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# Iron exclusion in rice genotypes as affected by different vapor pressure deficit conditions

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*ABSTRACT*

Root iron (Fe) exclusion capacity of four lowland rice genotypes were evaluated in increasing rate of $Fe^{2+}$ stresses (0, 500, 1000 and 1500 mg/L) in growing medium under the conditions of low and high vapor pressure deficit. Rice root excluded significantly higher amount of iron under dry atmospheric condition (655 mg Fe/g root dry matter) than moist atmospheric condition (118 mg Fe/g root dry matter). But their iron exclusion capacity reduced when they were gradually exposed to the higher levels of Fe stress. Tolerant genotype such as TOX3107 excluded more iron when they were exposed to dry atmospheric condition.

## INTRODUCTION

Iron toxicity is considered as a micro-nutritional disorder in lowland-rice production systems (Dobermann and Fairhurst 2000) and has been reported in many parts of South America, Asia, and Africa (Sahrawat 2004; Becker and Asch 2005). Iron toxicity is caused by excessive uptake and acropetal translocation of Fe (II) towards the leaves. However, rice genotypes can oxidize the Fe at their root surface as ferric hydroxide goethite and lepidocosite (Chen et al. 1980) forming root plaque. This root plaque forms a physical barrier for further influx of metals including reduced iron (Tanaka et al. 1966; Liu et al. 2004). Hence, root Fe exclusion is considered as one of the strategies of rice genotypes to adapt at iron toxicity conditions (Ando 1983). Capacity of rice genotypes to form such root plaque is genetically controlled and is also induced by anoxic condition. (Kawase 1981; Xu and Yu 2013). The effect of atmospheric moisture on root plaque formation is yet to be studied. In the present study, root Fe-excluding power of contrasting rice genotypes were evaluated under increasing rates of Fe (II) stress in growing medium under low and high air moisture conditions.

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## MATERIALS AND METHODS

An experiment was conducted in greenhouse of the Institute of Crop Science and Resource Conservation (INRES), Department of Plant Nutrition, University of Bonn, Germany between July to September 2009 using two chambers consisting of contrasting vapor pressure deficit (VPD) conditions. Pregerminated seeds (48 hours) of four rice genotypes namely Nipponbare, IR31785 (sensitives), and Pokkali and TOX3107 (tolerants) (Engel et al. 2012) were grown in sand for 5 days. The nine-day-old seedlings were transferred into the hydroponic setup (25 L, 25% strength of standard Yoshida nutrient solution) for five days. Then after, solution strength was increased to 50% for another 5 days before using full strength solution on $19^{th}$ day until the plants were subjected to the treatment application. At treatment application, the 36 day-old plants were grown in individual polythene tubes filled with 280 ml full strength Yoshida solution and adjusted to four additional levels of Fe (II) stress, namely 0 (control) and 500, 1000, and 1500 mg $Fe^{2+}$/L (pH 5.0 to 5.05). Then after, tubes were transferred into the moist (0.3 kPa) and dry (2.4 kPa) chambers and were completely randomized. After the harvest of plants at 40 days after sowing (DAS), root plaque was washed with 0.5 M HCl, root was oven dried to the constant weight and the total Fe oxidized at the root surface was determined by Atomic

Absorption Spectrophotometry (AAS). Data were subjected to ANOVA using SPSS 21. Descriptive statistics and plotting of graphs were done using SigmaPlot 11.0 software packages.

## RESULTS AND DISCUSSION

Result shows that high VPD significantly stimulated the root Fe exclusion in all genotypes and at all levels of Fe stresses. Thus, the amount of root plaque was on average 117 mg/g root dry matter when rice was grown in a moist atmosphere (low VPD) and it exceeded 650 mg/g root dry matter in the dry atmosphere (high VPD) ($p$=0.0001) (Figure 1). Irrespective of the genotypes, the concentration of Fe excluded at the root surface was stimulated when the $Fe^{2+}$ at growing medium increased from 0 to 500 mg/L at both VPD conditions. But it, started to diminish with further increase in Fe concentrations and this effect was pronounced when the genotypes were exposed at high VPD condition. The genotypic responses, however, varied.

Under the condition of Low VPD at 0 mg $Fe^{2+}$/L, sensitive Nipponbare excluded significantly highest root Fe (67 mg/g root DM) and other genotypes did not differ each other. At 500 mg $Fe^{2+}$/L, IR317 and TOX3107 showed highest Fe exclusion (450 and 423 mg/g root DM respectively) while Pokkali excluded the least with a plaque formation of only 26 mg/g root DM and this amount did not differ significantly with Nipponbare. Again, TOX3107 showed the highest root Fe exclusion with 208 mg/g root DM and

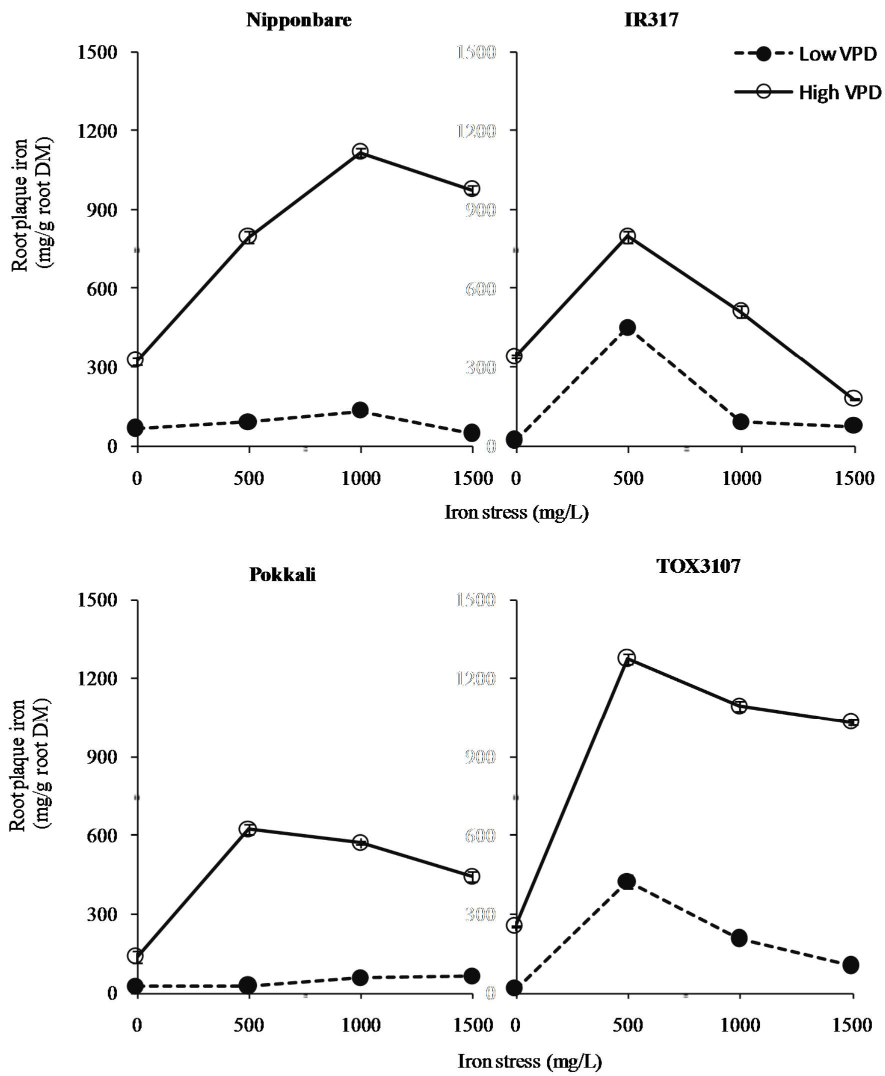


Figure 1: Amount of inactive iron excluded at the root surface of sensitive (upper) and tolerant (upper) rice genotypes when grown at additional levels of Fe (II) in growing medium for 4-day at 36-day growth stage under different vapor pressure deficit conditions . Bar indicates standard errors of mean (α=0.05; n=4). When no bar is visible, the error was smaller than the resolution of the axis.

Pokkali the lowest Fe exclusion (55 mg/g root DM) at 1000 mg $Fe^{2+}$/L while the IR317 and Nipponbare showed an intermediate behavior with plaque concentration of 90 mg/g and 132 mg/g root DM respectively. Though the root plaque concentration further decreased at 1500 mg $Fe^{2+}$/L,TOX3107 was able to maintain its highest excluding behavior (103 mg/g root DM). Nipponbare-which expressed the highest Fe exclusion at control of 0 mg $Fe^{2+}$/L excluded the least with plaque formation of only 47 mg/g root DM.

Under high VPD at 0 mg/L Fe stress, Sensitive IR317 and Nipponbare showed the highest Fe exclusion with root plaque 340 and 325 mg/g root DM and the Pokkali the least (137 mg/g root DM). At 500 mg/L Fe stress, TOX3107 showed the highest Fe exclusion (1,275 mg/g root DM) whereas Pokkali expressed lowest root Fe exclusion (622 mg/g root DM). Nipponbare showed significantly highest Fe exclusion at 1000 mg/L (1,117 mg/g root DM) but it did not differ with TOX3107 (1,093 mg/g root DM); and IR317 expressed the lowest Fe exclusion followed by Pokkali (512 and 572 mg/g root DM respectively). At 1,500 mg $Fe^{2+}$/L, TOX3107 showed significantly the highest root Fe exclusion (1,033 mg/g root DM) and IR317 excluded the least Fe (178 mg/g root DM).

Result suggests that dry air condition stimulates root Fe exclusion of the rice genotypes and it is reduced with higher intensities of Fe stress in growing medium. It can be expected that high VPD stimulates transpiration and consequently the amounts of iron moved towards the roots. Consequently, root Fe exclusion in the form of root plaque formation increased under high vapor pressure deficit conditions. Ethylene induced aerenchyma formation (Kawase 1981), thereafter the root respiration rate and root Fe exclusion may not be only stimulated by anoxic condition in root atmosphere but also by dry atmospheric condition.

## CONCLUSION

Higher rate of iron intensities in the growing medium reduces the root iron exclusion in rice genotypes but this capacity increases as the atmosphere become drier. Reportedly sensitive genotypes such as IR317 often lose their iron exclusion power when they are grown under dry atmospheric condition. But the tolerant genotypes such as TOX3107 exclude more iron at dry atmospheric condition. We can conclude that root Fe exclusion as a mechanism of iron toxicity tolerance is highly affected by atmospheric condition and this effect differs with rice genotypes.

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