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Amelioration of subsoil acidity using inorganic amendments

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Key findings

- Deep ripping had an adverse effect on crop establishment and crop yield in the establishment year.
- Both lime and magnesium silicate (a blended product of 70% Doonba dunite and 30% F70 lime) were capable of increasing soil pH and decreasing exchangeable aluminium (Al) at the 20–30 cm depth where the soil amendment was applied.
- Deep placement of gypsum had no effect on soil acidity and did not improve grain yield.

Introduction

A three year deep ripping experiment was conducted on a highly acidic soil to test how effective a range of inorganic soil amendments were to ameliorate subsoil acidity and improve crop growth and yield. A novel product, MgSi (a blend of 70% Doonba dunite and 30% F70 superfine lime), was tested in the field for the first time.

Site details

Location	'Billa', Holbrook NSW	
Soil type	Yellow chromosol (Isbell 1996)	
Previous crops	Millet (2010); canola (2011); wheat (2012); lupins (2013); wheat (2014)	
Crop sequence	2015 2016 2017	Hyola® 970CL canola EGA Wedgetail⁽ᵈ⁾ wheat EGA Wedgetail⁽ᵈ⁾ wheat
Liming history	2011 2015	2 t/ha 2 t/ha
Fallow rainfall (Nov–March)		2015 (263 mm) 2016 (250 mm) 2017 (253 mm)
In-crop rainfall (April–Oct)		2015 (409 mm) 2016 (712 mm) 2017 (337 mm)
Fertiliser at sowing	60 kg/ha mono-ammonium phosphate (MAP) – 11% nitrogen (N), 22.7% phosphorus (P), 2% sulfur (S) annually	
Top-dressing fertiliser (urea)		2015 (130 kg N/ha) 2016 (60 kg N/ha) 2017 (50 kg N/ha)
Ripping machine	A single tyne ripper to 30 cm depth	
Ripping width	50 cm for the deep liming treatment 80 cm for all remaining treatments	

Treatments

There were nine treatments (Table 1) with four treatment contrasts:

- Surface vs. deep application
- Lime vs. MgSi (blend with 30% of lime) vs. gypsum
- Surface application of urea vs calcium nitrate [$Ca(NO_3)_2$] under deep ripping
- Deep liming with ripping width of 50 cm vs. 80 cm.

Table 1. Soil amendment and treatment description at 'Billa', Holbrook, NSW.

ID	Treatment	Treatment description	Additional details
1	No amendment	Farmer's practice (surface limed at @ 2 t/ha)	
2	Surface liming	Surface liming @ additional 1.4 t/ha	Lime rate was calculated based on an incubation study, targeting average pH_{Ca} of 5.5 over four years.
3	Deep liming	Deep ripping + lime @ 1.4 t/ha (30 cm deep, 80 cm apart)	
4	Surface MgSi	Surface application with MgSi @ 1.4 t/ha	MgSi was a blend of 70% Doonba dunite (crushed to <250 µm) and 30% lime (F70). The neutralised value of the MgSi was estimated to be equivalent to F70 lime.
5	Deep MgSi	Deep ripping + MgSi @ 1.4 t/ha	
6	Deep ripping + urea	Deep ripping only (urea top-dressed 50–100 kg N/ha)	
7	Deep ripping + calcium nitrate	Deep ripping only (calcium nitrate top dressed at equivalent N rate as urea)	Calcium nitrate [$Ca(NO_3)_2$ $4H_2O$, 11.9% N], top-dressed at equivalent rate as urea.
8	Deep gypsum	Deep ripping + gypsum @ 3.0 t/ha	Gypsum (20.6% Ca and 15.3% S), applied at equivalent Ca concentration as lime.
9	Deep liming at 50 cm	Deep ripping + lime @ 1.4 t/ha (30 cm deep, 50 cm apart)	Deep ripped at 50 cm apart in contrast with 80 cm for the rest of the ripping

Results

Soil chemical properties

The initial soil samples were taken before treatments were implemented using large tubes (44 mm diameter) to a depth of 100 cm, two cores per plot composited every 10 cm in 0–40 cm and every 20 cm in 60–100 cm. The soil samples in year 3 were taken using a multi-corer to a depth of 60 cm, two locations per plot, composited with corresponding depths to the initial sampling. The multi-corer consists of six small tubes (25 mm diameter) in a row across 25 cm (Figure 1). At each sampling location, the multi-corer was positioned across a ripping line to ensure that at least one tube would strike soil amendment if applicable.

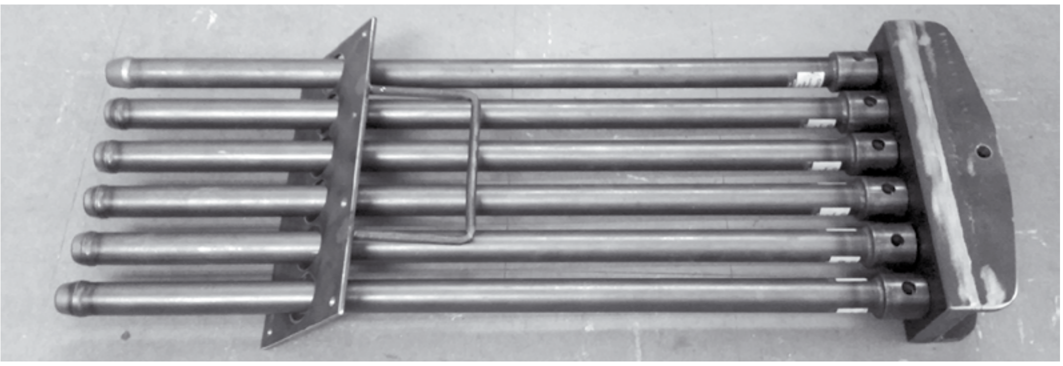

Figure 1. A new multi-core sampler.

Both deep liming and deep MgSi treatments increased soil pH significantly at the 20–30 cm depth (P<0.001) where soil amendments were applied compared with the no amendment treatment three years after treatments were implemented (Figure 2). However, there was no significant difference in soil pH between deep liming and deep MgSi treatments at either 10–20 cm or 20–30 cm. In the current study, the MgSi was blended with 30% of F70 lime to improve MgSi

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efficiency, and the neutralising value of the MgSi blend was assumed to be equivalent to F70 lime. There was no difference in soil pH between different ripping widths of 50 cm and 80 cm. As expected, deep placement of gypsum had no effect on soil acidity.

There was a significant difference in exchangeable Al% between treatments at 10–20 cm (P<0.01) and 20–30 cm (P<0.05) (Figure 3). The exchangeable Al% tended to be lower in the deep MgSi treatment than that in the deep liming treatment, but no significant difference was found between deep liming and deep MgSi treatments. Further research is required to explore whether MgSi is more efficient in decreasing Al toxicity than lime, as claimed by Castro and Crusciol (2013).

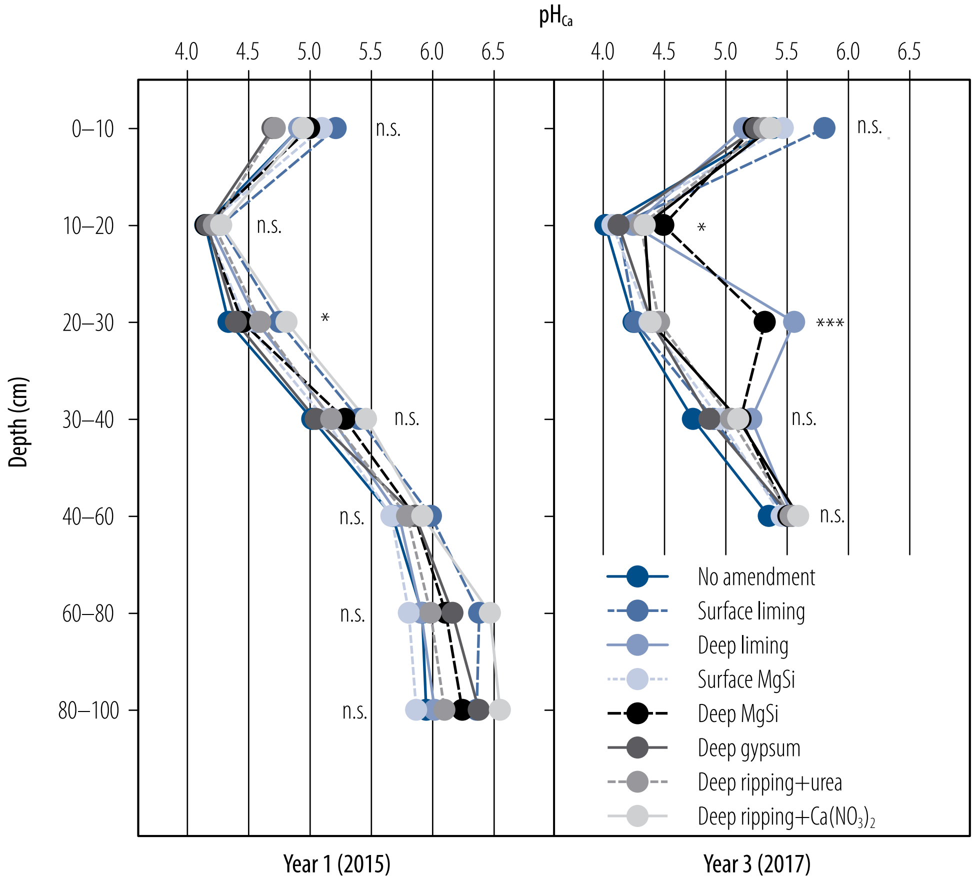

Figure 2. Soil pH_{Ca} under different soil amendment treatments in autumn in years one and three at the Holbrook site. n.s., not significant.

Agronomic performance

There was a significant difference in seedling density for the canola crop in year 1 only (P<0.001), but not for wheat crops in years 2 and 3 (Figure 4). In year 1, all ripped treatments had lower seedling densities, probably due to the uneven seedbed, or increased evaporation due to the ripping operation (Poile et al. 2012). There was a similar trend for seedling density in year 2, but not in year 3.

At anthesis, all deep ripping treatments tended to have higher dry matter (DM) production for the canola crop in year 1 at P = 0.06, but there were no differences in anthesis DM of treatments for wheat crops in years 2 and 3 (data not shown). At harvest, surface liming and surface MgSi, including the no amendment treatment, had a significantly higher yield than the deep liming, deep MgSi or deep gypsum treatments (P<0.05) (Figure 5). No difference was found in wheat grain yield in year 2, most likely due to plentiful in-crop rainfall in 2016, but the $Ca(NO_3)_2$ treatment in year 3 had a significantly higher yield than the remaining treatments (Figure 5), presumably due to less nitrogen volatilisation losses that would occur with urea application.

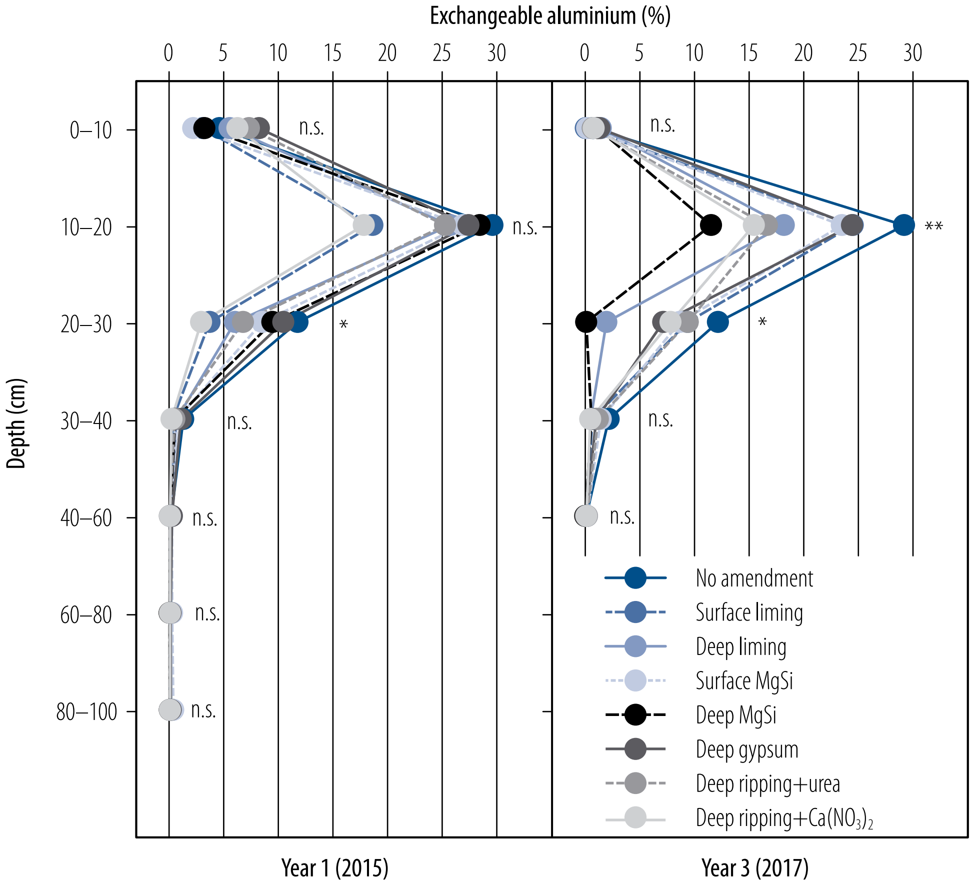

Figure 3. Soil exchangeable Al% under different soil amendment treatments in autumn in years one and three at the Holbrook site. n.s., not significant.

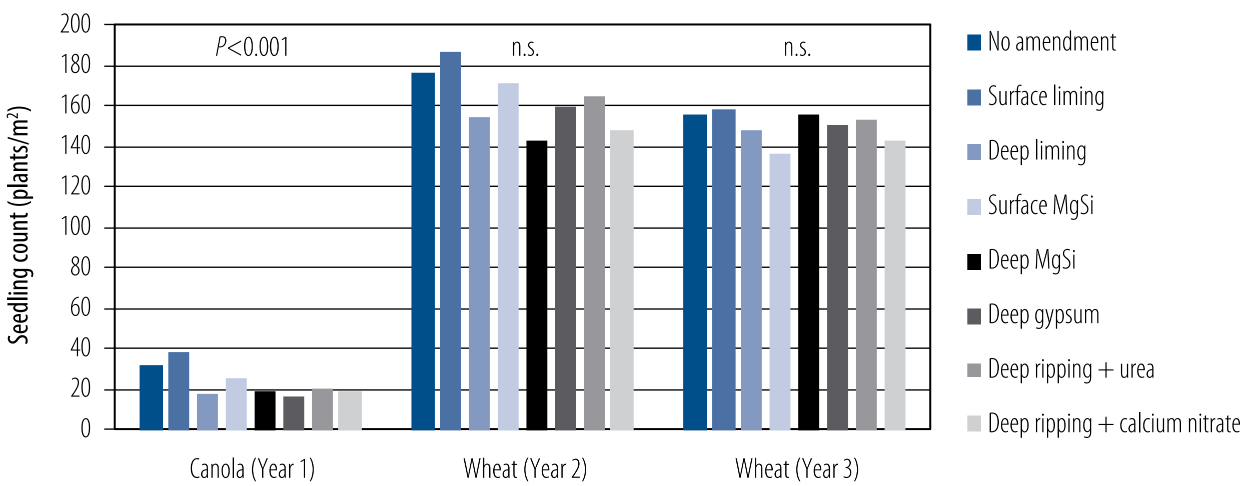

Figure 4. Seedling density (plants/m^2) at crop establishment in response to different soil amendments in years 1–3 at the Holbrook site. n.s., not significant.

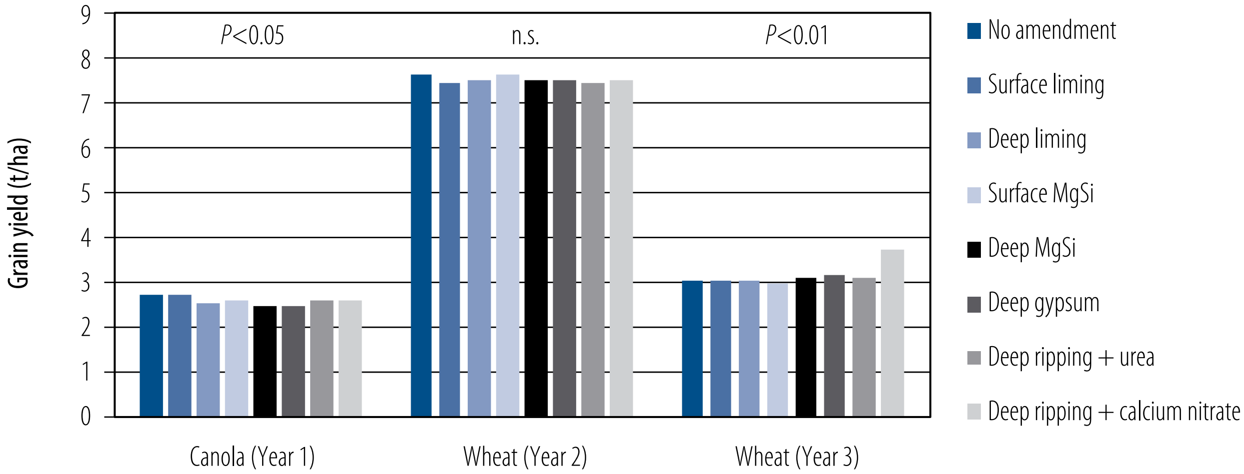

Figure 5. Grain yield (t/ha) in response to different soil amendments in years 1–3 at the Holbrook site. n.s., not significant.

Conclusion

The deep ripping operation had an adverse effect on canola establishment and crop yield in the first year, but no yield penalty was observed in the wheat crops in years 2 and 3. Deep placement of lime and MgSi increased soil pH and decreased exchangeable Al% significantly at 20–30 cm compared with the no amendment treatment. Deep placement of gypsum had no effect on soil acidity and did not improve grain yield at the current site.

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