Different Acidification and Oxygenation Processes in the Rhizosphere in Lowland and Upland Iranian Rice Cultivars Affect Genotypic Variation for Zinc Deficiency Tolerance

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INTRODUCTION

Rice roots can oxidize various compounds on the root surface and in close vicinity to the roots. The oxidizing power of rice roots compromises two components, oxygen release and enzymatic oxidation as α-naphtylamine (α-NA) oxidation (Ando et al. 1983). In flooded soils, reaction of oxygen with Fe(II) produces insoluble ferric hydroxide and acidity. Another process which causes a release of H^+ from roots is excess uptake of cations e.g. NH_4^+ (Kirk and Bajita 1995). It was demonstrated that root-induced changes in the rhizosphere of lowland rice can detoxify ferrous iron and solubilize phosphate and non-available Zn fractions in soil (Kirk and Bajita 1995). Rice is the second important food crop in Iran and is cultivated either under lowland (North of the country) or upland (centre and South of the country) conditions. Our previous work showed great genotypic differences between Iranian lowland cultivars in their acidification power of the rooting medium and its role in determination of Zn-deficiency tolerance of genotypes (Hajiboland and Salehi 2006). In contrast to lowland cultivars, the physiology of Zn-deficiency tolerance in aerobe rice cultivars has not received enough attention. The objective of this work was to compare rhizosphere properties of lowland and upland rice cultivars and their significance in determination of the response to Zn deficiency.

METHODS

Two genotypes of rice (*Oryza sativa* L.) including Amol (a lowland cultivar) and Gasrol-Dasht (an upland cultivar) were used in a hydroponic culture experiment. Flooding conditions were imposed by omitting aeration from nutrient solutions during pre-culture as well as treatment. Zinc treatments consisted of two levels of added $ZnSO_4$ at low (without adding Zn, using double-distilled water for preparation of nutrient solutions) and adequate (0.5 µM) Zn supply. The oxidizing power of roots was measured following Ando et al (1983). The determination of pH changes as well as the collection and determination of organic acids in root exudates were performed using methods described elsewhere (Hajiboland and Salehi 2006).

RESULTS AND DISCUSSION

Flooded conditions inhibited growth of the upland cultivar by about 25% and 46% for shoot and root, respectively. In contrast, the lowland cultivar had a significantly higher shoot (29%) and root (43%) biomass when grown under flooded conditions. Tolerance to Zn deficiency was strongly affected by the aeration treatment depending on genotypes. In the lowland cultivar, the reduction of growth due to Zn deficiency was lower under flooded conditions. In contrast, the upland cultivar showed higher susceptibility to Zn deficiency when grown in non-aerated nutrient solution (Fig. 1).

The acidification potential of the rooting medium in Zn-sufficient plants was similar in both cultivars. However, the Zn deficiency-induced release of H^+ from roots was higher in the lowland than in the upland cultivar. Oxalate was the predominant organic acid in root exudates of both cultivars, and its release increased with Zn deficiency.

Under flooded conditions, the oxygenation power of roots was much more prominent in the lowland than in the upland cultivar. Interestingly, Zn deficiency enhanced root oxygenation, which was only observed in the upland cultivar (Fig. 2).

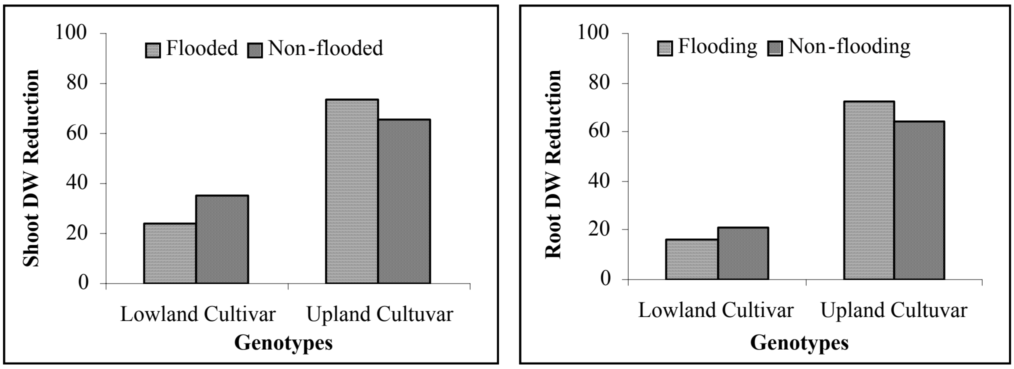

Fig. 1. Reduction (% over control) of shoot (left) and root (right) growth in two rice cultivars grown at low and adequate Zn under flooded or non-flooded conditions.

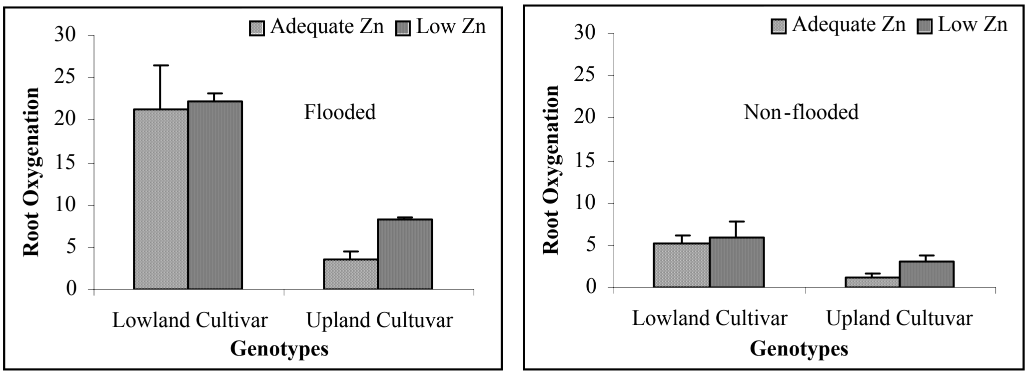

Fig. 2. Release of oxygen (µg O_2 min^{-1} g^{-1} RFW) from roots of two cultivars grown at low and adequate Zn under flooded or non-flooded conditions.

The highest α-NA oxidation was observed in Zn deficient non-flooded plants for lowland and in Zn sufficient flooded plants for upland cultivar (Table 1). The α-NA oxidation is part of the respiration, which consumes oxygen in roots. Therefore, oxygen which is not consumed by respiration diffuses into the surrounding environment (Ando et al. 1983).

Table 1. Oxidation of α-naphthylamine (µg g^{-1} RFW) by intact rice roots as affected by Zn supply level and aeration treatments.

	Lowland Cultivar		**Upland Cultivar**	
Zn treatment	**Flooded**	**Non-flooded**	**Flooded**	**Non-flooded**
Adequate Zn	317±91 b	310±58 b	538±119 a	219±25 b
Low Zn	298±24 b	537±72 a	388±109 ab	340±17 b

It was concluded that the constitutive high oxygen release, as one of the components of oxidizing power of rice roots under flooded conditions, plays an important role in tolerance to flooding and Zn deficiency in the used lowland rice cultivar. In the upland cultivar, however, the Zn deficiency-induced oxygenation of the rhizosphere, which was also reflected in a higher acidifying potential of the roots, is a mechanism for tolerance to Zn deficiency.

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