Liming to address subsurface acidity at Koppio

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PIRSA

RESEARCH

Location
Koppio - Karen, Tyler, Logan & Mitchell Dennis
Rainfall
Av. Annual: 480 mm
Av. GSR: 360 mm (Apr-Oct)
2018 Total: 295 mm
2018 GSR: 247 mm
Yield
Potential: 2.1 t/ha (C) (PIRSA crop monitoring guide 2006)
Actual: 1.2 t/ha
Paddock History
2017: Wheat
2016: Canola
2015: Barley
Soil Type
Shallow ironstone loamy sandy loam on clay: sandy loam A1 to 10 cm, overlying a coarse sandy bleached A2 to between 20 and 30 cm on top of poorly structured yellow/orange clay. Ironstone gravel over 50% abundance in the A2.
Soil Test
Table 2
Plot Size
18 m x 4 m 4 reps
Trial Design
Experimental: complete randomised block.
Yield Limiting Factors
Decile 2/3 GSR in 2018, acidic surface and subsurface layers, high extractable aluminium levels, waterlogging.

Key messages

- **Yield penalty from the sulphur treatment might provide a warning as to the potential impact of further acidification on yield on lower Eyre Peninsula soils.**
- **Yield benefit from application of lime is proving elusive on EP trial sites. Possible reasons for this might be use of varieties with some acidity tolerance in farmer scale trials and it takes some time for neutralisation reaction to take effect.**
- **There are some increased production trends from the ripping treatments (with and without ameliorants), which might suggest compaction as a key constraint on the site.**

Why do the trial?

There are around 186,000 ha (7%) of Eyre Peninsula's agricultural land which has surface soil acidity (0-10 cm depth). A further 500,000 ha (19%) are considered at risk of becoming acidic over the next 10 to 50 years if not treated (Forward and Hughes 2019).

Natural soil acidification rates are accelerated by the growing and removal of agricultural products. Acidification rates are higher in high production systems on low buffering (sandy) soils, particularly in high rainfall areas where nitrate leaching is high. Increased use of nitrogen fertiliser and higher yielding crops have increased the rate of acidification. If not treated by applying liming products, soil acidity can result in:

- Loss of production, particularly for acid-sensitive crop species and varieties. The estimated value of lost agricultural production in the EP region due to acid soils is between \$16 m and \$19 m per year, with most of this (more than 95%) estimated to result from lost crop production (Forward and Hughes 2019).
- Increased leaching of iron, aluminium and other nutrients from the soil, potentially contaminating surface and ground water.
- Reduced soil biological activity resulting in reduced crop fertiliser use efficiency and increased soil acidification.
- Reduced uptake of soil water that can lead to rising water tables and increased soil salinity.

In addition, if surface soil acidity is not treated by applying adequate amounts of lime, it will result in the progressive acidification of subsurface and subsoil layers (pH stratification), which is much more difficult and costly to treat. Around 4% of EP agricultural land is considered to have acidic subsurface layers.

It is estimated that around 21,000 tonnes of lime per year is required to be applied on acid prone soils in EP to balance the annual acidification resulting from agricultural production. An additional 223,000 tonnes of lime is needed to raise the pH of currently acidic soils above the target pH values (5.5 $CaCl_2$ for surface, 5.0 $CaCl_2$ subsurface), which includes approximately 213,000 tonnes of lime for acidic topsoils and about 9,000 tonnes of lime for acidic subsurface soils (10-20 cm depth) (Forward and Hughes 2019).

This trial (funded by GRDC project DAW00252 'Innovative approaches to managing subsoil acidity in the Western Region') aims to measure crop responses from ameliorating acidity in subsurface soil layers by surface application and deep placement of soil conditioners including lime and organic matter.

How was it done?

The trial was established in 2017 on a gently sloping ironstone sandy loam site at Koppio on lower Eyre Peninsula. The trial comprises 11 treatments x 4 replicates consisting of an unmodified control (managed as district practice), a number of surface lime application rates, surface applied sulphur, deep ripping, surface applied lime with ripping and subsurface lime applications, ripping with subsurface lime and organic matter applications (Table 1). Treatments were applied in 2017 only.

Surface rates of lime were based on the standard district application 2.5 t/ha (which is around the average maintenance rate required for 10 years acidification due to agricultural production given current farming practices and average rainfall, and the rate to change pH by 1 unit on this soil type). Double and triple rates were used to see if they provided a faster/larger pH and crop response and whether they moved deeper into the soil. The subsurface application rate was lower than the surface rate required to increase pH, due to the low buffering capacity of the bleached A2 horizon. The sulphur treatment was applied to provide an indicator of the negative impacts on crop production should the site further acidify.

The trial was sown and managed by the landholder as per the rest of the paddock and was sown with Corack wheat in 2017 and Bonito canola in 2018.

Ripping treatments were applied using a Yeoman's Keyline plough in March 2017 and ripping was undertaken at a depth of between 15 to 20 cm below the soil surface to ensure that the acidic subsurface layer (bleached A2) was ripped into and ameliorants were placed into this layer without bringing up any of the neutral B horizon material. Surface lime and sulphur treatments were spread on the plots by hand. Soil samples were taken to measure the pH on the control plots at the commencement of the trial (Table 2).

Plant emergence counts were taken on all plots 3 to 4 weeks after seeding in both years and dry matter cuts were taken as a measure of peak biomass at flowering. These measurements were taken from either side of a 50 cm ruler at four locations per plot and extrapolated to plant density (plants/m^2) and dry matter (t/ha) respectively. The trial was harvested using the SARDI small plot harvester in both 2017 and 2018 and plot yields extrapolated to t/ha.

What happened?

2017 results

An extremely dry start with opening rains not coming until the last week of June 2017 meant that the paddock was not sown until 4 July 2017. Plant density was variable, particularly on the ripped treatments which had significantly lower plant numbers than the unripped treatments (Figure 1). Plant numbers were also signficantly lower on the treatment where 8 t/ha lime was applied compared to the control and other surface liming treatments.

Plant tissue tests (YEBS) were taken at mid to late tillering in early September 2017. Only the first replicate was sampled so statistical analysis was unable to be undertaken and the results provide a guide only.

Major nutrients

All treatments had plant tissue nitrogen, potassium, sulphur and phosphorus levels above the desired minimum value for wheat. There was little difference in the nitrogen or potassium status between treatments. However, plant tissue phosphorus was lower than the control in most treatments which had lime applied, except when applied in the subsurface in conjunction with deep placed organic matter. Ripped treatments had generally higher sulphur than the control and surface lime treatments (Masters 2018).

Table 1 List of treatments applied in 2017

1.	Nil Control	7.	Surface lime (5 t/ha) + rip+ subsurface lime (2 t/ha)
2.	Surface Lime (2.5 t/ha)	8.	Surface lime (5 t/ha)
3.	Sulphur (elemental S 1 t/ha)	9.	Surface lime (8 t/ha)
4.	Rip	10.	Rip + deep organic matter (10 t/ha pelletised straw)
5.	Rip + subsurface lime (2 t/ha)	11.	Rip + deep organic matter (10 t/ha pelletised straw) + subsurface lime (2 t/ha)
6.	Surface lime (2.5 t/ha) + rip +lime (2 t/ha)		

Table 2 pH of surface and subsurface layers on control plot

Plot #	Surface soil $pH_{(CaCl2)}$	Subsurface $pH_{(CaCl2)}$	Extractable Al (mg/kg)	Extractable Al (mg/kg)
	0-10 cm	10-20 cm	0-10 cm	10-20 cm
8	4.4	4.5	2.79	2.95
17	4.2	4.3	4.58	3.16
27	4.7	4.6	1.24	1.63
36	4.6	4.5	2.14	2.29

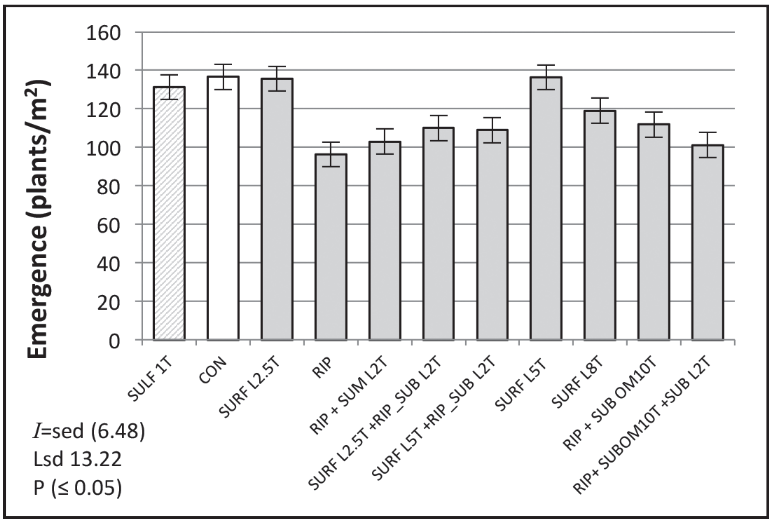

Figure 1 Plant densities (plants/m²) at crop emergence, August 2017

Minor nutrients

Whilst there was little difference in copper and manganese levels in plant tissue between treatments, there appeared to be a general trend of lower iron and zinc levels in the treatments with surface applied lime compared to the control and ripped treatments.

Exchangeable cations

Plant tissue analysis showed a general trend of higher calcium and magnesium % in ripped treatments compared to the control.

Spring biomass

Dry matter cuts were taken on 12 October 2017 at flowering (estimated to be at peak biomass). Dry weights were extrapolated to biomass (t/ha) (Figure 2). Despite lower plant numbers at crop emergence on the ripped treatments compared to the unripped treatments, this did not result in lower spring biomass production, and the only treatment where significant differences in dry matter were observed were in those where organic matter was placed at depth by the ripper.

Grain yield 2017

The site was harvested on 14 December 2017 using the SARDI small plot harvester. A single harvest run (1.5 m wide) was taken along the length of each plot with results extrapolated to grain yield (t/ha). Ripped treatments yielded higher than the control, with rip + subsurface organic matter applications yielding higher than ripping by itself or ripping with subsurface lime applications. Surface lime at 5 t/ha yield had significantly poorer yields than the control.

2018 results

Conditions were again dry during autumn in 2018, with the paddock sown to Bonito canola on 5 May 2018 following rain. Plant emergence counts were undertaken around 4 weeks after seeding. Emergence counts were highly variable with large standard errors, and whilst there were a few treatments that seemed to have higher plant numbers, these were not significantly different to the control and did not show any particular treatment trends (Figure 4).

Despite biomass cuts undertaken at flowering appearing to show a slight trend toward increased dry matter production on the ripped treatments compared to the unripped, these differences were not significant (Figure 5). Large standard errors show the high variability of biomass production in canola.

Grain yield 2018

Despite large variations in crop biomass production there were only small differences between in grain yield between plots at harvest. The only crop yield response which was significantly different to the control was reduced grain yield on the sulphur treatment (Figure 6).

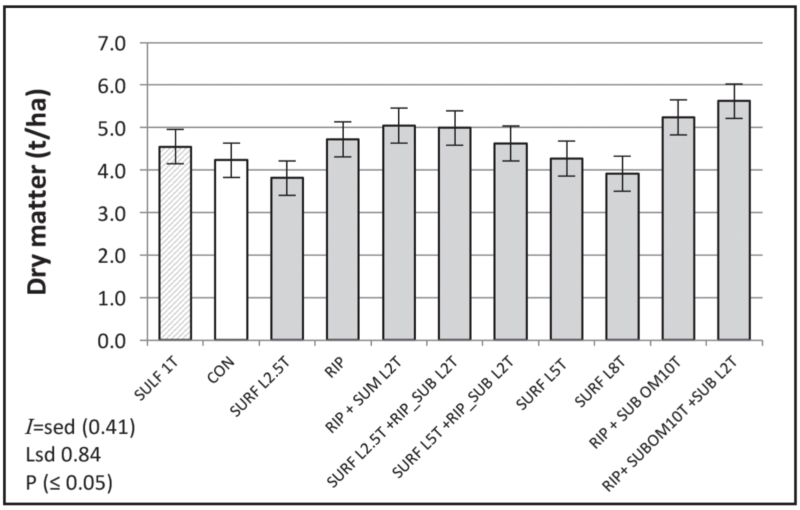

Figure 2 Dry matter (t/ha) at Dennis' site in spring 2017

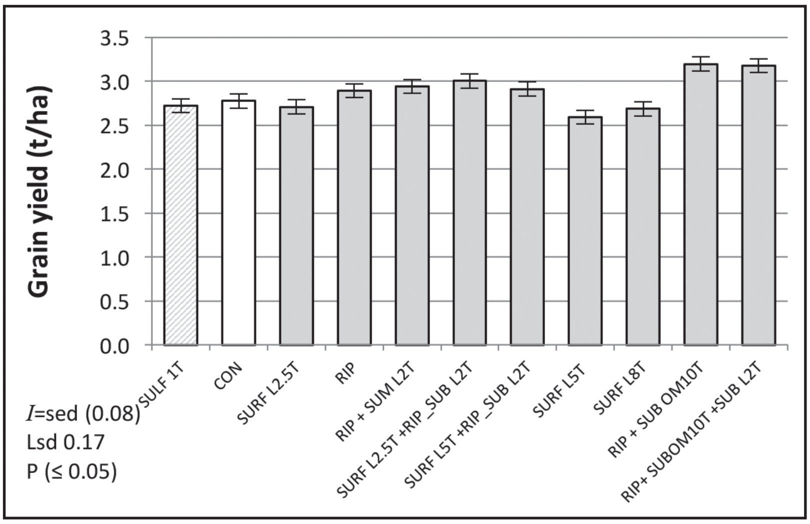

Figure 3 Wheat yield (t/ha) in 2017

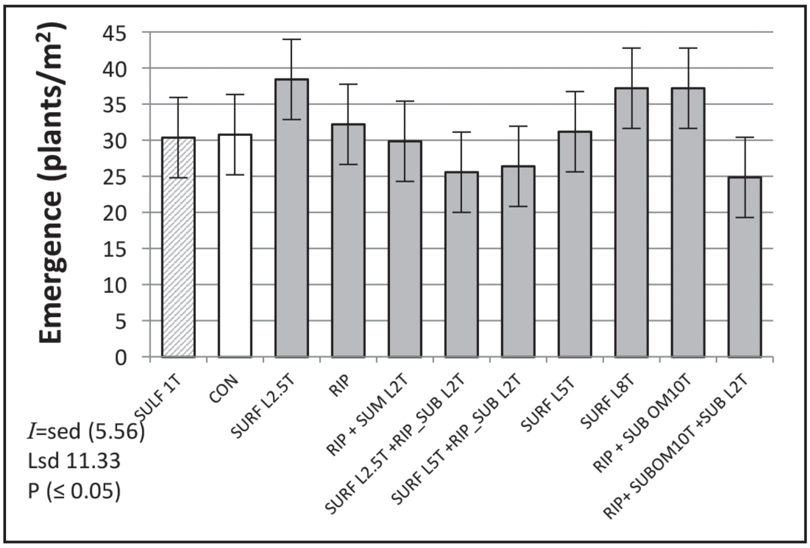

Figure 4 Plant density (plants/m²) at germination, 2018

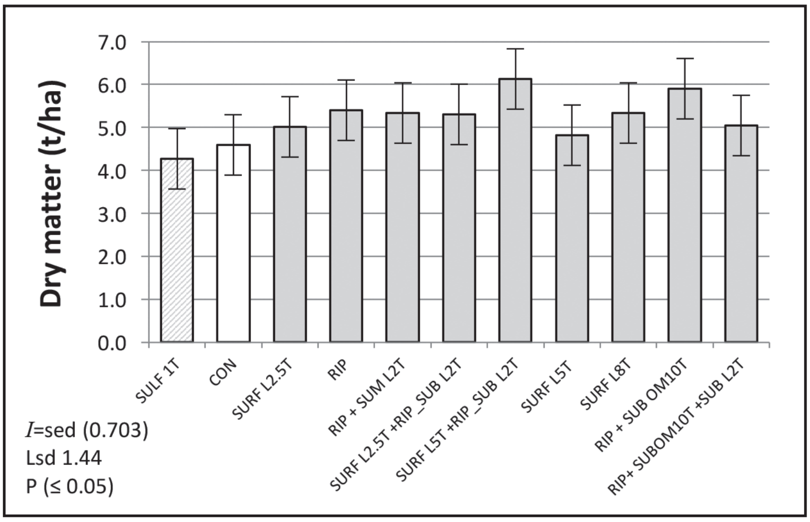

Figure 5 Dry matter (t/ha) at flowering, 2018

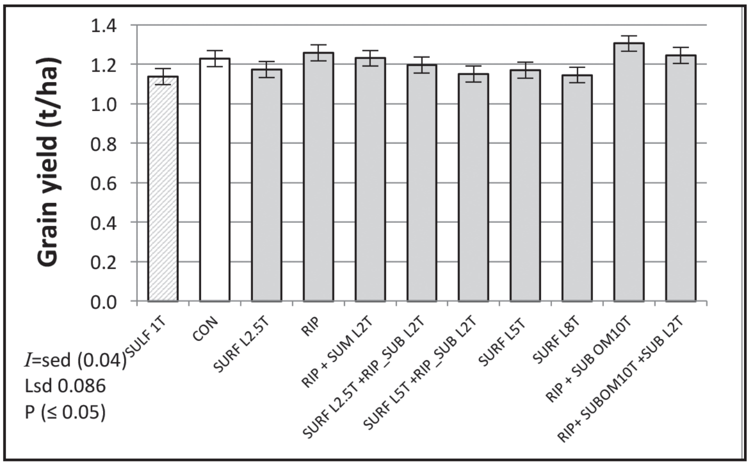

Figure 6 Grain yield (t/ha) in 2018

What does this mean?

Responses to lime treatments were not expected in the first year given that it often takes 12 months or more for the lime to neutralise the acidity. In addition the use of Corack wheat was unlikely to have shown large growth responses as it is a variety that has some tolerance to soil acidity. Similarly, the limited response of canola to the limed treatments in 2018 might have resulted from canola having some tolerance to acidity, with work from NSW (Helen Burns, pers comm November 2018) suggesting that canola roots can growth through acidic soil layers provided that this layer is not greater than 20 cm thick.

In 2017 the ripping treatments had lower plant numbers at crop establishment. This likely due to the severe disturbance of the surface soil by ripping leaving an uneven surface for seeding and crop germination. The large variation in crop emergence across the site in 2018 might have resulted from impact of very dry soil moisture conditions at crop germination on a small seed like canola.

The plant tissue results in 2017 showed some expected trends with lower phosphorus, zinc and iron uptake by plants on those treatments where lime was applied, possibly due to tie up of these nutrients by the lime.

Despite lower plant numbers on the ripped plots at crop establishment compared to unripped plots, this did not affect spring biomass production with only the deep ripped + organic matter treatments having significantly higher biomass. The ripped treatments yielded better than the unripped treatment which is perhaps due to improved crop root development due to ripping through layers of high soil strength and low fertility. It might be useful to undertake some assessment of soil strength on the different treatments to help explain these responses. Placing organic matter at depth gave an increased yield benefit over ripping alone suggesting possible fertility or soil biological activity benefits from the organic matter.

In 2018, although the biomass assessment suggested that there was better dry matter production on ripped treatments compared to unripped, these results were not significant, perhaps pointing to the capacity of canola to cope with some soil acidity under particular conditions. These trends did not carry through to harvest and it is suggested that the penalty compared to the control on the sulphur treatment highlights the impact of further acidification on crop growth.

The trial needs to be monitored to over several years to identify potential;

- further yield declines on the sulphur treatments,
- yield increases when lime treatments become effective,
- impact of ripped treatments once the effect of the initial ripping has settled down,
- pH amelioration down the profile with and without ripping, and
- lasting effect of subsurface organic matter treatments.

Soil sampling will be undertaken in 2019 to measure changes to soil pH. The trial will continue to be monitored in 2019 to assess the impact of the treatments on crop yield.

Acknowledgements

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