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Humic Acid and Water Management to Decrease Ferro (Fe^{2+}) Solution and Increase Productivity of Established New Rice Field

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ABSTRACT

The purpose of this research was to gain a technological breakthrough in controlling Fe toxicity (Fe^{2+}) on Ultisol in a new established rice field by using humic acid from rice straw compost and water management, so that optimal production of rice plants could be achieved. The experiment was designed using a 2 × 4 factorials with 3 replications in a split plot design. The main plot was water management consists of 2 levels: continuous and intermittent irrigation (2 weeks flooded and 2 weeks field capacity). Small plot was humic acid which was extracted from rice straw compost by NaOH 0.5 N which consists of 4 levels: 0, 200, 400, and 600 mg kg^{-1}. The results showed that applications of humic acid from 0 to 600 mg kg^{-1} that was followed by 2 weeks of intermittent irrigation decreased Fe^{2+} concentration. It was approaching levels that were not toxic to plants, with soil Fe^{2+} between 180-250 mg kg^{-1}. The best treatment was found at the application of 600 mg kg^{-1} humic acid extracted from rice straw compost combined with 2 week flooded – 2 weeks field capacity of water management. Those treatment decreased Fe^{2+} concentration from 1,614 to 180 mg kg^{-1} and increased the dry weight of grain from 5.15 to 16.73 g pot^{-1} compared to continuous flooding and without humic acid application.

Keywords: Humic acid, iron toxicity, new established rice field, rice straw compost extract

INTRODUCTION

Ultisols is one of the marginal soils in Indonesia that it has great potential to be developed as a new established rice field. However, the program to face constraint that is a very serious problem about iron (Fe) toxicity and macro nutrient deficiencies, especially phosphorus (P) of rice plants is needed. Herviyanti *et al.* (2006) reported that the problems of Ultisols from Sitiung I, West Sumatra were characterized by low of soil base saturation (15.46%), cation exchange capacity (15.20 c mol kg^{-1}), total nitrogen (0.07%), organic carbon (1.99 %), and available phosphorus (4.63 mg kg^{-1}). On the other hand, the aluminum (Al) saturation was high (49.89%) as well as exchangeable Fe content (57.32 mg kg^{-1} or 114.64 kg ha^{-1}).

However, the iron is an essential micro-nutrients that is needed in small amounts by plants (± 100 mg kg^{-1}). on the other hand, total availability of Fe in soil is very high (± 50,000 kg ha^{-1}), while the availability of macro elements such as N and P that are only 4,000 and 1,200 kg ha^{-1}, respectively (Gardner *et al.*2003). Under good drainage condition, the very high Fe avaibility does not cause problems for rice plant growth, because Fe is easily reacted with other elements and that are generally not soluble. Conversely, under worse drainage condition, the land becomes flooding, so that the Fe^{3+} will be reduced to soluble Fe^{2+}. The stagnant situation will also cause decreasing soil Eh and increasing the reduction of Fe to toxic levels for rice plants growth. If the high Fe^{2+} solubility of soil are not controlled, it can cause decreasing the growth and the production of rice crop to the lowest level, eventhought the productivity of crop maybe failure. The symptoms of Fe toxicity in the plant are visually marked with reddish brown spots along the edge strands of the leaf starting from the lower leaves or the oldest (Satari *et al*. 1990; Sahrawat 2000). Another consequence is the formation of plaque on root tips of plants that can inhibit the absorption of both macro and micro nutrients (Hagnesten 2006).

Many experiments have been conducted to conquer the Fe toxicity problems such as the addition of organic matter, the water management and the use of tolerant rice varieties. The suitable and applicable technology needs to be found through this research. Control of Fe toxicity by using water management technology (intermittent irigation) was aimed to obtain the oxidation of Fe^{2+} to Fe^{3+}. Thus, alternating intermittent irigation could reduce the levels of soluble Fe^{2+} in the soil and also improving macro-nutrient uptake. Beside that, alternating intermittent irigation technology could minimize the water usage in that was availability limited due to climate change.

The addition of organic matter in soil can improve the properties of soil. The technology has been carried out by local farmers on dry land, but the use of organic matter in paddy soil can cause negative effects for plant growth because of the affect of the organic material decomposition processes under the an aerobic condition. The process will produce organic acids such as phenolic acid and methane which can be toxic for plants growth (Prasetyo 1996; Tan 2010). In addition, the use of organic materials are usually done in the form of manure, compost, and others which requires considerable amounts of about 5-20 Mg ha^{-1} that is big problems for local farmers in preparation and transportation. Thus, new technology that can be applied practically by using the way of producing humic acid (humic material components) is needed. Humic acid can improve soil fertility in small amounts *i.e.* 0.5-1.5 Mg ha^{-1}.

Humic acid is a component of organic material that has active functional groups *i.e.* carboxyl (-COOH), amine($-NH_2$), hydroxyl(-OH), and phenol(Ar-OH), and has a negative charge in weakly acidic to basic media because of deprotonation (Evangelou *et al.* 2002). Using of humic acid can improve soil structure, increase soil water holding capacity and CEC, and it can also reduce the solubility of metal so that do not become toxic to plants such as Fe and Al ion through the formation of organo-metal complex compounds or chelate (Ahmad 1988; Stevenson 1994; Tan 2003). Humic acid can be extracted from plant residues, organic fertilizers, and various types of organic materials that have been decomposed as compost (rice straw compost). The ability of humic acid from rice straw compost that combined with water management to decrease Fe toxicity and increase yields of rice in the Ultisol used as a new established rice field was needed to be studied further.

The purpose of this research was to gain a technological breakthrough in controlling Fe toxicity by using humic acid from compost of rice straw and water management in new established rice fields of Ultisol, so that optimal production of rice plants could be achieved.

MATERIALS AND METHODS

Study Site

This research was done in the Greenhouse and Laboratory of Soil Department, Faculty of Agriculture, Andalas University, Padang from June to December 2006.

Soil Sample

Soil used is Ultisol. Soil sample was taken from a new established rice field in Sitiung, Dharmasraya Regency. The chemistry characteristics of soil were: pH H_2O 5.5. C-organic 1.99%, N-total 0.07%, K-exch 0.04 c mol kg^{-1}, Ca-exch 1.73 c mol kg^{-1}, Mg-exch c mol kg^{-1}, Al-exch 2.34 c mol kg^{-1}, Al-saturation 49.89%, CEC 15.20 c mol kg^{-1}, base- saturation 15.46 c mol kg^{-1}, and Fe- exch 57.32 mg kg^{-1}.

Experimental Design

This study was designed to observe the growth and nutrient content of crops, Fe dynamics of soil, and crop production. The experiment was prepared using 2 × 4 factorial with 3 replications in a split plot design. The main plot was water management that consists of 2 levels: continuous flooding and intermittent irigation (2 weeks flooded and 2 weeks field capacity). Small plot was the use of humic acid extracted from rice straw compost with NaOH 0.5 *N* (modified method of Tan 1996) that consists of 4 levels: 0, 200, 400, and 600 mg kg^{-1} humic acids.

Incubation of Humic Acids

The experiment was carried out using 30 cm diameter plastic pots. Each pot was filled as much as 10 kg of soil dry equivalent absolutely, then pot was flooded as high as 5 cm for 2 weeks. drying was done once to obtain intermittent flooded and was applied humic acid, mixed well, and then incubated for 3 days. Furthermore, soil samples were taken to observe the Fe^{2+} after treatment. Observations of soluble Fe^{2+} and soil Eh were done every 2 weeks and observation of P and soil CEC were done at 6 weeks old plants after planting (WAP) or 8 weeks after flooding.

Fertilization and Planting

Basic fertilizations of N, P, K were given as much as 200 kg ha^{-1} Urea (equivalent to 1.25 g pot^{-1}), 150 kg ha^{-1} SP-36 (equivalent to 0.9375 g pot^{-1}) and 100 kg ha^{-1} KCl (0.625 g pot^{-1}) by assuming a spacing of 25 cm × 25 cm. Urea and KCl were given 1/3 part at planting, 1/3 part when the plants were 2 WAP and the third part at 6 WAP, while the SP-36 was given all at 1 day before planting.

Each pot were planted with three of rice seedlings 21 days old. Rice variety used was cisokan plant maintenance was done by keeping the land to be always stagnant water for continuous flooded and humid for intermitten irrigation. When pests were attacked the crop was sprayed with insecticide Dharmabas with the concentration of 5-10 cc L^{-1}.

Sampling of Crop Leaf and Haversting

Sampling of plants leaves were done to determine plant nutrient levels and it were taken at the time of maximum vegetative growth (age 72 days). Dry weight of sample plant was measured on the oven at 60°C for 2 × 24 hours (the fixed weight) then samples were mashed with a grinder. At the same time, the number of tillers and plant height were observed. To determine productivity of plant harvesting was conducted on 115 days old after planting, and then measure the weight of dry grain and straw were measured.

RESULTS AND DISCUSSION

Eh Values after 8 Weeks Flooded

The results of regression analysis between soil Eh on new established rice field that were treated by various doses of humic acid from rice straw compost and followed by continuous and intermitten irrigation are presented in Figure 1. In general, the continuous and intermittent irrigation treatments reduced soil Eh value, but decreasing Eh value with intermittent irrigation was relatively smaller than the continuous irrigation treatment. This was caused by the soil was not always flooded, so that it would change from reductive into oxidative conditions in the soil. Oxygen can enter the soil when dried for 2 weeks *(i.e.* second to fourth weeks and sixth to eight weeks).

The intermittent irigation had 40-70 mV Eh value, this value was higher than the continuous flooding (15-25 mV). In other words that intermittent was more profitable than continuous flooding. This was caused by the value of high Eh could slightly decrease Fe^{3+} reduction, so that the plants could grow well (De Datta 1981; Sanchez 1992). Kyuma (2004) stated that total methane emission on paddy fields for one rice-cropping season was greatly reduced by practicing one or two short mid-term dryings.

Figure 1 showed, the addition of humic acid together with 2 weeks of intermittent irrigation generally caused the Eh values was lower than without humic acid treatment, but it was higher than continuously irrigation (the soil was always flooding). This was assumed that flooding and drying conditions would cause to change humic acid activity, so that it could contribute to more electrons than without the addition of humic acid. These electrons would reduce the value of soil Eh.

Increasing doses of humic acid from rice straw compost did not significantly affect soil Eh value on the both water managements. The addition of humic acid are in relatively small dosages (200 - 600 mg kg^{-1} = 0.02 to 0.06% = 2 - 6 g pot^{-1}) to the soil weight (10 kg pot^{-1}) was not able to accelerate the reduction process. Besides that, humic acid used was an organic compound that was relatively stable, so that it had a little electron donation. This condition was actually beneficial for plants, because humic acid application gard a sharp decreasing in Eh values due to more reduction from Fe^{3+} to Fe^{+2}. In addition, it would form organic acids that were toxic for plants such as lactic acid, pyruvate and H_2S.

Levels of Fe^{2+} after 8 Weeks flooded

Figure 2 shows that continuous irrigation that had a longer condition of flooding had the high levels of Fe^{2+} in soil for all humic acids treatments. But the addition of humic acid had lower Fe^{2+} than without humic acid. Application of humic acid wish doses of 200-600 mg kg^{-1} were capable to binding Fe^{2+} to form complex compounds through functional groups. Results obtained in this experiment were similar to the dynamics of the soluble Fe^{2+} in soil that were observed in the laboratory. Furthermore, the application of humic acid from rice straw compost of 100, 200, 300, and 400 mg kg^{-1} decreased the soluble Fe^{2+} at 425.17, 545.01, 634.04, and 643.08 mg kg^{-1}, respectively, at the fourth weeks flooded (Herviyanti *et al.* 2005).

The results of regression analysis in Figure 2 show that the inreasing doses of humic acid gard more flat regression line. Actually, it was showed at 2 weeks of intermittent irigation treatment. It means the more soluble Fe can be decreased by the use of humic acid at high dosages, although the land became flooded. The lowest level of soluble Fe^{2+} was approximately ± 180 mg kg^{-1} obtained by using 600 mg kg^{-1} dosage of humic acids followed by 2 weeks of intermittent irigation. Erdogan *et al.* (2007) stated that humic acid forms negatively charged complexes with heavy metal ions (especially Fe(III)). In accordance with HSAB (hard and soft acids and bases) theory, Cu(II) and Pb(II) ions react with humic acid via O and N atoms and form stable complexes.

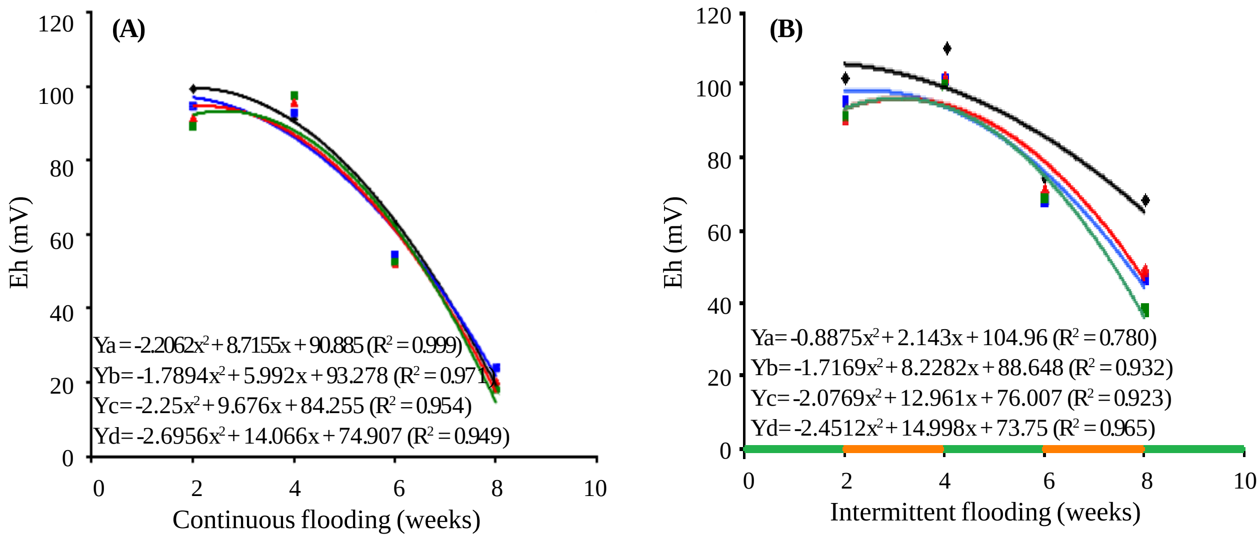

Figure 1. Changes in Eh value in paddy soil of new established rice field due to application humic acid from compost of rice straw with continuous (A) and intermittent (B) irrigation after 8 weeks of flooded. ▬ = flooding and ▬ = field capasity. ◆ = 0 ppm humic acid (a), ■ = 200 ppm humic acid (b), ▲ = 400 ppm humic acid (c), and ■ = 600 ppm humic acid (d)

In general, the intermittent irigation 2 weeks at various dosages of humic acid from compost of rice straw could reduce the levels of soluble Fe^{2+} in the soil greater than the continuously flooding. The highest levels of Fe^{2+} content in the soil was reached at intermittent irigation without the use of humic acid *i.e.* 520 mg kg^{-1}, while levels of Fe^{2+} content at continuous flooding as much as 1,614 mg kg^{-1}. Thus, intermittent flooded was able to suppress levels of Fe^{2+} as much as 1,094 mg kg^{-1}.

Available of Phosphorus (P) and Cation Exchange Capacity (CEC) in the Soil

Increasing doses of humic acid with two water management treatments had a significant effects on P and soil CEC. The effects of humic acid from rice straw compost and water management treatments on P availablity and CEC of the soil in a new established rice field are presented in Table 1.

Table 1 showed the increasing level of humic acid could increase the soil P available in continuous

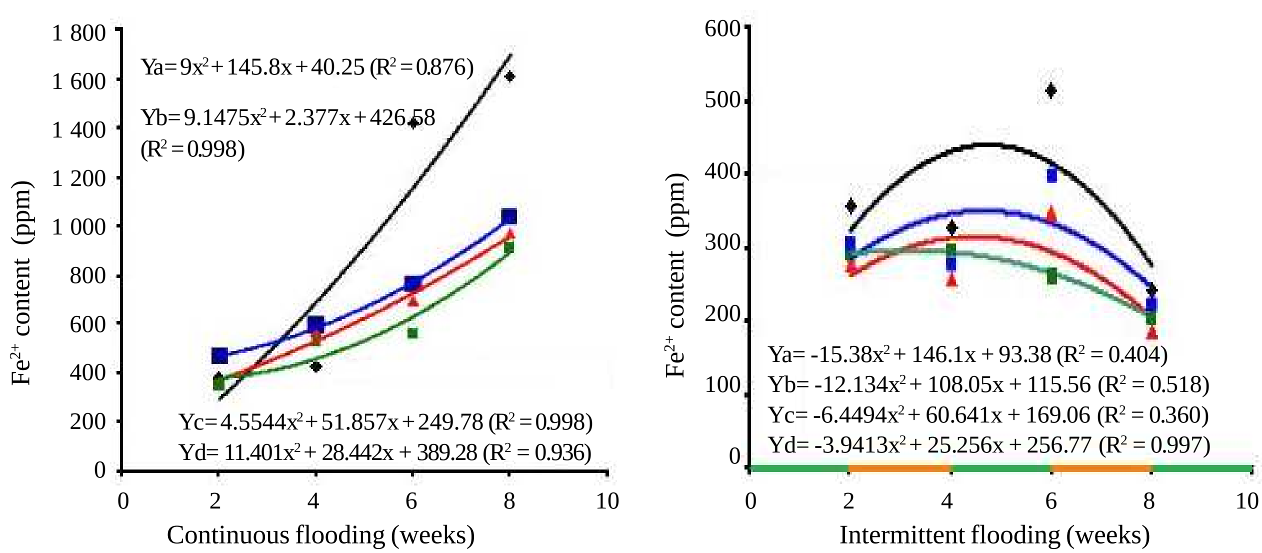

Figure 2. Changes in levels of Fe^{2+} in new established rice field due to application of humic acid from compost of rice straw with continuous (A) and intermittent (B) irrigation after 8 weeks of flooded. ▬ = flooding and ▬ = field capasity. ◆ = 0 ppm humic acid (a), ■ = 200 ppm humic acid (b), ▲ = 400 ppm humic acid (c), and ■ = 600 ppm humic acid (d).

Table 1. The effect of humic acid with continuously and intermittently flooded on soil P content and CEC in a new established rice field.

Flooding	Humic acid dosage ($mg\ kg^{-1}$)	P content ($mg\ kg^{-1}$)	CEC ($c\ mol\ kg^{-1}$)
Continuous	0	5.16 b	13.03 c
	200	6.19 b	22.12 b
	400	6.90 b	26.41 ab
	600	8.44 a	27.7 a
Average		6.67A	22.32 A
Intermittent	0	5.69 a	14.12 c
	200	6.14 a	22.06 b
	400	6.20 a	25.64 b
	600	6.77 a	31.52 a
Average		6.20 A	23.06 A

Note: The same small letters on the same column within each main plot and the same capital letter in the same column between the main plot is not significantly different according to HSD test at 5% significance level.

flooding and intermittent irigation. This was due to the more high dosages of humic acid would decrease the Fe soluble in solution because of the formation of organo-Fe complexes reaction. So that, the binding of P by Fe cation was reduced and P became more available.

Continuous flooding which was followed by the addition of 600 mg kg^{-1} humic acid had the higher P available than other treatments. This was caused by the continuous flooding could increase the reduction of Fe(III)P to Fe(II)P so that P content of soil was soluble and available to plants. However, this increasing was very little that included in the criteria of very low (<10 mg kg^{-1}). It was caused by the potential of soil P was also low *i.e.* 18.3 mg kg^{-1}, so that the use of humic acid did not play an important role in releasing P.

However, the soil used had extremely serious problems in the availability of P, where the levels of soil P was 4.63 mg kg^{-1} which included in the very low criteria. According to De Datta (1981) the availability of P would increase after flooding soil due to the reduction of Fe(III)P to Fe(II)P, while the increase in solubility of P was low in Ultisol and Oxisol. An effort to overcome the very low of soil P was to use the high dose of P fertilizer (> 150 kg ha^{-1}). Additionally, it is needed to improve the needs of P for plants and to compensate the disruptions of P uptake due to high soil Fe content.

Table 1 also shows that increasing dosages of humic acid from rice straw compost could increase soil CEC in both continuous flooding and intermittent irigation. The high dosage of humic acid inceased the contribution of humic acid functional group of carboxylic (-COOH) and phenolic (-OH) as the source of negative charge increased CEC. Value of soil CEC with humic acid treatments ranged from moderate (<17-24 c mol kg^{-1}) to high (25-40 c mol kg^{-1}). According to Buffle (1984) and Stevenson (1994) CEC of humic acid ranged from 62-279 c mol kg^{-1} was in the high criteria, so that the use of humic acid increased the value of soil CEC. Furthermore Coles and Yong (2006) stated that at pH 4, CEC of the humic acid would be approximately 190 meq 100 g^{-1}, meaning the HA could retain 1.90 m mol g^{-1} of monovalent cations or 0.95 m mol g^{-1} of divalent cations.

In general, soil CEC values of intermittent irigation treatment were almost the same with continuously flooded treatment in various dosages of humic acid, except for dosages of 600 mg kg^{-1}, in which CEC value of soil with intermittent flooded treatment was higher than the continuous flooded tretament. It supposes that the soil with intermittent flooded treatment would occur bigger decomposition of organic materials into organic acids due to a more oxidative reactions compared to continuous flooding treatment.

Plant Growth and Nutrient Levels

Observation of plant growth (height and number of productive tillers of rice plant) and levels of P and Fe plants grown at a new established rice field with giving various doses of humic acid and both water management treatments are presented in Table 2.

Table 2 shows, the addition of humic acid from rice straw compost with continuous and intermittent flooded treatment could improve plant growth and nutrient content of P, and decreased Fe content of plants. Use of 400 mg kg^{-1} humic acid increased

Table 2. The effect of humic acid with continuously and intermittently flooded on plant height, number of productive tillers, Fe and P content of plants in a new established rice field.

Flooding	Humic acid dosage (mg kg^{-1})	Plant height (cm)	Amount of productive tiller (number)	Plant Fe content (mg kg^{-1})	Plant P content (mg kg^{-1})
Continuous	0	76.17 c	4.67 b	249.20 a	460 c
	200	83.17 b	9.67 a	174.20 b	520 b
	400	88.67 ab	10.33 a	149.67 b	530 b
	600	93.17 a	12.00 a	113.93 c	600 a
Average		85.30 B	9.17 A	171.75 A	530 B
Intermittent	0	82.83 a	8.67 b	129.60 a	500 d
	200	89.00 bc	11.67 ab	92.03 b	570 c
	400	97.00 ab	13.67 a	86.67 b	630 ab
	600	102.33 a	13.33 a	83.47 b	690 a
Average		92.79 A	11.84 A	97.94 B	597.5 A

Note: The same small letters on the same column within each main plot and the same capital letter in the same column between the main plot is not significantly different according to HSD test at 5% significance level.

plant height as much as 12.50 and 14.17 cm in the both continuous and intermittent irigation, respectivelly compared to without humic acid. However, plant height that were applied by 400 and 600 mg kg^{-1} humic acid doses were relatively similar. In general, plant height by application of 2 weeks of intermittent flooded was 7.49 cm which was higher than the continuous flooded in various doses of humic acid. In addition, the intermittent flooded had plant height plants of 6.66 cm that was higher than the continuously flooded without humic acid. The differences were caused by the soil had small Fe content with intermitten flooded compared to continuous flooded (Figure 2).

It seems that plant growth reflected by height of plant was strongly influenced by the levels of soluble Fe^{2+} in soil. At the high Fe content of soil, the plant growth will be suppressed. In the treatment of without humic acid with continuous flooded, the plant growth was hindered. But with the use of humic acid, plant growth was much better. It mean that, the treatment of intermittent irrigation could improve the plant growth, although without application of humic acid.

Table 2 shows that the number of productive tillers of rice plants also increased by humic acids application from rice straw compost either in continuous or intermittent irigation. The application of 400 mg kg^{-1} humic acid would increase ± 5 tillers of rice field that were higher than without humic acid application. While, intermitten irigation also increased ± 3 tillers of rice field that were higher than the continuous flooding. Increasing the number of tillers due to humic acid and water management treatment on new established rice field were caused by the decreasing of Fe content of the two treatments.

Table 2 shows, the high doses of humic acid decreased progressively the Fe content of plants and increased P concentration of plants with both continuous and the intermittent flooded treatments. This was caused by high humic acid decreased Fe content of plants during the flooded. Effect of water management was greatly appear on Fe content of plants. Intermittent flooded without humic acid would suppressed Fe content of plants as 73.81 mg kg^{-1} or declined of 42.98% compared with continuous flooding. While, humic acid could decrease Fe content of plants which ranged from 28.99% to 30.10%. This was due to intermittent flooded treatment was able to suppress a large amount of the soluble Fe^{2+} in soil, this was due to the oxidation process of Fe^{2+} to Fe^{3+} which did not dissolve soluble Fe^{2+} when dried condition.

In general, the Fe content of plants in all treatments were likely still toxic to the plants, that it was visible from Fe toxicity symptoms on leaves namely reddish brown leaf (bronzing). Described by Marschner (1995); Yeo and Flowers (1994) that iron toxicity in rice plants will increase the oxygen and form peroxide radicals such as the following reaction: Furthermore, it can be explained that the hydroxyl radicals at a high Fe content will cause the peroxidation of membrane fats and protein degradation:

$$Fe^{2+} + O_2 \longrightarrow Fe^{3+} + O_2$$

$$H_2^- + O_2^- \xrightarrow{SOD} H_2O_2$$

$$Fe^{2+} + H_2O_2 \longrightarrow Fe^{3+} + HO + HO^-$$

SOD = Superoxsyde dismutase

Results of the research in pot experiment using soil in a new established rice field were nearly the same with the experimental sand medium which had $\geq$ 128 mg kg^{-1} total Fe in the plant top that showed toxicity symptoms (Herviyanti *et al*. 2005). However, decreasing levels of Fe^{2+} plants were quite large. Thus, the improvement of water management with the intermitten irigation was needed to be shorten in the time interval in order to minimize the accumulation of Fe^{2+}. Furtherfore, it is needed to be tested water management tretament with the one week of flooding and 2 weeks of drying.

Table 2 also shows that P content of plants on various types of humic acids at both intermitten and continuous flooding were still below the critical point that was 0.1% (1,000 mg kg^{-1} P) (Sanchez 1992). This was caused by soil P levels prior to the use of fertilizer and soil P concentration when plants were 8 WAP (a week after planting) were belonging to the very low criteria (Table 1). It seems that applying P as much as 150 kg SP-36 ha^{-1} had not been able to meet the P needs of plants.

To overcome this problem, increasing the doses of P fertilizer is needed. Gardner *et al.* (2003) suggested that the concentration of the element of P in soil solution is generally very low. On the other hand, P element is an important component of constituent compounds to transfer energy (ATP), and for genetic information systems (DNA and RNA), and to the cell membrane (phospholipids). P deficiency of plant will cause the leaf colored dark green or bluish green, the number and length of plant roots is reduced.

However, the addition of humic acid from rice straw compost with concentration of 200 mg kg^{-1} increased plant P content as much as 70 mg kg^{-1} if compared to without humic acid in both continuous and intermitten irigation. The highest P content of plants was found in the humic acid dosage of 600 mg kg^{-1}. High levels of P plant in humic acids and intermittent flooded treatments were caused by P fertilizer added to soil might be taken by plants. That was due to the fixation of P fertilizer by Fe^{2+} decreased by decreasing soluble Fe in soil (Figure 2). Besides that, by reducing the levels of soluble Fe^{2+} in soil it would provide an opportunity for roots to grow better, so it increased the a mount of P uptake by rice. This has been explained by Nyakpa *et al*. (1988) that the plant roots that grow healthy would be able to absorb the elements of P in higher numbers. Masjkur and Kasno (2008) stated that the application of organic matter in kaolinitic soils (Ultisol) would increase P uptake of lowland rice.

Plant Yields

Production (grain and straw dry weight) of rice plants grown in a new established rice field and application with various doses of humic acids from rice straw compost with continuous and intermittent flooded are presented in Table 3. The main influence of humic acid dosagee and water management increased significantly the dry weight of grain and straw.

Table 3 shows, increasing doses of humic acid from rice straw compost could improve the weight of dry grain and straw with both continuous and intermittent irigation. This was due to the greater the dose of humic acid, the better the properties of soil especially soluble Fe^{2+} content would be further down (Figure 2), as well as P content and soil CEC

Table 3. The effect of humic acid on the grain and straw dry weight of milled in new established rice field with continuous and intermitten irigation.

Flooding	Humic acid dosage (mg kg^{-1})	Grain Weight (g pot^{-1})	Straw weight (g pot^{-1})
Continuous	0	5.15 c	5.51 c
	200	9.32 bc	9.71 b
	400	11.22 b	13.03 a
	600	13.46 ab	15.98 a
Average		9.79 B	11.57 B
Intermittent	0	11.25 c	11.35 c
	200	11.86 c	13.97 b
	400	14.64 b	16.12 ab
	600	16.73 ab	18.31 a
Average		13.62 A	14.94 A

Note: The same small letters on the same column within each main plot and the same capital letter in the same column between the main plot is not significantly different according to HSD test at 5% significance level.

also increased (Table 1). Besides that, the levels of plant Fe content were also reduced and the concentration of plant P increased. If the characteristics of the soil better than it will support the plant growth and crop production.

In general, the dry weight of grains and rice straws with application of 2 weeks intermittent irigation were greater than continuous flooding at various doses of humic acid. Plant grain and straw dry weight with the humic acid dosage of 400 mg kg^{-1} would increase 6.07 and 8.52 g pot^{-1}, respectively, for continuous flooding and as much as 3.39 and 5.77 g pot^{-1}, respectively, for intermittent irigation. The higher dosage of humic acid application, the higher the grain dry weight was obtained. While, the grains and straws dry weight of plants were 3.83 and 3.88 g pot^{-1}, respectively. The value of 2 weeks intermittent flooded was higher than continuous flooding.

When the results was converted to Mg ha^{-1}, so that the results were equivalent to 1.31 Mg ha^{-1} for without humic acid, and ranged from 1.94 to 2.55 Mg ha^{-1} with the use of 200-600 mg kg^{-1} of humic acid for both continuous and intermittent irigation. While, the yield for continuous flooding was 1.85 Mg ha^{-1} and for intermittent irigation was 2.40 mg ha^{-1} at various doses of humic acid. Djakamihardja and Djakasutami (1990) explained that the productivity of new established rice fields in West Java in the first year was still low *i.e.* 1.0 Mg ha^{-1}, and 1.5 Mg ha^{-1} for the second year, 1.5 to 2.0 Mg ha^{-1} for third year, 2.0 to 2.5 Mg ha^{-1} in the fourth year, and over 2.5 Mg ha^{-1} after the fifth year.

CONCLUSIONS

Application of humic acid up to 600 mg kg^{-1} dose followed by 2 weeks of intermittent irrigation reduced soil Fe content which approached levels that were not toxic to plants, with low soil Fe content ranged between 180-250 mg kg^{-1}. Intermittent irrigation every 2 weeks with a variety of humic acid treatment of rice straw compost reduced soil Fe content as much as 1094 mg kg^{-1} compared to continuously flooded treatment. Fe content in soil of 520 mg kg^{-1} was found in intermittent irrigation treatment, whereas the Fe content in the continuous flooding was 1614 mg kg^{-1}, both without the use of humic acid. Growth and yield of rice increased due to the use of humic acid from rice straw compost with 2 weeks intermittent irrigation.

To control Fe toxicity in the rice field on the soil Fe-rich of new established rice field was using a combination treatment of 400-600 mg kg^{-1} dosage of humic acid coupled with water management through 2 weeks of intermittent irrigation. It is recommended to try flooding and drying treatment for 1 - 2 weeks. This means that the Fe content of soil in 1 week flooding did not reach the level of toxic for plants.

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