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

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Key points

- Surface soil acidity (0–10cm) limited crop yield by about 8–12%.

- Deep placement of reactive phosphate rock or organic matter (OM) achieved yield gains of up to 18% compared with surface-applied lime.

- Deep placement of OM may induce manganese (Mn) toxicity.

- The interaction between subsurface pH increase and nutrient release needs further investigation.

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 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 trial 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).

The treatments include a *nil control* (no additions) while 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. An additional treatment received a higher rate (2.7t/ha) of surface applied lime to achieve a target pH of 5.5 in the surface layer (*surface lime*).

Deep amendment treatments included: lime, dolomite, magnesium silicate (MgSi), lucerne pellets, reactive phosphate rock (RPR) and liquid phosphorus. The deep amendments were placed approximately 15–30cm 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

TABLE 1 Initial pH and exchangeable aluminium 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, 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 15–30cm 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	15 kg P/ha
Deep P + deep lime	1.7	5.0	Liquid phosphorus + lime	15 kg P/ha + 2.5t/ha lime

amendments were applied at rates to achieve a target pH 5.0 based on short-term laboratory incubation studies conducted at Charles Sturt University (CSU). Amendments 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.

Canola (Hyola 559 TT) was sown on 3 May 2017 at 3kg/ha, with 75kg MAP/ha placed with the seed using a cone seeder on a 25cm row spacing. Crop growth was monitored through the season and standard agronomic metrics (establishment counts, biomass, crop height, podding height) were recorded (data not presented).

The site was harvested on 22 November 2017 using a plot harvester. Yield data were statistically analysed using ANOVA and a Student-Newman-Keuls test to determine treatment differences. The mean yield data are graphically represented here using least significant difference (LSD) for simplicity, as results for statistical analyses were analogous.

The soil from each plot was sampled after harvest by taking two 50mm 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 analysed for soil water content and soil pH (CaCl$_2$). Air-dried soil subsamples have been stored for future analysis of other chemical properties, such as mineral nitrogen (N), aluminium, and available phosphorus.

Results

The application of lime to the surface (0–10cm) soil increased soil pH (Figure 1) compared with the untreated control (nil). However it can be seen that where only surface application of amendments occurred (limed control, surface lime, deep ripping only) the soil pH in the subsurface remained unchanged and acidic conditions persisted at depth.
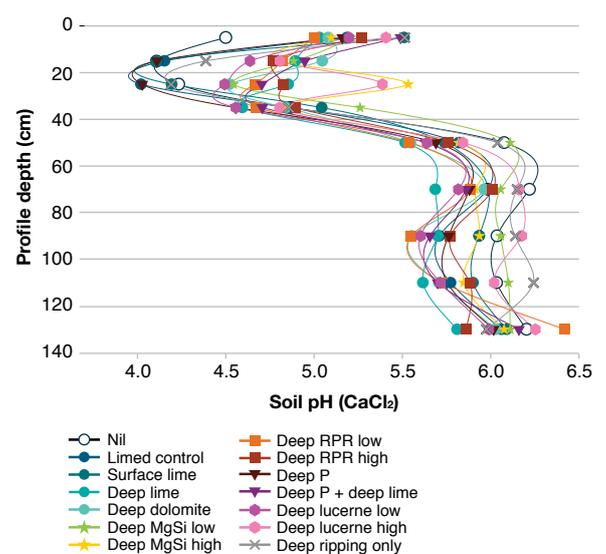

FIGURE 1 Profile soil pH (CaCl$_2$) measured post canola harvest (November 2017) of amendment treatments at Rutherglen site
Data are means of three replicates

All deep (15–30cm) amendments increased the pH of the soil at the depth of placement with the exception of the ripping only and deep phosphorus treatments, which had no alkali-producing material added.

Large increases in soil pH of the amended layer were recorded for the high rates of MgSi and lucerne pellets. The soil pH below the depth of placement was unchanged by treatments and exhibited considerable variation consistent with field sampling of subsoils.

Liming the surface (0–10cm) soil increased grain yield (Figure 2) compared with the untreated control (nil) indicating that unchecked acidity was limiting yield. However, the deep placement of amendments did not increase yield over the limed control, with the exception of the low and high RPR and high lucerne pellet treatments, which returned yield gains of about 0.5t/ha higher than the limed control.

The incorporation of lucerne pellets appeared to induce manganese toxicity during the growing season however the effect of this on yield was not able to be determined in this experiment.

Observations and comments

Deep placement of organic matter, such as lucerne pellets, may induce manganese toxicity due to enhanced oxygen consumption by microorganisms and poor aeration at depth. The increase in yield with RPR and lucerne pellets may be due to both a pH increase and improved nutrition at depth. Therefore, the interaction of these factors needs to be investigated for growers to realise efficiency gains by applying amendments at depth. A cereal crop will be sown in the experiment in 2018.

Visual symptoms of manganese toxicity in canola plots (14 August 2017) treated with deep-placed lucerne pellets. The symptoms appear on the ripping row.
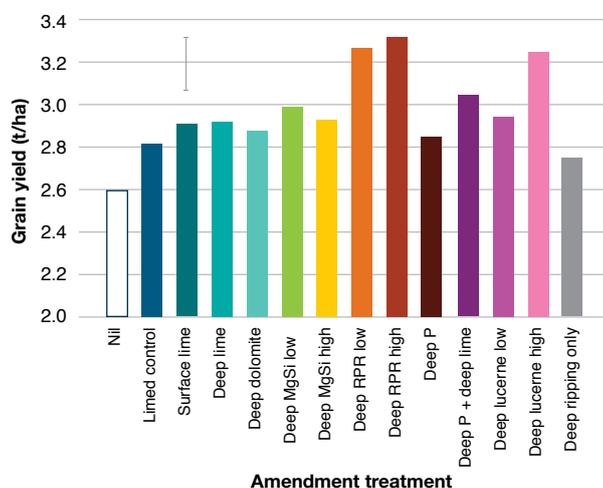*Photo: Dr Sergio Moroni*

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FIGURE 2 Yield of canola for amendment treatments at Rutherglen
Data are treatment means of three replicates.
Error bars indicate LSD (p=0.05).