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Response of Some Rice Cultivars in New Opening Paddy Fields with High Fe^{2+} Using Multi-packet Technology

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ABSTRACT

The main obstacle to increase rice yield in new opening paddy fields, is that high levels of dissolved ferrous ions (Fe^{2+}) which toxic to plants. This research aimed to study the growth and yield of several rice cultivars tolerant to Fe^{2+} in the new opening paddy fields with multi-packet technology. The experiment was conducted from April to December 2010, at the new opening pay fields in Koto Baru of Dharmasraya District, West Sumatra. Experiments used a factorial in a Completely Randomized Design with three replications. The first factor was, selected rice varieties which were: Krueng Aceh; IR 36; Tukad Balian; Ciherang; and Cisokan. The second factor was the different plant spacing which were a 30 × 30 cm with two seeds per hole, and Plant spacing (10 × 10) × 30 × (10 × 10) cm with one seed per hole. The rice cultivation with packet technology can improved the growth and yield of paddy rice cultivated in new opening paddy field high in Fe^{2+}. Technology package consisting a combination of rice variety (Krueng Aceh, IR36, and Tukad Balian) + SRI system + peat amelioran 20 Mg ha^{-1} + plant spacing (10 × 10) × 30 × (10 × 10) cm with one seed per hole, had the best growth and yield of rice cultivated in the new opening fields high in Fe^{2+}, especially in Koto Baru of Dharmasraya District, Krueng Aceh was a variety with the highest grain production by 5.65 Mg ha^{-1}.

Keywords: Fe^{2+}, new fields, rice cultivar, technology

INTRODUCTION

Increased productivity of rice has been attempted in Indonesia since the 1970's, in order to increase income and welfare and enhance national food security, either through the extensification or intensification. One effort to increase the productivity of rice is by utilizing the new opening paddy field, however there are many challenges associated with nutrient stress, climate, weeds, pests and diseases (Zubaidah and Munir 2002; Utama 2010b) as well as the lack of varieties tolerant to environmental stress (Suhartini 2004; Utama 2010a), particularly stress in ferrous ion (Fe^{2+}).

Potential land that could be utilized to increase rice production was found in the wetland area of Dharmasraya District which covered 2,691 hectares (Anonymous 2007). One of the new opening paddy fields was in the Koto Baru sub district which covered 1,196 hectares and it was affected by the high solubility of Fe^{2+} ion.

Serious problems of rice cultivation in new opening paddy fields are high Fe^{2+} toxicity that causes a nutrient deficiency, damaging plant cells, and water deficit (Marschner 1995) which lead to impaired growth and the number of disorders that can cause crop failure (Sahrawat 2010). Therefore, the plant growth obstacles are increasing, especially in the conditions under water, where Fe^{3+} is converted to Fe^{2+} (Rengel 2000; Barchia 2006) which are toxic to plants, and low solubility of essential nutrients such as deficiency of K, P, Ca, and Zn.

One method to overcome the problems in marginal lands is to use plants that are tolerant to environmental stress (Marschner 1995; Munns and Tester 2008; Utama 2010a). Efforts to enhance plant growth and neutralize the adverse effect of Fe^{2+} become increasingly important for plant growth promotion, especially rice cultivation in new opening paddy fields with a high content of Fe^{2+} ions. Plants that are tolerant to the environmental stress have the ability to adapt to the morphology and physiology (Pellet *et al.* 1995; Ma 2000; Sunadi *et al*. 2010). Some which are rice cultivars tolerant to nutrient stress such as salinity, aluminum and iron have the ability to adapt ion and can produce well (Utama 2010a; Utama 2010b; Sunadi *et al*. 2010).

The low production of rice in the new opening paddy fields was due to limited technology and lack of rice cultivars that are tolerant to stress Fe^{2+}. This research aimed to study the growth and yield of several rice cultivars tolerant to Fe^{2+} in the new opening fields with multi-packet technology.

MATERIALS AND METHODS

Study Site

Research was conducted in the new opening paddy field, in Koto Baru Sitiung I, Dharmasraya District, West Sumatra, Indonesia and Laboratory "Kopertis" Region X, from April to December 2010. Three most tolerant of rice varieties and two most sensitive rice varieties were used which were selected by Sunadi *et al*. (2010). New opening wetlands have a high level of dissolved Fe^{2+} (104.69 mg kg^{-1}) and other characteistics such as presented at Table 1.

Expeimental Set-up

Experiments were arranged by a Completely Randomized Design, prepared factorial with three replications. The first factor was selected rice varieties, namely: V_1 = Krueng Aceh; V_2 = IR 36; V_3 = Tukad Balian; V_4 = Ciherang; and V_5 = Cisokan. The second factor was different plant spacing, namely: J_0 = plant spacing of 30 × 30 cm with two seeds per hole, and J_1 = plant spacing (10 × 10) × 30 × (10 × 10) cm with one seed per hole.

Before germinating, rice seeds were immersed in the deltametrin solution, with the concentration of 3 g L^{-1} and 1 ml L^{-1} for 20 minutes, after that it was rinsed thoroughly and soaked for 24 hours. Flooded rice fields were watered for 7 days, then it was added by a peat soil amelioran as much as 20 Mg ha^{-1} as a source of organic material. The amelioran was treated to soil as deep as 25-30 cm. The plot experiments with size 2.5 × 1.5 meters were

Table 1. Physical and chemical characteristics of Ultisols soil in Koto Baru Sitiung I of Dharmasraya District.

Soil characteristics	Unit	Value	Criteria
Texture			
Sand	%	17.86	-
Silt	%	50.85	-
Clay	%	31.25	-
Class		Clay	-
Depth	cm	0-20	-
Bulk density		1.08	-
pH H_2O	-	5.07	sour
Organic Matter	%	2.56	-
Organic-C	%	1.49	low
Total-N	%	0.11	low
C/N ratio		12.04	medium
Available P (Bray 2)	mg kg^{-1}	3.29	very low
Arrangement of cations			
K^+	mol kg^{-1}	0.05	low
Na	mol kg^{-1}	0.13	low
Mg	mol kg^{-1}	0.20	very low
Ca	mol kg^{-1}	0.08	very low
		$\sum$ = 0.46	
CEC	mol kg^{-1}	14.93	low
Base saturated	%	3.08	very low
Exchangeable Acidity			
Al^{3+}	mol kg^{-1}	4.78	medium
H^+	mol kg^{-1}	0.87	-
Fe available (Fe^{2+})	mg kg^{-1}	104.69	high
Air dry water content	%	20	

created. Then, the rice field was incubated for 2 weeks. After it had reprocessed and continued to rake up the land was ready for planting. Germination of seeds were done by wrapping with burlap sacks of rice, and then planted in paddy fields. Rice seeds used in this experiment were in the age of 10 days in accordance with a predetermined treatment, with two different spacing.

Type of fertilizers given in the early planting were Urea 1/3 dose, SP 36 and KCl. Further provision of Urea 1/3 dose was applicated at age 6 weeks and 1/3 dose again was applicated at the generative phase. Weeding was done at the age of 2 and 6 weeks after transplanting. Watering was done intermediates, and stagnant water when primordial phose. Harvesting was done after the leaves had turned yellow flag 80% of the total population and grain on the panicles were wither.

Statisical Analysis

All data were statistically analyzed by analysis of variance (ANOVA). Comparisons among means were analyzed by using Tukey test calculated at $P < 0.05$.

RESULTS AND DISCUSSION

The low of soil organic matter, total-N, available-P and K-dd showed that the soil was poor and needed a great additional ameliorans such as organic materials. Amelioran added in this experiment was the saphrict type of peat soils origined from West Pasaman. If had low to moderate Al saturation which potential contribute to H^+ ions into the soil solution so that lower the soil acidity (Table 1).

While the ground color was changed from brown to gray and Fe^{2+}, dissolved in the soil in large quantities. Soluble iron concentrations were varied from 0.1 to 600 ppm shortly after the flooding. In acid sulfate soil, the concentration of Fe^{2+} reached 5000 ppm few weeks after the flooding. In acid soils with high levels of organic matter and oxides the concentrations of ferrous iron to toxic levels were (Table 1) in Ultisols soil, Oxsisol soil, Acid sulfate soil, and peat land tidal area (Barchia 2009).

High levels of Fe^{2+} in the new opening paddy field, had affected the growth of all rice varieties cultivated in paddy fields (Table 1). Growth of rice

Table 2. The number of tillers, plant height, leaf number, number of panicles, panicle length of several rice varieties tolerant to Fe^{2+} in new opening paddy fields with multi-packet technology.

Plant spacing	Rice cultivars				
	Krueng Aceh	IR 36	Tukad Balian	Ciherang	Cisokan
			Tillers number Unit^{-1}		
30 × 30 cm	41.33 de	54.07 c	43.40 d	31.93 e	39.67 de
(10 × 10) × 30 × (10 × 10) cm	70.67 b	91.53 a	71.13 b	58.87 c	55.13 c
			Plant height (cm)		
30 × 30 cm	105.00 d	86.67 e	90.60 e	91.73 de	90.20 e
(10 × 10) × 30 × (10 × 10) cm	208.13 a	162.73 c	175.73 c	173.87 c	193.40 b
			Leaves number strand		
30 × 30 cm	198.93 de	270.47 c	203.60 de	246.55 cd	191.73 e
(10 × 10) × 30 × (10 × 10) cm	335.47 b	468.80 a	339.13 b	285.60 bc	251.33 cd
			Panicles number unit		
30 × 30 cm	35.40 bc	37.06 b	34.80 bc	24.47 c	28.40 c
(10 × 10) × 30 × (10 × 10) cm	59.93 a	57.33 a	54.53 a	39.67 b	33.80 bc
			Panicle length (cm)		
30 × 30 cm	26.09 b	20.81 d	43.34 a	25.31 bc	23.91 c
(10 × 10) × 30 × (10 × 10) cm	25.99 b	21.82 d	43.64 a	25.64 b	25.97 b

Mean followed by different letters on the same variables in each treatment showed significantly different at 5% level by Tukey test.

varieties grown in mineral soil showed the diversity in the all parameters (Table 2 and 3). The diversity was, caused by the difference in genetic potential in response to growth environment, due to high in dissolved iron (Audebert and Sahrawat 2000; Ashraf and Harris 2004; Suhartini 2004).

The availability of hydrogen sulfide and ferrous sulfide in waterlogged soil have very reductive role in the availability of iron toxicity in the new opening paddy fields. It will affect nutrient status of rice plants to be tolerant to iron toxicity. Hydrogen sulfide and ferrous sulfide reduces the ability of roots to oxidize and thus more sensitive to iron poisoning. Due to deficiency of calcium, magnesium and manganese are rare in the paddy field, the potassium element is need attention. Potassium-deficient plants often have high iron levels and show severe symptoms of severe poisoning.

Rice varieties used in these experiments have different sensitivities to iron toxicity, it is seen from the observed parameters (Table 2 and 3). The growth of all rice varieties grown in the new opening fields showed the variation in tillers number (Table 2). This resulted in growing diversity of other indicators such as plant height, leaves number, panicles number, panicle length, spikilet number, grain number per clump, 1,000 grain weight and grain weight per ha (Table 2 and Table 3).

The tillers number on the treatment with a spacing of (10 × 10) × 30 × (10 × 10) cm were between 55 to 92 tillers per hill, while on the treatment of 30x30cm were between 32 to 54 puppies, as shown in Table 2 and Figures 1 and 2. The number of tillers increased between 40% to 85% (16-38) on each rice variety in the spacing compared to the difference of treatment (30 × 30) cm (10 × 10) × 30 × (10 × 10) cm, it was presumably because the number of seeds per hole and the distance between the seeds that caused the competition growth.

The results in the new opening fields were as it was expected. Since in the conventional cultivation has a nutrient deficiency, uses a non tolerant varieties, 21 days old seeds a lot member of seed (5-10) per hole planting, so that there is a growth competition from the initial planting causes nutrient deficiencies, damages to plant cells, and water deficit (Marschner 1995; Susilawati *et al*. 2010; Sahrawat 2010) which causes the inhibition of plant growth. Barriers to growth will increase, especially in waterlogged conditions, where Fe^{3+} is converted to Fe^{2+}, which are toxic to plants and the low solubility of nutrients resulting in deficiency of essential nutrients K, P, Ca, and Zn.

Using the package technology (varieties tolerant + system SRI + amelioran addition + plant spacing and number of seeds per planting hole), cultivated plants can grow well, this is presumably because the cultivation in this system causes: 1) competition between plants is minimized because the plant spacing used is sufficient and less number of seeds 1-2 seeds per planting hole, 2) the seeds used are in young age so that growth is more rapid, 3) the availability of sufficient organic material (20 Mg ha^{-1}) by addition peat soil amelioran, and the use of water-saving SRI cultivation system, which

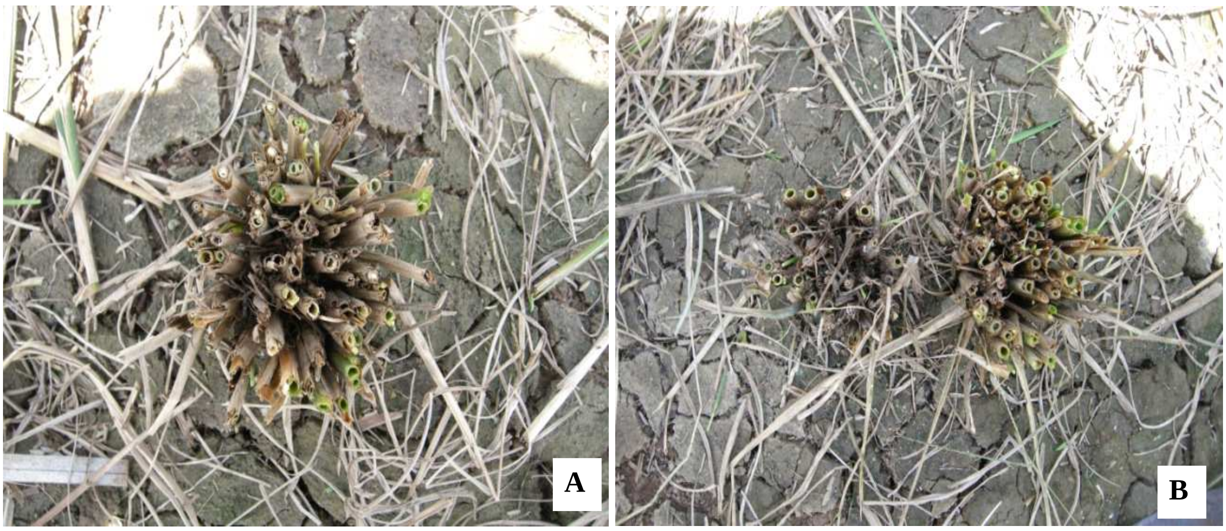

Figure 1. Cultivation of rice seedlings with planting distance between seedlings 30 × 30 cm with two seeds (A) and with inter-seed plant spacing (10 × 10) × 30 × (10 × 10) cm with one seed (B) per planting hole at the new opening paddy fields with high Fe^{2+}.

allows plants to establish more seedlings (Figures 1).

Spikilet number in some tested rice varieties ranged from 9.73-10.73. Ciherang varieties produced the largest number of spikilet, which was 10.73, while the lowest spikelet number was on the IR36 variety, which was 9:33. The highest amount of grain per cluster, the weight of 1,000 rice grains and grain weight ha^{-1}, occurred in the combination treatment with a variety Krueng Aceh (10 × 10) × 30 × (10 × 10) cm, respectively 2,955 grain, 25.66 g, and 5.65 tons ha^{-1} (Table 3).

All the rice varieties used in this experiment (tolerant and sensitive) were able to grow well (Tables 2 and 3). This was presumably because the plants grown with the technology package (varieties tolerant + system SRI + ameliorant additional + plant spacing and number of seeds per hole) had a better ability to adapt to the Fe tolerant conditions. As noted by Delhaize and Ryan 1995; Utama *et al*. 2005; Munns and Tester 2008, that the tolerance to stress can occur via two mechanisms, namely through exclusion and inclusion.

Adaptation through the exclusion mechanism requires an avoidance mechanism of water deficit internally, while the inclusion mechanism inclusion requires a tolerance of tissues to high ion ferrous (Fe^{2+}) or avoidance the high concentration of iron in the tissues (Dorlodot *et al*. 2005; Utama 2010b; Sahrawat 2010).

Figure 2. Growth of rice seedlings in conventional cultivation by farmers around the study sites with spacing of 25 × 25 cm using a 21-day old seedlings.

In the conventional cultivation, carried out by farmers around the study site (Figure 2) showed that tillernumber were formed very little, which were between 5-10, it was likely because of high levels of iron in the soil that caused toxicity (Table 1) and the use of rice varieties were sensitive to metal stress and were unable to adapt well. The high dissolved ferrous iron in the soil resulting in mineral nutrient imbalances, which will affect plant growth,

Table 3. Spikilet number, grain number per clump, 1,000 grain weight and grain weight to test the growth and productivity of several rice varieties tolerant to Fe^{2+} in new opening paddy fields with multi packet technology.

Plant spacing	Rice cultivars				
	Krueng Aceh	IR 36	Tukad Balian	Ciherang	Cisokan
	Spikilet number $Tassel^{-1}$				
30 × 30 cm	10.20 ab	9.33 b	9.40 b	10.13 ab	9.73 b
(10 × 10) × 30 × (10 × 10) cm	10.67 a	9.67 b	9.87 ab	10.73 a	10.20 ab
	Grain number $Clump^{-1}$				
30 × 30 cm	2474.8 ab	2033.9 b	2497.3 ab	2054.5 b	2411.7 ab
(10 × 10) × 30 × (10 × 10) cm	2955.0 a	1966.6 b	2931.5 a	2400.8 ab	2469.1 ab
	1,000 Grain weight (g)				
30 × 30 cm	19.95 bc	22.73 ab	25.84 a	15.51 e	18.70 cd
(10 × 10) × 30 × (10 × 10) cm	25.66 a	24.55 a	24.38 a	16.40 de	19.74 bc
	Grain weight (Mg ha^{-1})				
30 × 30 cm	4.76 b	3.90 bc	4.75 b	3.94 bc	3.05 d
(10 × 10) × 30 × (10 × 10) cm	5.65 a	4.62 ab	5.43 a	3.74 c	3.16 d

Mean followed by different letters on the same variables in each treatment showed significantly different at 5% level by Tukey test.

especially on varieties susceptible to iron stress (Suhartini 2004; Audebert 2006; Sunadi *et al*. 2010).

CONCLUSIONS

In the cultivation with the technology package (tolerant varieties + SRI system + peat soil amelioran + plant spacing and number of seeds per hole) increased the growth and yield of rice cultivated in the new opening fields that high in Fe content.

Rice cultivation in marginal land with high Fe^{2+} using technology package consisting of a combination of rice cultivars (Krueng Aceh, IR36, and Tukad Balian) + SRI system + peat soil amelioran 20 tonnes per hectare + plant spacing (10 × 10) × 30 × (10 × 10) cm with a seedlings per hole, had the best growth and yield in the new opening fields with high Fe^{2+}, especially in the Koto Baru of Dharmasraya District. However Krueng Aceh variety obtained grain production by 5.65 Mg ha^{-1}.

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