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Effect of Compost Combination on Methane Emission in Undisturbed Acid Sulphate soil in South Kalimantan of Indonesia

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ABSTRACT

A greenhouse experiment was conducted to examine the cumulative methane (CH_4) emission in paddy soils and correlation with soil redox potential (Eh), soil pH and plant growth. The experiment was arranged in two factorial randomized block designs with three replications. The first factor was a kind of of organic matter, *i.e*. without organic matter (T0), combination of 50% of composted straws and 50% composted rush weed (T1), combination of 30% of composted straws and 30% composted rush weed and 40% composted cattle manure (T2) and the second factor was the management of water that was continuously flooded and leaching. The methane emission was measured in South Kalimantan using the chamber and gas chromatogram technique. The results showed methane emission in undisturbed acid sulphate soil ranged from 0.05 to 0.32 mg $CH_4.m^{-2}.minute^{-1}$ during the rice-growing season. The methane emission from the paddy soil were lower when the paddy was drained than when it was flooded. Correlation analysis showed a negative relation between methane emission and soil redox potential (Eh) and soil pH in both water management. The rice plant height and number of buds has positively correlation with methane emission with coeffecient correlation of r=0.84**(P<0.0001) and r=0.64**(P=0.004), respectively.

Keywords: Acid sulphate soil, methane, organic matter

INTRODUCTION

Acid sulphate soil is often found in costal areas that are still affected by the tides and intrusion of brackish water. It is a type a soil with high acidity and it contains iron-sulphide (pyrite). The utilization of this soil for agriculture development represents a strategic choice in the effort to compensate for the diminishing productive soil in Java resulting from the functional shift in the use of soil from agricultural to non-agricultural purposes. Soil is a limiting factor that causes low productivity low of acid sulphate soil. The organic matter in a swamp soil serves to maintain a reduction condition, so that pyrite oxidation can be restrained and its able to bind the toxic elements. In addition to organic matter, water management through a unidirectional system could prevent and restrain pyrite oxidation and reduce the accumulation of toxic elements, through leaching. The effectiveness of organic matter depends on its quality, which is observed the C/N ratio and aliphatic methyl content.

Gaseous products in submerged soils are associated to organic materials decomposition (Neue and Scharpenseel 1984). According to Wassmann *et al.* (2002) organic inputs into the soil are generally enhanced methane emissions. Methane is released from submerged soils to the atmosphere by diffusion and ebullition and through roots and stems of rice plants. In a natural wetland, flooding a rice field cuts off the oxygen supply from the atmosphere to the soil, which results in anaerobic fermentation of soil organic matter. Methane is a major end product of anaerobic fermentation. Rennenberg *et al.* (1992) noted that both quantity and quality of the available carbon source either from amended organic matter or root exudates significantly influences the methane production. Upon flooding, soil microorganisms rapidly consume any O_2 in the soil within a few hours of soil submergence. The end products of gas are CO_2, H_2, CH_4, NH_3 and H_2S related to the anaerobic decomposition of organic matter (Ponnamperuma 1972). The composting process of the organic matter must be carried out before digging it into the soil in an inundated condition because it could increase the availability of nutrients besides reducing the methane emissions. Soil environments factors such as soil type, availability of nutrients, pH and Eh vary in decomposition patterns and also in the gaseous products (Neue and Scharpenseel 1984).

The sustainability of agriculture in acid sulphate soil depends on the management of the soil. One of the environment friendly efforts in improving the productivity of the soil is using local organic matter. The study aimed to observe the effect of rice straw and water management to increasing the growth of rice and reducing the emission of CH_4 in undisturbed acid sulphate soil.

MATERIAL AND METHODS

Research Design

The experiment was conducted in the greenhouse of Indonesian Swampland Agricultural Research Institute (ISARI), Banjarbaru, South Kalimantan from April to June 2012. Soil samples were collected, from Tanjung Harapan Village, Alalak Sub District, Barito Kuala Regency, South Kalimantan (03^o 10'S; 114^o 36'E). It used a factorial randomized block design with two factors. The first factor was the patterns of water management namely continuously flooded and leaching. The second factor was the kinds of organic matter, *i.e*: without any organic matter (T0), combination of 50% of composted straws and 50% composted rush weed (T1), combination of 30% of composted straws and 30% composted rush weed and 40% composted cattle manure (T2). The crop was growed till vegetative maximum.

Observation Methods

Methane, carbon dioxide, Eh and pH were measured 3 times, *i.e*: 30, 45 and 60 day after planting**.** Water leaching was conducted every 2 weeks, while gas samples were collected periodically every week using a syringe. Floodwater heights and air temperatures inside the chamber were recorded for calculation headspace volume and emission rate. Methane concentration in the syringe was immediately determined using Varian 4900 Gas Chromatograph (GC) with a flame ionization detector and helium as carrying gas. Whereas Soil redox-potential (Eh) was measured using electrode. Emission of methane was measured in laboratory of GRK (greenhouse gas emission) at Indonesian Agricultural Environment Research Institute, Jakenan-Central calculated using the equation as follows (Lantin *et al.* 1995):

$$E = \frac{dc}{dt}\frac{Vch}{Ach}\frac{Wm}{Vm}\frac{273.2}{273.2+T}$$

E = CH_4 flux (mg m^{-2} minute^{-1})
dc/dt = CH_4 rate per time (ìl l^{-1} minute^{-1})
Vch = chamber volume (m^3)
Ach = chamber area (m^2)
Wm = molecular weight of CH4 (16 x 10^3 mg)
Vm = volume of 1 mole of gas at standard temperature and air pressure (22.41 x 10^{-3} m^3)
T = average temperature inside the hamber during gas sampling (°C)

Data Analysis

Analysis of variance (ANOVA) was used to measure the significance among treatments and then mean comparison was calculated by Duncan's Multiple Range Test (DMRT). Statistical analyses were performed using SAS for Window Release 9.

RESULTS AND DISCUSSION

Changes of Soil pH and Redox Potential (Eh)

Soil pH were similar in both water management treatments. Soil pH of both treatments were ranged between 4.01 until 5.78 during the first thirty days after transplanting (DAT) with less fluctuation in pH there after. According to Vepraskas *et al.* (2001) reduction condition in acid soils generally increases the pH and the amount of pH change can be as high as three pH units following several weeks of submergence, although changes of <2 pH units are probably more typical. Inundation by flooding and organic matter application in paddy rice improves the strong acid conditions, probably because of the consumption of protons during the iron-reducing process. The highest pH values were found in continuously flooded treatments with T2. In contrast, the highest pH value was in leaching treatments with T3. The degree of change depends on the amount of reduction taking place and is determined by the amount of oxidizable organic tissue, as well as the amount of reducible electron acceptor. Increased pH upon flooding is the main reason why wetland rice cultivation is successful on normal acid sulfate soils (Muhrizal *et al.* 2006). The changes in pH during re-flooding of acid sulphate soil, as affected by addition of various organic materials, are shown in Figure 1. The composted organic matter strongly influenced soil pH until 60 DAT in both water management. In acid sulphate soil effect of organic matter addition increases electron donor supply and favors the development of alkalinity through rapid reduction of oxidants. Continuous consumption of protons during consumption of electrons results in an increase in pH (Reddy and Delaune 2008).

Soil redox potential (Eh) in continuously flooded and leaching was highly correlated to composted organic matter application, as shown in Figure 2. The soil redox potential values measured in this study were generally in the range of -57.2 to –177.4 mV.

Lowering the Eh of the soil due to flooded was resulted of increasing pH because many reduction reactions (such as the reduction of sulfate to sulfide, Fe^{3+} to Fe^{2+} and Mn^{4+} to Mn^{2+}) were involved in the uptake of protons or release of hydroxyls. This intensity of reduction can be thought of in terms of the pressure of the electrons that the microorganisms need to dispense with as they carry out the oxidation of the energy source (Reddy 2008). The lower quality of composted organic matter treatments resulted in lower soil redox potential. The same result was given for the redox values that produced a strong negative effect that was caused by the organic matter addition, not by the native organic matter (Gardiner *et al.* 2012). The intensity of reduction is higher in the presence of organic matter because organic matter is oxidized and soil components are reduced due to anaerobic microbial respiration (Ponnamperuma 1972). The water management treatments in this study had no significant effect on soil redox potential.

Correlation of Eh with Soil pH and Ferro Iron

In submerged soils, trace metal mobility depends on the chemical conditions, such as redox potential (Eh) and pH, as well as organic matter (OM) and Fe- oxyhydroxides content (Grybos *et al.* 2007). According to Vepraskas and Faulkner (2001) iron is element for concentrations increased with flooding because of Eh and pH changes. Both Eh and pH have strong effect on increasing metal solubility under submerged rice soils. The increase of pH in flooded soils is largely due to the presence of iron and manganese in the form of hydroxides and carbonates (Reddy 2008). The ferro iron values measured in this study were generally in the range 768.2 to 972.7 ppm. The ferro iron of the continuously flooded treatment was greater than the leaching treatment at all kinds of organic matter. Ferro iron and soil pH in both water management (continuously flooded and leaching) were negatively correlated with soil redox potential (Eh) as shown

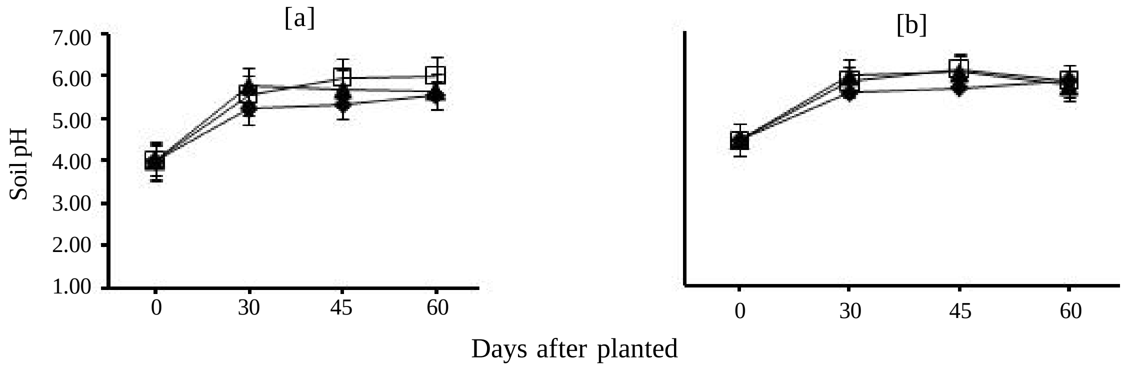

Figure 1. Effect of composted organic matter on soil pH, a) contiounusly flooded, b) leaching. —◆—: T0, —□—: T1, —▲—: T2.

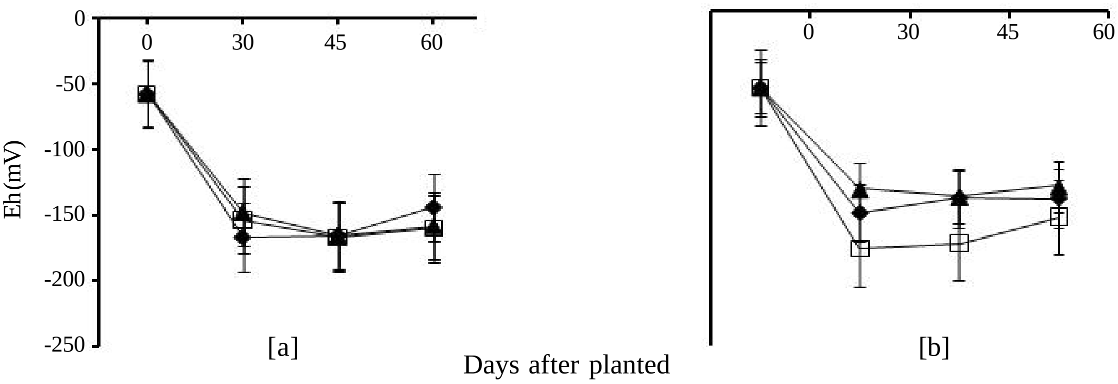

Figure 2. Effect of composted organic matter on soil Eh, a) contiounusly flooded, b) leaching. —◆—: T0, —□—: T1, —▲—: T2.

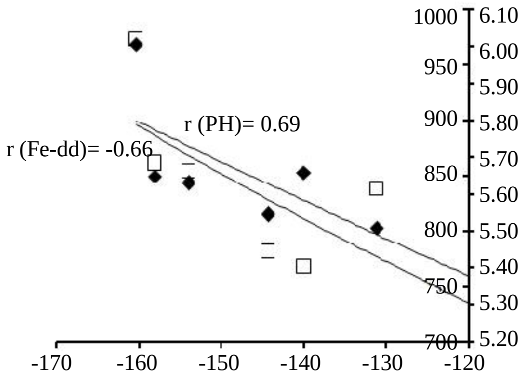

Figure 3. Correlation on soil redox potential with soil pH and Fe-dd. □: Fe-dd, ◆: pH.

with correlation values r=-0.66 (P>0.05) and r=-0.69 (P>0.05), respectively (Figure 3). According to Schwertmann (1966) the application of organic matter has an inhibitory effect on the crystallization of amorphous ferric hydroxides and keeps Fe in the amorphous and relatively reducible form. Similarly, a correlation between first-order Fe (III) oxide reduction rate constants and rates of organic carbon mineralization in wet land (Sahrawat 2002)

The Effect of Organic Matter and Water Management on Methane Emission

The complete mineralization of organic matter in anaerobic environments produces methane. The combination of the kinds of organic matter and water management were consistently able to reduce the CH_4 fluxes and to improve the chemical properties of the soil and had a significant affect on the growth of rice. The combination 30% of the composted rice straw and 30% of composted rush weed and 40% composted cattle manure (T2) with water management by leaching was the best treatment (Figure 4). The fact indicated that in undisturbed acid sulphate soil, leaching with T2 treatment was the best in restraining Fe solubility from 861,36 $mg.kg^{-1}$ to 838,64 $mg.kg^{-1}$. The results of the FTIR analysis of the chelate potential of the organic matter were indicated in the wave number of 1590-1640 cm^{-1}. The content of absorption on this wavelength indicated the existence of wider humate acid in the composted organic matter. The highest absorption took place to the composted cattle manure (10,98%), followed by composed rush weed (9,40%) and composted rice straw (9,17%) (Figure 5). Rennenberg *et al*. (1992) noted that both quantity and quality of the available carbon source either from amended organic matter or root exudates significantly influences the methane production. Under anaerobic conditions decomposition could take place through methanogenic bacteria to produce methane (Rosa *et al*. 2004)

The Rate of Methane Formation

The constant of the highest CH_4 formation rate observed in contiounusly flooded with the application of the combination of 50% of composted straws and 50% composted rush weed (T1) was (k CH_4 value) 0,001/day, the combination of 30% of composted straws and 30% composted rush weed and 40% composted cattle manure (T2) was 0,0009/d. While the CH_4 value of leaching with the application the combination of 50% of composted straws and 50% composted rush weed (T1) was 0,0009/day, the combination of 30% of composted straws and 30% composted rush weed and 40%

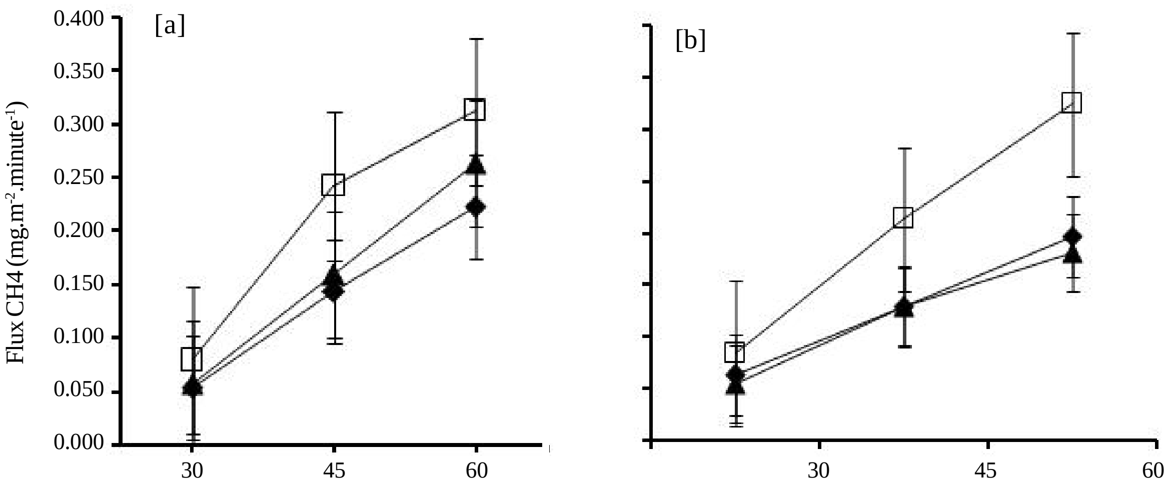

Figure 4. Effect of rice straw on methane emission: (a) the contiounusly flooded; (b) leaching. —◆—: T0, —□—: T1, —▲—: T2.

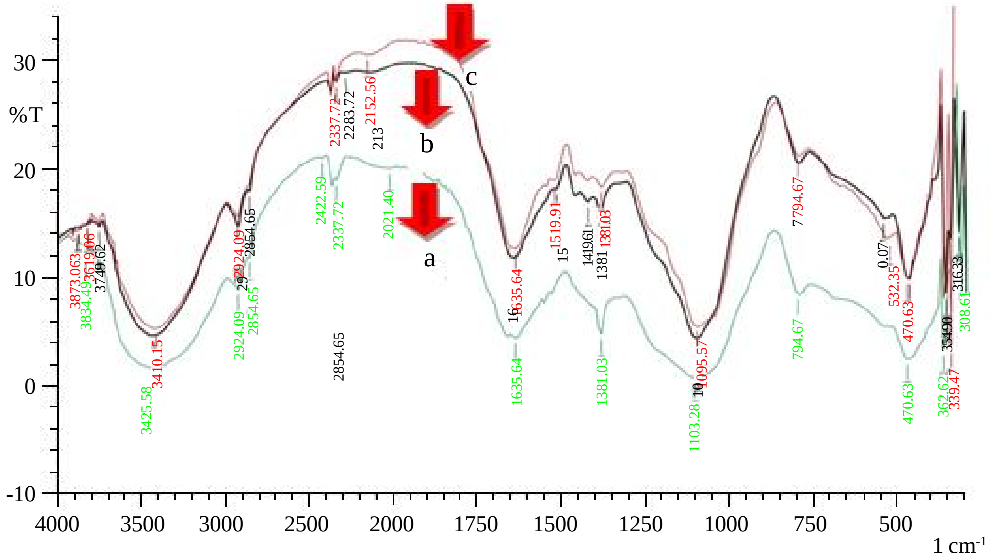

Figure 5. Fourier transform infrared (FTIR) spectra from composted rice straw, composted rush weed and composted cattle manure. —: Wahida sample 4; —: Wahida sample 5; —: Wahida sample 6, 1.

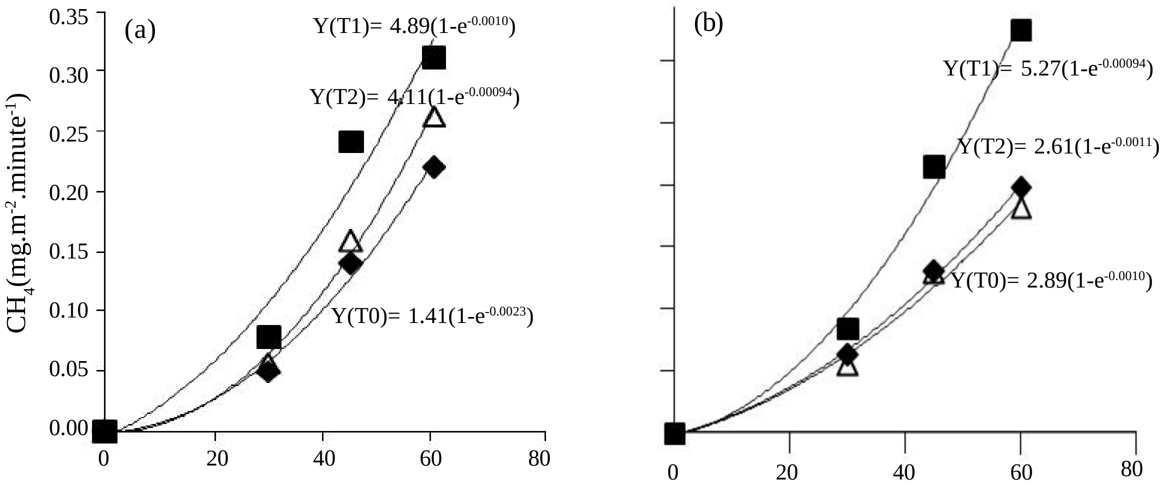

Figure 6. Effect of rice straw and water management on rate of methane formation: (a) contiounusly flooded; (b) leaching. ◆: T0, ■: T1, △: T2.

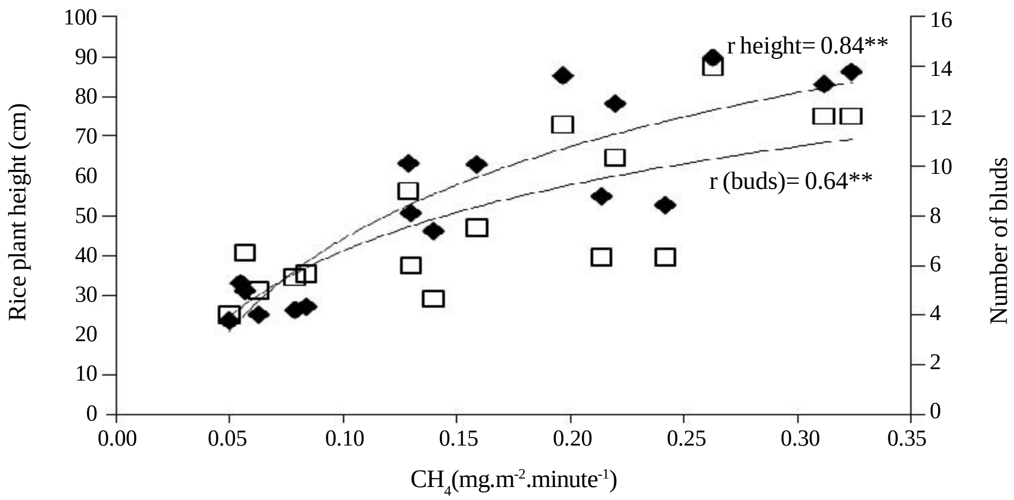

Figure 7. Correlation methane emission with plant growth (rice plant height and number of buds).

composted cattle manure (T2) was 0,001/d (Figure 6). According to Neue and Scharpenseel (1984) gaseous products in submerged soils are associated to organic materials decomposition. Upon flooding, soil microorganisms rapidly consume any O_2 in the soil within a few hours of soil submergence (Ponnamperuma 1972). The end products of gas are CO_2, H_2, CH_4, NH_3 and H_2S related to the anaerobic decomposition of organic matter. The methane emission flux intensity and its features were affected significantly by the hydrological condition (SONG *et al*. 2003).

Plant Growth with Methane Emission

The methane products as result of organic matter decompositions in anaerob decomposition significantly influence plant growth. Our study showed that the application of the combination 30% composted straw and 30% composted rush weeds and 40% composted cattle manure (T2) consistently had the best affect on the height of the crop and the number of buds. Methane emission in both water management (contiounusly flooded and leaching) were positively correlated with rice plant height and number of buds as shown with correlation values r=0.84**(P<0.0001) and r=0.64**(P=0.004), respectively (Figure 7). Similarly, there were a positive correlation between CH_4 production and rice plants at rice tillering stage and panicle initiationstage (Zhongjun Jia *et al*. 2001). According to Epp and Chanton (1993) CH_4 emission from rice field to the atmosphere was strongly influenced by rice plants in three distinct processes: two of which are positive and one is negative. Rice plants provide substrates in the form of root exudates or root autolysis products to the anaerobic food chain and ultimately to methanogenic bacteria and, thus, will enhance CH_4 production (Holzapfel-Pschorn *et al*. 1986; Wassmann *et al.* 1998).

CONCLUSIONS

The quantity and quality of the available carbon source either from organic matter significantly influenced the methane production fluxes. Application of the combination of 30% of composted straws and 30% composted rush weed and 40% composted cattle manure (T2) resulted in lower methane emission than the combination of 50% of composted straws and 50% composted rush weed (T1). Methane flux from rice soils were correlated significantly with rice plant height and number of buds with the correlation coefficient of r=0.84**(P<0.0001) and r=0.64**(P=0.004), respectively. The reduction of Fe (III) served as a function of Eh as indicated by the accumulation of ferrous and the ferrous iron was positively correlated with the soil redox potential and soil pH with the correlation coefficient of r=-0.66 (P>0.05) and r=-0.69 (P>0.05), respectively.

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