

# Screening Differential Zinc Efficiency in Barley Genotypes Grown to Maturity

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## INTRODUCTION

Zinc deficiency in crops is the most widespread micronutrient deficiency, with about 50% of the cereal-growing area worldwide containing low levels of plant-available Zn (Graham et al. 1992). Zinc deficiency in crops reduces not only grain yield, but also the nutritional quality of grains. High proportion of cereal-based foods with low levels and poor bioavailability of Zn in the diet is thought to be a major factor in the widespread occurrence of Zn deficiency in humans (Welch 1993).

Various mechanisms may explain Zn efficiency in crops, including increased Zn uptake, increased Zn availability in the rhizosphere due to release of root exudates, and more efficient internal Zn use. In wheat, Zn-uptake capacity of roots (Rengel and Graham 1996) is one of the mechanisms of Zn efficiency. In barley, Genc et al. (2002) found the greater efficiency of genotypes may be attributed to higher uptake of Zn from the soil and more efficient utilization.

There is considerable genotypic variation both within and between cereals for micronutrient efficiency. A number of studies have demonstrated differential Zn efficiency in barley (e.g. McDonald et al. 2001, Genc et al. 2002), suggesting that genotypic variation could be exploited in breeding programs to produce genotypes with higher Zn efficiency. Improving Zn efficiency has recently become a major plant breeding task in several countries.

With due attention to genotypic variation for Zn efficiency, the first step in breeding for Zn efficiency is to establish a reliable system for screening a large number of genotypes. The results of field screening can be variable because of variation in nutrient deficiency between sites and years as well as the effects of other growth-limiting factors like drought and disease. Therefore, reliable alternative methods are required. Developing molecular markers linked to Zn-efficiency genes may allow screening for Zn efficiency independently of the environmental variability or the growth stage. This paper summarises some of the current work on screening for Zn efficiency in barley aimed at developing molecular markers linked to Zn-efficiency genes.

## METHODS

The Australian cultivar Clipper (Zn-inefficient) and an Algerian landrace Sahara 3771 (Zn-efficient) have been tested in five Zn-deficient soil types from Western Australia (Lancelin, Kellerberrin, Wongan Hills and Merredin) at 0, 0.02 and 0.8 mg Zn kg<sup>-1</sup> applied. Also, chelator-buffered nutrient solution was used at 0, 0.05, 1 and 5 μM ZnHEDTA. Plants were grown under controlled conditions and harvested at different growth stages. Each experiment was set up as a completely randomised design to determine the extent of genotype variation in the response to Zn deficiency. The genotypes were also tested in the field.

## RESULTS AND DISCUSSION

Visual Zn-deficiency symptoms appeared first in Zn-inefficient Clipper and a few days later in Sahara when no Zn was applied. However, Zn-deficiency symptoms were more severe in Clipper than Sahara. Furthermore, the leaf elongation rates of fourth and fifth leaves were depressed by Zn deficiency in both genotypes in Lancelin soil, with a decrease being higher in Clipper than Sahara.

For both genotypes, concentration and content of Zn were higher in plants supplied with adequate Zn ( $Zn_{0.8}$ ) than deficient Zn ( $Zn \leq 0.02 \text{ mg kg}^{-1}$  soil) in each soil type at different plant growth stages. Shoot Zn concentration, content and Zn concentration in the youngest fully emerged leaves were higher in Sahara than Clipper at  $0.8 \text{ mg Zn kg}^{-1}$ . At maturity, Sahara shoot- and seed-Zn concentrations were greater than those in Clipper in all soils at  $0.8 \text{ mg Zn kg}^{-1}$ . There was significant difference in shoot Zn content in the two genotypes grown in Lancelin, Kelleberin-7A and Merredin soils. Flag leaf Zn concentration was not significantly different between the genotypes. Under Zn deficiency, the two genotypes did not differ in shoot- and seed-Zn concentration and content.

In a chelate-buffered nutrition solution system, the root:shoot dry matter ratio of both genotypes tended to increase as the Zn level fell, indicating higher sensitivity to Zn deficiency of shoot than root growth. The ratio for Clipper was higher than that for Sahara at all Zn levels. Shoot, root and whole plant Zn concentration and content in Sahara were significantly higher than those in Clipper at 1 and  $5 \mu\text{M Zn}$ , but these properties were similar in the genotypes at 0 and  $0.05 \mu\text{M Zn}$ .

In the field, Sahara accumulated more Zn in seed and the leaf just under flag leaf than Clipper. Seed-Zn concentration and content for Sahara were  $48 \text{ mg kg}^{-1}$  dry matter and  $1.9 \mu\text{g}$  per seed; corresponding numbers for Clipper were  $31 \text{ mg kg}^{-1}$  and  $1.9 \mu\text{g}$  per seed. Zinc concentrations of leaf just under flag leaf were for Sahara 44, and for Clipper  $13 \text{ mg kg}^{-1}$  dry matter.

The response of two barley genotypes to sufficient Zn was consistent with their response in the field. At deficient level of Zn, Sahara exhibited less severe symptoms of Zn deficiency. Under sufficient Zn supply, Sahara could accumulate more Zn in root, shoot, seed and youngest fully emerged leaf. Increased Zn-uptake capacity of plants was shown to be an important factor determining Zn efficiency of genotypes of rapeseed (Grewal et al. 1997), wheat (Cakmak et al. 1997) and barley (Genc et al. 2002). Although Zn-inefficient Clipper had a higher root:shoot ratio than Zn-efficient Sahara in this study, the root:shoot ratio may not always correlate well with sensitivity of genotypes to Zn deficiency (Genc et al. 2002).

## CONCLUSIONS

The greater efficiency of Sahara over Clipper under sufficient Zn supply may be attributed to its higher uptake of Zn. It appears that soil-based pot experiments under controlled condition may offer potential improvements over field experiments in screening for tolerance to Zn deficiency. The results also indicate that shoot- and seed-Zn concentration and content can be used to diagnose the Zn status of barley genotypes, and may be useful selection criteria for Zn efficiency in large populations like doubled-haploid populations aimed at developing molecular markers for Zn efficiency.

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