Rhizosheath as a future breeding target for improved abiotic stress tolerance in cereals

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Summary

Barley produces rhizosheaths of variable mass which improve tolerance to abiotic stress. Rhizosheath mass is a novel functional trait that we have used to rapidly screen populations to understand the genetic and physiological controls of cereal tolerance to phosphorus and water deficit.

Introduction

Temperate cereals produce rhizosheaths of variable mass which are potentially important in tolerance to abiotic stress. There is an overwhelming need for simple rapid screens of root traits that are related to abiotic stress tolerance. Rhizosheath mass is a novel functional trait that can be screened rapidly to understand the genetic and physiological controls of cereal tolerance to phosphorus and water deficit.

Key findings

Our data show that there was a strong relationship between rhizosheath weight and root hair length (Figure 1).

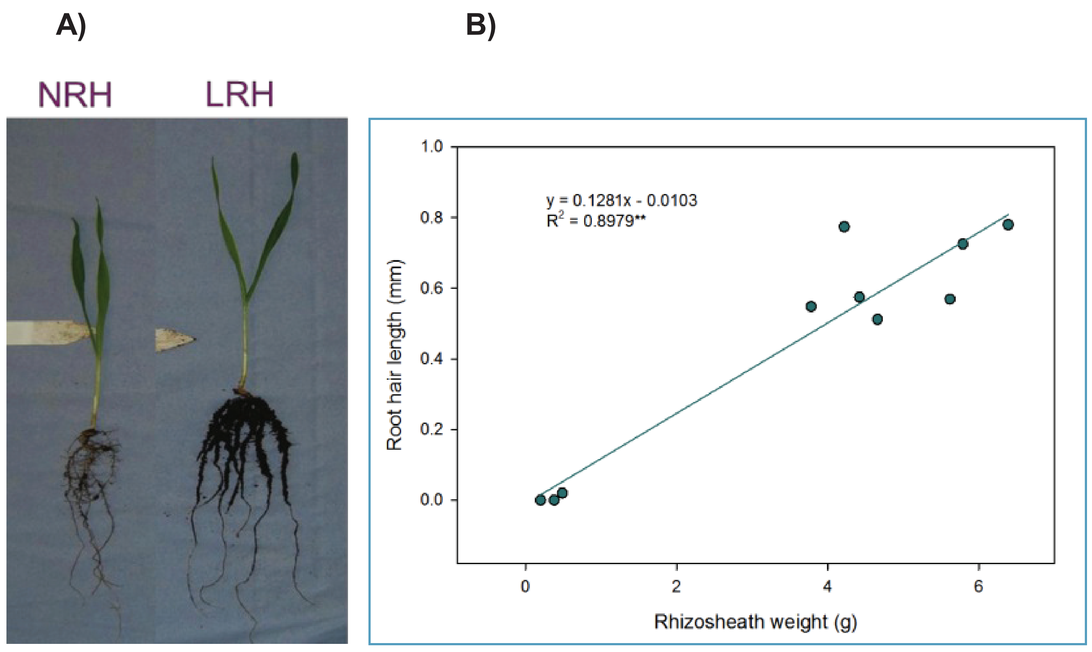

Figure 1 Relationship between root hair length and rhizosheath production. A) Photograph demonstrating the size of rhizosheath typical of a genotype with no root hairs (NRH) and one with long root hairs (LRH). B) Positive correlation between root hair length (measured with a compound light microscope) and rhizosheath weight.

We then went onto demonstrate that there was significant genotypic variation in barley rhizosheath production, >5-fold variation between elite varieties and >12-fold variation between mutant genotypes (Figure 2).

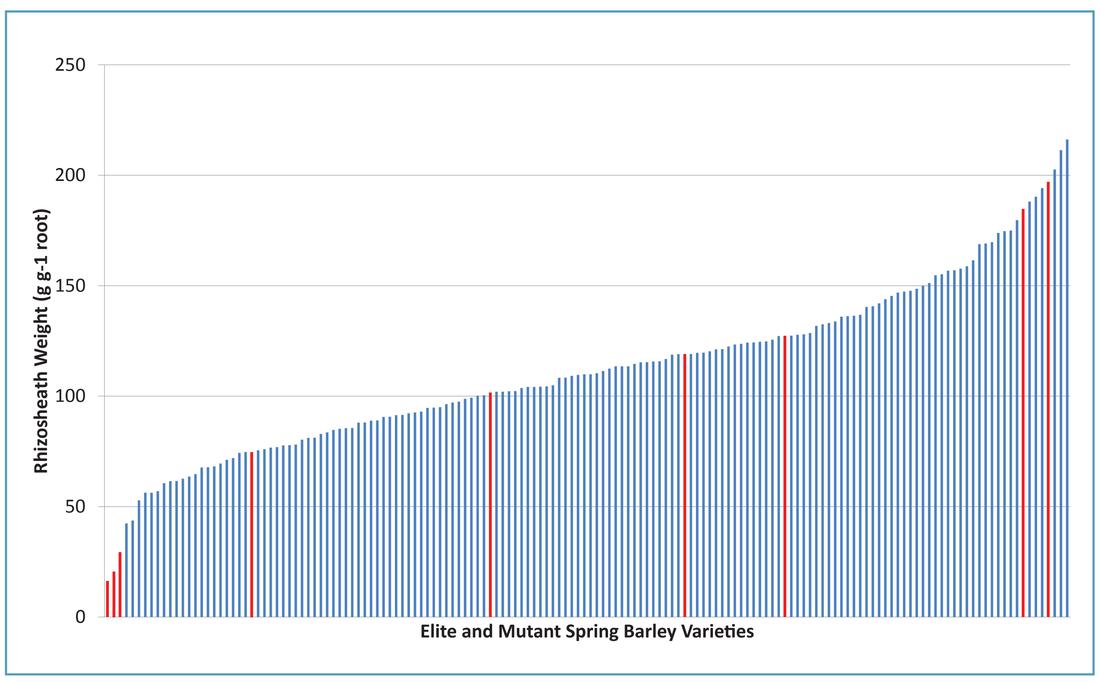

Figure 2 Genotypic variation in the rhizosheath trait (g soil g^{-1} root) in a population of 144 Elite Spring Barley (blue) varieties and a selection of 9 root hair mutants (red).

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Methods

We developed an assay for phenotyping rhizosheath traits based on plant growth in individual soil pouches. Plants were excavated, consistently shaken to remove loosely adhering soil, shoots removed and roots and rhizosheath weighed. We performed a preliminary screen of an association mapping population and a selection of root hair mutants. We have also grown mutant genotypes with small, moderate and large rhizosheaths in P-deficient soil under water deficit (50% field capacity [FC]) combined with a range of P-additions (0, 250 and 500 mgP kg^{-1})

Key findings

A preliminary QTL for the trait on chromosome 2H was generated (Figure 3) and it was observed that the presence of alleles associated with this QTL confer >10% increase in rhizosheath weight.

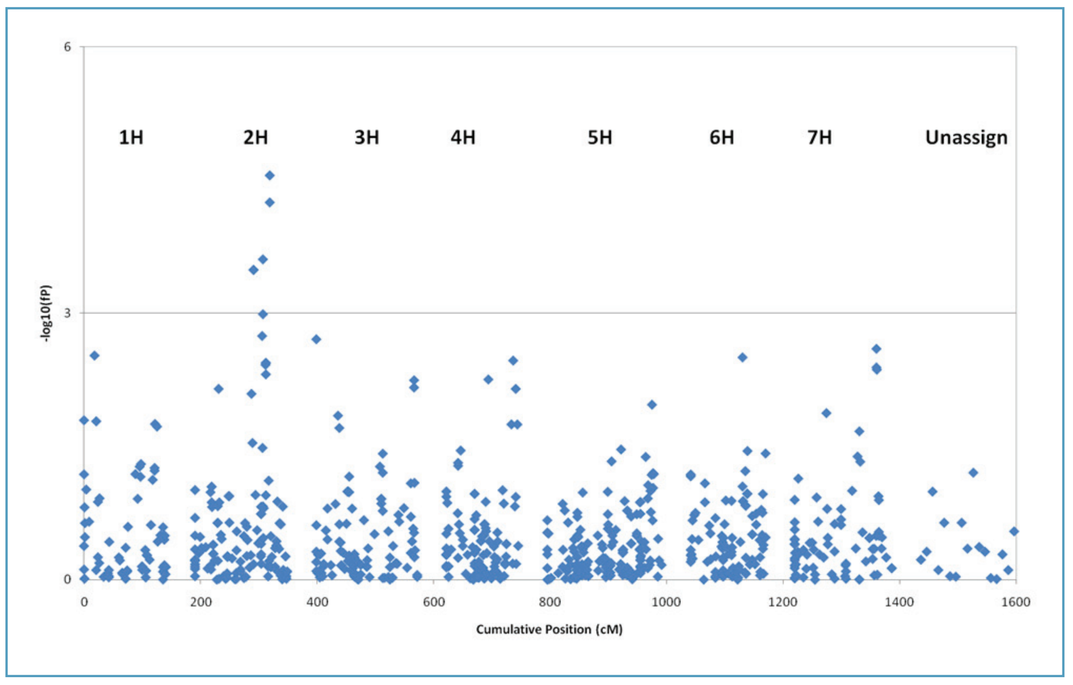

Figure 3 Manhattan plot showing the association mapping analysis of rhizosheath weight in 144 spring barley varieties. Associations are made, across all chromosomes of barley, to 1536 markers. Significant associations are indicated by log10P values greater than 3 and positions are as distance (cM) on the genetic map.

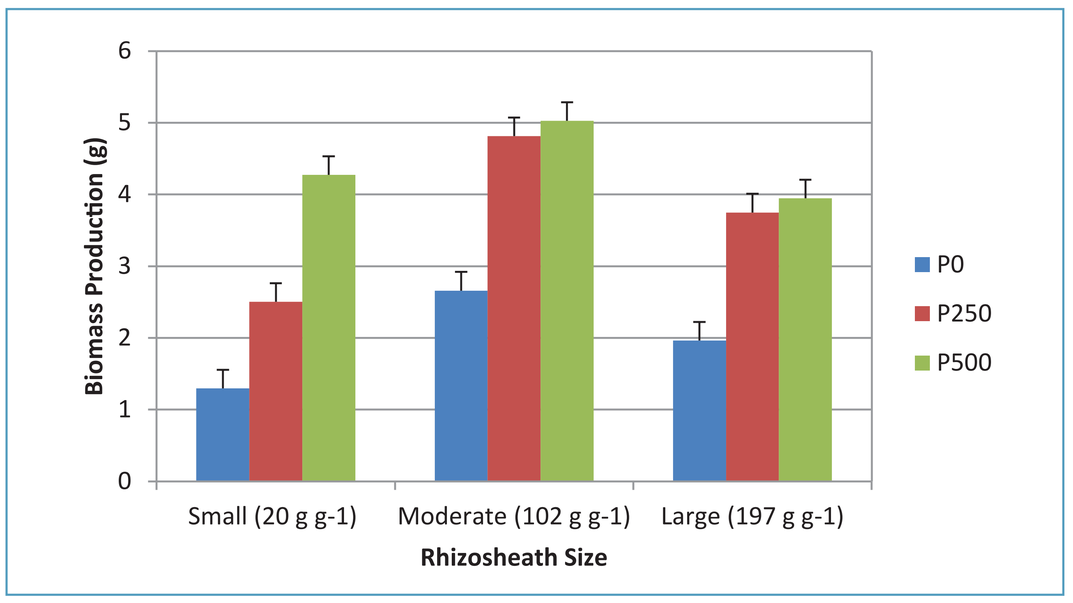

Figure 4 Biomass produced by plants with varying rhizosheath (small to large – representing the breadth of variation in figure 2) at a range of P additions (0, 250, 500 mg P kg^{-1} soil) under limited water content (50% F.C.). Data are the mean of 5 replicates and errors represent LSD $p<0.05$.

Conclusions

These data demonstrate significant genotypic variation associated with rhizosheath and that its genetic control is tractable. The trait appears to be related to root hairs and gives the plant an ability to tolerate combined abiotic stress. These data highlight the need to understand how the genotype interacts with the environment and ultimately what the best strategy for breeding varieties that will be robust in likely future environmental conditions. We are now well placed to take advantage of accurately genotyped populations of barley to understand the genetic control of rhizosheath formation by cereals. It is now timely to take advantage of this simple below ground trait screen to improve abiotic stress tolerance of temperate cereals.