Managing subsoil acidity – preliminary results from the long-term field experiment

Dr Guangdi Li, Richard Hayes, Dr Ehsan Tavakkoli, Helen Burns, Richard Lowrie, Adam Lowrie, Graeme Poile, Albert Oates and Andrew Price (NSW DPI, Wagga Wagga)

Key findings

- Significant crop biomass responses were observed on wheat, barley and canola crops at anthesis.
- The large crop biomass responses under organic amendment treatments were largely due to extra nutrients from lucerne pellets.
- The dramatic crop biomass responses observed at anthesis on canola and barley crops did not translate into grain yield under treatments with lucerne pellets applied, due to severe lodging.
- Soil chemical, physical and biological properties will be monitored to understand the soil-plant interactions, the factors driving the differences in crop response to the various treatments and the residual value of the amendments.

Introduction

A long-term field experiment was set up to run for at least two, 4-year crop rotation cycles, or one 8-year soil amendment cycle in 2016. The objectives were to:

1. manage subsoil acidity through innovative amelioration methods that will increase productivity, profitability and sustainability
2. study soil processes, such as the changes of soil chemical, physical and biological properties under vigorous soil amelioration techniques, over the longer term.

Site description and treatments

The site is located at Dirnaseer, west of Cootamundra, NSW. Soil pH in $CaCl_2$ (pH_{Ca}) was 4.5 at 0–10 cm, ~ 4.3 at 10–20 cm, and <4.5 at 20–30 cm. The exchangeable aluminium (Al) was >20% at 10–20 cm.

There were four crops in rotation arranged in a fully-phased design. The crops are in a sequence: wheat (*Triticum aestivum*); canola (*Brassica napus*); barley (*Hordeum vulgare*); pulse [faba bean (*Vicia faba*) or field pea (*Pisum sativum*), depending on seasons]. One feature in the phased design is that each crop appears once in any given year to:

1. assess responses of different crops to different soil amendments
2. compare underlying treatment effects taking account of seasonal variation. See experimental design in details in Li et al. (2017), in this book.

There were six treatments within each crop, arranged in a split-plot design with three replicates.

- Treatment 1 (control). No amendment, representing the 'do nothing' approach.
- Treatment 2 (surface liming). Lime was applied at 4.0 t/ha, incorporated into 0–10 cm depth, to achieve an average pH_{Ca} of 5.5 over eight years. The assumption is that pH_{Ca} 5.5 is high enough to balance acid-addition from the production system in the surface 0–10 cm and enable excess alkalinity to move down the profile over time (Li et al. 2001; Li et al. 2010).
- Treatment 3 (deep ripping only). Soil was ripped down to 30 cm to quantify the physical effect of ripping. No amendment was applied below 10 cm, but lime was applied at 2.5 t/ha at surface, incorporated into 0–10 cm depth after plots were ripped, to achieve an average pH_{Ca} of 5.0 over eight years.
- Treatment 4 (deep placement of liming). Lime was placed at three depths (surface, 10–20 cm and 20–30 cm). Approximately 5.0 t/ha of lime was applied in total to achieve a target pH_{Ca} ≥5.0 throughout the whole soil profile, which should eliminate pH restrictions to plant growth for most crops.

Nutrition & soil

- Treatment 5 (deep placement of organic amendment). Organic amendment (in the form of lucerne pellets) at 15 t/ha was placed at two depths: (10–20 cm and 20–30 cm). The rate was calculated to achieve a target pH_{Ca} of 5.0 at the corresponding depths based on the alkalinity of lucerne pellets. The surface was limed to pH_{Ca} 5.0 as per treatment 3.
- Treatment 6 (deep placement of lime and organic amendment). A combination of treatments 4 and 5 to maximise benefits of lime and organic amendment.

Results

It was extremely wet in 2016. The annual rainfall was 54% more than the long-term average (615 mm). From May–October, the site received over 60% more rainfall than the long-term average for each month, particularly in September where the site received 204 mm of rain (Figure 1).

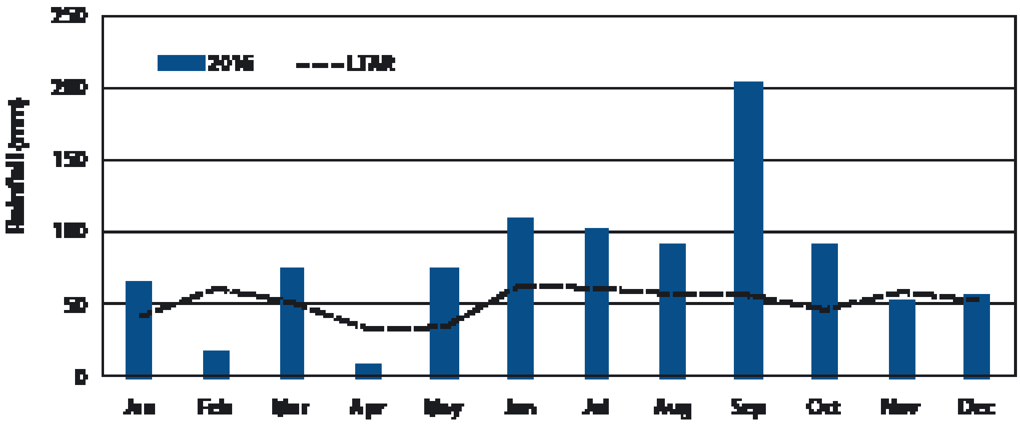

Figure 1. Monthly rainfall for 2016 and long-term average rainfall (LTAR) at Dirnaseer, west of Cootamundra, NSW. Total rainfall in 2016 was 947 mm, LTAR is 615 mm.

Visible responses to the soil treatments in the early growth of the wheat, barley and canola in August were unexpected so soon after the treatments were applied (Figure 2). Crop biomass at anthesis showed that while surface liming and deep ripping alone improved crop growth of wheat by about 15% and canola by about 25%, dry matter production was increased by a further 10–15% when lime and/or lucerne pellets were placed into the subsoil (Figure 3). Dry matter production in the barley was 15–35% greater for all deep amendment treatments, compared with the control. No response was observed for surface liming and deep ripping treatments for barley crops. The field pea response was much smaller compared with other crops (Figure 3).

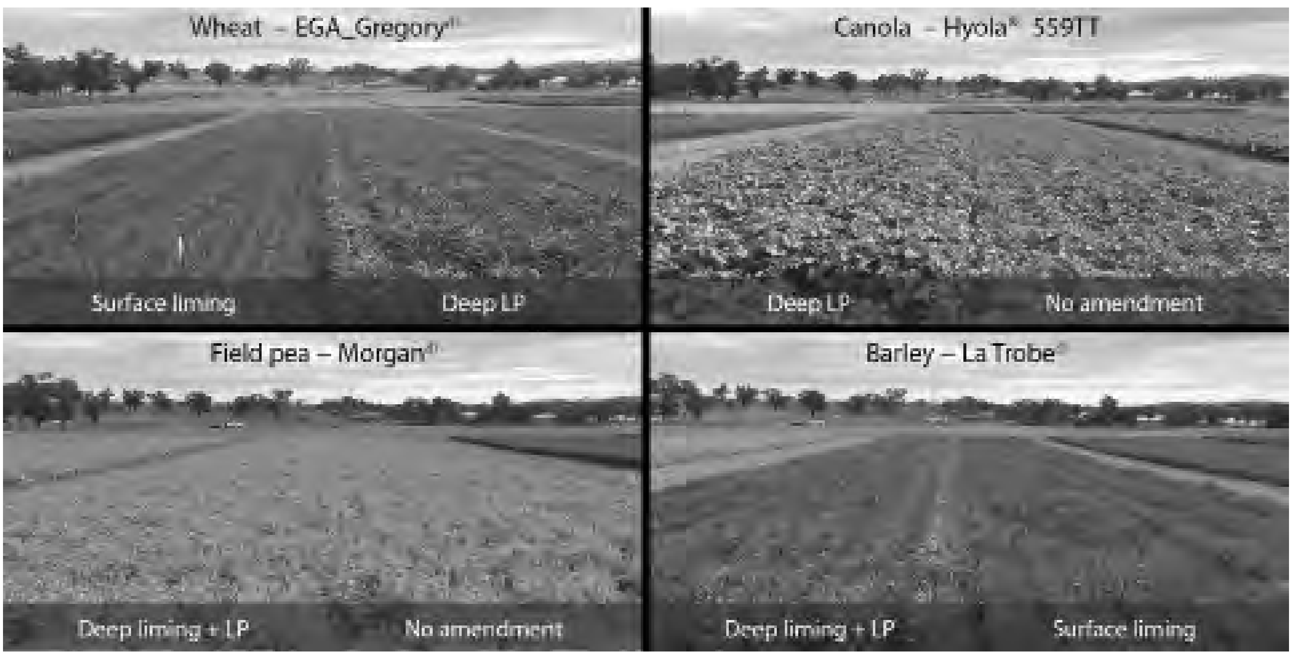

Figure 2. Crop responses to different soil amendments in late August 2016.

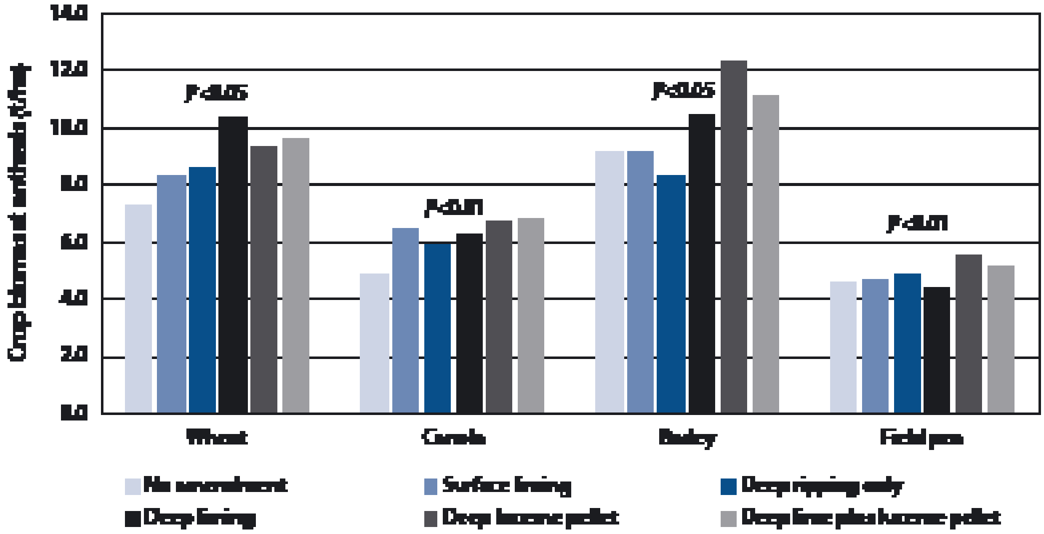

Figure 3. Crop biomass at anthesis in response to different soil amendments.

The dramatic crop biomass responses of the cereal and canola crops from treatments with lucerne pellets applied (treatments 5 and 6) were largely due to extra nutrients supplied from lucerne pellets (31 g/kg nitrogen, 451 g/kg carbon, 3 g/kg sulphur, 1.6 g/kg phosphorus and 16.6 g/kg potassium). Soil tests in late August 2016 showed that treatments with lucerne pellets applied (treatments 5 and 6) had about 70–100 kg/ha of extra mineral N available to crops in the 0–60 cm soil profile compared with other treatments (Figure 4).

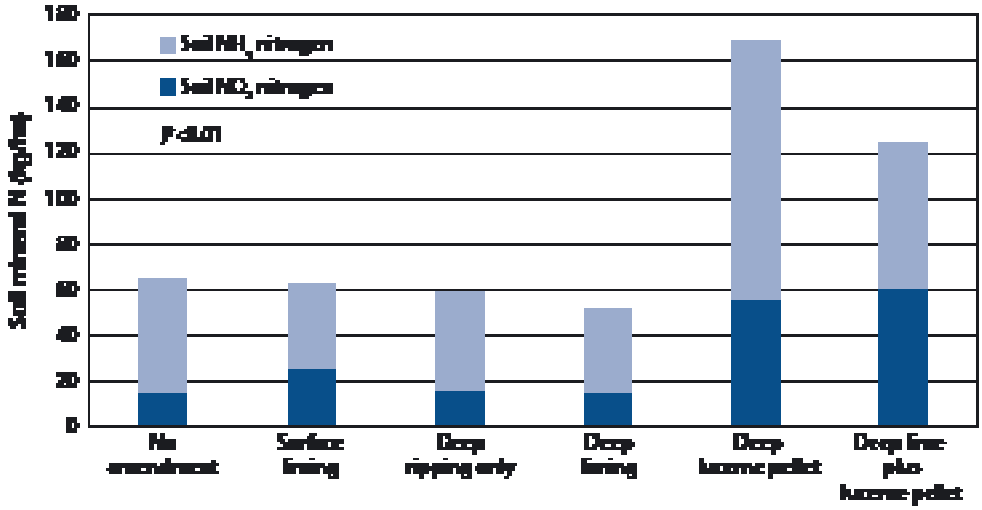

Figure 4. Soil mineral nitrogen under different soil amendments on wheat crops in late August 2016.

At crop harvest, the effect from surface liming diminished and no significant grain yield increases were recorded (Figure 5). However, both the deep ripping only and the deep liming treatment increased grain yield by up to 20% for both wheat and barley crops. The lack of any further crop response from adding lime at depth was expected, as the lime did not have sufficient time to react and increase soil pH to benefit the 2016 crops. Detailed soil testing will track changes in pH over time, and we expect that the deep-placed lime will continue to increase subsoil pH for about 18 months after application, and should produce a grain yield response in the 2017 crops.

The highest wheat grain yield was obtained from the two organic amendment treatments, as expected (Figure 5). Unfortunately, the dramatic dry matter response observed at anthesis on canola and barley crops in treatments with lucerne pellets did not translate into increased grain yield. The combination of high nitrogen levels and ideal spring growing conditions resulted in severe lodging after flowering, which is likely to have affected grain yield. There were no treatment effects on field pea grain yield.

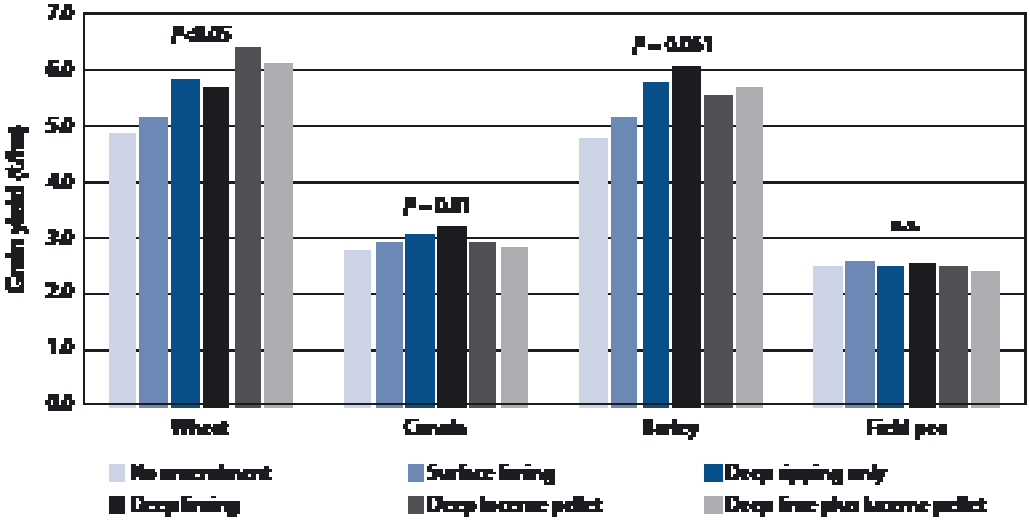

Figure 5. Grain yield at harvest in response to different soil amendments.

Future research

The research team will continue to monitor soil chemical, physical and biological properties to understand the soil–plant interactions and the factors driving the differences in crop response to the various treatments. We are particularly interested in understanding the residual effects of the amendments and how they could improve crop productivity through, for example, more efficient nutrient and water use. It is essential that growers who operate cropping systems on soils affected by subsoil acidity have this information in order to adapt the new technologies we are testing. We acknowledge that this technology requires considerable investment and therefore an important component of the project is a financial assessment. Costs and yield benefits will be analysed, as well as the economic impact and investment potential for the various treatments, taking into account the long-term residual value of the amendments on increasing subsoil pH.

References

Li G, Conyers M & Cullis B 2010. Long-term liming ameliorates subsoil acidity in high rainfall zone in south-eastern Australia. *Proceedings of the 19th World Congress of Soil Science; Soil Solutions for a Changing World*. Eds RJ Gilkes & N Prakongkep. Brisbane, Australia, 1–6 August 2010, pp. 136–139. International Union of Soil Science.

Li GD, Helyar KR, Conyers MK, Cullis BR, Cregan PD, Fisher RP, Castleman LJC, Poile GJ, Evans CM & Braysher B 2001. Crop responses to lime in long-term pasture–crop rotations in a high rainfall area in south-eastern Australia. *Australian Journal of Agricultural Research*. Vol. 52: 329–341.

Acknowledgements

'Innovative approaches to managing subsoil acidity in the southern grain region' (DAN00206, 2015–20) is a project with joint investment by NSW DPI and GRDC.