Do traditional Scottish landraces of barley have traits which could improve modern cultivars resilience to nutritional drought?

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Introduction

Global environment is changing and this has implications for Scottish agriculture. The cost of fertilisers and fuel is increasing rapidly and climate change scenarios predict warmer drier periods at times critical to crop production (Spring-Summer). Combined stress of drought and nutrient deficiency (nutritional drought), particularly phosphate, will become an increasing problem for Scottish farmers. Traditional Scottish landraces of barley (still grown in the western Isles, Shetland and Orkney) may have traits for tolerance to nutrient and water deficiency lost from elite varieties during the breeding process.

Methods

The ability of elite varieties to cope with nutrient deficit in soils typical of Scotland's arable east was determined by monitoring tissue P-concentration in field grown plants and the response of the most commonly grown variety (Optic) to the addition of inorganic P to a typical Scottish arable soil. We then looked for traits in traditional Scottish landraces of barley (Uist Bere barley) that may allow improved capture of resources. Firstly, exudates from the roots of both Uist Bere and Optic barley were tested for phosphatase activity. The two varieties were then grown in a split-pot system which allowed the implementation of nutritional drought (**Figure 1**). Shoot biomass and the partitioning of roots towards either water or P were established.

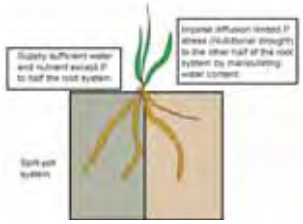

Figure 1: Schematic representation of the split-pot experimental system which allows imposition of nutritional drought.

Results

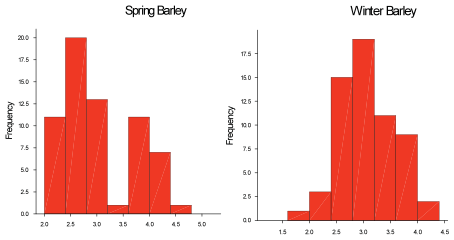

Figure 2: Histograms showing the frequency distribution of shoot P concentration (mg P g^{-1}) in spring and winter elite varieties of barley grown in a field site typical of the arable east of Scotland.

- The majority of elite lines of both spring and winter barley had tissue concentrations less than the physiological optimum (3.5mg P g^{-1}) for unlimited growth when grown in soils typical of the arable east of Scotland (**Figure 2**).
- When typical Scottish arable soil was amended with increasing levels of inorganic P the most commonly grown variety (Optic) showed a growth response, indicating intrinsic limitation due to P availability (**Figure 3**).
- Uist Bere barley had greater activities of phosphomonoesterase, phosphodiesterase and phytase than Optic (**Figure 4**).
- When grown under nutritional drought, Optic barley had a large reduction in shoot biomass (~50%), while Uist Bere barley grew to a similar size as plants with no nutritional drought applied (**Figure 5**).
- Optic barley partitioned its roots towards water under high P conditions and towards P under deficit, in contrast Uist Bere barley appeared to allocate roots equally between P and water under the range of conditions (**Figure 6**).

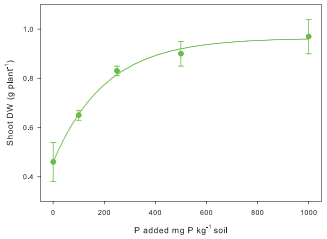

Figure 3: Above ground biomass production (g plant^{-1}) of Optic barley grown in soils amended with increasing amounts of inorganic P. Plants were grown under glasshouse conditions for 6 weeks.

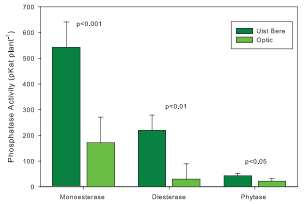

Figure 4: Activity of phosphatase enzymes collected in exudates of Optic and Uist Bere barley. Plants were grown for 3 weeks in hydroponics before being transferred to nutrient solution to collect exudates overnight. Exudates were then tested for activity against a range of substrates including p-nitrophenyl phosphate (phosphomonoesterase activity), bis-p-nitrophenyl phosphate (phosphodiesterase activity) and myo-inositol hexakisphosphate (phytase activity).

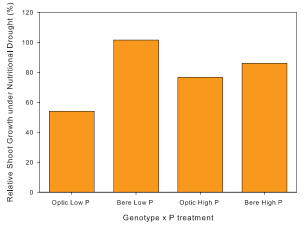

Figure 5: Relative shoot biomass production (%) of Optic and Uist Bere barley grown in the split-pot system under nutritional drought. Plants were grown with either low or high P applied to one half of the root system, which was kept at 50% field capacity. Shoot growth is relative to the equivalent plants grown with the P-treatment combined with unlimited water content.

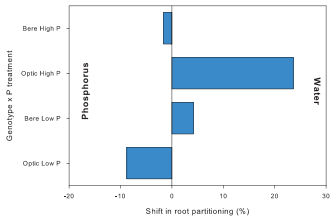

Figure 6: Shift in root partitioning (%) of Optic and Uist Bere barley grown in the split-pot system under nutritional drought. Plants were grown with either low or high P applied to one half of the root system, which was kept at 50% field capacity. Root partitioning was measured relative to the side of the pot which received no P.

Conclusions

1. Elite varieties of spring and winter barley are limited by P-deficit in soils typical of the arable east of Scotland.
2. Traditional Scottish landraces of barley (Uist Bere) have greater activity of phosphatase enzymes in their root exudates which may allow access to soil P contained in organic forms.
3. Uist Bere barley also appears to be able to cope better with nutritional drought than commercial varieties which incur a considerable growth penalty when P availability is limited by reduced soil water content.
4. This inability to cope with nutritional drought may be caused by Optics preferential partitioning of roots towards the most limiting resource under the combined stress, while Uist Bere tends to partition roots equally towards the two resources.
5. Traditional Scottish landraces appear to have useful traits to cope with P-deficit lost from elite varieties. Such traits should be reintroduced to elite varieties, which may allow Scottish farmers to better cope with the consequences of global environmental change.

Acknowledgements

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