Differences in the Physiological Response of Cereals to Zinc Deficiency

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INTRODUCTION

Zinc deficiency is one of the most widespread micronutritional disorders in crops, and occurs predominantly in calcareous soils of arid and semiarid regions. It causes severe reductions in grain yield and in nutritional quality of grains. To date, the mechanisms involved in Zn efficiency in cereals have not been clarified at a physiological level, and only two genotypes were mainly used in such physiological studies. Therefore, it was the main goal of this study to investigate several different mechanisms that might contribute to Zn efficiency including the release of Zn-mobilizing root exudates, inorganic Zn (Zn^{2+}) uptake by roots, Zn retranslocation, and the symbiosis with arbuscular mycorrhiza (AM).

METHODS

One rye (*Secale cereale* cv Aslim)), one triticale (x *Triticosecale* Wittmark cv. Presto), eight bread wheat (*Triticum aestivum* cvs. BDME-10, Bezostaja, Bul 63-68-7, Dagdas-94, Gerek-79, Partizanka Niska, SBVD 1-21, SBVD 2-22), and three durum wheat (*Triticum durum* cvs C-1252, Kiziltan, Kunduru-1149) cultivars were used in different stages of the study. Two experiments were conducted in a calcareous soil with low available Zn under greenhouse conditions to study the performance of cultivars in soil and the role of AM in Zn contribution and efficiency. The other experiments were conducted in nutrient solutions in controlled growth chambers.

RESULTS AND DISCUSSION

Arbuscular Mycorrhizae and Zn Uptake

To study the importance of AM for Zn nutrition in two bread wheat and one durum wheat cultivars, plants were grown in a Zn-deficient soil in pots under greenhouse conditions. Independent of P supply and AM, all cultivars showed Zn uptake rates that reflected their Zn efficiency under field and greenhouse conditions. As expected, mycorrhizal infection (%) enhanced the uptake of P in all cultivars regardless of genotypical differences in Zn efficiency. However, under Zn deficiency AM led to lower Zn uptake. Decreased Zn uptake in mycorrhizal plants coincided with a hindered growth indicating an altered carbohydrate metabolism or partitioning in these plants. In general, no relationship was found between Zn efficiency of wheat cultivars and the rate of mycorrhizal root infection.

Phytosiderophores and their Possible Role in Zn Efficiency of Cereals

To elucidate physiological mechanisms of Zn efficiency, phytosiderophore **(**PS) release of one rye, one triticale, seven bread wheat, and two durum wheat genotypes differing in Zn efficiency was investigated in nutrient solution culture. However, PS release of rye, triticale, and bread wheat cultivars did not correlate with Zn efficiencies observed in the field at low Zn availability. The results indicate that PS release cannot be regarded as a major physiological mechanism involved in Zn efficiency in cereals.

Relationship between Zn Uptake and Zn Efficiency of Cereals

To test the role of Zn-uptake capacity for Zn efficiency, one rye, one durum wheat, and three bread wheat cultivars were grown in nutrient solution. Short-term uptake of ^{65}Zn supplied as $ZnSO_4$ was determined in plants pre-cultured under -/+ Zn conditions. While Zn-efficient rye cv. Aslim showed the highest uptake rate, Zn-inefficient durum wheat cv. Kunduru-1149 had the lowest. The results suggest that a low Zn-uptake capacity of durum wheat might be an important reason for its higher susceptibility to Zn deficiency. However, the differential Zn efficiency among the bread wheat cultivars was not related to their capacity for the uptake of inorganic Zn.

Effect of Phloem Mobility of Zn in Differential Efficiency of Cereals

Finally, the role of Zn retranslocation for the internal utilization-efficiency of Zn was investigated in bread and durum wheat cultivars. There were no differences among these cultivars in translocation of foliar applied ^{65}Zn and in retranslocation of pre-loaded ^{65}Zn from older leaves to younger tissues. Thus, no indication was found for an important role of Zn retranslocation for the expression of Zn efficiency in wheat.

CONCLUSIONS

The release of PS, the uptake of Zn, the retranslocation and remobilisation of Zn from older leaves to younger leaves or AM did not explain the differences in Zn efficiency as observed among bread wheat cultivars in field and pot experiments. Differential resistance to low Zn availability in soils between durum wheat and other cereals species was attributed to the differences in the release of PSs. Among all cereals, the superior Zn efficiency of rye was most likely linked to a higher total Zn-uptake capacity. However, it is not clear if this was due to the uptake capacity or to root morphology. This issue should be clarified in future studies.

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