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FARMLINK RESEARCH REPORT 2021

FUTURE PROOFING AGRICULTURAL PRODUCTION THROUGH EFFECTIVE ACIDIC SOILS MANAGEMENT

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TRIAL SITE LOCATION	TAIC (Temora), Grenfell

INTRODUCTION

Soil acidity and declining soil organic carbon affect more than half the agricultural soils in southern and central NSW, and threaten the viability and resilience of farming systems. Current acid soil management practices are based on out-dated models that are failing to prevent the widespread development of subsurface acidity in contemporary cropping and pasture systems.

FarmLink will coordinate the gathering of historical and new soil data across south-eastern Australia through a new research project called 'Future proofing the soils of southern and central NSW from acidification and soil organic carbon decline' (or 'Future Soils').

Funded by the Australian Government's National Landcare Program, the work brings together an expert team from FarmLink, Holbrook Landcare Network and Central West Farming Systems (grower engagement/extension), the NSW DPI (agronomy/soil science) and the Australian National University (computer modelling/visualisation).

PROJECT PARTNERS

FarmLink
NSW Department of Primary Industries
Australian National University
CWFS Central West Farming Systems Inc.
Incitec Pivot Fertilisers
Holbrook Landcare Network

FUNDING PARTNER

Australian Government
National Landcare Programme

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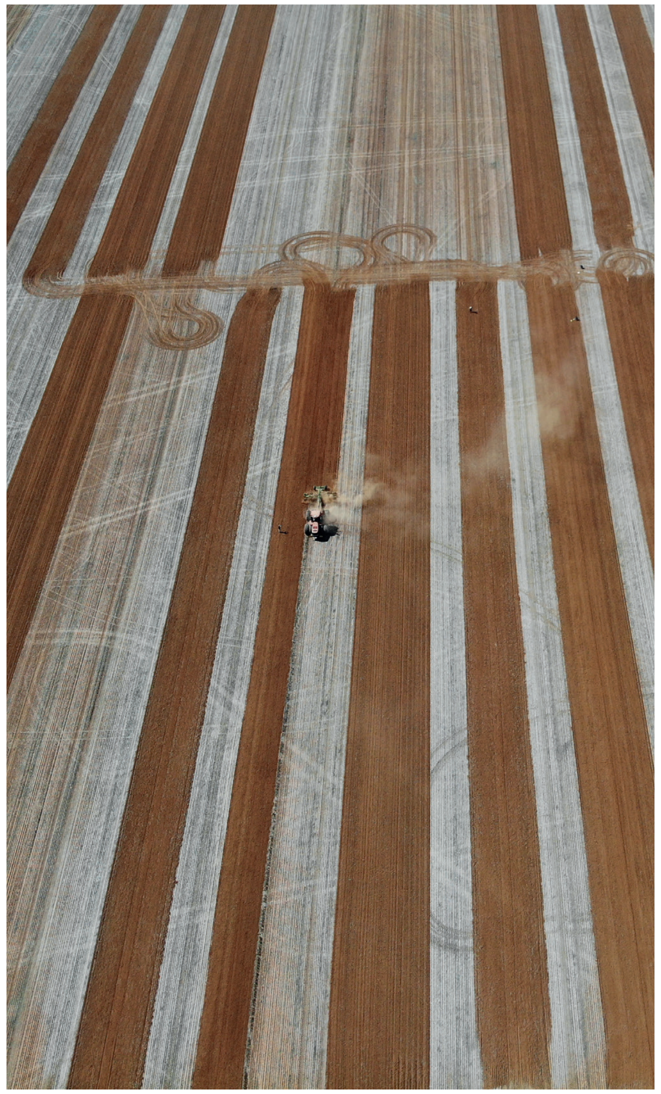
KEY FINDINGS

- Surface-applied lime that is only incorporated by the sowing operation has limited effect on increasing pH and decreasing exchangeable aluminium percent below the surface 0–5 cm layer.
- Incorporation of lime provides a head start in ameliorating subsurface acidity, increasing pH to the depth of mixing.
- There appears to be no benefit in multiple incorporation passes with tillage implements
- The soil/lime mixing capability of tillage equipment is a key attribute of effective soil acidity amelioration.



Introduction

Producer and advisor surveys indicate that current approaches to managing soil acidity are based on research and guidelines from the 1990s that were developed under very different and less productive farming systems than in operation today. Most fertiliser, lime and crop selection decisions are guided by soil sample analyses collected at traditional depths of 0–10 cm. Depending on the crop or pasture sequence, the common trigger to apply lime is when soil pH_{Ca} is around 4.5–4.8. It is applied at minimal rates to remove toxic aluminium (target pH_{Ca} 5–5.2).

These traditionally reactive approaches and a failure to effectively monitor acid soil management programs are responsible for widespread, undetected subsurface acidification in marginally acidic soils; even in those with a long history of soil testing and lime application (Burns and Norton 2018). Recent studies challenge the short-term focus of current acid soil management programs:

- Li et al. (2019) recommended revising pH targets and re-liming intervals in order to address subsurface acidification, proposing soil maintenance pH_{Ca} above 5.5 in the 0–10 cm surface layer to gradually increase subsurface pH.
- Condon et al. (2020) highlighted inadequacies of current acid soil management programs and reinforced the need for a shift from mitigating soil acidity to prevention, particularly in zero tillage farming systems.
- Conyers et al. (2020) concluded that ongoing reaction of limestone and reacidification processes influenced soil pH and that 'the slow but measurable improvement in subsurface acidity, and the sustained residual value to grain yield' required a long-term approach to amelioration efforts to manage and prevent subsurface acidification.

This paper reports preliminary soil test results from two large-scale, replicated field experiments established in March 2020. The sites near Temora and Grenfell were designed to monitor long-term changes in soil chemical properties and:

1. investigate the optimal rate of lime and application methods to prevent subsurface acidification via incorporation or enhanced movement of the lime effect
2. identify the longevity of the effect of lime application and the acidification rate of current farming practices.

Site details

Location/s

- Site 1: Temora site – approximately 5km north of Temora, NSW
- Site 2: Grenfell site – approximately 21km south east of Grenfell, NSW

Soil type

- Site 1: Temora; Red Chromosol; soil pH_{Ca} range of 4.7-5.2 in subsurface layers (5–15 cm)
- Site 2: Grenfell; Red Chromosol; soil pH_{Ca} range of 4.2-4.7 in subsurface layers (5–15 cm)

At the commencement of the trial in 2020 the Temora site was moderately to slightly acidic (pH_{Ca} 4.7 - 5.5 down to 20cm). There was no major pH stratification present at this site. In comparison, the Grenfell site was severely acidic and there was significant stratified soil pH and subsurface acidification (stratified acidification at 5-15cm of pH_{Ca} 4.2 - 4.7).

Neither site had a significant lime history. The Temora site was selected because it did not have a major acidity problem yet and therefore was an ideal site to test the effectiveness of proactive management of acidity to prevent formation of acidic constraints to plant production.. The Grenfell site had an acidity problem with severely acidic subsurface layers which need amelioration. This site was chosen as it represents a large area of cropping land that requires immediate amelioration.

Soil sampling

Soil samples were collected 13 months and 25 months after lime application for comprehensive chemical analysis. Soil cores were divided into 2.5 cm increments within depths of 0–15 cm, then 15-20 cm and 20-30 cm to detect change in soil pH and movement of alkali down the soil profile. The effectiveness of each lime treatment is gauged by the increase in soil pH and decrease in exchangeable aluminium percent (Al_{ex}%) compared with the control (nil lime).

Previous crops

- Site 1: Temora; Barley (Spartacus) 2021, Wheat (Vixen) 2020
- Site 2: Grenfell; Wheat (Coolah) 2021, Canola (45Y90CL) 2020

Rainfall (2020)

- Site 1: Temora; 686mm
- Site 2: Grenfell; 763mm

Rainfall (2021)

- Site 1: Temora; 776mm
- Site 2: Grenfell; 942mm

Treatments

Large-scale, replicated field sites were established in early 2020 to monitor change in soil chemical properties to 0–30 cm deep, under high input, mixed farming systems. A range of lime and incorporation treatments were applied in March 2020 (Temora, Table 1) and April 2020 (Grenfell, Table 2). Lime (NV= >95%, >70% particles finer than 250 um) sourced from Westlime Parkes and was applied using a direct drop lime spreader at Temora and a commercial agricultural spreader at Grenfell. At Temora the plot size is 85 m long by 5.4 m wide, and at Grenfell plots are 180 m long by 9 m wide. The Temora site has six treatments and four replications. The Grenfell site has eight treatments and four replications.

Treatments were designed to answer the following questions raised by local growers and advisors:

- What is the optimal rate of lime and application methods to prevent and/or ameliorate subsurface acidification?
- Does incorporation increase the rate and depth of pH increase in the soil subsurface?

Table 1. Lime rates and incorporation treatments applied to small-scale field site at Temora.

Treatment ID	Incorporation treatment	Description	Site 1: Temora
			Rate of lime applied (t/ha)
1	Control	Nil lime, Not incorporated (NI)	0
2	Incorporation (Year 1 pre sowing)	Surface lime (target pH_{Ca}>5.5 at 0-20cm depth) incorporated with offset	4
3	No incorporation	Surface lime (target pH_{Ca}>5.5 at 0-20cm depth)	4
4	No incorporation	Surface lime (target pH_{Ca}>5 at 0-20cm depth)	1
5	Incorporated stubble after year 1 harvest	Surface lime (pH_{Ca}>5.5 at 0-20cm depth) + Organic matter (stubble), incorporated with offset	4
6	Incorporation x 2 (Year 1 pre sowing)	Lime (pH_{Ca}>5.5 at 0-20cm depth) incorporated with offset twice	4

Table 2. Lime rates and incorporation treatments applied to large-scale field site at Grenfell.

Treatment ID	Incorporation treatment	Description	Site 2: Grenfell
			Rate of lime applied (t/ha)
1	Control	Nil lime, Not incorporated (NI)	0
2	No incorporation	Surface lime (target pH_{Ca}>5.5 at 0-20cm depth), incorporated by sowing	7
3	Incorporation (Year 1 pre sowing)	No lime, incorporated with offset disc	0
4	Incorporation (Year 1 pre sowing)	Surface lime (target pH_{Ca}>5.5 at 0-20cm depth), incorporated with offset disc	7
5	Incorporation (Year 1 pre sowing)	No lime, incorporated with speed tiller	0
6	Incorporation (Year 1 pre sowing)	Surface lime (target pH_{Ca}>5.5 at 0-20cm depth), incorporated with speed tiller	7
7	Incorporation (Year 1 pre sowing)	No lime, incorporated with speed chisel	0
8	Incorporation (Year 1 pre sowing)	Surface lime (target pH_{Ca}>5.5 at 0-20cm depth), incorporated with speed chisel	7

Lime application dates and incorporation method

- Site 1: Temora; Limed on 5 May 2020; incorporation to estimated depth of 10cm with offset discs.
- Site 2: Grenfell; Limed on 31 March 2020; incorporation to estimated depth of 10cm for speed tiller, 15cm for offset discs and 25cm for speed chisel.

Seasonal conditions

Conditions were very dry in 2019 and into early 2020. This dry period ended with increased rainfall from February/March onwards at both sites.

The Temora site received 63 mm in February, 97 mm in March, 97 mm in April leading up to the incorporation event on 15 May 2020. This high rainfall provided ideal incorporation conditions at the Temora site, and the above average rainfall continued for the majority of 2020, 2021 and 2022.

The Grenfell site received 34 mm in February and 82 mm in March in the lead up to the incorporation event on the 31 March 2020. This increased rainfall at the Grenfell site resulted in ideal incorporation conditions. This above average rainfall also continued for the majority of 2020, 2021 and 2022.

Results and discussion

Soil test results

The Temora and Grenfell sites received average to above average rainfall in their first three years (2020, 2021 and 2022). This rainfall would have benefited the reactivity and neutralisation rate of the lime applied. The trials have been cropped each year so the pH results shown are the combined effect of neutralisation from lime and any acidification from 2 years of production.

Site 1: Temora

By the 3rd year of the trial, lime application to achieve pH$_{\text{Ca}}$ 5 in the surface 10 cm significantly increased soil pH relative to the untreated control in the surface 5 cm only. The standard practice of targeting near pH$_{\text{Ca}}$ 5 is shown to be ineffective at increasing pH in the subsurface soil. Surface application of lime at rates targeting pH$_{\text{Ca}}$>5.5 resulted in significant pH increase to 10 cm.

The cultivation of the offset discs was measured down to a depth of approximately 10 cm at the time of lime incorporation. The year 3 soil results indicate that incorporation with offsets caused significant increase in pH, relative to the control, to a depth of 12.5 cm. The pH of the surface 0-2.5 cm layer was less than surface applied lime as more lime would have been mixed to lower depths by the action of the offset disc. The incorporation of lime applied to target pH$_{\text{Ca}}$ >5.5 significantly increased soil pH in the 5 to 12.5 cm layers relative to surface application of the same rate of lime. Incorporation provides head-start of the movement of the liming effect of applied lime.

Incorporation with two passes of the offset disc increased the effective depth of pH increase to 15 cm relative to the control but did not result in any differences in soil pH compared to a single pass in any layer. This is an important finding; effective incorporation in a single pass saves fuel, time and presumably provides less damage to soil structure than two passes.

Given that the profile did not have severe acidity and had relatively low proportions of exchangeable aluminium, surface application of lime targeting pH>5.5 would be an effective practice to proactively manage soil acidification in this soil. The head-start that incorporation provides is not vital to production if the soil does not have severe acidic subsurface layers present. That is, surface application with lime targeting pH$_{\text{Ca}}$>5.5 and adequate time may serve to stop acidic subsurface layers forming. However, it is imperative that the depth and severity of acidity is determined by soil testing pH and Al% in 5 cm intervals to a depth of 20 cm before determining the best strategy for proactive management of acidity.

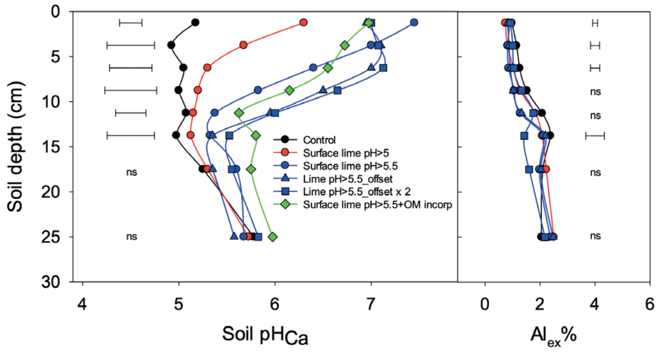


Figure 1. Soil pH$_{\text{Ca}}$ and exchangeable aluminium percentage (Al$_{\text{ex}}$%) from soil sampled in 2022 at the Temora field site following various liming strategies applied in 2020. Horizontal bars indicate least significant differences (lsd, p<0.05), ns indicates no significant difference between treatments.

It is important to note that this site was selected because it did not have a major soil acidity problem and the aim was to identify best practice preventative management strategies.

Results and discussion

Site 2: Grenfell

Three years after treatment application there was no significant difference in the soil pH profiles of treatments that did not receive lime, regardless of the type of cultivation conducted. Surface applied lime at a rate to achieve pH$_{\text{Ca}}$>5.5 significantly increased soil pH, relative to the control, however this effect was only significant in the surface 5 cm.

The incorporation of that rate of lime with any implement decreased the soil pH in the 0-2.5 cm layer compared to surface applied lime treatment due to mixing of lime to lower depths. There was no significant difference in the pH profiles created by lime incorporation with the speedtiller or offset disc. Both implements significantly increased pH and decreased Al% to a depth of 12.5 cm compared to the untreated control.

The speedchisel was as effective at increasing soil pH with lime as other implements to a depth of 7.5 cm. However, in the 7.5-10 cm layer, the unlimed treatment that was cultivated with the speedchisel had significantly increased pH in this layer compared to the control. It is possible that this was due to the extraction and mixing of clay from below 17.5 cm which has a higher soil pH. This also resulted in the unlimed speedchiseled plots having significantly lower percentages of exchangeable aluminium than the control.

This trial site showed the benefits of targeting pH>5.5 with lime rates higher than traditional application rates, in this case 7t lime/ha. The type of implement used to incorporate lime had minor influence on the depth or extent of amelioration with incorporation effectively doubling the depth of amelioration compared to surface applied lime.

This site has an acid throttle at about 5-20cm and this can be easily seen in the untreated control. While incorporating lime increased soil pH in the surface 12.5 cm after 2 years the acidic subsurface layer remains below that depth. Therefore the acid throttle remains to threaten production in suboptimal years (for example, with poor autumn breaks) or when acid sensitive plants are grown.

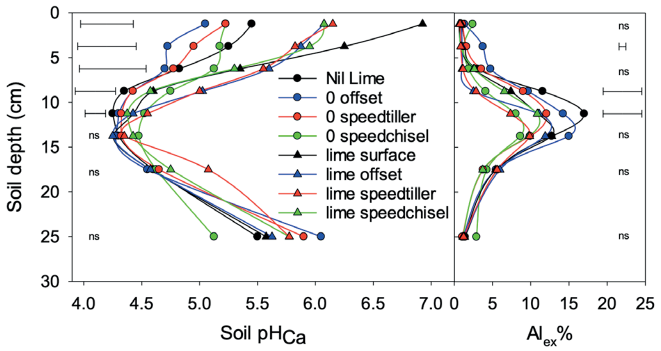


Figure 2. Soil pH$_{\text{Ca}}$ and exchangeable aluminium percentage (Al$_{\text{ex}}$%) from soil sampled in 2022 at the Grenfell field site following lime application (0 and 7 t/ha) with incorporation via different implements or surface application only in 2020. Horizontal bars indicate least significant differences (lsd, p<0.05), ns indicates no significant difference between treatments.

It was expected that the speedchisel would have been more effective at ameliorating deeper acidity than the speedtiller or offset disc due to the greater depth of tillage of the speedchisel (25 cm) compared to the speedtiller and offset (10cm). Whilst there is evidence of the speedchisel mixing soil from lower in the profile, the mixing effect of all implements in the surface 10cm appear similar. Soil mixing is a key attribute of any incorporation machine and not just the depth of tillage.

The Grenfell site demonstrates the benefit of applying lime to target pH$_{\text{Ca}}$>5.5 and incorporating that lime to gain a head-start in the amelioration of subsurface acidity. Even with incorporation, an acid throttle remains, although due to maintaining pH$_{\text{Ca}}$>5.5 the expected enhanced movement of the lime effect below the depth of incorporation will ameliorate the acid constraint in the next few years.

Summary

Preliminary soil test results indicate that across both sites and all treatments, targeting pH_{Ca} >5.5 results in greater depth of lime benefit and subsequent pH increase. When lime was incorporated, the magnitude of pH and Al_{ex}% change was accelerated to the depth of incorporation, or deeper. When lime was not incorporated the depth of lime effect increased with the rate of lime application, but even then, the greatest change in pH and Al_{ex}% was concentrated in the 0–5 cm surface layer.

Initial results indicate that:

- A target pH_{Ca} >5.5 in the 0–10 cm layers enhances amelioration of subsurface acidity
- Incorporation will increase the depth to which pH increases.
- There appears no benefit in multiple passes of incorporation machinery
- Effective soil/lime mixing is a key attribute when selecting tillage equipment rather than depth alone.
- Soil sampling in 5 cm intervals enables the depth and severity of acidity to be understood allowing targeted liming/incorporation strategies to be determined.

Average to above average rainfall at both sites following lime application aided lime reaction. The response to lime treatments in marginal years/seasons is yet to be investigated. Further monitoring of these sites is required to assess the role for more frequently applied, lower rates of lime in zero tillage systems, the residual value of lime and potential to prevent subsurface acidification through early intervention on marginally acidic sites.

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The contribution by participating landowners is greatly appreciated.

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