Better identification and management of subsurface acidity on sandy soils of the Northern Yorke Peninsula

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Key messages

- Incorporation method (deep ripping or spading) reduced plant establishment in both barley (2022) and lentil (2023) as a result of soft and uneven seedbed conditions. However, later in the season NDVI showed the crop had recovered with values similar or higher compared to the control.
- The application of lime in 2022 increased NDVI in all incorporation treatments by an average of 10% on 1st September in the following season lentils.
- In both seasons grain yields were increased by an average of 0.7 t/ha in barley and 1.03 t/ha in lentil from spading and deep ripping. However, this was not influenced by the incorporation of 10.7 t/ha Kulpara lime.
- Soil sampling one year after the trial was established generally showed lime with and without incorporation increased group E/F rhizobia levels compared to the control.
- Long-term monitoring is required to understand the movement and benefit of lime incorporation at depth.

Why do the trial?

The aim of this project is to improve the capacity of growers to identify and manage subsurface acidity on the Northern Yorke Peninsula. Soil testing and pH mapping for acidity has become common practice in the district. However, this sampling and mapping has focused on the top 0-10 cm of soil. Recent reports and preliminary work have confirmed an acidic band of soil is often occurring at the 5-15 cm depth and beyond in certain soil types.

There are two main components to this project:

1) Spatially identifying subsurface acidity by validating the relationship between soil pH and EC (electrical conductivity).
2) Develop best management practices for lime amelioration to manage subsurface acidity.

How was it done?

Site selection and soil sampling

The trial site was located in a paddock near Bute, SA. The paddock was mapped using the Veris MSP3 on-the-go soil mapper in March 2021. The mapped Veris soil pH and EC values were used to predict subsoil pH (0-30 cm) (Figure 1). This prediction for subsoil pH has been based on a large data set of local soils (Trengove et al. 2021).

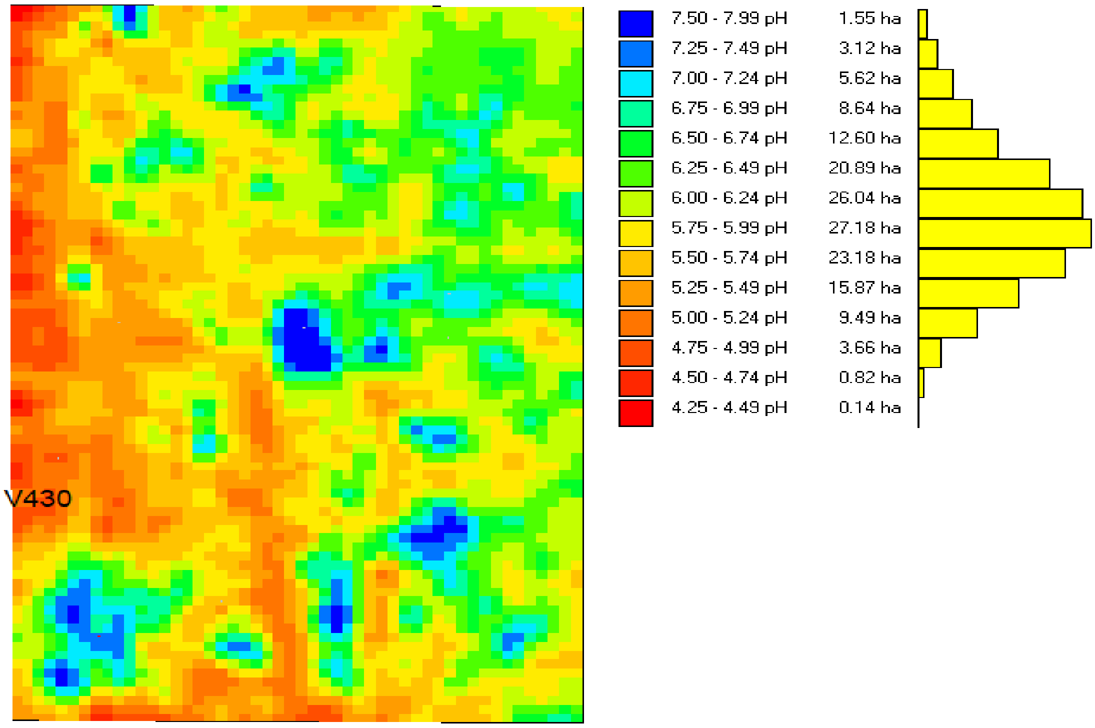

Figure 1. Interpolated paddock map showing 0 - 30 cm pH $CaCl_2$ and soil sampling location for segmented core 0-30 cm.

A segmented soil core from the Bute paddock (Figure 1) was analysed for pH and soil texture which was used to calibrate the Veris data (Table 1). The trial site was a sandy loam profile with soil acidity in the surface and subsurface. The lowest pH values (3.9-4.0) were present in the 5-15 cm soil layers. Both the paddock map and lab results confirmed the presence of a highly acidic subsurface layer.

Table 1. Segmented soil test results for pH $CaCl_2$ and MIR soil texture for sample site V430.

Depth	pH $CaCl_2$	Soil texture
0-5 cm	4.4	Sand
5-10 cm	3.9	Loamy sand
10-15 cm	4.0	Loamy sand
15-20 cm	4.5	Sandy loam
20-25 cm	5.2	Sandy loam
25-30 cm	5.7	Sandy loam

Trial design and treatments

The trial was a split-plot design with whole plots as incorporation method, subplots as lime rate and four replicates. The trial was sown using a commercial seeder and resulting plot size was 3 m x 12 m.

Lime was sourced from Kulpara Quarry with a 78% effective neutralising value. A lime application rate was calculated based on treating the average 0-30 cm layer pH (4.6) and raising this to a target pH of 6. Limes rates of nil or 10.7 t/ha were used to treat the 0-30 cm layer.

Lime incorporation methods included deep ripping with inclusion plates and spading. The deep ripping treatments were working to a depth of 45 cm, the inclusion plates were aiming to improve topsoil inclusion into the 10-20 cm layer (Photo 1) and spading was to a depth of 30 cm. The lime spreading, deep ripping and spading were completed in April-May 2022.

The trial was sown to barley (2022) followed by lentils (2023) by the grower with a broadacre air-seeder in 2023.

Photo 1. Soil pit face of a plot deep ripped with inclusion plates to incorporate lime. Acid test indicator has been sprayed on the surface and purple colours show the level of lime incorporation. The yellow and red colours show slightly acidic to acidic soil that has not been affected by the application of lime. Photo taken April 2022.

Soil and crop assessments

In 2022 plant establishment was scored for each plot on the 29th July, ranged from 0 (no plant emergence) – 10 (full plant emergence). All plots were assessed for barley grain yield (t/ha) using a plot harvester on 29th November 2022. Grain quality assessments included retention (%), test weight (kg/hL), screenings (%) and protein (%).

Prior to seeding in 2023 the treatments were soil sampled (0-10 cm) for Predicta rNod testing. Crop establishment was assessed on the 11th July. In-season GreenSeeker NDVI was recorded on the 28th of July and 1st of September. Plots were hand harvested and threshed through a plot harvester for lentil grain yield.

Results and discussion

First season - barley 2022

Plant establishment was reduced by incorporation treatment (Table 2). On average the highest establishment score was in the nil (86%), compared with deep ripping (63%) and spading (45%). Achieving good establishment after incorporation can be challenging depending on the resulting soil surface conditions. Generally, where crop establishment is poor in spaded and deep ripped soils, it is a result of seed placed too deep in the soft soil.

The addition of 10.7 t/ha lime (ENV 78%) had no effect on plant establishment or barley grain yield in year one for either incorporation method (Table 2). A lack of crop response is not uncommon from lime application in year one. Lime gradually moves through the soil with rainfall, but this can take many years. However, in this trial it is expected the effects of the lime application plus incorporation at depth will be measured faster compared to surface applied. Long-term monitoring of this site will be required to understand the benefit of lime incorporation at depth.

Barley grain yield was improved as a result of deep ripping or spading averaging 5.2 and 5.5 t/ha, respectively (Table 2). The nil had the lowest grain yield of 4.7 t/ha. Deep ripping and spading have been shown to alleviate high soil strength or compaction on sandy soils resulting in significant yield gains through improved access to soil moisture. Previous research has also reported yield responses in soils with low nutrient levels in the subsoil and/or constrained by a layer of subsoil acidity. Placing topsoil containing nutrients and organic matter at depth through spading or deep ripping with inclusion plates can supply nutrients to the crop that can be taken up from the moist subsoil.

Table 2. Plant establishment (%), grain yield and grain quality averaged for all lime rates in the subsoil acidity trial at Bute, 2022.

Treatment	**Establishment score**	**Grain yield (t/ha)**	**Test weight (kg/hL)**	**Retention (%)**	**Protein (%)**	**Screenings (%)**
Nil	86 a	4.7 a	63.4	93.9	11.0	1.9
Ripping	63 b	5.2 b	63.8	93.6	11.3	2.4
Spading	45 c	5.5 b	63.8	94.6	11.5	1.9
LSD ($P \leq 0.05$)	12	0.48	ns	ns	ns	ns

Grain quality was not affected by the addition of lime or incorporation treatment (Table 2). Commodus CL barley is currently pending malting accreditation. In 2022, grain quality results from this trial met BAR 1 receival standards with an average test weight of 63.7 kg/hL (>62.5%) and low screenings averaging 2.1%

Second season – lentil 2023

Assessment of rhizobia levels one year after incorporation and lime treatments were imposed, showed there was an increase in group E/F rhizobia numbers (Table 3). Only three treatments sampled contained rhizobia numbers sufficient for lentil nodulation. Generally, 100 – 1,000 rhizobia /g soil are required for adequate nodulation of the target crop species.

The surface applied lime with no incorporation increased rhizobia levels (1031 rhizobia/g soil) compared to the untreated control (18 rhizobia /g soil). Despite nil incorporation of lime, this treatment was as effective as ripping with lime and spading with and without lime. The incorporation of lime is less likely to affect rhizobia number as they are concentrated in the top 0-10 cm of soil (sampling depth for Predicta rNod). The results for spading without lime treatment were surprising given no alkaline material has been added to this soil profile and all soil layers that were mixed are acidic. The spading process mixed the surface soil with higher levels of organic matter deeper into the profile. This means that the higher organic matter surface soil that is moved deeper into the profile, including to the depth of 5 – 10 cm, is wet for longer periods likely resulting in increased microbial activity and creating an environment more conducive to rhizobial growth despite the acidity.

Lentil crop establishment was variable across the trial, ranging from 55 – 82 plants/m^2. This was influenced by the variation in soil softness and undulations as a result of the incorporation treatments.

Similarly, the NDVI data was variable throughout the season and had significant treatment effects (Table 3). Low NDVI values in the spading treatments on 28th July are due to poor crop establishment caused by the uneven seedbed. The NDVI recorded in September shows the crop recovered in the spading treatments with higher NDVI compared to the control. At this time there was also a positive response to lime for all treatments, with an increase in NDVI of 12.6%, 9.6% and 7.7% for nil, ripping and spading treatments, respectively. The September NDVI recording had a weak positive relationship with grain yield (R^2=0.19). Previous work on lentils in constrained sandy soils typically shows stronger relationship between spring crop growth (NDVI) and final grain yield (Trengove et al. 2021).

The grain yield of all ripping and spading treatments regardless of lime was on average 1.03 t/ha (87%) greater than the control (Table 3). This is likely a result of increased access to soil moisture due to the ripping and spading treatments. Photo 2 shows the early senescence of lentils in the untreated plots compared to those that were ripped or spaded. The application of lime without incorporation yielded similar to the control.

Table 3. Soil and crop assessments for the subsurface acidity trial at Bute, 2023.

Treatment	Incorp.	Lime	Rhizobia Group E/F (rhizobia/g soil)		Crop establishment (plants/m²)		NDVI 28th July 2023		NDVI 1st Sep 2023		Grain yield (t/ha)	
1	Nil	No	18	c	80	a	0.346	a	0.571	c	1.19	c
2	Nil	Yes	1031	ab	73	ab	0.362	a	0.643	b	1.58	bc
3	Ripping	No	47	bc	55	c	0.307	bc	0.654	b	2.49	a
4	Ripping	Yes	79	ab	68	b	0.342	ab	0.717	a	2.13	ab
5	Spading	No	516	ab	65	bc	0.282	c	0.672	b	2.09	ab
6	Spading	Yes	1326	a	82	a	0.294	c	0.724	a	2.13	ab
Pr(>F)			0.012#		<0.001		0.005		<0.001		0.02	

**Group E/F strains of rhizobia are suitable for field pea, lentil, vetch and faba bean*

#Statistical analysis conducted on log transformed rhizobia population.

Photo 2. Earlier maturing lentils on Oct 4th, 2023 in the nil plots due to the onset of moisture stress before the other treatments.

Acknowledgements

The authors gratefully acknowledge the investment from the National Landcare Program Smart Farms Grant 'Improving the capacity of growers to identify and manage subsurface acidity on sandy soils on the Northern Yorke Peninsula'. We also recognise the support of the Davidson family for hosting the demonstration site and applying the inputs. GRDC investment through TGC2304-002RTX is also acknowledged for soil rhizobia assessments.

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