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P AND FE UPTAKE OF RICE WITH HIGH SOIL FE AMENDED BY COMPOST AND DOLOMITE WITH DIFFERENT WATER MANAGEMENT

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ABSTRACT

Rice production in Poso district on the average is only 4.24 t ha^{-1}, much lower than the national production (5.15 t ha^{-1}) caused by a high iron (Fe) content (11.6-22.6 g kg^{-1}) and low soil fertility. Lands with poor drainage will accumulate organic matter, causing very reductive conditions, i.e highly reduced iron occurs and is toxic for rice crops. The application of compost and dolomite with intermittent irrigation is expected to reduce the negative effects of the excessive amount of Fe and increase the P uptake and yield of rice. The experiment that used 5 t ha^{-1} compost(rice straw and cocoa husks) and dolomite with different water management has been conducted consisting of control(A0), agrochemical fertilizer application and intermittent irrigation (A1), 25% straw compost +75% cocoa husks with saturated water irrigation (A2), 100% straw compost with intermittent irrigation (A3), A2 + 60 kg P_2O_5 ha^{-1} (A4), A3 + 60 kg P_2O_5 ha^{-1} (A5), and dolomite with intermittent irrigation (A6), repeatedthree times and set based on randomized complete block design (RCBD).The results showed that the treatments have no significant effects on available P, organic Fe and available Fe, but they have significant effects on P and the Fe uptake, the weight of 1000 grains and yield of paddy field. The effects of composting significantly increase both levels and P uptake of plant, decrease Felevels of plants and increase the P uptake of plants, the weight of 1000 grains and grain yield. The application of 100% straw compost (5 t ha^{-1}) with intermittent irrigation produces the highest grain yield (6.44 t ha^{-1}) which is significantly different from those without composting.

Keywords: available P, Fe-DTPA, Fe-p, Fe uptake, P uptake.

INTRODUCTION

Typical paddy soils with high levels of iron (Fe) content can be found in lowlands and uplands, depending on the type of parent material; higher levels of iron (Fe) can be found in those types of parent materials which tend to gabbro and basalt. In low land areas which are influenced by the tide phenomenon, pyrite (FeS_2) can be found, while in the medium-level plains anduplands, pyrite will not be formed.

Basin areas in the middle-level and high plains have thepotential to storesaturated water which causes reductive conditions. Soil reaction (pH) in the soil can be classified into acidic to neutral as found in the Inceptisol of swampy rice fieldsaround Lake Poso, with PH 5.0-7.0, while for soils that have pyrite content, the pH is ≤4,5. The solubility of iron in acid sulphate soils is influenced more by very low pH, but for paddy soils categorized into non acid sulphate with a high Fe content and saturated water condition for a long time, the solubility of Fe is very high. This is not only caused by low soil pH but also by factors that cause reductive conditions, namely high levels of organic matter and poor drainage that cause the low redox potential (Eh). The accumulation of organic matter occurs because therate of decomposition of organic matter in anaerobic conditionsis slower than in aerobic conditions (Kannan, *et al*., 2014). The high solubility Fe is then considered as potential toxic for paddy field.

In Indonesia, the Fe toxicity of paddy field can be found in several centers for rice productionsuch as West Java, East Java, Lampung, South Sumatra, Bengkulu, Riau, Jambi, West Sumatra, West Kalimantan, East Kalimantan, South Kalimantan, Southeast Sulawesi and Central Sulawesi with total areas of about 1 million hectares (Andiantoro & Slamet, 1991; Ismunadji, 1990). The soilsrich in Fe with intensive reductive conditions causeFe toxicity to the plants (Nawas *et al*., 2014). According to Ethan *et al*. (2011), Fe toxicity is a major constraint for rice production in waterlogged conditions for a long period (Samaranayake *et al*., 2012), related to excess Fe^{2+} in the soil, poor drainage, low Eh (Ottow *et al*., 1982; Ponnamperuma, 1994), P deficiency, Zn and H_2S toxicity (Kirk, 2004), low oxygen content in the soils (Ponnamperuma *et al*., 1967), low and unbalanced status of plant nutrients (Benckiser *et al*., 1982; Yamauchi, 1989) and the supply of organic material that is not easily decomposed (Dobermann and Fairhurst, 2000; Fairhurst *et al*., 2002). Hakim*et al*. (2012) stated that themain cause of Fe toxicity is excessive Fe^{2+} uptake by plants, at low pH (Jahan *et al*., 2016). Soil with high Fe content in waterlogged conditions and high level of organic matter will dissolve iron as Fe^{2+}. According to Jahan *et al*. (2013), waterlogged conditions will increase the concentrations of Fe^{2+} in the soil in proportion to the length of time. The solubility can range from 500-5000 mg kg^{-1} on swampland and 300-900 mg kg^{-1} in non-marsh soil (Becker & Asch, 2005) or 6000-8000 mg kg^{-1} (Patrick & Reddy, 1978), and the concentration of Fe^{2+} from 1000 to 2000 mg kg^{-1} may affect rice production (Asch *et al*., 2005).The critical limit of Fe toxicity in young rice leaves is >300-500 mg kg^{-1} at tillers phase to panicle initiation, depending on the age and plant nutrients status. The content of Fe toxicity in plants can reach 2000 mg kg^{-1}

(Dobermann and Fairhurst, 2000; Sahrawat, 2000) and it then may reduce yield. The Decrease in yield production due to Fe toxicity ranges from 50% (Audebert, 2006), 52% (Ismunadji *et al*., 1973), 30-100% depending on variety tolerance to Fe, Fe toxicity intensity and soil fertility status (Indradewa *et al*., 2010) or 12-100% depending on variety and toxicity level (Gunawardena *et al*., 1982; Masajo *et al*., 1986; Abifarin, 1988; Sahrawat, 2004).

The average rice yield production in Poso is 4.24 t ha^{-1} (BBS, 2011; BPS, 2015a; BPS, 2015b) or 2-3 t ha^{-1} at farm level. These results are lower than the average national paddy yield production in the last five years (2011-2015) of 5.15 t ha^{-1} or with the average rice yield production in West Java (5.95 t ha^{-1}), Central Java (5.64 t ha^{-1}) and DIY (5.89 t ha^{-1}) (BPS, 2016), compared to the potential yield rice varieties (6-10 t ha^{-1}). This low production is caused by the high level and solubility of Fe, in addition to low soil fertility. Total Fe content in lowland swamp land around Lake Poso is very high, which is about 11.6-22.6 g kg^{-1} (Mowidu, *et al*., 2015). The high level of Fe total results in highly soluble Fe leading to low P availability. Controling Fe solubility is therefore required in order to increase rice yield production.

The purpose of controlling the solubility of Fe is to keep it below toxicity level and to increase P availability to plants. Although most soils contain adequate P, due to fixation, the availability of P is generally low. In acid soils, P fixation is generated by Al, Fe, Mn, clay mineral and hydrate oxides of Al, Fe (Tisdale and Nelson, 1975). In anaerobic conditions, the reduction of ferri hydrated oxide into more soluble ferrous hydroxide will release theembedded phosphate making it available to plants. The solubility of P species $H_2PO_4^-$with pH 5-6 is high and Eh<100 mV in the soil within redox reactions, which is derived from the reduction of strengit ($FePO_4$) (Reddy & Delaune, 2008).

The control of Fe solubility and theincrease ofP available can be conducted through these following three main procedures: management of water irrigation, the use of organic matter and increasing soil pH. The management of water irrigation through supplying water intermittently and saturated water during plant growth can affect Fe solubility and P available in soil with high Fe content. Anaerobic condition due to waterloggingwill dissolve Fe as a result of Eh reduction, and P solubility will increase at low Eh. On the other hand, the drying process will decrease the level of Fe hydroxide gel hydration thus increasing P adsorption (Reddy & Delaune 2008). According to Sahrawat (2012), waterlogged conditions will neutralize problematic soils, in which pH is generally stable at approximately neutral pH (6.5-7.5), and increase the availability of nutrients for N-ammonium, P, K, Ca, Mg, Fe, Mn and Si. To reduce P adsorption, the pH can be raised to about 5.5 and surface adsorptionis saturated with other anion competitors, such as organic anions derived from the organic materials decomposition.

The organic materials that can be used to control the solubility of Fe and increase the availability of P include compost of straw and husk of cocoa. Decomposition of organic matter by organisms in anaerobic condition causes accumulation of electrons resulting in decreased Eh. The decrease of Eh to a certain value (+180 mV or +120 mV) can cause $Fe^{3+}$to be reduced to more soluble Fe^{2+}, so that the solubility increases, followed by the release ofphosphate ions ($H_2PO_4^-$) into the soil solution so thatits availability increases. According to Murthy *et al*. (2010), organic materials increase the availability of plant nutrients through theincreasing activity of biochemical microorganisms. Dolomite can accelerate the increase in the pH of soil solution so that it can release phosphate from Al and Fe as its fixation. The solubility of phosphate soil tends to a maximum in the pH range 6-7 (Ponnamperuma, 1977), 6.0-6.5 (Havlin *et al*., 2005), 5.5-6.5 (Prasad & Power, 1977), but according to Patrick and Reddy (1978) the maximum solubility of the added phosphate and native soil phosphate in waterlogged soils is at pH 5.

This study focussed on the availability of P and Fe on a lowland swamp with high Fe content that is applied by compost and dolomite with different irrigation systems, P and Fe uptake and their effects ongrowth and yield of rice.

MATERIALS AND METHODS

Chemical soil properties before the experiment is shown in Table-1:

Table-1. Chemical soil properties before experiment.

Chemical soil properties	Unit	Level value	Category
pH H_2O (1:5)	-	5,7	Slightly acid
pH KCl (1:5)	-	5,2	-
C organic (Walkley & Black)	g kg^{-1}	44,8	high
N total (Kjeldahl)	g kg^{-1}	3,2	moderate
C:N ratio	-	14	-
P potential (extract HCl 25%)	mg kg^{-1}	1,9	low
P available (Olsen)	mg kg^{-1}	24	very high
K potential (extract HCl 25%)	mg kg^{-1}	0,5	very low
K available (Morgan)	mg kg^{-1}	6	very low
Fe total (wet ashing)	g kg^{-1}	19,9	very high
CEC (NH_4-asetat 1 N, pH 7)	cmol (+) kg^{-1}	11,53	low

The experiment thatusedone factor to determine the effect of compost and dolomite with different water managementon the availability of P and Fe in soil solution, P and Fe uptake and the performance of paddy field in lowland swamps with ahigh Fe content has been conducted involving the application of compost with a dosage of5 t ha^{-1}, taken from local agricultural waste (rice straw and cocoa husks) and dolomite consisting of control, without compost application, dolomite and chemical fertilizers using intermittent irrigation (A0), agrochemical fertilizer application 300 kg ha^{-1}phonska 15-15-15 and urea 60 kg ha^{-1} and intermittent irrigation (A1), 25% straw compost + 75% cocoa husks with saturated waterirrigation (A2), 100% straw compost with intermittent irrigation (A3), A2 + 60 kg P_2O_5 ha^{-1} (A4), A3 + 60 kg P_2O_5 ha^{-1} (A5), and dolomite 1x Al-dd with intermittent irrigation (A6). Each treatment was repeated(3) three times and the experimental units were set based on randomized complete block design (RCBD) on plots of 4 m x 5 m. Compost and dolomite were evenly dispersed and mixed with soil surface two weeks before planting. Rice seedlings of Inpari-1 at the age of 15 days were planted, three plants per hill with a spacing of 25 cm x 25 cm. As basal fertilizer, for each experimental unit (except A0), 200 kg urea ha^{-1} and120 kg KCl ha^{-1} were applied. The application of urea was done 7, 28 and 56 DAT, while KCl and SP-36 (source of P_2O_5) were applied entirely at 7 DAT.

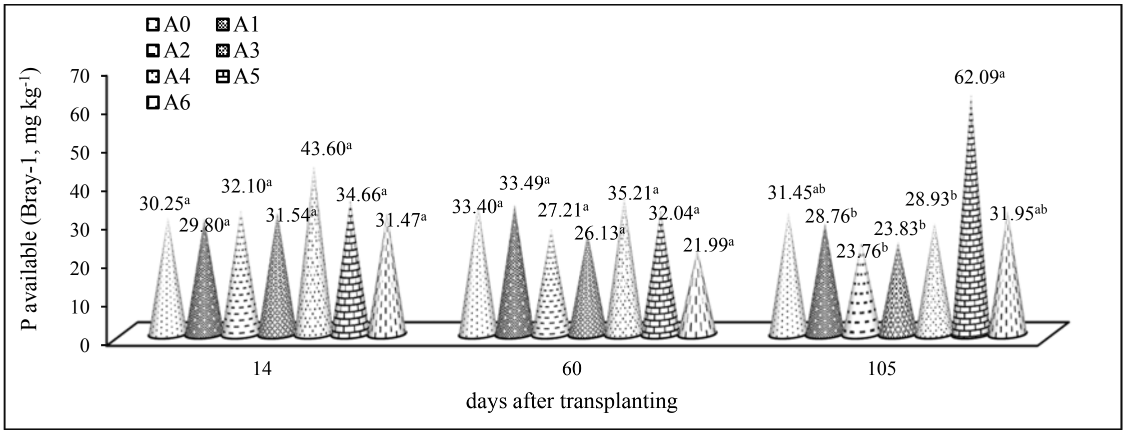
The soil samples and plants were taken at 14, 60, and 105 DAT for analysis purposes involving available P (Bray-1), organic Fe (Fe-p) and available Fe (Fe-DTPA) and P and Fe content of plants. P and Fe uptake of paddy was calculated by multiplying P and the Fe content of plants with theweight of dry plants per hill. Soil samples were taken from each experimental unit of20 cm in depth followed by a drying process and prepared for chemical analysis for each time of observation. The plant samples per experimental unit were taken, involving the whole individual plantcompletely, in order to determine the dry weight and content analysis to calculate P and Fe uptake. The availableP (Bray-1) analysis using Bray and Kurts 1 extractor (0.025 N HCl and NH_4F 0.03 N solution) wasapplied according to USDA procedure (2004) using spectrophotometer, natrium pyrophosphate extraction ($Na_4P_2O_7.10H_2O$) 0.1 M for Fe-p by selecting Fe which form complex compounds with soil organic matter done according to ISRIC procedure (1993) measured by AAS, and Fe-DTPA use DTPA extractor (*dietilene triamine penta acetic acid*) pH 7.3 to extract Fe by forming Fe-DTPA chelate done according to ISRIC procedures (1993) measured by AAS. P and Fe content of plants was determined by wet ashing procedure using concentrated acid HNO_3 and $HClO_4$ (ACIAR, 1990) measured by AAS. Other observation involves plant height, maximum number of productive tillers, weight of 1000 grains and rice production yield. The analysis of soil samples and plant were conducted at the Laboratory of Soil Research Institute in Bogor. Data were then analyzed using SAS for Windows version 9.1 for the F test and median value of treatment with Duncan's multiple range test (DMRT) at 5% significance level. Meanwhile, regression and correlation tests to determine therelationship of various components usedSPSS version 16.0.

RESULTS AND DISCUSSIONS

Availability of P in the soil

Application of compost and dolomite with different irrigation systemshas no significant effect onP available during observation, but the use of straw compost 100% + 60 kg P_2O_5 ha^{-1} with intermittent irrigation producedthehighest available P at 105 DAT and it was significantly different from other treatments, except with the control and theuse of dolomite. Results of initial soil analysis showed that availableP (Olsen) was very high (24 mg kg^{-1}) and potential P was low (19 mg 100 g soil^{-1}). During the observation, the status of availableP (Bray-1) was very high with a value range from 29.80 to 43.60 mg kg^{-1} at 14 DAT, 21.99-35.00 mg kg^{-1} at 60 DAT, and 23.76-62.09 mg kg^{-1} at 105 DAT (Figure-1). Figure 1 shows the change dynamics of available P vary for treatments. According to Tamuly *et al*. (2014) available P decreases from the vegetative to the flowering phase, and increases after flowering to harvest, as indicated by A5 treatment. Garnett *et al*. (2015) states that irrigation regime affects the dynamics of P.

Compared to the available P level for the previous soil, there was an increase in available P 24-82% at 14 DAT, 9-47% at 60 DAT (except for the A6 which decreased to 8%) and 20-159% at 105 DAT (except for A2 and A3 which decreased to 1%). The application of 25% straw compost + 75% compost of cocoa husks with saturated water irrigation (A2 and A4) resulted in a higher available P, but it was not significantly different, compared to100% straw compost and intermittent irrigation (A3 and A5), the use of P fertilizer or withou it with the use of dolomite (A6) at 14 and 60 DAT. However, at 105 DAT, the application of 100% straw compost and P fertilizer with intermittent irrigation (A5) resulting in the highest available P and significantly different from 25% straw compost + 75% compost of cocoa husks and saturated water irrigation (A2 and A4), the application of 100% straw compost without P fertilizer and intermittent irrigation (A3), and agrochemical fertilizer without compost and intermittent irrigation (A1). The organic acid can dissolve P nutrients, so that what is previously unavailable becomes available (Marschner, 1997; Murthy *et al*., 2010), and there are many outputs produced by A5 treatment. According to Rodkoly *et al*. (2015), the Fe-bound P has a wide range of change, 0-590 mg kg^{-1} and organic P is the highest form of P in paddy fields lands. But the water-soluble Fe can react to other ions such as phosphate ions and have precipitation as vivianit (Ponnamperuma, 1977) thereby reducing the availability of P, as occured in the A0 to A4 at 105 DAT.



A0: without compost, dolomiteand chemical fertilizer; A1: chemical fertilizer300 kg ha^{-1} phonska 15-15-15 + 60 kg ha^{-1} urea, intermittent irrigation; A2: 25% straw compost + 75%cocoa husks, saturated water irrigation; A3: 100% straw compost, intermittent irrigation; A4: A2 + 60 kg P_2O_5 ha^{-1}; A5: A3 + 60 kg P_2O_5 ha^{-1}; A6: dolomiteapplication 1xAl-dd.

Figure-1. Level of available P (Bray-1) as a result of compost and dolomit application in Inceptisol with a high Fe content in saturated water and intermittent irrigation.

The insignificant effect of treatment to available P may be caused by a range of pH values when the observation is in the range where the availability of P as a species of $H_2PO_4^-$ is high i.e 5.63 to 6.33 at 14 DAT, from 5.68 to 6.55 at 60 DAT, and 5.85 to 6.26 at 105 DAT due toreduction of Fe^{3+}in waterlogged soil with ahigh organic matter content (Table-2). The pH value is lower in soil containing high organic material (Holah, *et al*., 2015). According to Reddy & Delaune (2008) available P as species of $H_2PO_4^-$is high for pH range from 4-6.5, or 5.5-6.5 (Prasad & Power, 1977) and 6.0-6.5 (Havlin *et al* ., 2005), while according to Fageria & Baligar (2008), theavailable P increase in pH with arange of 5.0-6.5 is related to therelease of P ion from Fe and Al oxides.

Table-2. pH value and organic C level as a result of compost and dolomite application in Inceptisol with high Fe level insaturated water and intermittent irrigation.

Treatment	pH (1:5) at days after transplanting			organic C (g kg^{-1})at days after transplanting		
	14	60	105	14	60	105
A0	5.93	6.21	6.26	50.1	42.0	41.4
A1	5.86	5.68	6.05	43.0	40.4	36.4
A2	5.75	6.03	6.03	44.4	40.2	41.1
A3	5.63	6.02	5.98	46.4	43.4	41.6
A4	5.77	5.84	5.85	41.7	41.8	38.7
A5	5.85	5.86	6.25	43.4	46.1	38.1
A6	6.33	6.55	6.13	41.0	36.0	34.8

A0: without compost, dolomiteand chemical fertilizer; A1: chemical fertilizer 300 kg ha^{-1} phonska 15-15-15 + 60 kg ha^{-1} urea, intermittent irrigation; A2: 25% straw compost + 75% cocoa husks, saturated water irrigation; A3: 100% straw compost, intermittent irrigation; A4: A2 + 60 kg P_2O_5 ha^{-1}; A5: A3 + 60 kg P_2O_5 ha^{-1}; A6: dolomiteapplication 1xAl-dd.

The strength of a reduction process depends on the amount of organic material that is easily decomposed and soil temperature. The higher the organic matter contents the higher thereduction strength (Ponnamperuma, 1965). The level of C organic (>30 g kg^{-1}) was high during the observation resulting in increasing reduction strength, and the reduced amount of Fe was high causing an increase in soil pH around neutral. Moazed *et al*. (2010) stated that P adsorption is strongly influenced by organic C and soil pH. Organic materials decrease theadsorption capacity of P as a direct result of competition of surface adsorptionbetween phosphate and organic ligands, and also because organic materials decrease thepositive charge on the soil that has variable chargethrough a decrease in pH and decrease in P attraction to soil surface.

According to Huang *et al*. (2013), land management practice through water logging during growth and intermittent drainage cause reductive conditionsresulting in water soluble P through thefollowing process (1) Fe (III) and Al phosphate hydrolysis, (2) release of P through anion exchange on clay and hydrous oxides of Fe (III) and Al, and (3) reduction of Fe (III) to Fe (II) by releasing P that is adsorbed and chemically bonded. Reduction conditions occurred because the diffusion rate of oxygen in the air through a layer of water or pore containing water 10000 times slower than through air and air-filled pores (Sanchez, 1976).

P availability increased significantly with increasing pH at 105 DAT (r = 0.603 *), organic C and Fe-DTPA at 60 DAT (r = 0.552 * and 0.637 *), but the increase in pH at 60 DAT decreased theavailable P significantly (r = -0.728 *). The decrease of available P due to increase of pH at 60 DAT is parallel to the decrease of Fe-DTPA (r = -0.940 *) due to the increase in pH at the same time. It reflectsthat an increase in pH will decrease thereduction of Fe so that the amount of Fe-DTPA and available P decreases, while the increase of organic Fe (Fe-p) will increase theavailable P at 60 DAT(r = 0.351^{ns}) and 105 DAT (r = 0.512^{ns}). Increased available P as a result of increased Fe-p occurred because the surface adsorption on colloid surface was saturated by organic anion until P was released.

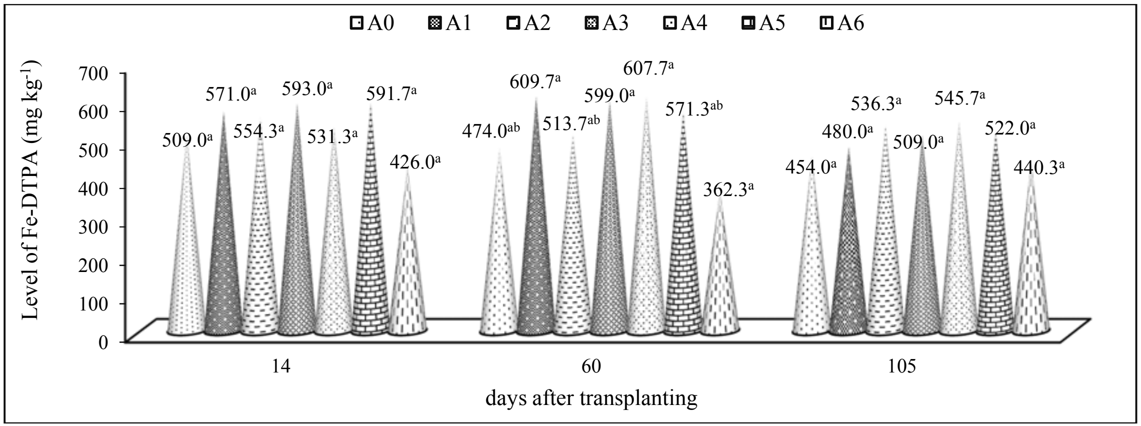
Available phosphorus increased the number of maximum tillers (r = 0.134^{ns}), plant height during flowering (r = 0.027^{ns}) and rice yields (r = 0.333^{ns}). It is also reported by Chiangmai & Yodminkwan (2011) who state that theadequacy of P significantly increasesthe growth of roots and shoots. Prakash *et al*. (2013) obtained the highest grain yield with the use of 80 kg P_2O_5 ha^{-1}, which indicates that grain yield is affected by levels of P in the soil. The increase of suppling P causes an increase in balance of P (Naguno *et al*. 2013).

Availability of Fe in the soil

Application of compost and dolomite with different irrigation systems has no significant effect on available Fe (Fe-DTPA) in the soil. Fe-DTPA status during the observation was quite enough (4.5 mg kg^{-1}) and mostly exceeded Fe stress levels that arestill tolerated by plants. Critical Fe concentrations in soil solution vary according to pH; 100 mg kg^{-1} at pH 3.7; 300 mg kg^{-1} or higher at a pH of 5.0 (Tanaka *et al*., 1966). Fe-DTPA value range with composting 531.3-593.0 mg kg^{-1} and dolomite 426.0 mg kg^{-1} at 14 DAT, from 513.7 to 607.7 mg kg^{-1} and 362.3 mg kg^{-1} at 60 DAT, and 509.0 to 545.7 mg kg^{-1} and 440.3 mg kg^{-1} at 105 DAT (Figure-2). The application of dolomite decreased Fe-DTPA, while composting increasedFe-DTPA compared to the control during the observation. Reduction of Fe^{3+} increased with the addition of organic material so that the Fe-DTPA increased. The initial status of Fe total of soil was very high (19.9 g kg^{-1}) and potentially reduced at reductive conditions.

The addition of compost creates more reductive environment so that Fe reduction increases and improves Fe-DTPA. According to Fageria and Baligar (2008), properties of soil involving organic matter content, clay type, redox status and soil pH are the main factors that determine the availability of heavy metals (including Fe) in the soil. Hasegawa *et al*. (2012) reported that concentrations of dissolved Fe in the growing medium increase with increase of concentrations of ligand. Furthermore, according to Starch & Mukhopadhyay (2010), pH and organic C in the soil is a major factor that causes diversity ofexchangeable cation.

For clayed acid soils, the Fe content in sediments that comes from intensive weathered soil, Fe concentrations of 300-1000 mg kg^{-1} usually occur in a month or more after planting (Becker & Asch, 2005). As shown in Figure 2the level of Fe-DTPA was more than 300 mg kg^{-1} during the observation, both in the control and the use of compost and dolomite. High Fe solubility, with or without composting, and dolomite, either in intermittent or saturated water irrigation. If the availability of other nutrients is low or even deficient, high available Fe content will negatively affect the growth and rice yield when absorbed in high quantities, and plants are susceptible to excess Fe.



A0: without compost, dolomiteand chemical fertilizer; A1: chemical fertilizer 300 kg ha^{-1}; phonska 15-15-15 + 60 kg ha^{-1} urea, intermittent irrigation; A2: 25% straw compost + 75% cocoa husks, saturated water irrigation; A3: 100% straw compost, intermittent irrigation; A4: A2 + 60 kg P_2O_5 ha^{-1}; A5: A3 + 60 kg P_2O_5 ha^{-1}; A6: dolomiteapplication 1xAl-dd.

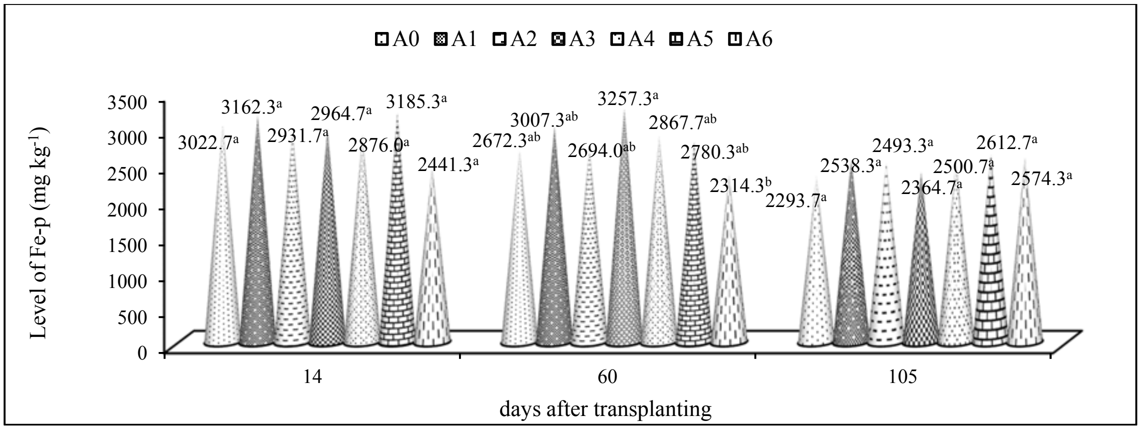
Figure-2. Level of Fe-DTPA as a result of compost and dolomite application in inceptisols with a high Fe content insaturated water and intermittent irrigation.

During the observation, soil pH significantly decreasedFe-DTPA (r=-0.882* at 14 DAT, -0.940* at 60 DATand -0.558* at 105 DAT), while organic C increased Fe-DTPA significantly at 60 DAT (r=0.678*). Fe-DTPA also increased with the increase in K available at 60 DAT (r=0.562*). The decrease of Fe-DTPA thatoccurredwith the increase of pH was related to the deposition of Fe in the form of insoluble hydroxides and oxides. Tening & Omueti (2011) stated that extractable Fe increases with the decrease of soil pH. Conversely, an increase in Fe-DTPA occurs with the increase of available K because K increases the mobility and solubility of Fe. Kyuma (2004) stated that the presence of NO_3 in soil inhibits the release of water-soluble Fe^{2+}, but it does not prevent a high concentration later. Total N decreased Fe-DTPA at 14 and 105 DAT (r=-0.484^{ns} and -0.403^{ns}), but at 60 DAT, it will increased Fe-DTPA (r=0.423^{ns}). This occurs because at reductive conditions, $NO_3^-$is more easily reduced than Fe^{3+}. To prevent the increase of Fe solubility, it can be done through increasing soil pH up to the neutral condition. Breemen & Pons (1978) stated that the reduction of Fe in waterlogged soil reaches the maximum at pH 4.5-5, and the reduction rate depends on the organic matter content.

The increase of Fe-DTPA increased the number of maximum tillers (r=0.736*), plant height during flowering (r=0.670*) and rice yield (r=0.794*) significantly. The increased maximum number of tillers, plant height during flowering and rice yield with increased levels of Fe-DTPA may be caused by increased N uptake at 60 DAT (r=0.423^{ns}) and decreased N uptake at 105 DAT (r=-0.403^{ns}), as well as increased P and K uptake at 60 DAT (r=0.582*; 0.352^{ns}) and at 105 DAT(r=0.793*; 0.759*) as a result of increased levels of Fe-DTPA. Rout &Sahoo (2015) stated that at high Fe concentration, the concentration of P increased in roots. Furthermore, according to Rout *et al*. (2014), Fe toxicity can be reduced through the application of other nutrients that have anegative effect on high Fe concentration. Thus it can improve both growth and rice yield.

Fe organic in the soils

Application of compost and dolomite with different irrigation systems had insignificant effects onorganic Fe (Fe-p) levelsduring the observation. The levels of Fe-p were very high during the observation. The Fe-p value range at 14 DATwas 2441.3 to 3185.3 mg kg^{-1}, at 60 DAT was 2314.3 to 3007.3 mg kg^{-1}, and at 105 DAT was 2293.7 to 2612.7 mg kg^{-1} (Figure 3). Olumo *et al*., (1973) found that all of Fe in waterlogged soils with organic material is dissolved. Fe-organic complex increases the solubility and supply of Fe to roots of plants, which move to the surface of root through the process of diffusion and mass flow (Havlin *et al*., 2005). Fe-organic chelate is a soluble form that can be absorbed by plants. Lindsay described that an organic component can be considered as a "carrier" that carries and releases Fe to the root surface (Havlin *et al*., 2005). The cycle of chelate of micro-nutrients is avery important mechanism in the soil which contributes greatly to the availability of Fe to plants.



A0: without compost, dolomiteand chemical fertilizer; A1: chemical fertilizer 300 kg ha^{-1}; phonska 15-15-15 + 60 kg ha^{-1} urea, intermittent irrigation; A2: 25% straw compost + 75% cocoa husks, saturated water irrigation; A3: 100% straw compost, intermittent irrigation; A4: A2 + 60 kg P_2O_5 ha^{-1}; A5: A3 + 60 kg P_2O_5 ha^{-1}; A6: dolomiteapplication 1xAl-dd.

Figure-3. Level of Fe-p soil as a result of application of compost and dolomite in Inceptisols with a high Fe content insaturated water and intermittent irigation

Figure-3 shows that the use of 100% straw compost and P fertilizer with intermittent irrigation (A5) produces higher Fe-p at 14 and 105 DAT, and at 60 DAT, Fe-p is high on without P fertilizer (A3). This indicates that straw compost produces higher organic acids and potentially chelate to Fe, which increases the solubility of Fe. According Havlin *et al*. (2005), organic material increases the solubility of Fe through chelation reaction. Chest & Aminu (2013) stated that composting on Fe toxic soil is a good agronomic practice that can be used to reduce thenegative impact of dissolved Fe^{2+}on paddy growth environment. Furthermore, according to Rengel (2015), exudates of plants contain a variety of organic compounds and inorganic ions that can change the chemical and biological properties of rhizosphere and improve the availability of micro-nutrient.

The level of Fe-pthat is more than 2000 mg kg^{-1} during the observation (Figure 3) is a potential toxic to the plants, especially when other nutrient availability is low or deficient. According to Asch *et al.* (2005), the concentration of Fe^{2+} from 1000 to 2000 mg kg^{-1} may affect rice yield production. Noor *et al.* (2012) found that the concentrations of Fe$\geq$200 mg kg^{-1} in solution can affect plant growth, Fe concentration of 600 mg kg^{-1} causes plants to die 4 weeks after application, and the length of roots begins to be inhibited at concentrations of $\geq$200 mg kg^{-1}.

The increase of organic C then increased Fe-p at 14 DAT (r=0.396^{ns}), and at 60 DAT (r=0.602*), but at 105 DAT, the increase of organic C decreased Fe-p (r=-0.765*). This shows that reduction of Fe and high organic acid release from 14 to 60 DATproducedhigh Fe-p chelation. In contrast, at 105 DAT, the increase of organic C didnot increases Fe-p because Fe precipitation occurred due to drying before harvest. Hasegawa *et al*. (2012) stated that at high ligand concentration, most Fe^{3+} in the growth medium produces dissolved Fe-L(L=ligan) complex. Organic acid is a ligand that can form complexes with Fe. Furthermore, an increase in soil pH can significantly decrease Fe-p at 14 and 60 DAT (r=-0.694* and -0.717*), and not significantlyat 105 DAT (r=-0.019^{ns}). The increase in pH can decrease the solubility of Fe resulting in lower formation of Fe-organic complex.

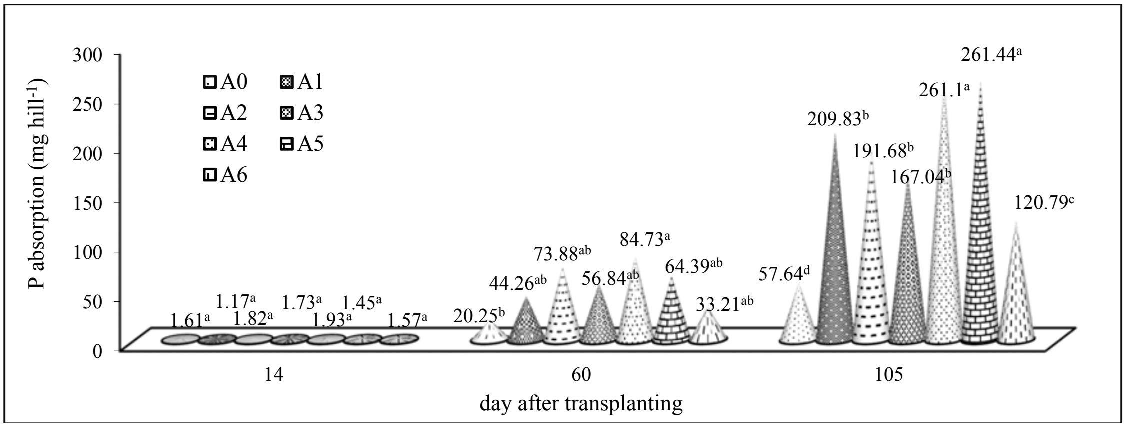
The increase of Fe-p significantly increased the maximum number of tillers (r=0.594*) and plant height at the flowering stage (r=0.565*), and also increased rice production yield (r=0.350^{ns}).Increased maximum number of tillers, plant height during flowering and rice yield caused by increased Fe-p may be caused by the increased N, P and K uptake at 60 DAT (r=0.102^{ns}; 0.334^{ns}; 0.171^{ns}) and 105 DAT(r=0.617*; 0.651*; 0.607*). Thus, eventhough thelevel of Fe-pwas high, because the absorption of N, P and K increased, the growth and rice yield was thereforealso increased. Hakim*et al*. (2012) found that the use of organic fertilizers Tithonia-Plus increases the availability of N, P and K in paddy fields of new openings.

P Uptake

Application of compost and dolomite with different irrigation systems had no significant effects on P uptake at 14 and 60 DAT, but at 105 DAT, it had a significant effect. Although the use of compost and dolomite had significant effects on P levels for plant at 60 and 105 DAT, because P uptake was obtained by multiplying P level in the plant by the weight of dry plant, P uptake was also determined by the weight of dry plant. Supplied compost and dolomite with different irrigation systems significantly affected dry plant weight only at 105 DAT (data not shown). The very high status of available P did not lead to higher P uptake by plants. This was determined by the needs of the plant, the plant's ability to absorb and environmental factors that affect nutrient uptake by plants. According to Yoshida (1981), nutrient uptake is influenced by climate, soil properties, amount and procedures of fertilizer application, varieties and cultivation techniques, while the total uptake of nutrients is influenced by the percentage of dry matter and dry ingredients yield.

P nutrient content in plant material ranged from 0.40 to 0.51% at 14 DAT, 0.36 to 0.55% at 60 DAT and 0.33 to 0.52% at 105 DAT. Composting increased P content 2-27% at 14 DAT, 5-12% at 60 DAT, and2-31% decreased the P of plantsat 105 DAT compared with the controls (A0). However, when compared with the agrochemical fertilizer (A1), the use of compost decreased the P level of plants9-33% at 60 DAT and 13-35% at 105 DAT. The use of dolomite decreased theP level of plant 5 and 33% at 60 and 105 DAT when compared with controls (A0), and 34 and 40% at 60 and 105 DAT when compared withagrochemical fertilizer (A1). According to Yoshida (1981), the P level for high photosynthetic rate is approximately 0.4% P_2O_5. Ishizuka (1965) stated that P absorption occurs quickly during growth and reaches its maximum at the time of flowering, thus, during the ripening, P absorption is low. P_2O_5 levels in leaves and stems during the planting phase to floweringrange from 0.48 to 0.99% of dry matter, while for the ripening phase, it is 0.58 to 0.29% of dry matter (Ishizuka, 1965). Tamuly *et al.* (2014) found that the level of total P (%) is higher in the flowering phase (0.15 to 0.47) compared withmaximum tillers (0.09 to 0.17), panicle initiation (0.11 to 0.17) and at harvest time (0.10 to 0.18).

The P uptake as a result of compost application ranged from 1.45 to 1.93 mghill^{-1} at 14 DAT, 56.84 to 84.73 mg hill^{-1} at 60 DAT, and 191.68 to 261.44 mg hill^{-1}at 105 DAT (Figure-4). The P uptake for the use of dolomite was1.57 mg hill^{-1} at 14 DAT, 33.21 mg hill^{-1} at 60 DAT and 120.79 mg hill^{-1} at 105 DAT. When compared with the control (A0), P uptake for composting increased by 7-20% at 14 DAT (except A5; decrease of10%), 181-318% at 60 DAT, and 150-353% at 105 DAT. The application of less dolomite had a significant impact on the P uptake. Ishizuka (1965) reported that the uptake of P in the leaves and stems during theplanting phase to primordial flowering range from 0.34 to 12.9 mg plant^{-1}; during stem elongation until harvest itis 35-15 mg plant^{-1}, and at panicles during stem elongation until harvesting time it is 3-50 mg plant^{-1}, so that the total P uptake during stem elongation until harvest is 38-65 mg plant^{-1}.



A0: without compost, dolomiteand chemical fertilizer; A1: chemical fertilizer 300 kg ha^{-1}; phonska 15-15-15 + 60 kg ha^{-1} urea, intermittent irrigation; A2: 25% straw compost + 75% cocoa husks, saturated water irrigation; A3: 100% straw compost, intermittent irrigation; A4: A2 + 60 kg P_2O_5 ha^{-1}; A5: A3 + 60 kg P_2O_5 ha^{-1}; A6: dolomiteapplication 1xAl-dd.

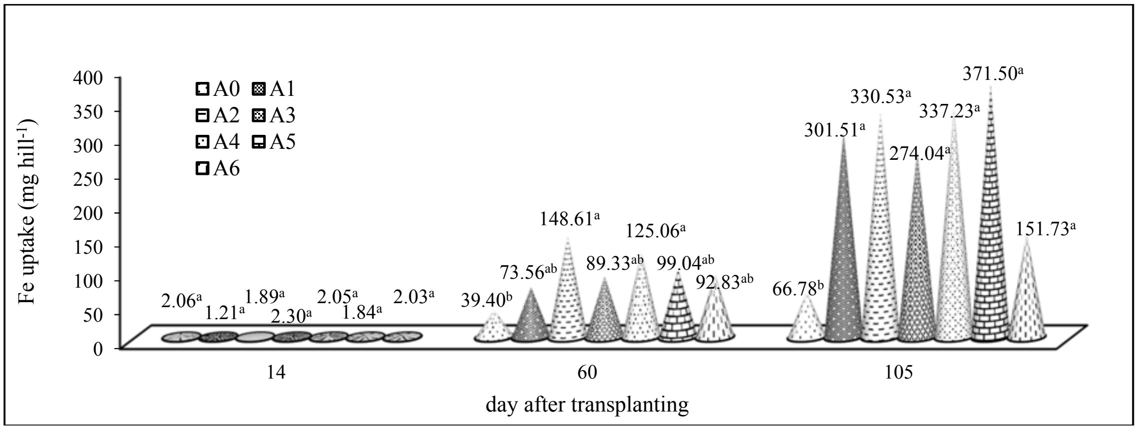
Figure-4. P uptake as a result of compost and dolomite application at high Fe level of Inceptisol with saturated water and intermittent irrigation.

The increase inP uptake occurred with the increasing Fe-DTPA soil at 60 and 105 DAT (r=0.582* and 0.793*), P available at 14 DAT (r=0.584 *), K uptake at 60 and 105 DAT (r=0.931* and 0.816*), Fe uptake at 14, 60 and 105 DAT(r=0.755*; 0.864* and 0.956*), and N uptake at 14, 60 and 105 DAT (r=0.878*; 0.927* and 0.880*). This shows that P uptake is determined not only by the availability ofP in the soil, but also by the availability and uptakeof other nutrients, namely Fe-DTPA, N, K, and Fe uptake. Murthy *et al*. (2010) reported that an increase in P uptake is determined by the increase in P of the native soil by adding compost that produces organic acid during organic materials decomposition. According to Yoshida (1981), N, Palong withS are components of protein, absorbed quickly during the vegetative growth and translocated from the vegetative organs to seeds after flowering. K and Ca as regulatorsof various metabolic processes are absorbed at the same rate in dry matter production, but there is no sign of translocation of these elements from the vegetative organs to seeds during ripening. The mobility of nutrients in rice plant refers to the order of P>N>S>Mg>K>Ca. The high P mobility in plants causes an increase in the P uptake with increased N, K, and Fe uptake; while Fe-DTPA has indirect effect on increased P uptake, through increasing available P in the soil.

Fe uptake

Application of compost and dolomite with different irrigation systems had no significant effects on Fe uptake at 14 and 60 DAT, but asignificant effect at 105 DAT, while the Fe content of plants as a result of compost and dolomite application had a significant effect at 60 DAT. The Fe content in dry matter as a result of compost application ranged from 4850.0 to 6250.0 mg kg^{-1} at 14 DAT, 6540.3 to 7904.3 mg kg^{-1} at 60 DAT, and 5695-6957 mg kg^{-1} at 105 DAT. Takahashi (1965) reported that theFe level in rice straw at harvest may vary, depending on location, i.e Yamagata 290 mg kg^{-1}, Nagano 370 mg kg^{-1}, Chibo 640 mg kg^{-1}, Tochigi 220 mg kg^{-1}, Gifu 230 mg kg^{-1}, Yamaguchi 200 mg kg^{-1}, and Mie 860 mg kg^{-1}. Critical concentrations of Fe toxicity in paddy fields has a value range of 20 to 2500 mg kg^{-1}, depending on the accumulation of H_2S and organic acids (Tadano & Yoshida, 1978) and the availability of other nutrients (Ottow *et al*., 1982). Rout & Sahoo (2015) stated that Fe toxicity is a disturbed complex nutrient and other nutrient deficiency, particularly P, K, Ca, Mg and Zn. High concentrations of Fe leads to unbalanced nutrients through the antagonistic effect on nutrient uptake involving K and Zn (Rout *et al*., 2014).

Fe uptake as a result of composting ranged from 1.84 to 2.30 mg hill^{-1} at 14 DAT, 89.33 to 148.61 mg hill^{-1} at 60 DAT, and from 274.04 to 371.50 mg hill^{-1} at 105 DAT, while the use of dolomite resulted in Fe uptake 2.03 mg hill^{-1} at 14 DAT, 92.83 mg hill^{-1} at 60 DAT, and 151.73 mg hill^{-1} at 105 DAT (Figure-5). Compared with the control (A0), composting with P fertilizer decreased theFe uptake 5-11% at 14 DAT, increased the Fe uptake 151-217% at 60 DAT, and 405-456% at 105 DAT,while the use of dolomite decreased Fe uptake 1% at 14 DAT, increased of 136% in the Fe uptake at 60 DAT, and 127% at 105 DAT. Meanwhile, when compared with the agrochemical fertilizer (A1), the use of compost with P fertilizer increased the Fe uptake by 52-69% at 14 DAT, 35-70% at 60 DAT, and 12-23% at 105 DAT. The application of dolomite increased the Fe uptake by 68% at 14 DAT, 26% at 60 DAT, and increased the Fe uptake by 50% at 105 DAT.



A0: without compost, dolomiteand chemical fertilizer; A1: chemical fertilizer 300 kg ha^{-1}; phonska 15-15-15 + 60 kg ha^{-1} urea, intermittent irrigation; A2: 25% straw compost + 75% cocoa husks, saturated water irrigation; A3: 100% straw compost, intermittent irrigation; A4: A2 + 60 kg P_2O_5 ha^{-1}; A5: A3 + 60 kg P_2O_5 ha^{-1}; A6: dolomiteapplication 1xAl-dd.

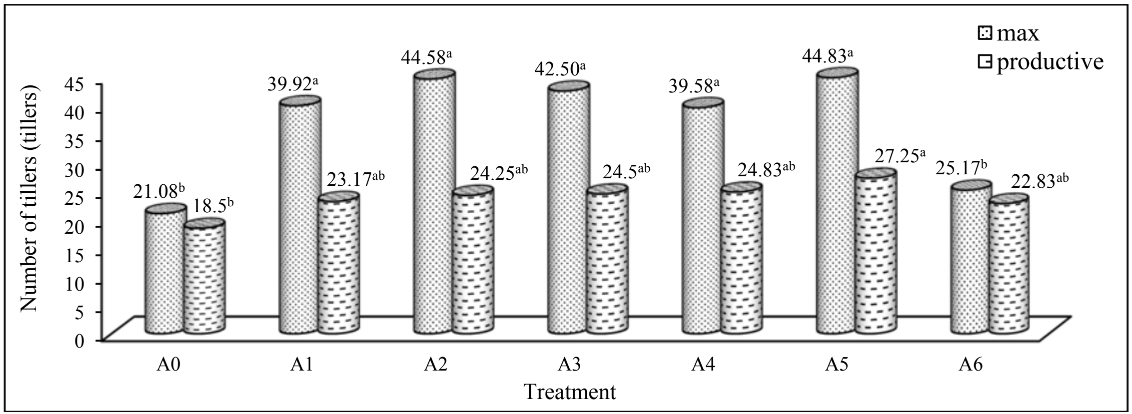
Figure-5. Fe uptake as a result of compost and dolomite application at high Fe level of Inceptisol with saturated water and intermittent irrigation.

In paddy soil, Fe cannot be considered as micro-elements. Paddy fields assimilate Fe in large quantities, 12 kg ha^{-1} on average, slightly lower than the P uptake (Tanaka *et al*., 1964). Tissue Fe concentration is 300-800 mg kg^{-1} in acid soils with clay content containing Fe (Becker & Asch, 2005). Furthermore, it is stated that there are several publications on Fe toxicity based on its levels such as Fe soils (20-5000 mg kg^{-1}), Fe leaf concentrations (300-2000 mg kg^{-1}), when Fe toxicity occurs (2 weeks after flooding or during planting to the slow reproductive phase), distribution of toxic symptoms in the soil (the entire plot, spots, isolated plants), and observed yield losses (10-100%).

Increased Fe uptake significantly occurred with increasing Fe-DTPA at 105 DAT (r=0.850*), K uptake at 60 and 105 DAT (r=0.960* and 0.877*), N uptake at 14, 60 and105 DAT (r=0.782*; 0.937* and 0.871*), and P uptake at 14, 60 and 105 DAT(r=0.775*; 0.864* and 0.956*). This may be related to the role of Fe in plants. Inside plants, Fe assiststhe establishment of respiratory enzymes system, serving as the implementer of electron transport in the process of metabolism (Dobermann and Fairhurst, 2000),as part of porphyrin development, the main component of chloroplasts and mitochondria (Dobermann and Fairhurst, 2000; Marschner, 1997; Mengel and Kirkby, 1987), necessary for the proper functioning of a number of enzymes in plants, especially those involving oxidation and reduction reactions in respiration and photosynthesis (Havlin *et al*., 2005). Enhancement ofN, P and K uptake increases the activity of metabolism in plants, which is required for Fe involvement as an activator of enzymes, thus increasing theFe uptake. Especially for N, it is different from that found by Ethan *et al*. (2011) where the addition of N 40-100 kg ha^{-1} decreases theFe content of plant tissue from 287.25 mg kg^{-1} to 216.81 mg kg^{-1}.

Growth and yield of Rice

Application of compost and dolomite with different irrigation systems significantly affected the maximum number of tillers, plant height at 60 DAT and the flowering phase, the weight of 1000 grains, as well as milled dry rice yield, but the effect on thenumber of productive tillers was not significant. The highest maximum number of tillers (44.83 tillers) was obtained by using of 100%straw compost with the addition of P fertilizer with intermittent irrigation, which was significantly different from the control (A0) and the use of dolomite (A6). The highest number of productive tillers (27.25 tillers) was also obtained by the use of 100% straw compost with the addition of P fertilizer and intermittent irrigation (Figure-6), whereas according to the variety description of productive tillers, the total number is 16 tillers (Suprihatno, *et al*., 2009). The increase in themaximum number of seedlings as a result of composting addition ranged between 88 and 113%, when compared with A0, and 6-13% when compared with the agrochemical fertilizer (A1), except for theapplication of 25% straw compost and 75% cocoa huskwith P fertilizer addition and saturated water irrigation, the maximum number of tillers decreased by 0.8%. The increase in the number of maximum tillers was significantly affected by the increasing available K at 60 DAT (r=0.780*), Fe-DTPA at 60 DAT (r=0.736*), as well as N, P, K, and Fe uptake at 60 DAT (respectively r=0.710*; 0.820*; 0.803* and 0.657*). The number of productive tillers significantly increased with the increase of available K at 60 DAT (r=0.558*), as well as N, P, K, and Fe uptake at 60 DAT (respectively r=0.787*; 0.775*; 0.760* and 0.668*). Murthy *et al*. (2010) found that the recommended application of organic and chemical fertilizer increases the availability of N, P, K and number of tillers, panicles number and other growth components as a result of better nutrient uptake. According to Kumar *et al*. (2014) growth components increased with the increasein thefertilizer dose as recommended and vermicompost.

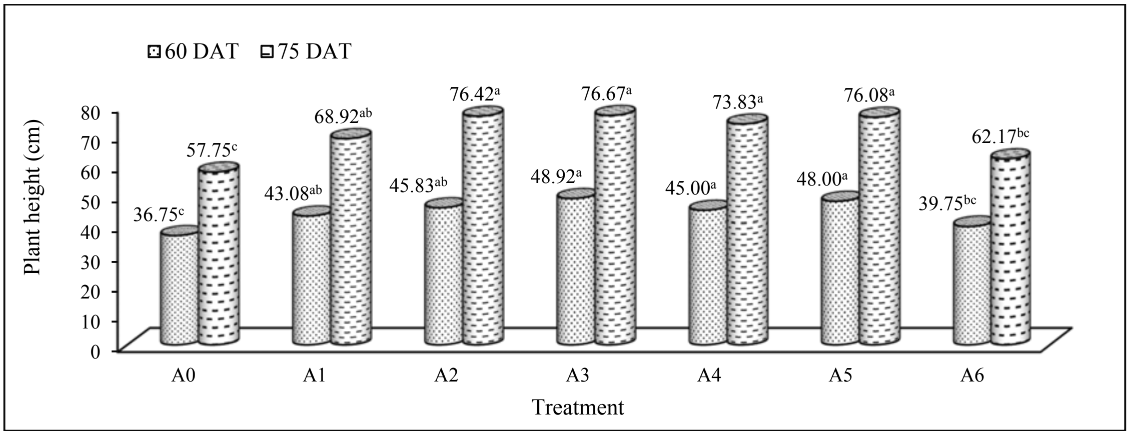


A0: without compost, dolomiteand chemical fertilizer; A1: chemical fertilizer 300 kg ha^{-1}; phonska 15-15-15 + 60 kg ha^{-1} urea, intermittent irrigation; A2: 25% straw compost + 75% cocoa husks, saturated water irrigation; A3: 100% straw compost, intermittent irrigation; A4: A2 + 60 kg P_2O_5 ha^{-1}; A5: A3 + 60 kg P_2O_5 ha^{-1}; A6: dolomiteapplication 1xAl-dd.

Figure-6. Number of maximum tillers and productive tillers as a result of compost and dolomite application at high Fe level of Inceptisol with saturated water and intermittent irrigation.

Improved available K directly increased the K uptake significantly (r=0.560*). Inside the plant, K increases the photosynthesis process and the activities of a variety of enzyme systems (Abdurachman *et al*., 2008) so that it can stimulate the formation of tillers accompanied with other nutrients. Indirectly, the increase of K available will increase the available P at 60 DAT through increased Fe-DTPA caused by increased available K at the same time (r=0.562*). Furthermore, the increase of Fe-DTPA increased the available P (r=0.637*). The enhancement of available P increased the P uptake (r=0.728*), and the P uptake at 60 DAT will increase the number of maximum tillers (r=0.820*). According to Abdurachman *et al*. (2008), P is an important factor to develop ATP for the storage and transfer of energy for metabolism, and promotes the formation of roots and the increase in the number of tillers. In the paddy field, N is the main element to produce protein, the main element of protoplasm, chloroplasts, and enzymes, and it affects tillers development (Abdurachmann *et al*., 2008). The more roots are formed, the more nutrients are absorbed by plants so that the number of tillers is increasingly greater.

Application of compost increased plant height at 60 DAT and during flowering and then it was significantly different from the control (A0) and dolomite application (A6). The highest plant height was obtained by using of 100% straw compost and intermittent irrigation at 60 DAT (48.92 cm) and during theflowering phase (76.67 cm) (Figure-7), but it hadnosignificant effectson the application of other composts and agrochemical fertilizers. Plant height based on description of varieties is 93 cm (Suprihatno *et al*., 2009), so that the difference with highest plant height in this study is 16 cm.

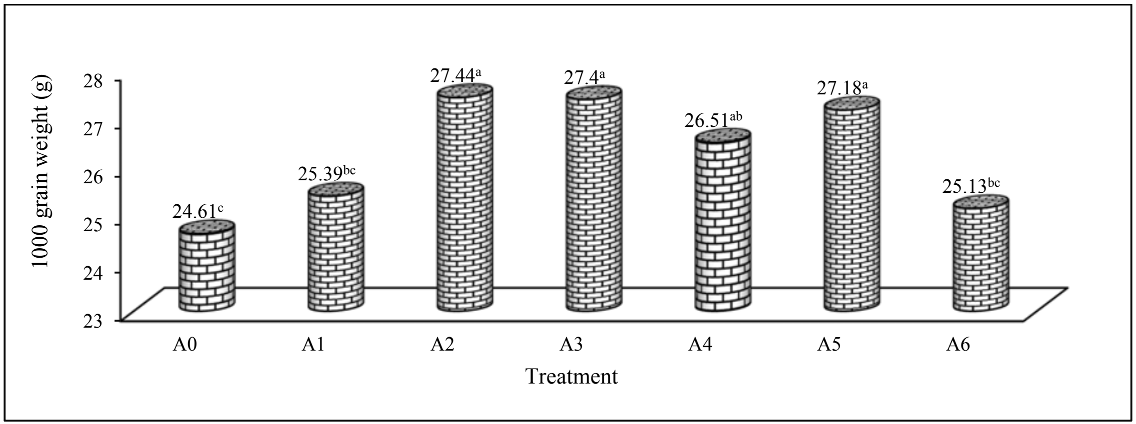


A0: without compost, dolomiteand chemical fertilizer; A1: chemical fertilizer 300 kg ha^{-1}; phonska 15-15-15 + 60 kg ha^{-1} urea, intermittent irrigation; A2: 25% straw compost + 75% cocoa husks, saturated water irrigation; A3: 100% straw compost, intermittent irrigation; A4: A2 + 60 kg P_2O_5 ha^{-1}; A5: A3 + 60 kg P_2O_5 ha^{-1}; A6: dolomiteapplication 1xAl-dd.

Figure-7. Plant height as a result of compost and dolomite application at high Fe level of Inceptisol with saturated water and intermittent irrigation.

The increase in plant height at 60 DAT and the flowering phase occurred with increasing K available and Fe-DTPA at 60 DAT, and N, P, K, and the Fe uptake at 60 DAT. In addition, N, P, K, and Fe uptake increased the plant height at 60 DAT and during flowering, although the highest plant height that could be achieved was still lower than plant height according to variety description. In addition to affecting tillers, N also affects plant height (Abdurachman *et al*., 2008), and P is important at the early stages of growth (Fairhurst *et al*., 2002). The most essential function of P is its contribution to storage and transfer of energy in plants (Havlin *et al*., 2005). K improves the process of photosynthesis (Abdurachman *et al*., 2008) because it is involved in the synthesis of ATP, the production of photosynthesis enzymes, CO_2 absorption, maintaining the balance of energy for photo phosphorylation in chloroplasts (Havlin *et al*., 2005). Fe is required for photosynthesis (Fairhurst *et al*., 2002) and it has contribution for oxidation and reduction reactions during respiration and photosynthesis (Havlin *et al*., 2005), and it is considered as catalyst or a part of enzyme systems related to the formation of chlorophyll. The high N, P, K, and Fe uptake leads to high plants metabolic activity resulting in increased plant height.

Application of compost and dolomite with different irrigation systems had asignificant effect on theweight of 1000 grains and milled dry grain yield. The highest 1000 grain weight (27.44 g) was obtained in the use of 25% straw compost with 75% cocoa husks with saturated water irrigation (Figure-8) and it was significantly different from the control (A0), agrochemical fertilizer (A1) and theuse of dolomite (A6). Compost application produces a weight of 1000 grains similar to those listed in the description of varieties (27 g), except for theuse of 25% straw compost and 75% cocoa husks with saturated water irrigation and P fertilizer application, whichslightly lower than the description (26.52 g).



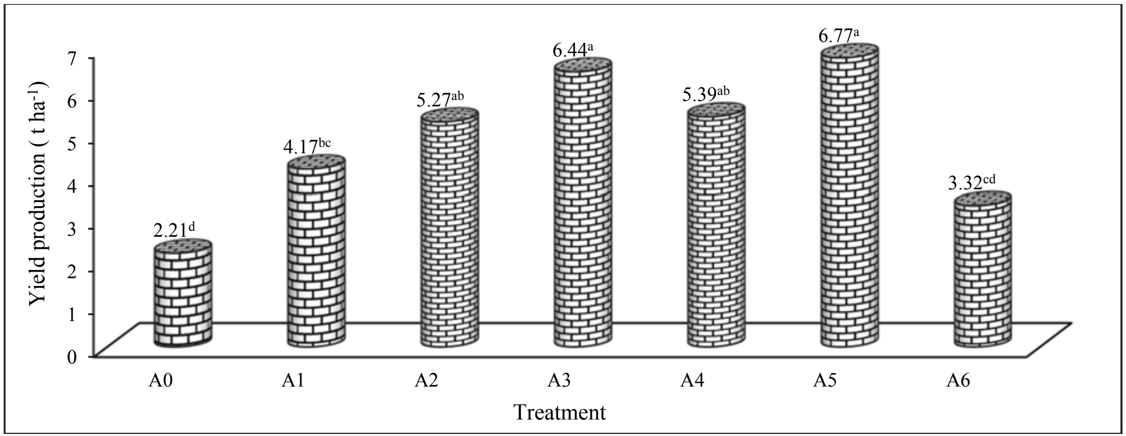
A0: without compost, dolomiteand chemical fertilizer; A1: chemical fertilizer 300 kg ha^{-1}; phonska 15-15-15 + 60 kg ha^{-1} urea, intermittent irrigation; A2: 25% straw compost + 75% cocoa husks, saturated water irrigation; A3: 100% straw compost, intermittent irrigation; A4: A2 + 60 kg P_2O_5 ha^{-1}; A5: A3 + 60 kg P_2O_5 ha^{-1}; A6: dolomiteapplication 1xAl-dd.

Figure-8. Weight of 1000 rice grains as a result of compost and dolomite application at high Fe level of Inceptisol with saturated water and intermittent irrigation.

The highest rice yield production (6.77 t ha^{-1}) was obtained in the use of 100% straw compost with P fertilizer addition and intermittent irrigation, which was significantly different from the control (A0, 2.21 t ha^{-1}), agrochemical fertilizer (A1, 4.71 t ha^{-1}) and dolomite application (A6, 3.32 t ha^{-1}) (Figure-9). The use of compost increased rice yields by 138-206% of A0, and 26-62% of A1. Although it was not significantly different, the application of 100% straw compost and intermittent irrigation produced higher grain yields (19-28%) compared to using 25% straw compost and 75% cocoa husk with saturated water irrigation. Prakash *et al*. (2013) found that grain yield was significantly affected by the concentrations of N and P, in which the highest grain yield was obtained by the use of 240 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1}. Furthermore, Sukristiyonubowo *et al*. (2012) stated that the recommended NPK fertilizer application + 2 t ha^{-1}dolomite + 2 t ha^{-1}straw compost increased rice yields in the new opening of paddy field land. The highest N, P and K uptake was obtained at harvest (Sukristiyonubowo *et al*., 2012), or the uptake was increasingly higher with the age of plants and the number decreased following the order of K>N>P (Tamuly *et al*., 2014), leading to the increasein rice yield. Significantly, grain yield (5.29 t ha^{-1}) was higher with 125% recommended fertilizer dosage + 5 t ha^{-1} vermicompost (Kumar, *et al*., 2014). The higher grain yield was achieved with the application of N, P and K related to the number of grains, panicle weight and the weight of 1000 grains (Sanjivkumar & Malarvizhi, 2014). The application of P_2O_5 50 kg ha^{-1} produced the highest grain yield (7.85 t ha^{-1}) (Hasanuzzaman *et al*., 2012).

The average yield production of Inpari-1 based on the description of varieties is 7.32 t ha^{-1}, with a potential yield of 10 t ha^{-1} (Suprihatno *et al*., 2009). Based on these data, the results obtained by straw composting of 100% without addition of P fertilizer and intermittent irrigation in this study (6.44 t ha^{-1}) were12% lower than the average yield or 35.6% lower than thepotential yields.

Furthermore, with the same compost and P fertilizer addition, the results obtained (6.77 t ha^{-1}) were7.5% lower than the average yield or 32% lower than thepotential yield,while the results obtained with the use of agrochemical fertilizer (4.17 t ha^{-1})were43% lower than the average yield or 58% lower than potential yield. This shows that the application of straw compost and intermittent irrigation provides a significantly higher yield production due to agrochemical fertilizers addition and it is close to the average yield production based on the description of variety.



A0: without compost, dolomiteand chemical fertilizer; A1: chemical fertilizer 300 kg ha^{-1} phonska 15-15-15 + 60 kg ha^{-1} urea, intermittent irrigation; A2: 25% straw compost + 75% cocoa husks, saturated water irrigation; A3: 100% straw compost, intermittent irrigation; A4: A2 + 60 kg P_2O_5 ha^{-1}; A5: A3 + 60 kg P_2O_5 ha^{-1}; A6: dolomiteapplication 1xAl-dd.

Figure-9. Rice yield production as a result of compost and dolomite application at high Fe level of Inceptisol with saturated water and intermittent irrigation.

The weight of 1000 grains increased significantly with increasing K available of soil at 60 and 105 DAT (r=0.780* and 0.596*), N, P, K, and Fe uptake at 60 DAT (respectively r=0.844*; 0.815*; 0.881* and 0.729*) and N, P, K, and Fe uptake at 105 DAT (r=0.787*; 0.644*; 0.847* and 0.795*). Furthermore, rice yield increased with increasing available K and Fe-DTPA at 60 DAT (r=0.744* and 0.630*), N, P, K, and Fe uptake at 60 DAT (respectively r=0.761*; 0.781*; 0.756* and 0.581*) and N, P, K, and Fe uptake at 105 DAT (r=0.881*; 0.787*; 0.854* and 0.865*). The N, P, K, and Fe uptake during thevegetative growth until the seed loading and ripening increased yield production. According Abdurachman *et al*. (2008), N affects the amount of grain, P accelerates flowering and seed ripening, K strengthen the roots and stems. Fe plays an important role in basic biological processes such as photosynthesis, chlorophyll synthesis, respiration, fixation and N uptake (Kim & Rees, 1992).

CONCLUSIONS

Application of compost and dolomite with different irrigation systems has no significant effectsonavailable P (Bray-1), organic Fe (Fe-p), available Fe (Fe-DTPA) and the number of productive tillers, but it has significant effects on P and Fe uptake at 105 DAT, the maximum number of tillers, plant height, the weightof 1000 grains and rice yield production.

The status ofavailable P (Bray-1) is extremely high during the observation with a range of 23.76 to 62.09 mg kg^{-1}. Increased available P occurs with increasing Fe-p and Fe-DTPA at 60 and 105 DAT. The value ranges of Fe-p and Fe-DTPA as a result of treatments are 2293.7 to 3257.3 mg kg^{-1} and 363.3 to 607.7 mg kg^{-1}. The increase inorganic Cwill increase Fe-p at 14 and 60 DAT, but Fe-p decreases with the increasing organic C at 105 DAT and theincrease of pH during the observation. The increase in organic C at 60 DAT can increase Fe-DTPA, but increased pH will decrease Fe-DTPA during the observation.

Application of compost increases the level and P uptake of plants significantly, decreases Fe levels of plants and increases theFe uptake of plants, the maximum number of tillers, plant height, the weight of 1000 grain, and yield production significantly compared with the control. The use of dolomite increases the P and Fe uptake by paddy field and increases the grain yield compared with controls. P and Fe uptake in saturated water irrigation is higher than in intermittent irrigation, but the grain yield insaturated water irrigation is lower than in intermittent irrigation. The application of 100% straw compost (5 t ha^{-1}) with intermittent irrigation producesthe highest grain yield (6.44 t ha^{-1}), which issignificantly different from those without theuse of compost.

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