Addressing soil acidity: subsurface soil amendments increasing pH and crop yield at Rutherglen

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Key points

- Deep placement of soil ameliorants improved soil pH and decreased aluminium (Al) concentrations in the subsurface soil layer.
- The benefits of soil amendments to soil pH and aluminium concentration remain for future seasons.
- No yield improvement was recorded during 2018 due to low growing season rainfall (GSR) and frost events.

Introduction

Acidity of subsurface soil (below 10cm from the soil surface) is a major constraint to crop production in the high-rainfall (500–800mm) cropping zone. While acidic surface soil (0–10cm) can be easily and effectively addressed by incorporating lime at the soil surface, amelioration of the subsurface (below 10cm) soil has not been practical.

The current GRDC-funded project *Innovative approaches to managing subsoil acidity in the southern grain region* (DAN00206) aims to identify and evaluate a range of products, which may be used to overcome adverse effects of subsurface soil acidity. These products include alkaline materials, such as lime and dolomite, and novel products, such as magnesium silicate (which reacts to create alkali) or reactive phosphate rock (which can increase pH and release plant available phosphorus (P) as it dissolves in acidic soil).

Organic amendments, such as lucerne pellets, are known to increase soil pH either by being an alkali source or by enabling alkaline reactions to occur during the decomposition of organics. The influence of these products on the conditions of subsurface acidity (soil pH and toxic aluminium) and crop yield were investigated.

Aim

To quantify the yield limitation caused by subsoil acidity and evaluate innovative soil amendments that act to ameliorate subsurface acidity.

Method

A three-year, replicated field experiment was established at Rutherglen, Victoria, on a site located adjacent to the Rutherglen–Wahgunyah Road. The site has a history of more than 20 years of clover pasture, which was grazed and cut for hay. The absence of any lime applications to the site during this time, has resulted in highly acidic soil and high aluminium (Al) concentrations in both the surface (0–10cm) and subsurface soil (10–30cm) (Table 1).

Existing pasture was sprayed out and 14 amendment treatments were applied during March 2017 in a randomised block design with three replicates, with plots measuring 5m x 20m (Table 2). Canola was grown during 2017, wheat during 2018 and canola was sown again in 2019.

There were 14 treatments, including 11 deep amendment treatments to contrast with a nil control (no additions), lime control and surface lime treatments. Apart from the nil control, all other treatments received surface application of superfine lime (neutralising value = 98%) at 1.7t/ha to achieve a soil pH in the 0–10cm of pH 5.0 in order to ameliorate surface acidity. The surface lime treatment received a higher rate (2.7t/ha) of surface applied lime to achieve a target pH of 5.5 in the surface layer.

Deep amendment treatments included: lime, dolomite, magnesium silicate (MgSi), lucerne pellets, reactive phosphate rock (RPR) and liquid phosphorus (P). The deep amendments were placed approximately 10–30cm deep in the profile at a 50cm row spacing using the 3D Ripper machine engineered by NSW DPI. A deep-ripped control, which had surface lime (pH 5.0) but was deep ripped with no amendment added (deep ripping only), was included to contrast the deep amendment treatments. Deep amendments were applied at rates to achieve a target pH 5.0 based on short-term laboratory incubation studies conducted at Charles Sturt University. Amendments

TABLE 1 Initial pH and exchangeable aluminium (Al) percentage* of the Rutherglen field trial, January 2017

Soil depth (cm)	Soil pH ($CaCl_2$)	Al%
0–10	4.55	12
10–20	4.22	30
20–30	4.32	10
30–40	5.05	3

* Exchangeable aluminium percentage is determined as the percentage of the measured cation exchange capacity (CEC), which is comprised of aluminium. A value greater than 6% generally indicates aluminium to be likely to cause plant phytotoxicity.



TABLE 2 Surface and deep amendment treatments applied to the Rutherglen, Victoria trial site during 2017

Treatment	Surface lime application rate (t/ha)	Target surface pH ($CaCl_2$)	Deep amendment (placed about 10–30cm deep)	Deep amendment application rate (t/ha)
Nil control	0	-	n/a	n/a
Limed control	1.7	5.0	n/a	n/a
Surface lime	2.7	5.5	n/a	n/a
Deep ripping only	1.7	5.0	Deep ripping only	n/a
Deep lime	1.7	5.0	Lime	2.5
Deep dolomite	1.7	5.0	Dolomite	2.3
Deep MgSi (low)	1.7	5.0	Magnesium silicate	4
Deep MgSi (high)	1.7	5.0	Magnesium silicate	8
Deep lucerne (low)	1.7	5.0	Lucerne pellets	7.5
Deep lucerne (high)	1.7	5.0	Lucerne pellets	15
Deep RPR (low)	1.7	5.0	Reactive phosphate rock	4
Deep RPR (high)	1.7	5.0	Reactive phosphate rock	8
Deep P	1.7	5.0	Liquid phosphorus	15kg P/ha
Deep P + deep lime	1.7	5.0	Liquid phosphorus + lime	15kg P/ha + 2.5t/ha Lime

applied at two rates (MgSi, RPR and lucerne pellets) were labelled high and low, for the targeted pH 5.0 rate and half that rate, respectively.

Lancer wheat was sown on 14 May 2018 at 80kg/ha, with 75kg DAP/ha placed with the seed using an air seeder on a 25cm row spacing. Urea was top-dressed at 50kg N/ha to all plots on 25 July 2018. Crop growth was monitored through the season and standard agronomic metrics (establishment counts, biomass, tiller numbers) were recorded (data not presented).

The site was harvested on 7 December 2018 using a plot harvester. Yield data were statistically analysed using ANOVA and a Student-Newman-Keuls test to determine treatment differences.

The soil from each plot was sampled after harvest by taking two 44mm diameter cores on the rip-line and two cores between rip lines to a depth of 140cm. Core samples were divided into depth increments of 0–10, 10–20, 20–30, 30–40, 40–60, 60–80, 80–100, 100–120, 120–140cm with depth increments from duplicate cores bulked to produce representative soil samples for each sampling depth, on and off the rip-line.

Each soil sample was air-dried and analysed for soil water content, soil pH ($CaCl_2$), and other chemical properties, such as mineral nitrogen (N), aluminium, and available phosphorus.

Results

The experimental site received 170mm rainfall during the growing season (long-term average rainfall during that period is 400mm) and the site experienced 16 nights of negative temperatures.

Following harvest during December 2018, the soil pH in the surface (0–10cm) soil ranged pH 4.6 to 5.4 (Figure 1) as a result of the surface lime application during 2017. In the 10–20cm layer, large increases in soil pH were recorded, relative to the control, in the lime and dolomite treatments resulting in soil pH of approximately 6. All other treatments containing liming agents resulted in soil pH of approximately 5 in that layer. Changes in pH below 20cm were not significantly different between treatments. The exchangeable aluminium percentage for most treatments receiving liming agents was less than 5% of effective cation exchange capacity (ECEC) (Figure 1). Aluminium toxicity would have had the potential to limit yield in the nil control, deep ripping only, and surface lime only treatments as their 10–20cm layers exhibited an aluminium percentage greater than 15%.

However, there were no significant differences between treatments for any plant production measures taken during the experiment in 2018 (Table 3). A combination of drought and frost appeared to be the greatest limitation to plant growth in that year.

Observations and comments

Treatment differences were observed visually during the first four weeks of growth. The nil control and surface lime treatments only had small, spindly growth, while deep amended treatments appeared healthier. However, due to the harsh conditions experienced during the growing season, the early visual symptoms did not carry through to result in significant differences between treatments at harvest. Despite the poor agronomic result achieved during 2018, data from soil sampling indicated that, in general, liming agents applied at the start of the 2017

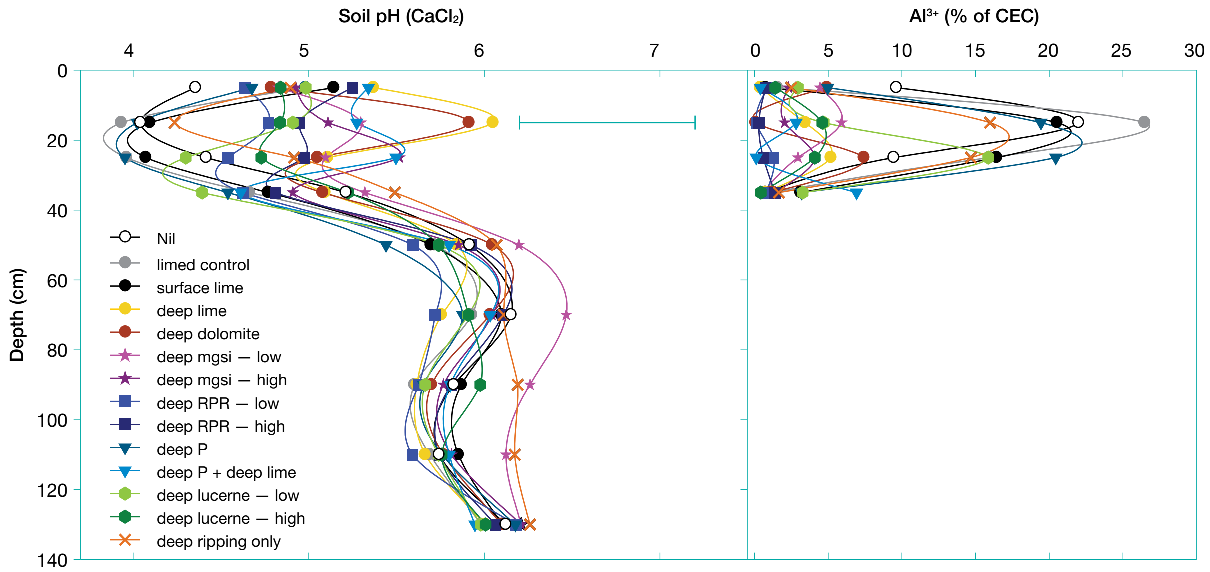

FIGURE 1 Profile soil pH ($CaCl_2$) and exchangeable aluminium percentage (% of ECEC) of amendment treatments at Rutherglen site measured after wheat harvest, December 2018

Data are means of three replicates of each treatment. Bar represents LSD for pH data at P=0.05 at the only depth increment where significant differences occurred (10–20cm)

TABLE 3 Establishment counts, flowering head counts, flowering and harvest biomass and grain yield of Lancer wheat, 2018

Treatment	Establishment (plants/m²)	Head counts at flowering (heads/m²)	Biomass at flowering (t/ha)	Biomass at harvest (t/ha)	Grain yield (t/ha)
Nil control	154 (6.5)	343 (25.7)	5.0 (0.6)	5.2 (0.7)	1.5 (0.4)
Limed control	139 (4.2)	321 (7.3)	4.5 (0.0)	4.5 (0.2)	1.2 (0.2)
Surface lime	157 (2.1)	341 (12.5)	5.0 (0.2)	5.1 (0.4)	1.4 (0.4)
Deep ripping only	140 (5.4)	332 (23.3)	5.2 (0.2)	5.3 (0.1)	1.4 (0.1)
Deep lime	141 (1.4)	334 (27.1)	5.5 (0.4)	5.5 (0.7)	1.5 (0.7)
Deep dolomite	154 (4.8)	379 (25.4)	6.2 (0.4)	6.4 (0.2)	2.1 (0.2)
Deep MgSi (low)	147 (3.5)	349 (23.9)	5.6 (0.6)	5.9 (0.6)	1.7 (0.3)
Deep MgSi (high)	143 (4.3)	350 (25.1)	5.3 (0.4)	5.9 (0)	1.7 (0.2)
Deep lucerne (low)	136 (0.4)	344 (5.0)	5.2 (0.0)	5.1 (0)	1.4 (0.2)
Deep lucerne (high)	151 (7.3)	341 (72.5)	6.3 (0.7)	5.9 (1)	1.3 (0.6)
Deep RPR (low)	139 (2.7)	342 (29.4)	5.4 (0.5)	6.1 (0.9)	1.7 (0.2)
Deep RPR (high)	139 (4.4)	370 (14.8)	5.5 (0.5)	5.4 (0.5)	1.4 (0.2)
Deep P	134 (5.5)	340 (31.6)	5.1 (0.5)	4.6 (0.5)	1.2 (0.4)
Deep P + deep lime	143 (5.8)	326 (20.7)	5.0 (0.4)	5.4 (0.2)	1.5 (0.0)

Note: There was no significant difference between treatments and values in parentheses are standard error of means.

season still maintained positive effects on soil pH and exchangeable aluminium concentrations when measured during December 2018. This should act to improve plant growth if better seasonal conditions are experienced in future years. This also indicates the potential benefit from amendments spans more than the year of application, reducing the risk of loss of investment from inputs applied to the field.

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