Dissecting drought-response strategies of perennial ryegrass (*Lolium perenne* L.)

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**Introduction**

Periodic drought is a severe constraint on the profitability and sustainability of pastoral production. As a result of climate change, drought events are anticipated to increase in frequency and intensity even in regions where annual precipitation is unchanged, as well as where it is reduced.

Many studies have been carried out on drought resistance of forage species (Holloway-Phillips and Brodribb 2011). However, for most experiments, it is unclear which mechanism(s) are responsible for variation in plant performance under moisture stress, whether drought response mechanisms were triggered, or whether differences in performance were simply the result of intrinsic plant vigour. The objective of the reported research was to understand the underlying physiological and genetic mechanisms responsible for production of perennial ryegrass under summer drought and recovery and regrowth after drought.

**Methods**

**Plant material**

Perennial ryegrass mapping population RM4 is a random sample of the full-sibling F1 progeny from a pair cross between a genotype from the New Zealand cultivar ‘Grasslands Samson’ and a Moroccan genotype. The maternal ‘Grasslands Samson’ parent is the same genotype used to develop a previously-described mapping population (Sartie et al. 2011) and is widely used in New Zealand farming systems. The Moroccan genotype was sourced from an accession (PI 598854) obtained from the National Plant Germplasm System of the USDA-ARS with anecdotal evidence of good dry matter production during drought.

**Experimental design**

This experiment was conducted in a rainout shelter in the field. A total of 164 genotypes were clonally propagated to make plants available for two treatments (drought and control) and three replicates within each treatment. Soil water content, leaf elongation rate, tiller survival after trimming, and shoot dry matter yield were measured from each plant of the mapping population progeny, after plant establishment and exposure to mild drought (Mild), severe drought (Severe) and after recovery (Post). The resulting progeny-by-trait matrix was used to detect quantiative trait loci (QTL) for the various traits.

**Discussion**

There was no genotype effect detected on soil water content and leaf elongation rate but a significant genotype effect on tiller survival (Table 1). This suggests that some genotypes could be suitable for grazing during drought.

Vigour and drought tolerance can both independently enhance plant performance during moisture deficit. This was shown by the presence of both drought-resistant genotypes and genotypes for which performance was reduced when compared to their irrigated clones, yet was high enough for those genotypes to be in the top half of the population both at the beginning of the experiment and during severe drought (Fig. 1).

These results were in accordance with those from the QTL analysis (Fig. 2). The LG2 QTL affects tiller

![Figure 1. DM yield potential during the severe drought treatment and the extent of DM yield reduction compared to irrigated clonal replicate. (75% of plants with the greatest reduction in yield within each sampling date: ●, top 25% within each sampling date, respectively; ns, P>0.05; *P<0.05).](image-url)
Table 1. Wald tests for fixed effects on genotypes for volumetric Soil Water Content (SWC), Tiller survival (TS) and Leaf Elongation Rate (LER) for perennial ryegrass plants subjected to severe drought.

<table>
<thead>
<tr>
<th>Fixed term</th>
<th>Wald statistic</th>
<th>d.f.</th>
<th>Wald/d.f.</th>
<th>P</th>
<th>ns</th>
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</thead>
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<tr>
<td>Genotype SWC</td>
<td>139.23</td>
<td>137</td>
<td>1.02</td>
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<tr>
<td>Genotype Tiller survival</td>
<td>167.96</td>
<td>137</td>
<td>1.23</td>
<td>0.037</td>
<td>*</td>
</tr>
<tr>
<td>Genotype LER</td>
<td>143.08</td>
<td>135</td>
<td>1.06</td>
<td>0.301</td>
<td>ns</td>
</tr>
</tbody>
</table>

Figure 2. The genetic linkage map showing seven linkage groups (LG1 - LG7) representing the seven ryegrass chromosomes and QTL discovered for traits measured in the drought response experiment: DM (dry matter), TS (tiller survival) and LER (leaf elongation rate).

survival after defoliation and Dry Weight for irrigated and non irrigated plants. It is therefore related to traits for both vigour and drought tolerance. The LG4 QTL occurs only for non-irrigated so it represents a true drought tolerance effect.

**Conclusion**

Data suggest that the vegetative growth of perennial ryegrass during the summer drought treatment was influenced both by genes that control intrinsic plant vigour and by genes that triggered a response to drought stress.

**References**


Lucerne for acid soils: A field evaluation of early generation aluminium tolerant genotypes

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Keywords: Aluminium toxicity, manganese toxicity, alfalfa, establishment, sowing

Introduction

The development of lucerne germplasm tolerant of acidic soil conditions has long been a research objective of international significance. Many initiatives have previously failed to produce genotypes with adequate improvement in tolerance to be deemed economically viable and as a consequence, still no cultivar of lucerne exists that has improved adaptation to acidic soils. An Australian research program spanning the previous decade sought to redress this issue by developing lucerne genotypes with significantly enhanced tolerance to aluminium (Al) toxicity. Using recurrent selection in hydroponic solution culture, populations selected comprised individuals which displayed enhanced seedling root growth following a pulse of Al toxic solution (Scott et al. 2008). A subsequent pot experiment showed that these populations exhibited up to 40% increase in seedling root length when grown in an acidic soil with high Al concentration, though there was a differential response observed between the elite populations (Hayes et al. 2011).

The current study tested the hypothesis that lucerne establishment in the field would be higher in populations selected in high Al solution culture when grown in an acidic soil environment.

Methods

Two field experiments were sown in September 2005, near the townships of Binalong and Cootamundra in southern NSW, Australia. Soil pH was 4.0-4.1 and 4.7-6.2 and Al comprised 13-30% and 0-3% of the effective cation exchange capacity at the Binalong and Cootamundra sites, respectively. The treatments consisted of 28 early generation genotypes selected in solution culture for enhanced seedling root growth under conditions of Al toxicity, and 12 control populations, either commercial cultivars or advanced breeding lines. Both experiments were randomised block designs with three replicates, sown using a cone seeder at a sowing rate of 5 kg/ha inoculated lucerne seed. Plot dimensions were 1 m x 5 m. Seedling density was counted in four 0.1 m² quadrats per plot 8 weeks post sowing. Data were analysed at the 95% confidence level by an analysis of variance using Genstat version 11.1 (VSN International Ltd, Hemel Hempstead).

Results and discussion

There was a significant difference between some populations in lucerne seedling density (P=0.05) at the Cootamundra site. However, there was no consistent advantage in seedling establishment conveyed by the populations that had been selected under high Al solution culture. That is, some control populations established at higher densities than some elite populations, and vice versa (Fig. 1). Four populations tested in the field had previously been tested in the pot experiment described by Hayes et al. (2011), three of which were previously shown to exhibit root responses in soil consistent with improved Al tolerance. These populations also failed to show a consistent advantage in terms of seedling establishment in the field (Fig.1). There was no significant difference in seedling density at the Binalong site (mean 48 seedlings/m²) where average establishment density was approximately half that observed at the Cootamundra site (mean 94 seedlings/m²).

We tested the hypothesis that lucerne establishment in the field would be higher in populations selected in high Al solution culture when grown in acidic soil environments. Figure 1 shows that whilst the seedling density of some selected populations was significantly higher than some controls, 7 of the controls established at densities similar to the best of the elite populations. Seed quality is not likely to be a reason for the apparent inconsistent response given that the same seed was used at the Binalong site at which no difference in establishment was observed between populations. However, there are a number of other factors contributing to the results we observed. Firstly, the expression of the Al tolerance trait in the field might depend upon the seasonal conditions experienced as Culvenor et al. (2011) demonstrated for the perennial grass, Phalaris aquatica L., assuming the same principle applied to lucerne. Even at the one field site, differences in establishment would need to be monitored over several contrasting seasons. Secondly, the controlled environment experiment (Hayes et al. 2011) revealed that not all populations selected in high Al solution culture exhibited responses consistent with improved Al tolerance. Therefore, future field evaluations of elite lucerne germplasm should focus only on those populations that have demonstrated enhanced Al tolerance. Furthermore, lucerne populations selected for tolerance to Al will