 + 2\ H_2O$

CONCLUSIONS

Soil type determined pattern of changes in soil pH, concentration of Fe^{2+}, organic Fe, and P in soil due to rice straw application. The different pattern of changes of soil chemical properties may be related to soil buffering capacity, initial soil pH, organic Fe concentration, and rice straw quality.

REFERENCES

Balai Penelitian Tanah. 2005. *Analisis Kimia Tanah, Tanaman, Air dan Pupuk.* Badan Penelitian dan Pengembangan Pertanian. Departemen Pertanian. Bogor. p: 136 (in Indonesian).

Banach AM, K Banach, RCJH Peters, RHM Jansen, EJW Visser, Z Stepniewska, JGM Roelofs and LPM Lamers. 2009. Effects of long-term flooding on biogeochemistry and vegetation development in floodplains; a mesocosm experiment to study interacting effects of land use and water quality. *Biogeosciences* 6: 1325-1339. doi:10.5194/bg-6-1325-2009.

Bonneville S. 2005. Kinetics of Microbial Fe (III) Oxyhydroxide Reduction : The Role of Mineral Properties. [*Dissertation*]. Department of Earth Sciences-Geochemistry, Faculty of Geosciences, Utrecht University. The Netherlands. 117 p.

Cayuela ML, T Sinicco and C Mondini. 2009. Mineralization dynamics and biochemical properties during initial decomposition of plant and animal residues in soil. *App Soil Ecol* 41: 118 -127.

De-Campos AB, AL Mamedov and C Huang. 2009. Short-term reducing conditions decrease soil aggregation. *Soil Sci Soc Am J* 73: 550-559.

Dent D. 1986. Acid Sulphate Soils: *A Baseline for Research and Development*. International Land Reclamation Institute Pub. 39. Wageningen, The Netherlands. 204 p.

Dobermann A and T Fairhurst. 2000. *Rice: Nutrient Disorders and Nutrient Management*. International Rice Research Institute. Makati city, The Fhillipines. 191 p.

Fahmi A, B Radjagukguk and BH Purwanto. 2009. Kelarutan posfat dan ferro pada tanah sulfat masam yang diberi bahan organik jerami padi. *J Tanah Trop* 14: 119 -125 (in Indonesian).

Fahmi A. 2010. Pengaruh pemberian jerami padi terhadap pertumbuhan tanaman padi (*Oryza sativa*) di tanah sulfat masam. *J Berita Biol* 10: 7-14 (in Indonesian).

Havlin JL, JD Beaton, SL Tisdale and WL Nelson. 2005. *Soil Fertility and Fertilizers, an introduction to nutrient management.* 7th edition. Prentice Hall. 515 p.

Indrayati L and A Jumberi. 2002. Pengelolaan jerami padi pada pertanaman padi di lahan pasang surut sulfat masam. In: Pengelolaan Tanaman Pangan Lahan Rawa. Badan Penelitian dan Pengembangan Pertanian, Puslitbang Tanaman Pangan, Bogor.

Kirk G. 2004. *The Biogeochemistry of Submerged Soils*. John Willey and Sons. Chicester, England. 291 p.

Kongchum M. 2005. Effect of Plant Residue and Water Management Practices on Soil Redox Chemistry, Methane Emission and Rice Productivity. *[Dissertation]*. Graduate Faculty of the Louisiana State University. USA. 201 p

Kyuma K. 2004. *Paddy Soil Science*. Kyoto University Press dan Trans Pacific Press. Melbourne. Australia. 279 p.

Liang X, J Liu, Y Chen, H Li, Y Ye, Z Nie, M Su and Z Xu. 2010. Effect of pH on the release of soil colloidal phosphorus. *J Soils Sediments* 10: 1548-1556.

Lindsay WL. 1979. *Chemical Equilibria in Soils.* John Willey & Sons. New York. 449 p.

Liu C, M Chen and F Li. 2010. Fe(III) reduction in soils from South China. In: RJ Gilkes and N Prakongkep (eds). *Soil Solutions for a Changing World. Soil minerals and contaminants*, *19th World Congress of Soil Science*. Brisbane, Australia, pp.70-73.

McIntyre RES, MA Adams, DJ Ford and PF Grierson. 2009. Rewetting and litter addition influence mineralization and microbial communities in soils from a semi-arid intermittent stream. *Soil Biol Biochem* 41: 92-101.

Morris AJ. 2011. Phosphate Binding to Fe and Al in Organic Matter as Affected by Redox Potential and pH. *[Dissertation]*. Soil Science, North Carolina State University**,** Raleigh, North Carolina, USA. 229 p.

Olomu MO, GJ Racz and CM Cho. 1973. Effect of flooding on the Eh, pH, and concentrations of Fe and Mn in several manitoba soils. *Soil Sci Soc Am J* 37: 220 - 224.

Ponnamperuma FN. 1984. Effects of flooding on soils. In: T Kozlawski (ed). Flooding and Plant Growth: Physical Ecology. A Series Monographs, Text and Treatises. Academic Press Inc. Harcourt Brace Javanovich Publisher, USA, pp. 10-45.

Reddy KR and RD Delaune. 2008. *The Biogeochemistry of Wetland; Science and Application.* CRC Press. New York.

Rukhsana F, C Butterly, J Baldock and C Tang. 2010. Model carbon compounds differ in their effects on pH change of soils with different initial pH. In: RJ Gilkes and N Prakongkep (eds). *19th World Congress of Soil Science, Soil Solutions for a Changing World*, 1 – 6 August 2010, Brisbane, Australia, pp. 160-163.

Syahrawat KL. 2006. Organic matter and mineralizable nitrogen relationships in wetland rice soils. *Commun Soil Sci Plant Anal* 37: 787-796.

Wagai R and LM Mayer. 2007. Sorptive stabilization of organik matter in soils by hydrous iron oxides. *Geochim Cosmochim Act* 71: 25-35.

Watanabe I. 1984. Anaerobic decomposition of organic matter in flooded rice soils. In: *Organic Matter and Rice*. Intenational Rice Research Institute. Los Banos Laguna, Philippines, pp. 237-258.

Wickham TH and VP Singh. 1978. Water movement through wet soils. *Soil and Rice.* International Rice Research Institute. Los Baños, Philippines, pp. 337-358.