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Morphological Characteristics of Rice Varieties on Iron Stress in Nutrient Culture Media

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Abstract

Decreased rice productivity due to high iron concentrations especially in the vegetative phase, this causes the morphological character of rice to be affected until the metabolic process is disrupted. This study used 6 varieties, namely Batu Tegi, Inpara 9, Situ Patenggang, Inpara 8, Hawarabunar and Inpago 8, with iron concentrations of 0 and 250 ppm. The seeds were germinated for 3 days, then planted in Kimura B 10% nutrient culture media for 9 days, for 2 weeks then each week the media was changed to 100% Kimura B solution with the addition of 250 ppm iron concentration which was sampled every week until the 35th day. The results of the analysis of variance of the variables of plant height and root length showed that the combination Inpara 8-01 was the best combination and had a significant effect compared to other combinations with an average value of 61.31 cm and 30.77 cm. In the variable number of leaves the best average value was found in the combination of Batu Tegi-01 and Inpara 9-01 which had a significant effect compared to other treatments with an average value of 5.87 strands and 9.60 strands, respectively. On the stem dry weight variable, the combination of Hawarabunar-250 ppm Fe had a significant effect on other treatment combinations with the highest value of 0.17 g and the lowest value of treatment combination Inpara 9-250 ppm with a value of 0.08 g. Based on the results of treatment with 250 ppm Fe stress on plant morphological characters, the Hawarabunar variety had the best response in tolerating Fe stress, while the Batu Tegi variety was the lowest in tolerating Fe stress.

Keywords : Iron stress, nutrient culture media, rice, vegetative phase

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1. Introduction

The productivity of rice yields that are affected by high iron concentrations can cause a decrease in production. Although iron is an essential micronutrient, the presence of too much iron in the soil can affect plant growth, causing poisoning. As the main obstacle to the opening of new paddy fields in tidal and lowland areas in the basin [1], efforts to increase the development of rice production on marginal lands are by applying the available technology more optimally, including the following the use of superior rice varieties that are resistant to iron poisoning [2].

The defense mechanism of rice plants against iron poisoning by morphological and physiological means. However, this mechanism can be different for each rice variety. This is due to differences in the absorption and distribution of iron in each plant organ, namely roots, stems and leaves. In varieties that are more tolerant of iron poisoning, usually iron will accumulate in the stems and will be present less in the leaves, compared to varieties that are more sensitive to iron. In more sensitive varieties, plants do not have an inhibitory mechanism in the absorption of iron in different plant organs, this is because the more sensitive varieties do not have selectivity to their own plant organs [3].

Varieties that are sensitive to iron poisoning since the vegetative phase have shown clear symptoms where plant height growth is disrupted, this is characterized by plants becoming stunted, which results in stunted development of the reproductive phase, which ultimately causes plants to produce only a few panicles and the grains become hollow [4]. Other than that disturbed metabolic processes due to the absorption of excess iron in rice plants can be seen clearly when the leaves start to rust (*bronzing*). The rusty leaves of the rice plant also change their structure to become stiffer and the color from green to dark brown, with continuous symptoms, namely the leaves begin to turn yellow and dry until eventually all parts of the leaves will turn yellowish and turn dark brown or called rust. In addition, the process of root development becomes disrupted and does not develop perfectly. The symptoms of these changes have shown that the level of iron poisoning is very severe [5; 6]. If the condition of the rice plant is like that, it can cause a reduction in rice production from 12-100% with the condition of the difference in the severity of iron poisoning and the genotype of rice planted [7; 8].

The use of the right varieties for each existing land, can make a high increase in rice production, and also enrich the rice germplasm. This study will test 6 varieties of rice against iron stress with different concentrations in the vegetative phase using nutrient culture media.

2. Materials and Methods

The research was carried out in a greenhouse and Plant Physiology Laboratory, Agronomy Study Program, Faculty of Agriculture, Sriwijaya University, Indralaya. The experiments were arranged in a factorial randomized block design (FRBD) and each had 3 replications, with two factors. The first factor is iron concentration (K1=0 ppm and K2=250 ppm) and the second factor is rice varieties (Batu Tegi (V1), Inpara 9 (V2), Situ Patenggang (V3), Inpara 8 (V4), Hawarabunar (V5) and Inpago 8 (V6), then continued with the Least Significant Difference Test at the 5% confidence level.

2.1. Preparation of Planting Media

Preparation of the planting medium, namely nutrient culture media in a plastic container measuring 25 x 25 15 cm using the Kimura B solution medium (stock solution A, namely Ammonium Sulfate ($(NH_4)_2.SO_4$) 48.2 g, Magnesium Sulfate ($MgSO_4$ $7H_2O$) 134.8 g, Potassium Nitrate (KNO_3) 18.3 g and Potassium Double Superphosphate (KH_2PO_4) 24.8 g, and stock solution B consists of Calcium Nitrate ($Ca\ (NO_3)$. $2H_2O$) 86.17 g, Ferosulfate ($FeSO_4.7H_2O$) 16 g and Nitrogen Hydro Chloride (1 N HCl) 42 ml which have been prepared.

2.2. Germination

Germination is carried out for 2 days by placing the seeds in a moistened cotton tissue, placing the container at room temperature and avoiding sunlight. Then for one day the seeds are dried and aired. After that, the seeds that germinate are selected with good and uniform roots, namely by looking at the uniformity sprouting of growth, have long roots and cotyledons, normal and the have grown parts of the sprouts have grown large, then the seeds are cultured in Kimura B medium.

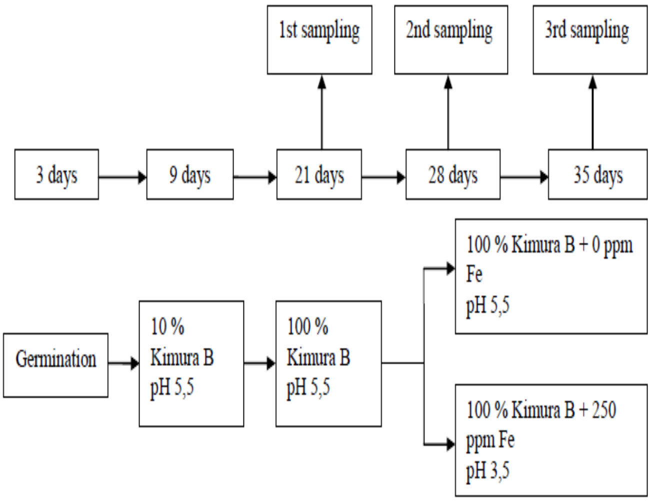

Figure 1. Flow nutrient culture treatment

2.3. Nutrient Solution Culture

Experiments on the tolerance level to iron stress will be carried out in a greenhouse using the nutrient culture media that has been prepared. The germinated seeds were placed on the perforated Styrofoam, placed into a plastic container / bucket (5 L in size) and aerated and put in 10% Kimura B solution of 5 L with a pH concentration of 5.5 for 9 days. After 9 days, the water culture medium was changed to 100% Kimura solution with a constant pH of 5.5 until day 21. On the 21st day the first sampling was carried out. On the 22nd day, the water culture medium was replaced with a new 100% Kimura B solution with the addition of an iron solution with a concentration of 250 ppm with the pH of the solution being 3.5 and allowed to stand until the 28th day. On the 28th day, a second sampling was carried out. After taking the second sampling, namely the 29th day, the water culture media was replaced with a new 100% Kimura B solution with the addition of iron solution with a concentration of 250 ppm with the pH of the solution being 3.5 and allowed to stand until the 35th day and the 3rd sampling was carried out.

3. Results and Discussion

The high concentration of Fe in this experiment affected the growth of the rice varieties planted. The results showed that the growth of rice varieties in the vegetative phase showed diversity in morphological characters that varied in plant height, root length, leaf number, root dry weight, stem dry weight and leaf dry weight (Table 1). This can lead to a decrease in rice yields when planted in the field under inundated stress conditions. Several studies have shown that Fe poisoning in rice only resulted in 48% of healthy plants [9], where in Fe-poisoned land the decrease in rice yield for sensitive varieties could reach 70%, and 30% for tolerant varieties, and for land with very high levels of Fe toxicity, rice production can achieve a production reduction of 90%, which means that only 10% produce healthy plants [9]. These problems can be overcome by using environmental manipulation, namely proper cultivation techniques can reduce the negative effects of high iron concentrations in rice plants that cause poisoning, for example through water management [11], balanced fertilization [12; 13], application of organic matter [14], lime [15], and soil amelioration [16].

Treatment of Fe stress was significantly different to plant height, root length, number of leaves, and leaf dry weight, however not significantly different on root dry weight and stem dry weight (Table 1). It is suspected that the concentration of Fe stress has an influence on several parameters of rice plant growth. Although it is an essential micronutrient, Fe can cause poisoning to plants if it is absorbed in excess. This can cause a more dominant effect on plants compared to other nutrients [17].

Table 1. Quantitative parameters consist of plant height, root length, number of leaves, root dry weight, stem dry weight, and leaf dry weight on 6 varieties observed with treatment 0 ppm and 250 ppm Fe

Rice varieties	**Plant height (cm) Concent. Fe**		**Root length (cm) Concent. Fe**		**Number of leaves (strands) Concent. Fe**		**Root dry weight (g) Concent. Fe**		**Stem dry weight (g) Concent. Fe**		**Leaf dry weight (g) Concent. Fe**	
	0 ppm	**250 ppm**	**0 ppm**	**250 ppm**	**0 ppm**	**250 ppm**	**0 ppm**	**250 ppm**	**0 ppm**	**250 ppm**	**0 ppm**	**250 ppm**
Batu Tegi	54,1 c	36,91 a	25,95 c	15,26 a	5,87 c	0,87 a	0,08 a	0,12 a	0,10 ab	0,10 ab	0,15 b	0,11 a
Inpara 9	55,2 c	39,93 ab	28,1 de	15,91 a	9,60 e	1,80 a	0,08 a	0,08 a	0,11 b	0,08 a	0,17 bc	0,09 a
Situ Patenggang	52,4 c	37,11 a	28,7 de	15,78 a	8,47 d	2,27 b	0,11 a	0,09 a	0,12 b	0,10 ab	0,17 bc	0,10 a
Inpara 8	61,3 d	39,55 ab	30,77 e	19,5 b	7,60 d	1,93 ab	0,11 a	0,12 a	0,13 b	0,14 b	0,18 bc	0,12 ab
Hawara Bunar	54,1 c	43,7 b	24,16 c	19,4 b	7,67 d	2,13 ab	0,10 a	0,13 a	0,11 b	0,17 c	0,18 bc	0,15 b
Inpago 8	56,4 c	39,79 ab	28,01 d	16,73 a	7,60 d	0,00 a	0,10 a	0,11 a	0,13 b	0,09 ab	0,20 c	0,12 ab

Note: Numbers followed by letters in the same column show results that are not significantly different with a 5% confidence level (Least Significant Difference test

The effect of treatment on varieties showed significantly different results on root length, number of leaves, and root dry weight (Table 1). This can be due to each variety having a different response to the treatment given, so that it has significantly different results. Tolerant and intolerant varieties give different responses to Fe toxicity, this is related to the amount of Fe availability in the plant growing environment, and how the response of rice plants to absorb Fe [17].

The 0 ppm Fe treatment had better plant height, root length, and leaf dry weight than the 250 ppm treatment (Table 1). This is because in the treatment of 250 ppm Fe poisoning occurs in the environment where plants grow. Fe toxicity can affect several agronomic and physiological characters of plants, causing growth disturbances and reducing rice yields [18]. Fe poisoning in rice occurs due to excess in Fe absorption which is influenced by environmental factors such as high Fe levels, deficiency or imbalanced nutrients, low pH, poor drainage (flooded) or sensitive rice varieties [18]. According to [19] in [20] symptoms of Fe poisoning in plants can be indicated by decreased plant height, reduced tillers, and reduced plant chlorophyll count.

The plant height parameters against the treatment combinations showed that the results were not significantly different from all other treatment combinations (Table 1). The highest treatment was found in the Inpara treatment of 8-0 ppm Fe with an average value of 61.31 cm and the lowest was found in the Batu Tegi-250 ppm treatment (Figure 2). The highest value is suspected to be the absence of Fe poisoning so that the response of the variety has the best plant height. Based on the results of treatment with 250 ppm Fe stress on plantheight variables, the Hawarabunar variety had the best response in tolerating Fe stress, while the Batu Tegi variety was the lowest in tolerating Fe stress. In varieties that have a susceptible response to Fe stress. In varieties that are susceptible to Fe stress, the inhibition of growth and development of rice plants caused by the influence of high Fe inhibits cell division at the growing point due to disruption of metabolic activity, so that plant growth becomes stunted and even causes a small number of tillers [13].

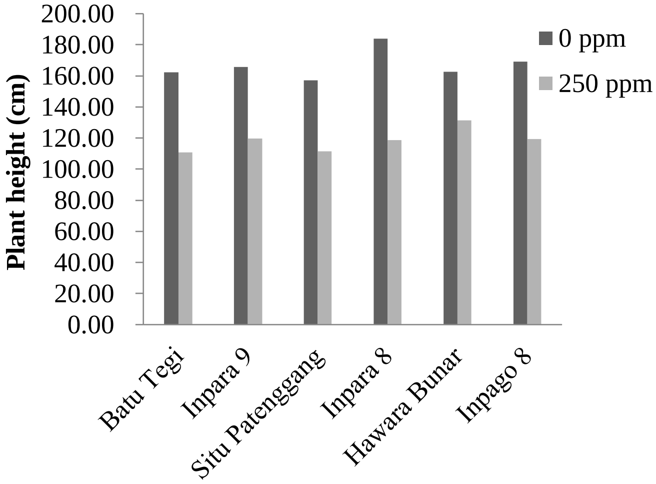

Figure 2. Effect of Fe concentration treatment on plant height

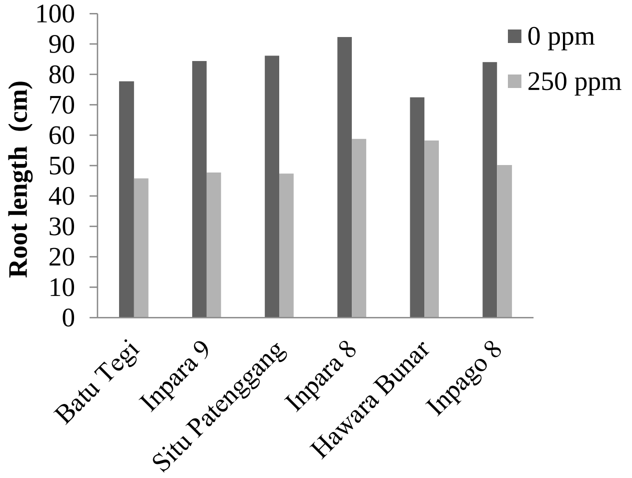

Figure 3. Effect of Fe concentration treatment on root length

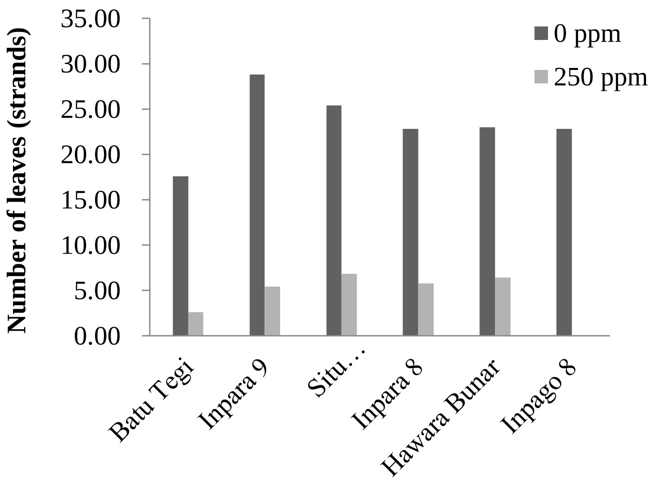

Figure 4. Effect of Fe concentration treatment on number of leaves

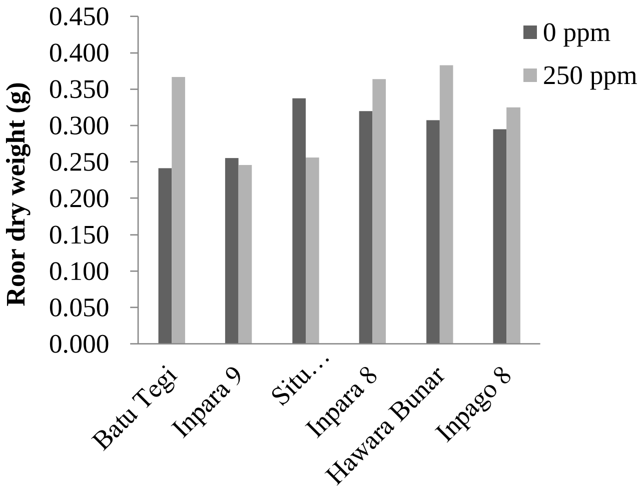

Figure 5. Effect of Fe concentration treatment on root dry weight

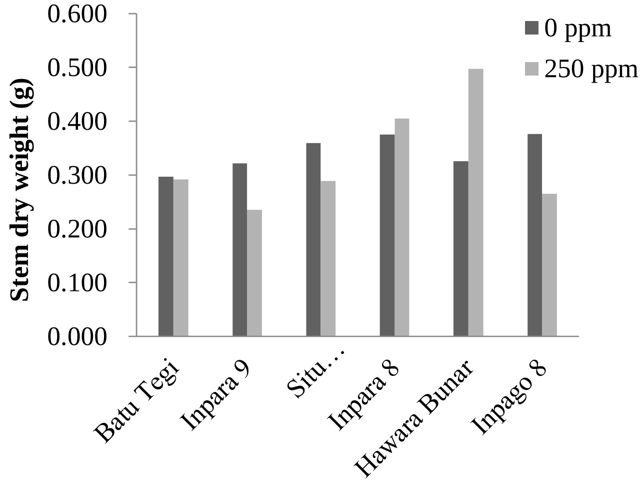

Figure 6. Effect of Fe concentration treatment on weight stem dryness

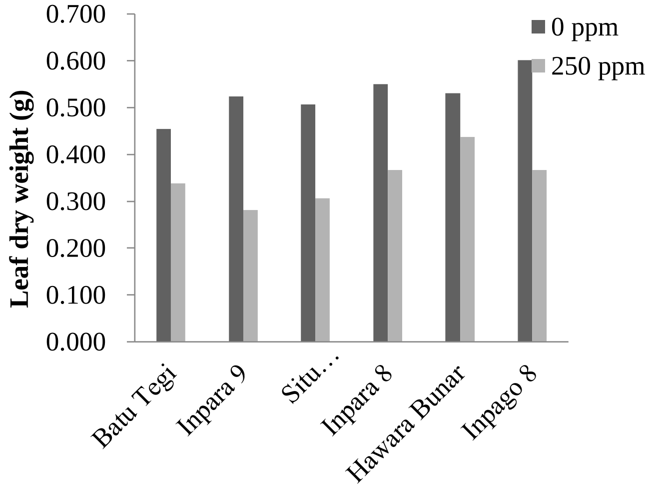

Figure 7. Effect of Fe concentration treatment on leaf dry weight

Root length growth was influenced by varietal factors and Fe stress. Fe stress treatment with varieties had a very significant effect on root length variables (Table 1). The longest roots were found in thetreatment of Inpara8-0 ppm Fe with an average value of 30.77 cm and the lowest value in the Batu Tegi treatment and 250 ppm (Figure 3). Based on the results of treatment with 250 ppm Fe stress on root length variables, the Hawarabunar variety had the best response in tolerating Fe stress, while the Batu Tegi variety was the lowest in tolerating Fe stress. It is suspected that the 250 ppm Fe stress treatment inhibited the root growth of rice plants. Root length growth will be more depressed where there is no increase in root length with higher Fe concentrations [21] Fe stress causes the roots to be unable to develop, hampering the absorption of nutrients, this is a result of the root surface being coated with iron oxide Fe_2O_3 which is dark brown to black in color. Under conditions of severe Fe stress since the early stages of the vegetative phase, roots age and die more quickly [22].

The parameter number of leaves on the treatment combinations from the results of the analysis of diversity showed that the treatment of Fe stress with varieties had a very significant effect on the number of leaves.). The highest number was found in the Inpara 9-0 ppm Fe treatment with an average value of 9.60 strands and the lowest amount was found in the V602 treatment (Inpago 8 and 250 ppm) with an average value of 0.00 strands (Figure 4). Based on the results of treatment with a concentration of 250 ppm Fe on the number of leaves, the Hawarabunar variety had the best response in tolerating Fe stress, while the Inpago 8 variety was the lowest in tolerating Fe stress. The decrease in the number of leaves in susceptible varieties was related to the occurrence of bronzing due to high Fe stress. In severe conditions, the visible symptoms show the color of the leaves to become brownish like rust, and cause the leaves to have a stiff and hard texture [6].

All varietal treatments and Fe stress on root dry weight parameters were not significantly different from other treatments. All different treatment combinations had no significant effect on root dry weight variables (Table 1). The highest average value was found in the treatment combination of Hawarabunar-250 ppm Fe, which was 0.13 g, while the lowest value was found in the treatment combination of Batu Tegi-0 ppm Fe and Inpara 9-0 ppm Fe with the same value of 0.08 g (Figure 5). The results of the diversity analysis showed that the treatment of Fe stress with varieties had a very significant effect on the stem dry weight variables (Table 1). Where the combination of stem dry weight treatment with the highest value was found in treatment Hawarabunar-250 ppm Fe which was 0.17 g and the lowest value was in treatment Inpara 9-250 ppm Fe (Figure 6). As for the leaf dry weight parameter, the results of the analysis of diversity showed that the Fe stress treatment with varieties had no significant effect (Table 1). The treatment combination Inpago 8-0 ppm Fe had the highest average value of 0.20 g, and the treatment combination Inpara 9-250 ppm Fe had the lowest average value of 0.09 g (Figure 7).

Based on the results of treatment with a concentration of 250 ppm Fe on plant dry weight variables (roots, stems and leaves), the Hawarabunar variety had a response the best in tolerating Fe stress, while the Inpara 9 variety was the lowest in tolerating Fe stress. Fe toxicity in plants has more effect on plant dry weight and the number of tillers that are the top part of the plant than the root part of the plant [20], this is related to the inhibition of the reproductive process in plants, namely the number of panicles that appear [23]. The higher the concentration of Fe stress, the lower the dry weight of roots and shoots. This is related to the process of photosynthesis and photosynthate storage. When the process of respiration and assimilation uses the products of photosynthesis, the excess of the process will be stored as a net photosynthesis (net photosynthate) of plants which ultimately determines the dry weight of roots and shoots [24].

4. Conclusion

1. Based on the observation of quantitative parameters, the higher the concentration of Fe solution, the growth of rice plants in 6 varieties became inhibited.
2. In this study, it was found that the effect of 250 ppm Fe stress in the vegetative phase on the response of the morphological characters of 6 varieties, namely the Hawarabunar variety being the best, followed by the second Inpara 8 variety, then the third Inpago 8 variety, then the fourth Batu Tegi variety, and the fifth Situ Patenggang variety, while the Inpara 9 variety was the last.

Reference

[1] Harahap, Z. dan T.S. Silitonga. 1993. Perbaikan varietas padi. *Dalam* Buku Padi 2. Badan Pertanian dan Pengembangan Pertanian. Pusat Penelitian dan Pengembangan Tanaman Pangan Bogor. hlm. 335-375.

[2] Suhartini, T., A.A. Daradjat, Adijono Pa, dan Warsono. 1999. Penelitian perbaikan toleransi padi sawah terhadap keracunan Fe. Laporan Penelitian Proyek PAATP, Balai Penelitian Padi, Badan Litbang Pertanian 1999/2000.

[3] Audebert, A. 2006. Iron partitioning as a mechanism for iron toxicity tolerance in lowland rice. In: Audebert A. LT Narteh. D Millar. B Beks (*Eds*). Iron Toxicity in Rice-Base System in West Africa. Africa Rice Center (WARDA). P. 34-46.

[4] Abu MB, Tucker ES, Harding SS, Sesay JS. 1989. Cultural practice to reduce iron toxicity in rice. *Inlt. Rice Res Newsl* 14:19-19.

[5] Yamanouchi M, Yoshida S. 1981. Physiological mechanisms of rice's tolerance for iron toxicity. Paper presented at the IRRI Saturday Seminar June 6 1981. The International Rice Research Institute Manila The Philippines.

[6] Fairhurst, T.H., Witt, C. 2002. Rice: A Practical Guide for Nutrient Management. Potash and Phosphate Institute of Canada and International Rice Research Institute, Singapore and Los Banos.

[7] Sahrawat, K.L. 2004. Iron toxicity in wetland rice and the role of other nutrients. *J. Plant Nutr*. 27(8):1471–1504.

[8] Sahrawat, K.L. 2010. Reducing iron toxicity in lowland rice with tolerant genotypes and plant nutrition. *Plant Stress* 4:7075.

[9] Ismunadji M., Ardjasa WS., Uexkull HRV. 1989. Increasing productivity of lowland rice grown on iron toxic soils. In Deturk, P. and F. Ponnamperuma (*Eds*.). *Rice Production on Acid Soils of the Tropics. Procceding of International Symposium*, Institute of Fundamental Study, Kandy. Sri Lanka. 26-30 June 1989. hlm 205-211.

[10] Virmani SS. 1977. Varietal tolerance of rice to iron toxicity in Liberia. *International Rice Res Newsl* 2(1):4-5.

[11] Yang, C., L. Yang, Y. Yang, and Z. Ouyang. 2004. Rice root growth and nutrient uptake as influenced by organic manure in continuously and alternately flooded paddy soils. *Agri. Water Manage*. 70:67–81. doi:10.1016/j.agwat.2004.05.003.

[12] Ramirez, LM., N. Claassen., A.A. Ubiera, H. Werner, and A.M. Moawad. 2002. Effect of phosphorus, potassium and zinc fertilizers on iron toxicity in wetland ric (*Oryza sativa* L.). *Plant Soil* 239:197–206. doi: 10.1023/ a:1015099422778

[13] Sahrawat, K.L., S. Diatta, and B.N. Singh. 2000. Reducing iron toxicity in lowland rice through an integrated use of tolerant genotypes and plant nutrient management. *Oryza* 37:44-47.

[14] Muhrizal, S., T.J. Shamshuddin, I. Fauziah, and M.A.H. Husni. 2006. Changes in iron-poor acid sulfate soil upon submergence. *Geoderma* 131:110-122. doi:10.1016/j.geoderma. 2005.03.006

[15] Jena, D., S.C. Nayak, A.K. Dash, B. Mohanty, and B. Jena. 2008. Effect of soil amendments on yield and iron content of rice in iron toxic soil. *Asian J. Soil Sci*. 3(2):264-268.

[16] Nozoe, T., T. Shinano, M. Tachibana, and A. Uchino. 2010. Tolerance of rice (*Oryza sativa* L.) and echinochloa weeds to growth suppression by rice straw added to paddy soil in relation to iron toxicity. *Plant Prod. Sci.* 13(3):314¯318. doi: 10.1626/pps.13.314

[17] Nugraha, Y., & Rumanti, A. 2017. Perakitan Varietas Padi Toleran Keracunan Besi Breeding for Rice Variety Tolerant to Iron Toxicity. *Jurnal Iptek Tanaman Pangan*, *12*(1), 9–24

[18] Aidi, N. dan K. 2013. Keracunan Besi Pada Padi: Aspek Ekologi Dan Fisiologi-Agronomi. *Prosiding Seminar Nasional Inovasi Pertanian*, *2000*, 306–318.

[19] Fageria, N.K., A. B. Santos, M.P. Barbosa Filho, and C.M. Guimaraes. 2008. Iron Toxicity in Lowland Rice. *J. Plant Nutr*. 31:1676–1697

[20] Lubis, I., & Noor, D. A. 2010. Pengaruh Dua Level Cekaman Besi dalam Larutan Hara Terhadap Gejala Keracunan Besi dan Hubungannya dengan Pertumbuhan Padi. *2008*, 978–979.

[21] Amnal. 2009. *Respon Fisiologi Beberapa Varietas Padi terhadap Cekaman Besi* (Master's Thesis).

Sekolah Pasca Sarjana Institut Pertanian Bogor. Bogor.

[22] Suhartini T. 2004. Perbaikan Varietas Padi untuk Lahan Keracunan Besi. Balai Besar Penelitian dan Pengembangan Bioteknologi dan Sumberdaya Genetik Pertanian. Bogor: Buletin Plasma Nutfah. Vol. 10 No.1 Th, 2004.

[23] Singh M, Prad B, Ram M. 1992. Characteristics of Fe-toxic soils and affected plants and their correction in acid Haplaquents of Meghalaya. *Int. Ice Res Newsl* 17:18-19.

[24] Sitompul SM, Guritno B. 1995. Analisis Pertumbuhan Tanaman. Gadjah Mada University Press. Yogjakarta. Hlm 147-168.