Subsoil acidity determines survival of lucerne on a highly acidic soil

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Introduction

Lucerne (*Medicago sativa*) is one of most productive perennial species in southern Australia. However, productivity is severely restricted under acid soils (Irwin *et al.* 2001). Fenton *et al.* (1996) reported that lucerne performs poorly if soil pH was below 5 and exchangeable aluminium was over 5%. It is estimated that there are 24 m ha of acidic subsoil in southern Australia (Dolling *et al.* 2001). A long-term liming experiment, 1992 to 2010, aimed to ameliorate subsoil acidity via a vigorous liming program (Li *et al.* 2001). This paper reports survival of lucerne during the 3rd cycle of the experiment from 2004 to 2009.

Methods

The experiment was located at Book Book (147°30′E; 35°23′S) 40 km south-east of Wagga Wagga, NSW, Australia. The soil was a subnatric yellow sodosol (Isbell 1996) soil pH 4.1 (in $CaCl_2$) 0-10 cm and 4.2, 10-20 cm (Li *et al.* 2001). The exchangeable Al% was 31% and 43% at 0-10 and 10-20 cm, respectively. The site had been limed every 6 years with an initial lime rate of 3.7 t/ha in 1992 and maintenance rates of 2.6 t/ha during the 2nd cycle and 1.6 t/ha during the 3rd cycle. By 2004, two contrasting soil profiles existed with soil pH of 4.0 and 5.5, 0-10 cm on the unlimed and limed treatments. The soil pH at 15-20 cm increased 0.05 units per year (Li *et al.* 2010) with exchangeable Al% below 10% since 2004 on the limed treatment.

In 2004, the experiment was re-sown with the original pasture mixes as described in Li *et al.* (2001). A pair of unlimed and limed perennial pastures was chosen to monitor the persistence of perennial species over 6 years after being established in 2004. The perennial species included were lucerne, phalaris (*Phalaris aquatica*) and cocksfoot (*Dactylis glomerata*) sown with subterranean clover (*Trifolium subterraneum*). Pasture persistence was assessed using basal area as percentage of ground cover of crown or stem base of perennial species. Basal area was monitored over 5 years in autumn at break of season from the second year after pasture was sown. Data were analysed using a repeated measures model (Genstat Release 15.1).

Results and Discussion

Despite a drier than normal year in 2004 (Table 1) we had reasonable establishment of pastures for both limed and unlimed treatments. Seedling numbers at establishment were 13-23 plants/m^2 for lucerne, 25-27 for phalaris, 25-31 for cocksfoot and 46-49 for subclover. In 2005, the site received above-average rainfall which help pasture establish, but it was an extremely dry year in 2006 (288 mm) which had a detrimental effect on the survival of perennial species.

The basal area of lucerne was 11% on the limed treatment and only 2% on the unlimed treatment in the 2nd year of its establishment in 2005 (Fig. 1*a*). The basal area maintained around 2-3% for the next 4 years on the limed treatment, but virtually no lucerne plants survived on the unlimed treatments. Prior to the 3rd cycle of rotation, there was only 6 plants/m^2 of lucerne on the limed treatment and 1 plant/m^2 on the unlimed treatment at the establishment year. None survived from the second season during the 2nd cycle of rotation (1997-2003). At the start of the third cycle in year 13, a reasonable numbers of lucerne plants (13-23 plants/m^2) survived at the establishment year and persisted over next 5 years with basal area from 2-3% on the limed treatment, indicating the significant improvement of subsoil acidity.

Table 1. Monthly rainfall from 2004 to 2009 and long-term average rainfall (LTAR) at the experimental site.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2004	19.4	7.0	13.4	16.0	50.0	92.4	58.2	74.6	53.6	22.6	93.6	39.0	539.8
2005	26.1	40.0	11.3	24.0	3.2	135.4	78.8	87.0	119.8	88.8	34.8	93.7	742.9
2006	29.6	0.4	20.2	27.2	8.4	47.8	57.2	19.2	28.8	6.4	42.0	1.2	288.4
2007	17.0	64.2	75.2	59.4	83.8	21.8	76.4	32.6	14.2	70.8	138.0	111.0	764.4
2008	81.6	69.0	27.4	16.4	25.6	57.6	116.6	37.8	30.2	29.0	68.6	54.2	614.0
2009	6.4	8.6	15.0	73.6	14.6	78.0	44.6	54.4	33.4	36.2	61.0	105.6	531.4
LTAR	34.3	43.2	49.8	38.1	47.9	58.8	65.5	58.3	59.1	70.7	60.7	58.6	645.0

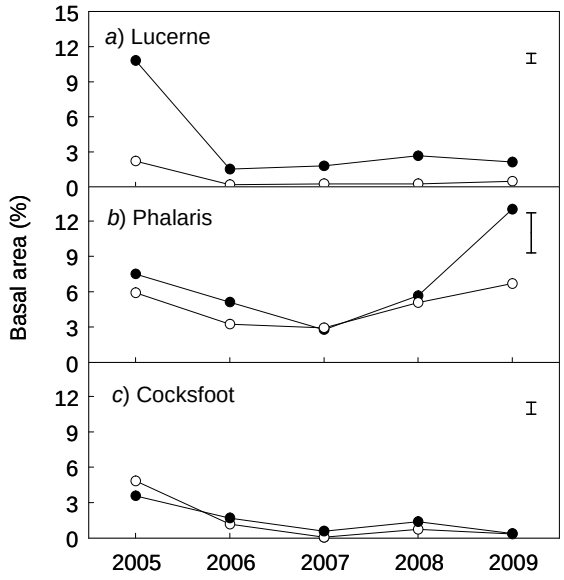

Figure 1. Basal area of a) lucerne, b) phalaris and c) cocksfoot on limed (●) and unlimed (○) treatments from years 2 to 7 after established in 2004. Vertical bars represented LSD at *P* < 0.05.

The basal areas of phalaris and cocksfoot reduced sharply in 2006 and were least in 2007 (Fig. 1 b and c). Phalaris recovered after above average rainfall in 2007, while cocksfoot never recovered from the drought due to its shallow root systems (Ridley and Simpson 1994). From 2008, the pasture was dominated by phalaris, especially on the limed treatment.

Conclusion

With a vigorous liming program, lucerne can be established on highly acidic soil as subsoil acidity was gradually ameliorated over the long-term, though phalaris was more responsive.

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