Soil pH and pasture responses to lime and organic amendments on an acidic soil in south-eastern Australia

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Abstract

Two types of pastures were established in 2020 on an acidic soil in the mixed farming zone in south-eastern Australia. The site was treated with lime and organic amendment as lucerne hay pellets (LP) in 2016 with two major treatment contrasts, *a*) surface lime vs. deep lime and *b*) lime vs. LP. The objective was to assess pasture response to different soil amendments in terms of pasture DM and botanical composition. Results showed lime increased soil pH at depths where it was placed, whereas deep placement of LP had a limited effect on soil pH. Deep placement of lime and LP increased pasture DM of sown perennial species and supressed weeds significantly compared with the control and surface lime treatments.

Keywords

Subsoil acidity, pasture DM, chicory, phalaris, subterranean clover

Introduction

Subsoil acidity is a major constraint to ongoing productivity in the high rainfall zone (500–800 mm) of south-eastern Australia. The loss to agricultural production across Australia from soil acidity is estimated to be $1.6 billion annually (SoE 2011) and the risk of further acidification inevitably increases with productivity. Lime application has proven to be one of the most effective ways to alleviate the acidity problem in mixed farming systems where cropping enterprises can be used to pay for high initial rates of lime over a short period (Scott *et al.* 1997). Unlike crops, pasture and animal responses to soil management changes can be slow and are often difficult to detect. In more recent years, a number of laboratory and glasshouse studies (up to 3 months) demonstrated that organic amendments, such as crop residues, animal wastes and garden composts, have the potential to increase pH and reduce Al toxicity. Furthermore, it appears that the combination of lime with organic materials could facilitate and accelerate downward movement of alkalinity from the lime as demonstrated from several soil column experiments (Butterly et al. 2021). However, there are limited data for the pasture responses to organic amendments in Australia. The objective of the current study was to assess the pasture responses to soil amendments on an acidic soil in a mixed farming environment in south-eastern Australia.

Methods

The site was located at “Ferndale”, Dirnaseer (34.6411S, 147.8282E), west of Cootamundra, NSW on a Red Chromosol soil (Isbell 1996). The experiment was a split-plot design with crop as main plot and soil amendment as subplot, replicated 3 times. Four crops were fully phased with wheat (*Triticum aestivum*), canola (*Brassica napus*), barley (*Hordeum vulgare*), and pulse [faba bean (*Vicia faba*) or field peas (*Pisum sativum*)] in a 4-year rotation, followed by four years of pastures. During the pasture phase (2020-2023), two types of pastures were compared, including chicory (*Cichorium intybus*)-subterranean clover (subclover, *Trifolium subterraneum*) and phalaris (*Phalaris aquatica*)-subclover pastures. There were six soil treatments, including surface lime, deep rip, deep lime, deep lucerne hay pellets (LP), and deep lime & LP as well as a nil control (no lime addition). Treatment details are described in Li *et al.* (2019). All deep soil amendments were implemented in 2016 using the 3D Ripping Machine designed and fabricated by NSW Department of Primary Industries. Soil samples were taken in autumn in years 1 and 5 using multi-core sampler (Lowrie *et al.* 2018). This paper only reports the soil pH changes over 4 years and pasture response to soil amendments in the pasture establishment year.

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Results and discussion

Soil pH changes

In the nil control treatment (i.e. no lime addition), there was no change in soil pH from year 1 to year 5, except at 30-40 cm (Figure 1). Soil pH tended to decrease below 20 cm over these 4 years, indicating the ongoing acidification of soil if not addressed. Soil surveys in 2006 and in 2015-2017 across the mixed farming zone of southern NSW have also showed that subsurface layers continued to acidify even where lime was applied regularly, albeit at below required rates (Burns and Norton 2018). For the surface lime treatment, soil pH was significantly higher at 0-10 cm in year 5 compared to that in year 1, but there was no difference below 10 cm (Figure 1). This result showed that there was no detectable lime movement beyond the applied depth over 4 years.

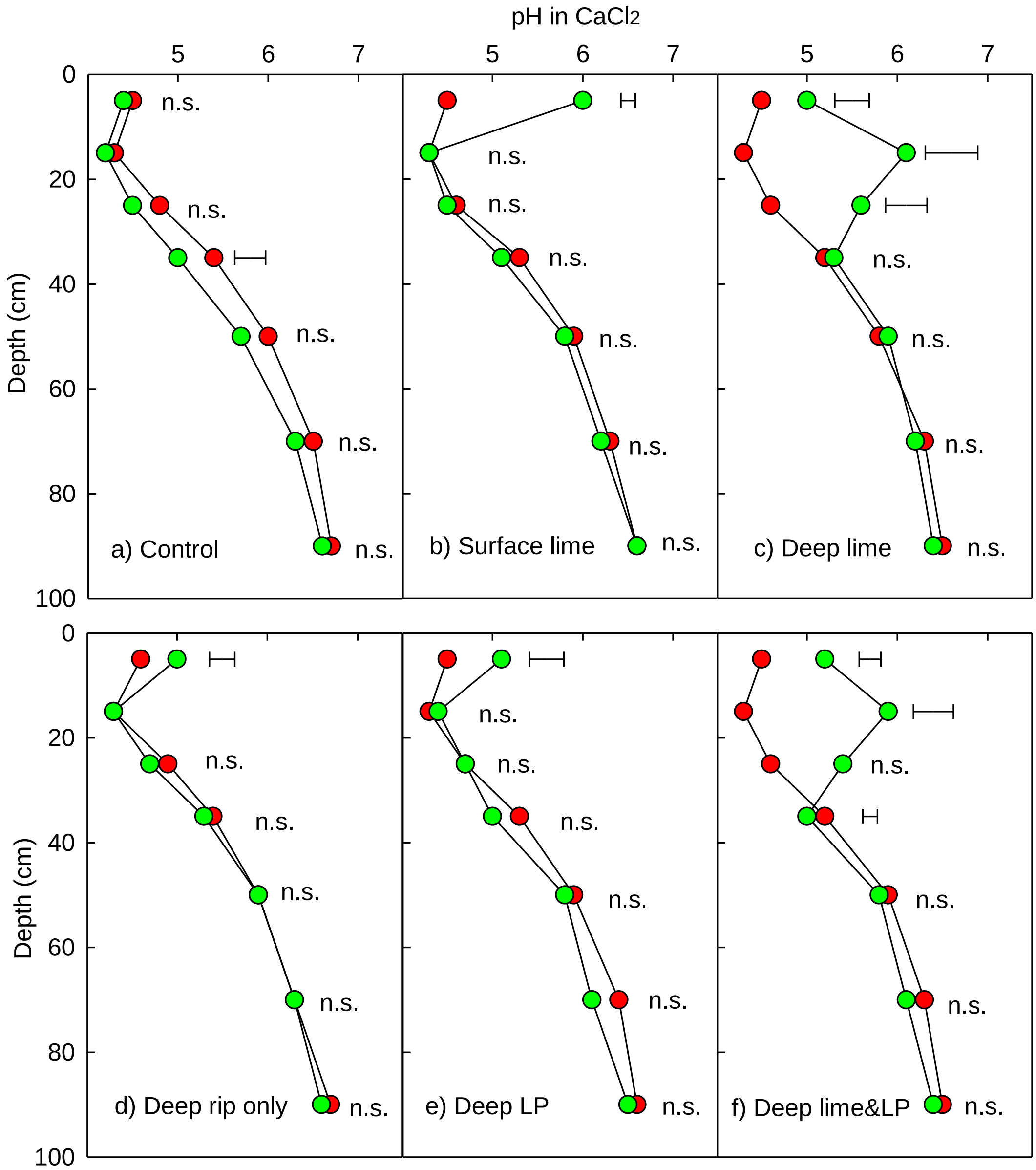

Figure 1. Soil pH$_{Ca}$ changes from year 1 (red symbol) to year 5 (green symbol) on a) control; b) surface lime; c) deep lime; d) rip only; e) deep lucerne hay pellets (LP); and f) deep lime & LP. Horizontal bar represents LSD at P = 0.05. n.s., no significant difference.

There were significant differences in soil pH at 0-30 cm on the deep lime treatment, reflecting the efficacy of the 3-D Ripping Machine which delivered the soil amendment to where it was most needed. However, it was observed that lime was still where it was placed without any sign of lateral and vertical movement 4 years after application Therefore, the soil acidity has not been fully addressed in the bulk soil given lime was delivered in ripping lines at 50 cm spacing. As a result, the lime added was unlikely to have substantial yield improvement in crop and pasture production over a short period of time.

On the deep LP treatment, there were no differences in soil pH at any depth below 10cm (Figure 1). This result suggested that deep placement of organic materials had a limited effect on soil pH. However, LP did reduce exchangeable Al% significantly (data not shown). A number of soil column experiments demonstrated that organic amendment could increase soil pH initially, but the acid-neutralizing effect from organic amendment does not persist due to subsequent nitrification (Butterly *et al.* 2010).

When lime combined with LP, the soil pH changes were similar to the deep lime treatment (Figure 1), possibly because the pH increase from lime was cancelled by the pH decrease due to nitrification effect from LP. A number of soil column experiments have demonstrated that the soluble component from organic materials moves down the soil profile with alkali if combined with lime (Nguyen *et al.* 2018). However, there was no evidence to show the alkalinity being moved vertically under lime plus organic amendment in the first 4 years under field conditions.

Pasture responses

On chicory-based pastures, total pasture DM was more than 10 t DM/ha in the establishment year on all treatments with deep amendments, whereas total pasture DM on control and surface lime were between 8.6-8.8 t/ha. However, there was a significantly greater weed burden on the control treatment compared with other treatments. Although the total pasture DM was similar on the control and surface lime treatments, the proportion of chicory was much higher on the surface lime treatment (85%) than that on the control treatment (63%) (Table 1).

On phalaris-based pastures, there was no significant difference in total pasture DM between soil treatments. Similar to chicory-based pastures, the proportion of weeds was significantly higher on the control and surface lime treatment compared with other treatments. Phalaris component was over 90% on both deep LP treatments with and without lime, but only 74% on the control treatment (Table 1). This result is consistent to the finding from a long-term lime experiment at mixed farming zone where Li *et al.* (2006) showed that lime increased pasture yield and improved feed quality by changing botanic composition in swards (Li et al. 2003).

Table 1. Effects of soil amelioration treatment on accumulated pasture DM and pasture composition over spring and summer in the establishment year on different pasture mixes.

	Total DM (t/ha)	Chicory (%)	Subclover (%)	Weeds (%)
Chicory-subclover mix				
Control	8.6	63.0	9.5	27.5
Surface lime	8.8	84.6	3.8	11.6
Deep rip only	9.4	81.3	5.1	13.5
Deep lime	10.2	82.3	4.4	13.3
Deep lucerne hay pellet	10.7	89.9	4.3	5.8
(LP) Deep lime plus LP	10.6	87.7	3.7	8.6
P-level	**	***	*	***
$LSD_{0.05}$	1.05	7.50	3.56	6.69
Phalaris-subclover mix	Total DM	Phalaris%	Subclover%	Weeds%
Control	10.1	74.0	7.6	18.4
Surface lime	9.8	80.6	6.3	13.1
Deep rip only	10.4	84.7	6.5	8.8
Deep lime	10.9	84.6	6.0	9.4
Deep lucerne hay pellet	11.3	90.8	4.0	5.2
(LP) Deep lime plus LP	10.5	91.1	4.2	4.8
P-level	n.s.	***	***	***
$LSD_{0.05}$	-	4.44	1.04	4.39

*, $P < 0.05$; **, $P < 0.01$; **, $P < 0.001$; n.s., not significant.

Conclusion

Lime increased soil pH significantly at depths where placed. Lucerne hay pellets had a limited effect on soil pH. Deep placement of lime and LP increased pasture DM of sown perennial species and supressed weeds significantly compared with the control and surface lime treatments.

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