The effect of lime application to an acid soil on perennial grass establishment

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Abstract

Trials were conducted over three consecutive years (2006-2008) to study the effect of lime application to an acid soil (pH 4.2 in $CaCl_2$) on establishment of phalaris (*Phalaris aquatica* L). Lime was applied in two different ways. Firstly, the site chosen had previously hosted a trial where one of the treatments had applied sufficient lime in 1998 to raise the 0-10 cm soil profile to pH 5.0 while no lime was added to the adjacent control treatment at that time. The second lime application methods undertaken between 2006 and 2008 involved both reliming of 1998 limed plots as well as initial liming of 1998 control plots. These occurred in the form of various quantities of powdered (2006, 2007) and prilled (2008) lime placed in close contact with the seed at each of the trial sowings. The treatments separated the effects of the lime applied to ameliorate bulk soil acidity in 1998 from the application of small amounts of lime aimed at ameliorating acidity in the immediate vicinity of the seed. Establishment was measured by comparing the frequency of a rooted grass crown in a fixed quadrat before and after the first summer. No effects of any type of lime application occurred in the 2006 and 2007 trials. The severe drought of 2006 did not permit survival of any seedlings over the summer. In contrast, the summer of 2007 was much wetter, with such high overall seedling survival that no differences due to lime were apparent. In the 2008 trial greater grass survival was apparent where the 0-10 cm soil profile pH had been raised in response to the 1998 liming whereas there was no increase in establishment as a result of more recent prilled lime application.

Key Words

Soil acidity, lime application, amelioration, grass establishment, summer survival, *Phalaris aquatica*

Introduction

The benefits of applying lime to the establishment and nodulation of legumes on acid soils have been known for many years (Anderson and Spencer 1948) so the lime-pelleting of legume seed has become recommended practise. The effects of soil acidity (and of actions to ameliorate acidity) on establishment of a perennial grass is less well understood than with annual legumes particularly in environments with hot and dry summers. In contrast to cool-season annual legumes which set seed before the onset of summer, the establishment of a perennial species can only be considered successful after the plant has survived the first summer.

It is believed that seedlings are particularly susceptible to low pH and high aluminium although interestingly observations of mature, supposedly acid-soil susceptible grasses such as phalaris, growing in highly acidic soils are not uncommon. If the seedling of a species is very susceptible to low pH and high aluminium levels it is reasonable to question how susceptible plants could ever establish on such soils. This question becomes more pressing because some recently available (2008) commercial liming products are being marketed purporting to assist pasture establishment and there is a need for independent testing of these claims. The paper here focuses on determining the impact of a range of different liming rates applied immediately prior to sowing and also up to 10 years previously on establishment of a perennial grass.

Methods

The experiments were conducted at the property, Bywong (35.12? S, 149.27? E, altitude 635 m), approx. 30 km north of Canberra on the Southern Tablelands of NSW in 2006, 2007 and 2008. The site chosen had previously hosted a trial where one of the treatments had applied sufficient lime in 1998 to raise the

0-10 cm soil profile to pH 5.0 while no lime at that time was added to the adjacent control treatment. Subsequent lime application employed between 2006 and 2008 involved both reliming of 1998 limed plots as well as initial liming of 1998 control plots. This occurred in the form of various quantities of powdered (2006, 2007) and prilled (2008) lime placed in close contact with the seed at each of the trial sowings. In all three years of experimentation the effects of a range of rates of lime applied in close proximity to the seed at sowing were studied through observing the establishment of *Phalaris aquatica*, cv. Landmaster (phalaris) sown at 4 kg/ha. A basal application of superphosphate (9% P, 11% S) at 135kg/ha was applied at sowing in 2006, whereas in 2007 and 2008 the same rate of Granulock 15? (14% N, 12% P, 11% S) was used instead.

The soils at the site are predominately shallow, stony and texture contrast having brown loam topsoils overlying reddish to reddish brown light clays and clay loams. The two predominant soil groups comprise Red Chromosols (Red Podzolic soils) covering the larger area with Leptic Rudosols (Lithosols) confined to the higher portions of the landscape (Isbell 1996).

In 1998 half of the plots received sufficient lime to raise soil pH ($CaCl_2$) in the 0-10 cm soil profile to 5.0 and between 2006 and 2008 the pH in these plots ranged from 4.8 to 4.9 while aluminium (Al) was generally steady at around 3 % of effective cation exchange capacity (ECEC). The pH reducing effect of liming to pH 5.0 in 1998 took 9 years to reach the 15-20 cm profile because only by 2007 was there a significantly higher pH at this depth than in the non-limed treatments. When Al was expressed as a percentage of ECEC when assessed in 2008, the application of lime in 1998 reduced this percentage at both the 10-15 and 15-20 cm depths although the levels in the limed plots were still high at between 30 and 40%. In the unlimed paddocks the soil pH in the 0-10 and 15-20 cm profile between 2006 and 2008 varied between 4.1 and 4.2. In these same plots aluminium as a percentage of ECEC in 2008 varied between 32 to 35% in the 0-10 profile over the same period, but was more than 50% in the 10-15 and 15-20 cm profile.

Two trials were sown in 2006 at Bywong with one in plot 7, which had received sufficient lime in 1998 to raise pH to 5.0. and another in the adjacent plot 8, which was an unlimed control in 1998. Trials were sown immediately prior to spring (18 August 2006) and each had 4 lime-at-sowing treatments with 4 replications. The treatments comprised: nil lime; lime applied into the drill row at 230 kg/ha; lime applied into the drill row at 460 kg/ha; lime applied only to the surface at 2.5 t/ha. Statistical comparison between the two trials was not possible and each trial was analysed individually as a randomised complete block.

In 2007 the trial involved a sowing in both autumn (30 April) and immediately prior to spring (30 August) with only 2 soil lime treatments employed at each sowing, viz. nil lime; lime applied immediately post-sowing by hand into the drill row at 460 kg/ha. A split-plot design with 4 replications was used. Mainplots (dimensions 8 x 5 m), were assigned on the basis of whether they had received lime in 1998 to raise pH to 5.0 (plot 4, 5, 16 and 24) or not (plot 13, 14, 21 and 27). Subplots (dimensions 2 x 5m) addressed the different lime application rates and seasons of sowing employed in 2007 and 2008. In contrast to the trial design used in 2006, this design did permit statistical analysis between plots in the different paddocks.

A third year of establishment trials (2008) was sown in early (26 June) and late winter (26 August). This experiment was located adjacent to the 2007 trial plots and in the same paddocks. The only difference in this 2008 trial was that a new, commercially-available prilled lime product, was used instead of the F70 powdered lime which had been applied by hand in 2007. In contrast to the application of the powdered lime, prilled lime (88% $CaCO_3$, 5% $MgCO_3$, 2% Calcium lignosulfonate binder) was applied at sowing (200 kg/ha) directly through the fertiliser box of the seed drill. Neutralising values of 98 and 95 are quoted for F70 powdered lime and prilled lime respectively (E. Barry pers. comm.). A lower lime application rate was used in 2008 than in 2007 because this was a rate more likely to be used commercially.

Measurements of plant crown frequency were used to assess establishment and consisted of the counting of the squares containing a plant crown in fixed quadrats. Each quadrat comprised squares of 2.5 ? 2.5 cm. In each plot, 100 such squares in total were measured, with 33 squares measured in each of 2 rows and 34 squares in a third location. All sampling positions were fixed. These measurements were

performed twice, firstly in late spring of the year of sowing and finally after the break of season in the following autumn/early winter.

Results and Discussion

While there was no effect of the rate of lime application in 2006 on establishment of either trial it was noted in November 2006 that 34% of the quadrats contained a plant crown in the plot limed in 1998 whereas in the control treatment of 1998 only 13% of quadrats contained a plant. The severity of the subsequent drought over the summer 2006-2007, caused total sward mortality with no surviving plants in May 2007. However, the apparent difference in plant frequency in November 2006 raised the possibility that the prior application of lime (in 1998) contributed to the apparently superior early establishment in the limed paddock. It seemed possible that the application of lime 8 years previously may have had a beneficial effect on the subsoil, allowing better root growth and exploitation of soil water leading to longer survival into a dry period. This suggests a possible interaction between better subsoil conditions for root growth (brought about by the liming in 1998), the degree of summer moisture deficit and the level of plant survival over summer.

The result at the 'break-of-season' observation following the first summer after sowing is a key test of whether the plants are robust enough to survive the moisture stress and heat of summer, one of the more life-threatening seasons of the year. Therefore, the break-of-season observation is critical in determining whether a soil amelioration treatment can have a positive impact on plant survival. The median rainfall over the 6 month period from November to April in this region is approximately 267 mm. During the extremely severe drought conditions of 2006 only 184 mm fell during this period and this led to the death of all the seedlings before they could be counted a second time at the break of season in autumn 2007. In this context it is reasonable to conclude that actions which increase the amount of plant available soil water by increasing rooting depth or density can help to improve plant survival especially over seasons such as summer when water deficits are likely to be most severe.

In 2007 the second series of pasture establishment trials experienced seasonal conditions contrasting markedly to those of the previous year. Substantially above average late spring and summer rainfall fell with 377 mm received (267 mm average) in the 6 month period from November 2007 to April 2008. Approximately 60% of all treatment quadrats contained a grass crown and no significant differences in grass crown frequency between any of the different lime seed-application treatments were observed at the break-of-season measurements in autumn 2008 irrespective of whether sown in the preceding autumn or spring. There were also no differences between plots which had received lime in 1998 or not. The actual reason for the absence of differences was unclear but it could be because the seedlings experienced much less moisture stress over the summer than would be normally expected. The late spring and summer of 2007/08 was substantially wetter than normal, so that the absence of moisture stress at this time precluded the development of mortality within the young developing swards at a time when normally some plant death due to drought stress would be expected.

A third series of establishment trials with similar treatments to those of 2007 was sown in autumn and spring 2008. Over the 6 month period from November 2008 to April 2009, 334 mm of rainfall fell which was approximately 60 mm more than the mean over this period. Sowing in spring 2008 led to significantly greater establishment (62 and 65 % quadrats occupied in spring) than sowing in autumn 2008 (52 % occupied after autumn sowing) irrespective of whether prilled lime had been applied at sowing or not (Table 1). It was possible that the poorer establishment after autumn sowing was because temperatures at germination were lower and less favourable than those experienced after the spring sowings because autumn sowing had to be delayed later than desirable because of lack of moisture. Nevertheless, the use of prilled lime in spring gave superior establishment to the autumn-sown treatment without prilled lime. There was also a non-significant trend (F prob.= 0.069) for better establishment to occur on those plots which had been limed in 1998 (63.2%) in comparison to those which had not received lime in that year (51.9 %).

Table 1: The effect of the application of lime in 1998 and prilled lime application at sowing combined with season of sowing in 2008 on frequency of grass crowns (as percentage of

quadrats occupied) after the Autumn 2009 break-of-season observation in a pasture establishment trial at Bywong, NSW.

Lime in 1998	Crown frequency (%)	Season and prilled lime at sowing	Crown frequency (%)
Lime to pH 5.0	63.2	Autumn control	51.5[a]
		Autumn prilled lime	52.4[ab]
Nil lime	51.9	Spring control	61.6[bc]
		Spring prilled lime	64.8[c]
($LSD_{0.05}$)	n.s.		9.26

To assess the survival and development of seedlings over summer the ratio of post summer/pre summer plant crown frequencies was evaluated (Table 2). This ratio places emphasis on the fate of plants over the summer period as it recognizes that this is the key period that plants must survive in summer-dry environments for them to be considered to be truly established (Norton et al. 2006). When viewed this way the frequency of phalaris on plots which had received lime in 1998 increased significantly over the period between the spring 2008 and autumn 2009 observations (from 100 to 124) in contrast to the 1998 control plots which were little different (100 to 104). In contrast, there were no effects on establishment of the application of prilled lime at sowing in 2008 whether sown in autumn or spring (Table 2).

Table 2: The effect of the application of lime in 1998, prilled lime application at sowing combined with season of sowing in 2008 on the ratio of the post-summer to pre-summer frequency of grass crowns (as percentage of quadrats occupied) after the Autumn 2009 break-of-season observation in an establishment trial at Bywong, NSW.

Lime in 1998	Crown frequency (%)	Season and prilled lime at sowing	Crown frequency (%)
Lime to pH 5.0	124.4	Autumn control	112.6
		Autumn prilled lime	113.3
Nil lime	104.4	Spring control	115.2
		Spring prilled lime	116.6
($LSD_{0.05}$)	16.4		ns

Conclusion

In conclusion, the results presented here do not provide any evidence that the application of lime in close proximity to the seed at sowing improves the establishment of phalaris. Any amelioration to the soil associated with the lime applied around the seed at sowing will be expected to have only a very localised

effect and it would be likely that it would not take long for roots to grow out of the soil volume affected by a small quantity of lime. The beneficial effect of small quantities of lime applied at sowing would therefore be expected to have only a short term effect. In the case of these experiments it appears the period between the pre-summer (late spring) and post-summer (autumn) observations (5-6 months) was longer than any short term positive effect that the lime applied at sowing might be expected to give.

Different results were obtained in each of the 3 seasons of experimentation and it appears that the level of moisture stress in the first post-sowing summer may mediate the survival of seedlings which emerge initially. In the year of severe drought (2006/07) establishment of all swards failed with lime application making no difference. In the year of much higher than average summer rainfall (2007/08) all swards survived well with no treatment differences again apparent. However, in the 2008 trial establishment was higher on plots which had received sufficient lime to raise the soil in the 0-10 cm profile to pH 5.0 in 1998. These establishment differences appear to have been mediated by levels of summer moisture stress which were higher than 2007/08 but lower than those of 2006/07. It seems possible that the grasses in the plots limed in 1998 had deeper better developed roots possibly associated with the lower levels of aluminium saturation in the subsoil (10-20 cm profile). Denser and deeper root growth will allow grasses to extract more water from the soil and permit plants to survive longer periods of moisture stress than neighbouring plants with smaller and shallower root systems. An examination of root characteristics to determine whether the earlier applied lime actually increased depth and density of roots in the subsoil will be the subject of future research.

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