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A CASE STUDY

Effect of vapour pressure deficit on iron exclusion in rice genotypes

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SUMMARY

Root iron (Fe) exclusion in rice is considered as a strategy of iron toxicity tolerance in lowland rice. Two lowland rice genotypes with contrasting responses to Fe^{2+} stress in hydroponics were evaluated in green house condition. Plants were subjected to the four levels of Fe stresses (0, 500, 1000 and 1500 mg Fe^{2+} L^{-1}) for four days under conditions of low and high vapor pressure deficit. Irrespective of rice genotypes, lower levels of Fe stresses stimulated the root Fe oxidation. It, however, declined at higher rates of Fe stresses. Dry atmospheric significantly enhanced the root Fe exclusion. Rice root excluded on average of 114 mg Fe g^{-1} root dry matter when rice was grown in a moist atmosphere and exceeded 671 mg Fe g^{-1} root dry matter in the dry atmosphere.

Key Words : Hydroponic, Iron toxicity, *Oryza sativa*, Root oxidation, Vapor pressure deficit

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Iron toxicity is a micro-nutritional disorder in lowland-rice production systems (Dobermann and Fairhurst, 2000) and has been reported in 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. In leaf, the excessive Fe (II) in symplast enhances the production of radical oxygen species (ROS) which causes oxidation of phenols and thereafter membrane damage. However, rice genotypes can oxide the Fe at its root surface (Chen *et al*., 1980) forming root plaque. This root plaque is thought to form a physical barrier for further influx of reduced iron (Tanaka *et al.,* 1966). Hence, such Fe exclusion at the root surface is considered as one of the mechanism of iron toxicity tolerance in rice (Nozoe *et al.,* 2008). Such root plaque formation is induced by anoxic condition, genetic makeup of the plants (Kawase, 1981; Xu and Yu, 2013). The effect of atmospheric moisture on root plaque formation, however, 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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MATERIAL AND METHODS

A pot experiment was conducted in greenhouse of the institute of Crop Science and Resource Conservation (INRES), 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 two contrasting rice genotypes, *viz.*, WAS161 (sensitive) and CK73 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 per cent for another 5 days before using full strength solution on 19th days 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 levels of Fe (II) stress, namely 0 (control) and 500, 1000, and 1500 mg Fe^{2+} L^{-1}. Then after, tubes were transferred into the moist (0.3 Kpa) and dry (2.4 Kpa) chambers. Media solutions were changed two days after treatment application. The pH of the Yoshida solution during whole experiment was adjusted to 55.0 to 5.05. Within the chambers, treatments (six genotypes at four Fe (II) levels) were completely randomized. After the harvest of plant 40 days after sowing (DAS), root plaque was washed with 0.5 M HCl 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 Sigma Plot 11.0 software packages.

RESULTS AND DISCUSSION

Irrespective of the genotype, the share of Fe excluded at the root surface was increased with root exposure to the lower levels of Fe stress. But it started to diminished with increasing rates of applied Fe (II) beyond 500 mg L^{-1}; and the effects of VPD-irrespective of Fe stresses and genotypes- on root Fe exclusion was significant (p=0.0001). Thus, the amount of root plaque was on average 114 mg g^{-1} root dry matter when rice was grown in a moist atmosphere (low VPD) and exceeded 671 mg g^{-1} root dry matter in the dry atmosphere (high VPD) (Fig. 1). Individual genotypes changed their root Fe exclusion behaviour with changes in the Fe stress level. This occurred at both air moisture conditions.

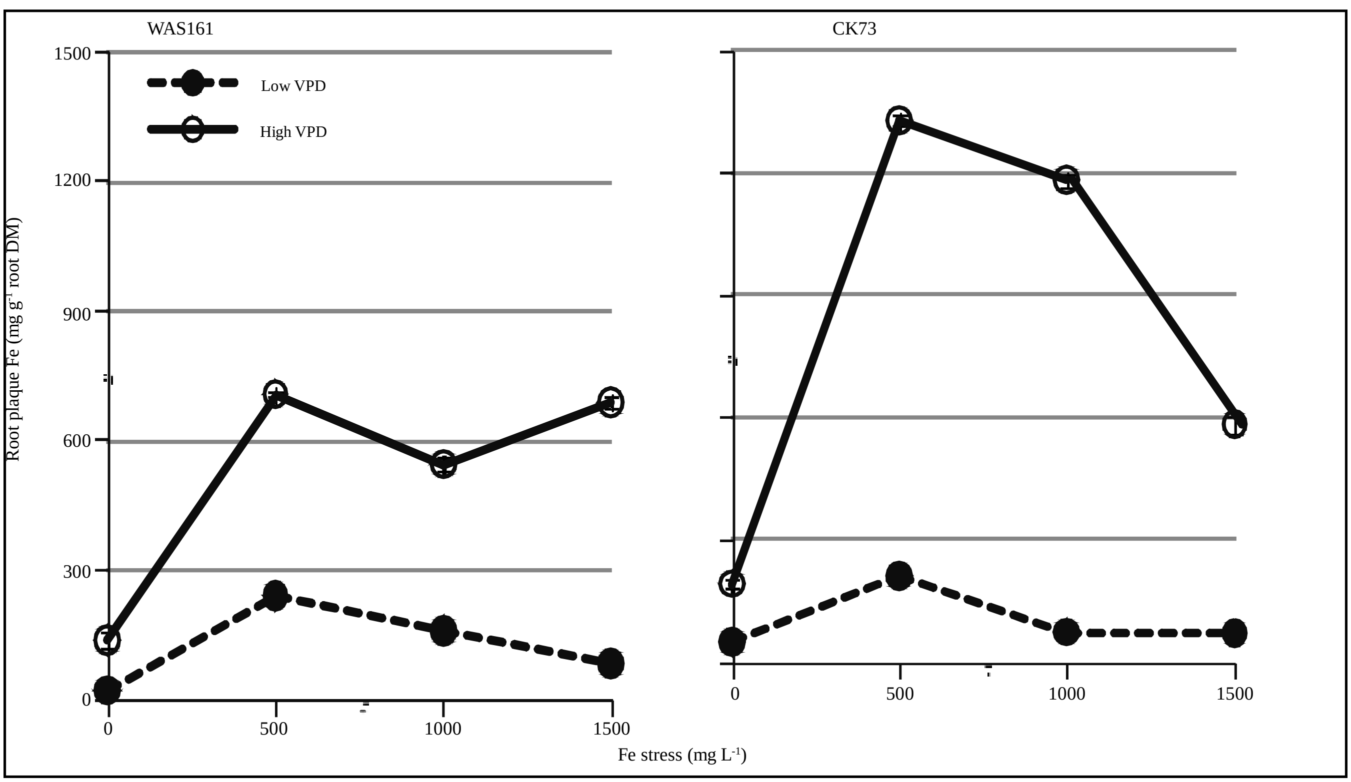

Fig. 1: **Amount of inactive Fe (mg g^{-1} root DM) excluded at the root surface of rice genotypes affected by amount of added Fe (II) to culture solution at 36-day growth stage for 4 days at different vapor pressure deficit conditions. Bars represent standard errors of the mean (n=4). When no error bar is visible, the error was smaller than the resolution of the axis**

Under the conditions of low VPD at 0 mg Fe^{2+} L^{-1}, CK73 showed significantly higher Fe exclusion (48.102 mg g^{-1} root DM) but WAS161 excluded significantly higher Fe at 1000 and 1500 mg Fe^{2+} L^{-1}. The Fe exclusion did not differ for the genotypes at 500 mg Fe^{2+} L^{-1}. CK73 excluded significantly highest root Fe at 500 mg Fe^{2+} L^{-1} (212 mg g^{-1} root DM) and the exclusion did not differ at 0 mg Fe^{2+} L^{-1}, 1000 mg Fe^{2+} L^{-1} and 1500 mg Fe^{2+} L^{-1}. WAS161 also excluded the highest root Fe at 500 mg Fe^{2+} L^{-1}(240 mg g^{-1} root DM) followed by 1000, 1500 and 0 mg Fe^{2+} L^{-1}.

At higher air moisture condition (high VPD), the Fe exclusion did not significantly differ at 0 mg Fe^{2+} L^{-1} but CK73 excluded significantly higher root Fe at 500 and 1000 mg Fe^{2+} L^{-1} and the exclusion was higher for WAS161 at 1500 mg Fe^{2+} L^{-1}. Though the genotypes excluded significantly higher amount of Fe at each level of the Fe stress at high VPD, CK73 maintain the similar trend of Fe exclusion as it was exposed to increasing rates of Fe stresses. So, it excluded highest root Fe at 500 mg Fe^{2+} L^{-1} (1327 mg g^{-1} root DM) followed by at 1000, 1500 and 0 Fe^{2+} L^{-1}. The genotype WAS161 dramatically excluded significantly higher when the Fe stress increase from 1000 to 1500 mg Fe^{2+} L^{-1}.

Result suggests that dry air condition stimulates root Fe exclusion of the rice genotypes and it is reduced when they are exposed to the higher intensities of Fe stress in growing medium. It can be expected that both dry atmosphere and lower level of Fe stress stimulates transpiration and hence 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 in all genotypes. Formation of aerenchyma is stimulated not only by anoxic condition in root atmosphere (Kawase, 1981) but also highly stimulated by other environmental stresses such as high vapor pressure deficit.

Conclusion :

Root Fe exclusion as a mechanism of iron toxicity tolerance is highly affected by atmospheric condition and this effect differs with rice genotypes. In general, higher rate of iron intensities in the growing medium reduces the root iron oxidation capacity in rice genotypes but this capacity increases when they are exposed to drier atmospheric condition.

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