Wheat root ideotypes for improved resource use in reduced input agriculture

Karley A.J., Valentine T.A., Squire G.R., Binnie K., Skiba A.K. & Doherty S.B.

The James Hutton Institute, Invergowrie, Dundee, DD2 5DA, U.K.

Email: Alison.Karley@hutton.ac.uk

The James Hutton Institute

Introduction

The main challenges for wheat breeding are to stabilise yield as environmental conditions change, to reduce dependence on limited resources (particularly mineral fertilisers), and to minimise environmental impacts. However, limited availability of water and key nutrients like nitrogen can severely reduce wheat yield.

The New Wheat Root Ideotypes LINK project aims to identify root traits that might improve wheat performance in reduced input systems.

The primary objective was to characterise the extent to which root traits vary in a wide range of wheat genotypes. A second objective was to assess the degree of variation in water and N use efficiency, and to determine any relation with root phenotype.

Methods

Plant material

Three replicate plants of each of 100 wheat genotypes were grown in metre-long rhizotubes in an inert grit-sand-gravel substrate with defined nutrient supply (Karley et al., 2011). Plants were monitored throughout development and harvested as the main stem reached maturity. The structure and partitioning of dry matter to roots and to shoot structures was determined.

$\delta^{13}C$-composition of leaf tissue

Dried tissues were milled to a powder and 0.2 mg leaf samples of a subset of genotypes (24) were analysed for ^{13}C isotopic composition using an elemental analyser (Flash EA-1112) coupled to a Delta V Advantage isotope ratio mass spectrometer (Thermo-Fisher, Bremen, Germany). International reference materials (USGS40 and IAEA-CH6, International Atomic Energy Agency, Vienna, Austria) were used for scale calibration of ^{13}C isotope results to Vienna PeeDee Belemnite (VPDB). Relative enrichment with ^{13}C (less negative $\delta^{13}C$ values) indicates reduced stomatal aperture during plant growth and therefore reduced water loss and higher transpiration efficiency.

Data analysis

Genotypic differences in dry mass allocation to root and shoot structures and grain, and in leaf $\delta^{13}C$ values, were tested by ANOVA in Genstat (v. 14, VSN International Ltd.). Principle component analysis was applied to root dry mass accumulated down the depth profile to explore genotypic differences in spatial patterns of root dry mass allocation, and to test for correlations with grain production or water use efficiency.

Results

Significant genotypic variation was detected in wheat plant development, grain yield, and dry matter accumulation and allocation to root and shoot structures.

Root phenotype

Principle component analysis of root dry mass data (not shown) identified genotypes that differed in root size and distribution with depth (Fig. 1). Variation along PC1 (97.1% of the variation) was largely due to differences in total root size (Figure 1A), while variation along PC2 (2.5% of the variation) differentiated genotypes that allocated relatively more or less root mass to the upper part of the root-depth profile (Figure 1B).

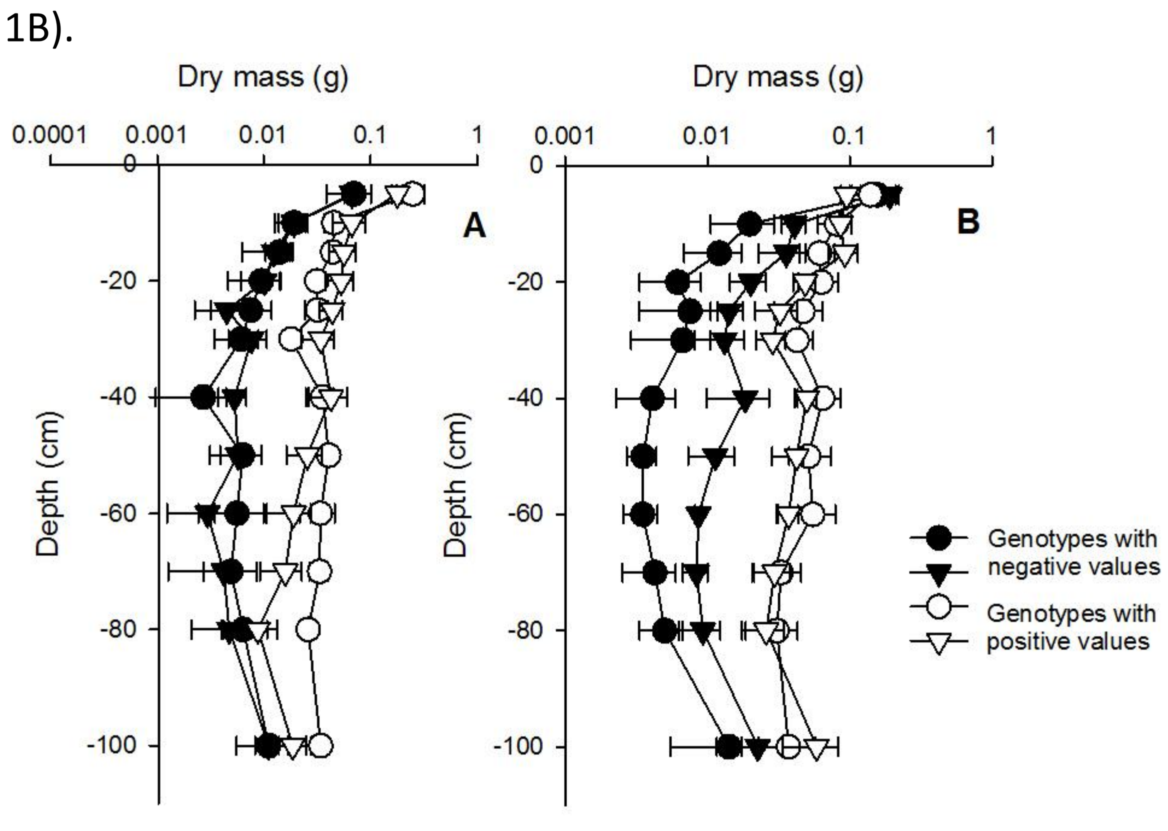

Figure 1 Root mass distribution patterns for eight different wheat genotypes showing extreme values on (A) PC1 and (B) PC2 in principle component analysis of root dry matter allocation.

Water use efficiency

Genotypic variation in water use efficiency, measured as $\delta^{13}C$ value, was significant ($F_{23,41}$ = 2.00, P=0.026) and was weakly negatively correlated with overall root mass (score values on PC1; Figure 2) but not with root distribution with depth or grain production.

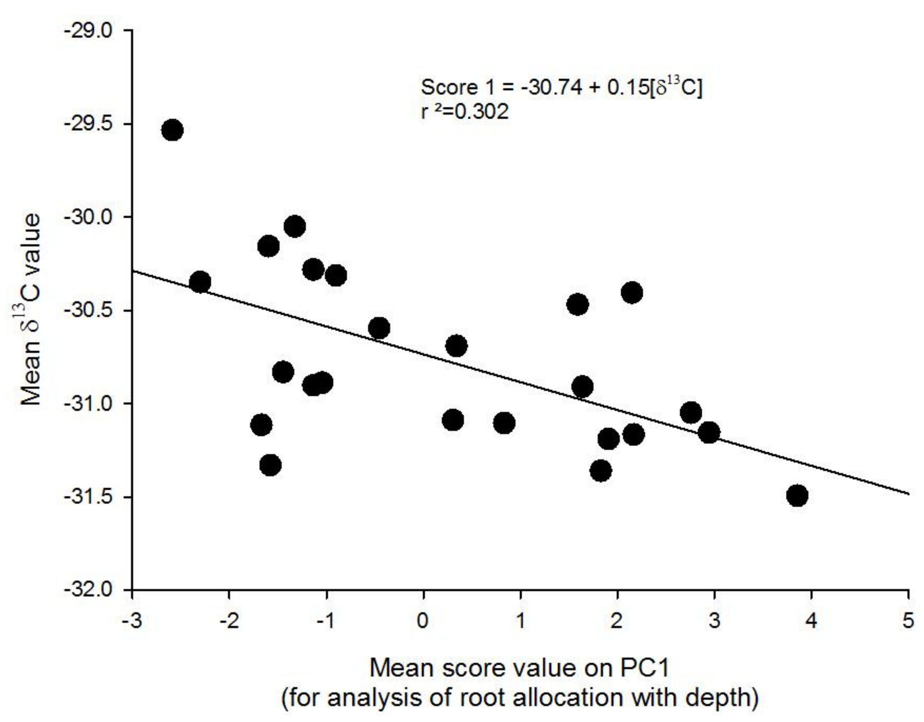

Figure 2 Relation between wheat genotypic differences in water use efficiency (indicated by $\delta^{13}C$ value) and root size (indicated by values on PC1 derived from principle component analysis of the root mass-depth profile).

Conclusions

- Wheat root phenotype (root mass and distribution) varies significantly amongst 100 tested genotypes
- Amongst a subset of 24 genotypes, there were significant differences in water use efficiency, indicated by less negative δ^{13}-C values
- Water use efficiency tended to be highest in wheat genotypes with smaller root systems, potentially indicating that smaller root systems limit the quantity of water taken up by the plant
- Further analysis will examine the potential impact of genotypic differences in root phenotype and water use efficiency on plant nitrogen acquisition.

Acknowledgements

This work was carried out within the NWRI LINK project funded by Defra, RESAS, BBSRC and HGCA, with additional funding provided by the Scottish Society for Crop Research (Dundee) for ^{13}C isotope analysis. We are grateful to HFK and WMA (Stable Isotope Unit, James Hutton Institute, Dundee, UK) for carrying out the ^{13}C isotope analyses. Thanks to consortium partners KWS and NIAB for seed, and to the rest of the consortium for support (ADAS, BASF, Frontier, Monsanto, Nickerson, RAGT, Syngenta, and Prof Peter Young at the University of York).

References

Karley, A.J., Valentine, T.A. & Squire, G.R. 2011. Dwarf alleles differentially affect barley root traits influencing nitrogen acquisition under low nutrient supply. *Journal of Experimental Botany* **62**, 3917-3927.