What are the implications of variation in root hair length on P-limited yield in barley (*Hordeum vulgare* L.)?

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Introduction

In Scotland the major cereal crop is barley and here we investigate the variation between barley mutants in relation to root characteristics and their ability to respond to phosphorus (P) deficiency. A screen of a mutant population in an Optic genetic background has identified variation in rooting characteristics (root hairs, root length and root angle) and a sub sample of mutants demonstrating variation in root hair characteristics (no root hairs, short root hairs and long root hairs) have been grown in pot experiments to establish links between specific root hair characteristics, rhizosheath development and tolerance to combined resource deficiency. Ultimately this will help us to identify candidate genes for root traits which improve resource efficiency in barley allowing their introduction into commercial varieties which will be beneficial to the long term sustainability of agriculture.

Mutant Screen

A phenotypic screen for rooting characteristics in a mutant population of barley (*Hordeum vulgare* L. cv Optic) revealed 13 visible root phenotypes (Fig.1).

- 25% were as the standard cultivar Optic (=), 9% were positive (+) in their potential to improve resource capture and 66% were negative (-).
- The most common trait was “short roots” at 30%.
- Other variations included differences in root hair numbers and root hair lengths.

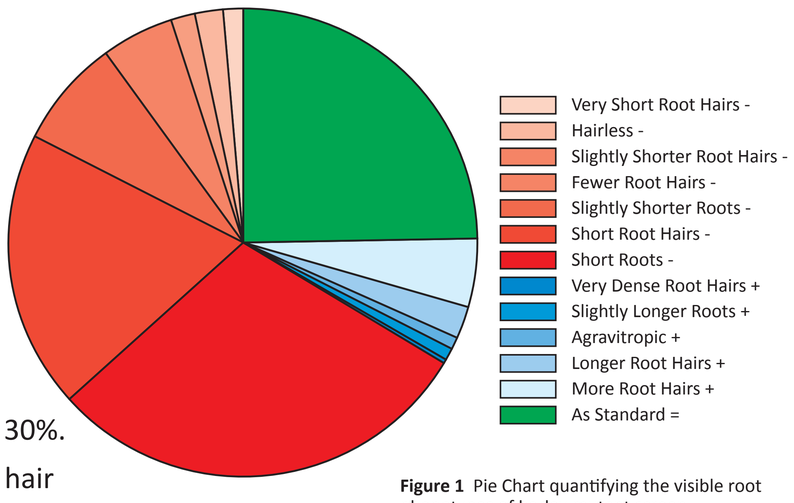


Figure 1 Pie Chart quantifying the visible root phenotypes of barley mutant screen

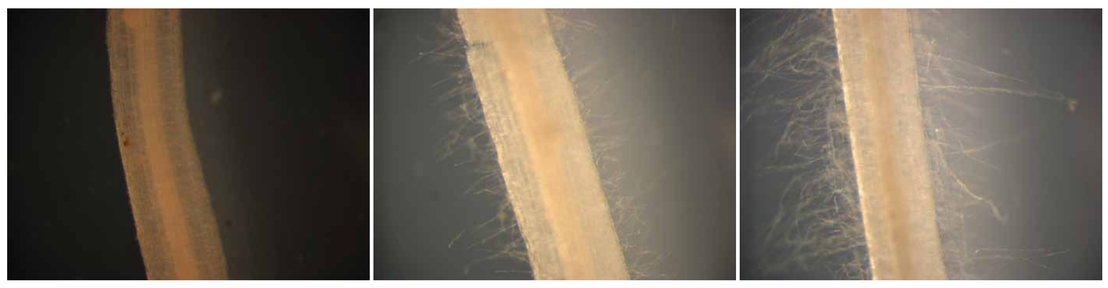
A database of mutational phenotypes, allied with a photographic record (Fig.2), provides a valuable resource for future investigations.

2a No root hairs 2b Short root hairs 2c Long root hairs

Figure 2 Photographic records of mutational phenotypes

Growth Study

The impact of root hair length on nutrient acquisition, yield and tolerance to combined abiotic stress were studied using a sub-sample of mutant lines exhibiting no root hair (NRH), short root hair (SRH) and long root hair (LRH) phenotypes. Mutants were grown in soil filled pots with different P treatments in three experiments, one of which had combined water stress, which were harvested at 7 days, 8 weeks and 14 weeks. Measurements included root and shoot mass, root length, rhizosheath weight, root hair length, shoot P accumulation, grain weight and number and total shoot biomass.



3a No root hairs 3b Short root hairs 3c Long root hairs

Figure 3 Images of roots of soil grown mutants

- The root hair images of soil grown mutants (fig.3) show the mutant screen to be robust with the root hair characteristics being consistent between the two methods.

Figure 4a Observed differences between the rhizosheaths of no root hair mutants (left) and long root hair mutants (right)

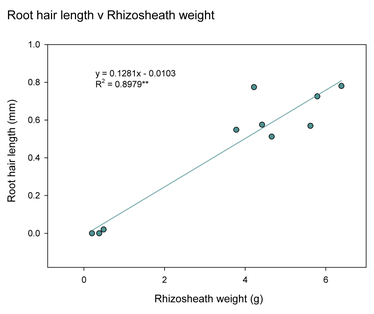


Figure 4b Relationship between rhizosheath weight and average root hair length

- Figure 4a demonstrates the clear differences between the rhizosheaths of NRH (right) and LRH (left) mutants.
- There was a strong correlation ($R^2 = 0.89$) between rhizosheath weight and root hair length (fig.4b)

- LRH phenotypes accumulated 35% more P than NRH phenotypes while there was a significant P treatment response (fig 5a).
- Grain weight was used to calculate the percentage agronomic effectiveness of phenotype on yield (fig 5b). Significant differences were found in yield between the phenotypes with root hairs and those without.

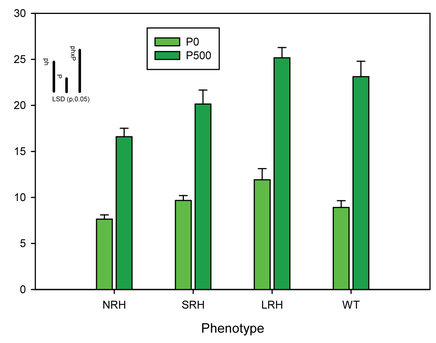


Figure 5a Variation in P accumulation by phenotype (mgP/plant)

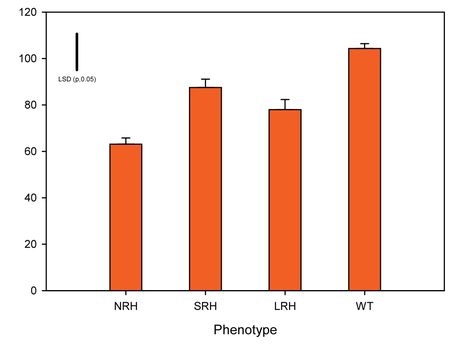


Figure 5b Relative agronomic effectiveness of phenotype on yield (yield of phenotype %)

- The three root hair phenotypes responded differently when subjected to varying levels of P and water deprivation depending on the existence of root hairs. Phenotypes with root hairs out performed those without in biomass production in conditions of combined resource deficit.

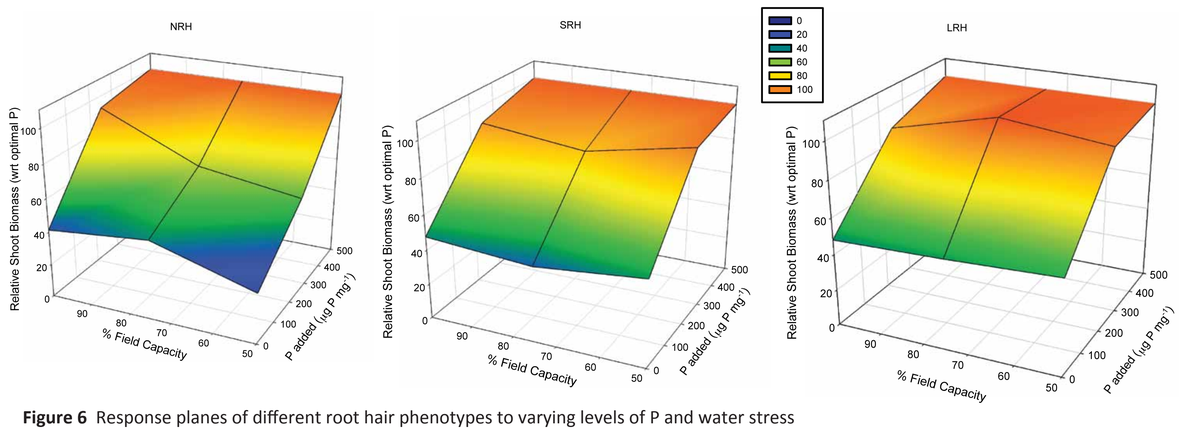


Figure 6 Response planes of different root hair phenotypes to varying levels of P and water stress

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Conclusions

- Root hair characteristics found in the initial screen are robust when plants are grown in soil.
- There are significant differences between phenotypes and P treatments.
- There is a strong correlation between rhizosheath weight and root hair length which have important implications for nutrient acquisition.
- The presence of root hairs is implicit to the sustainability of yield although root hair length had no impact.
- The presence of root hairs is imperative to the plant’s ability to respond to combined abiotic stress while maintaining yield.
- This study will help to establish an understanding of the genetic control of these traits, assisting in the identification of candidate genes and ultimately in the introduction of beneficial traits into commercial varieties with a positive impact on the long term sustainability of agriculture.