Lucerne for Acid Soils: A Field Evaluation of Early Generation Aluminium Tolerant Genotypes

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

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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_{CaCl2} ranged from 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 m^2 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/m^2) where average establishment density was approximately half that observed at the Cootamundra site (mean 94 seedlings/m^2).

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

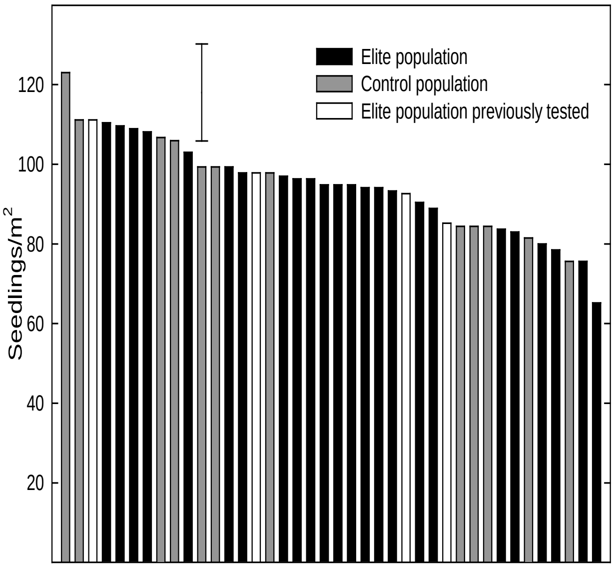

Figure 1. Seedling density of 40 lucerne populations 8 weeks post sowing at the Cootamundra field site.

not necessarily exhibit tolerance to other pH-related impacts such as poor nodulation or Mn toxicity. The consistently low density of all populations at the Binalong site is possibly associated with very high levels of Mn later observed in the soil at that site (Hayes *et al.* 2012). Genuinely acid-soil tolerant lucerne populations may need to possess several traits and even where this is achieved the environments in which the genotypes are expected to convey an advantage need to be more precisely defined as it is unlikely production benefits will be realised in all acid-soil environments.

Recommendations

To guide continuing research initiatives to develop the world's first acid-tolerant lucerne cultivar we offer the following recommendations for future research: (1) expression of Al tolerance traits are likely to be seasonally dependant and so differences in establishment would need to be monitored over several contrasting seasons; (2) variability of response between lucerne populations suggests that future field evaluations of elite lucerne germplasm should focus only on those populations that have demonstrated enhanced Al tolerance; and (3) prior to elite populations being commercialised, the environments in which the Al-tolerant genotypes are expected to convey an advantage need to be more precisely defined as it is unlikely production benefits will be realised in all acid-soil environments, such as where Mn toxicity limits performance.

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