Research update for ameliorating subsoil acidity using organic amendments

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Key findings

- Lime increased soil pH and decreased the exchangeable aluminium percentage (Al_{ex}%) significantly.
- Organic amendments could be used to ameliorate soil acidity, but they were not as effective as lime.
- Crops responded more to nutrient addition than amelioration of soil acidity with organic amendments in the short term.
- The long-term effect of organic amendments on soil acidity and crop yield response needs further investigation.

Introduction

A range of organic amendments have been tested to assess their effectiveness on ameliorating soil acidity in the field. The crop yield was monitored over three years from 2018 to 2020.

Site details

Location: Billa, Holbrook NSW

Soil type: Yellow chromosol (Isbell and National Committee on Soil and Terrain 2021)

Crops

Previous crops	Crops in experiment period
2015, Hyola® 970CL canola	2018, SF Edimax® CL canola
2016, EGA Wedgetail⫽ wheat	2019, LongReach Kittyhawk⫽ wheat
2017, EGA Wedgetail⫽ wheat	2020, LongReach Kittyhawk⫽ wheat

Rainfall (mm)

Year	In-crop rainfall (April–October)	Fallow rainfall (November–March)	Annual rainfall
2018	213.6 mm	208.2 mm	421.8 mm
2019	242.6 mm	171.8 mm	414.4 mm
2020	509.5 mm	206.6 mm	716.1 mm
Long-term average	386.4 mm	243.1 mm	629.4 mm

Fertiliser

Year	At sowing	Top-dressing
2018	70kg mono-ammonium phosphate (MAP)	100 kg/ha urea
2019	70kg MAP	100 kg/ha urea
2020	70kg MAP	100 kg/ha urea

This research paper is an extract from the publication *Southern NSW Research Results 2021*, available at https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/southern-nsw-research-results

Ripping machine	3-D Ripper (5 tynes), designed and fabricated by NSW DPI (Li and Burns 2016)
Ripping width and depth	50 cm between rip lines; to 30 cm deep

Treatments

There were 20 treatments in this experiment. All organic amendments were applied in the 10–30 cm depth with and without lime in contrast with surface lime in February 2018.

All treatments were surface limed to pH 5.0 at 0–10 cm deep except for the surface lime treatment with a high lime rate (limed to pH 5.5). All surface lime was applied after deep ripping with amendments, then incorporated to 10 cm deep. Plot size: 5×20 m = 100 m^2. Buffer between plots: 2.5 m, buffer between blocks: 20 m.

Organic amendments used in this experiment:

- Deep lucerne hay pellet at 15 t/ha.
- Deep pea-hay pellet at 15 t/ha.
- Deep wheat straw pellet at 15 t/ha.
- Deep wheat straw pellet at 15 t/ha plus nitrogen [N], phosphorus [P] and sulfur [S] at 5N:2P:1.3S as per Kirkby et al. (2013).
- Deep poultry litter pellets as Yates Dynamic Lifter at 10 t/ha.
- Deep biochar pellet blended with pea hay 50:50 at 10 t/ha.

Measurements

Soil samples were taken in autumn using a multi-core sampler (Lowrie et al. 2018) at 0–60 cm deep across a rip line and a large soil core (44 mm in diameter) for the 60–100 cm depth on a rip line at two locations in each plot. The rip lines were located with permanent marks. Soil samples were bulked into 10 cm increments from 0–40 cm and 20 cm increments from 40–100 cm. Soil pH_{Ca} and exchangeable cations were analysed as per Gillman and Sumpter (1986). Grain yield was obtained with a plot header.

Results and discussion

Rainfall pattern

It was extremely dry in 2018 and 2019 with in-crop rainfall of 214 mm and 243 mm, respectively. In contrast, it was a wet year in 2020 with in-crop rainfall of 510 mm, compared with the long-term average in-crop rainfall of 386 mm (Figure 1).

Organic amendments

Results demonstrated that organic amendments could be used as soil ameliorants to increase soil pH and reduce aluminium (Al) toxicity in acidic soils. However, the magnitude of any pH increase varied between the type of organic amendments used, depending on their ash alkalinity, and the concentration of excess base cations, which reflects the concentration of stored organic acid anions (Tang and Yu 1999). All organic ameliorants slightly increased soil pH in 2018 and 2019 in the 10–20 cm and 20–30 cm depths where they were placed, but were not as effective as lime (Figure 2). The increase in pH was most likely due to OH^- being released during the decarboxylation process of organic matter and ammonification of organic nitrogen compounds. However, the subsequent nitrification process would decrease soil pH. Organic ameliorants also significantly reduced Al_{ex}% in the 10–20 cm and 20–30 cm depths in 2020, compared with the surface lime treatment (Figure 2). This is likely to be due to the soluble organic molecules from organic amendments combining with active Al^{3+} to form insoluble hydroxy-Al compounds (Haynes and Mokolobate 2001), which would reduce Al toxicity to plant root systems.

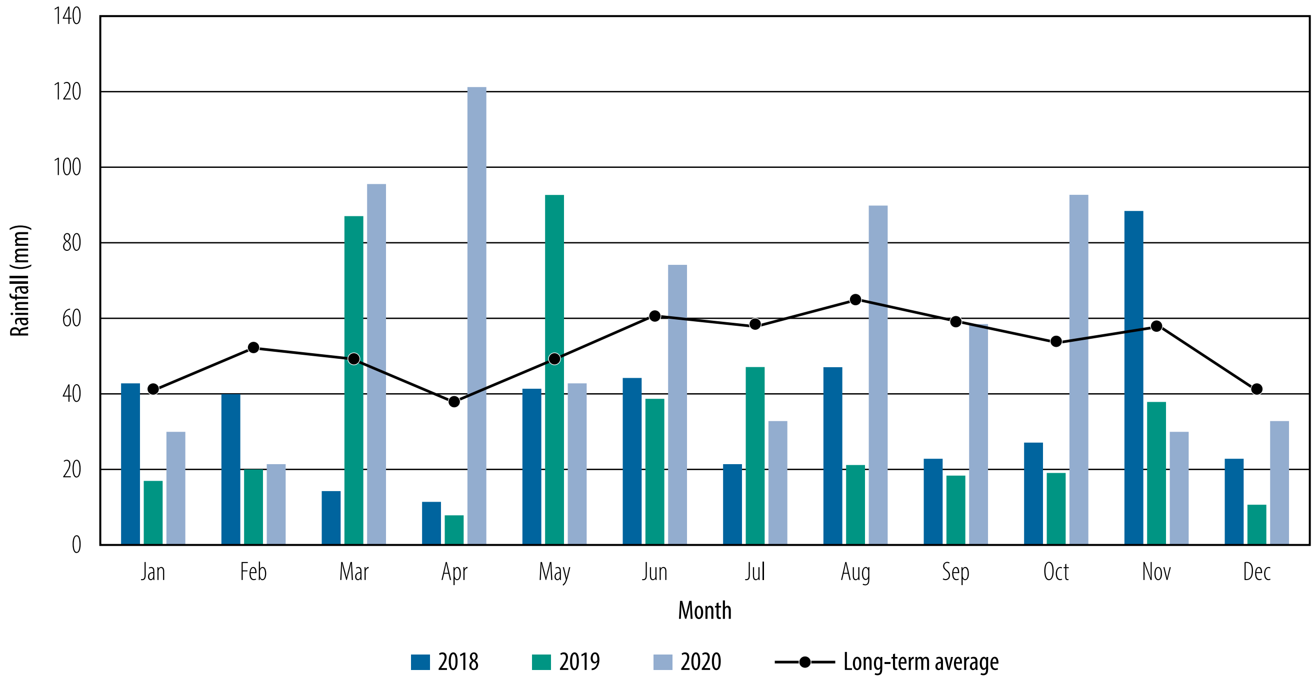
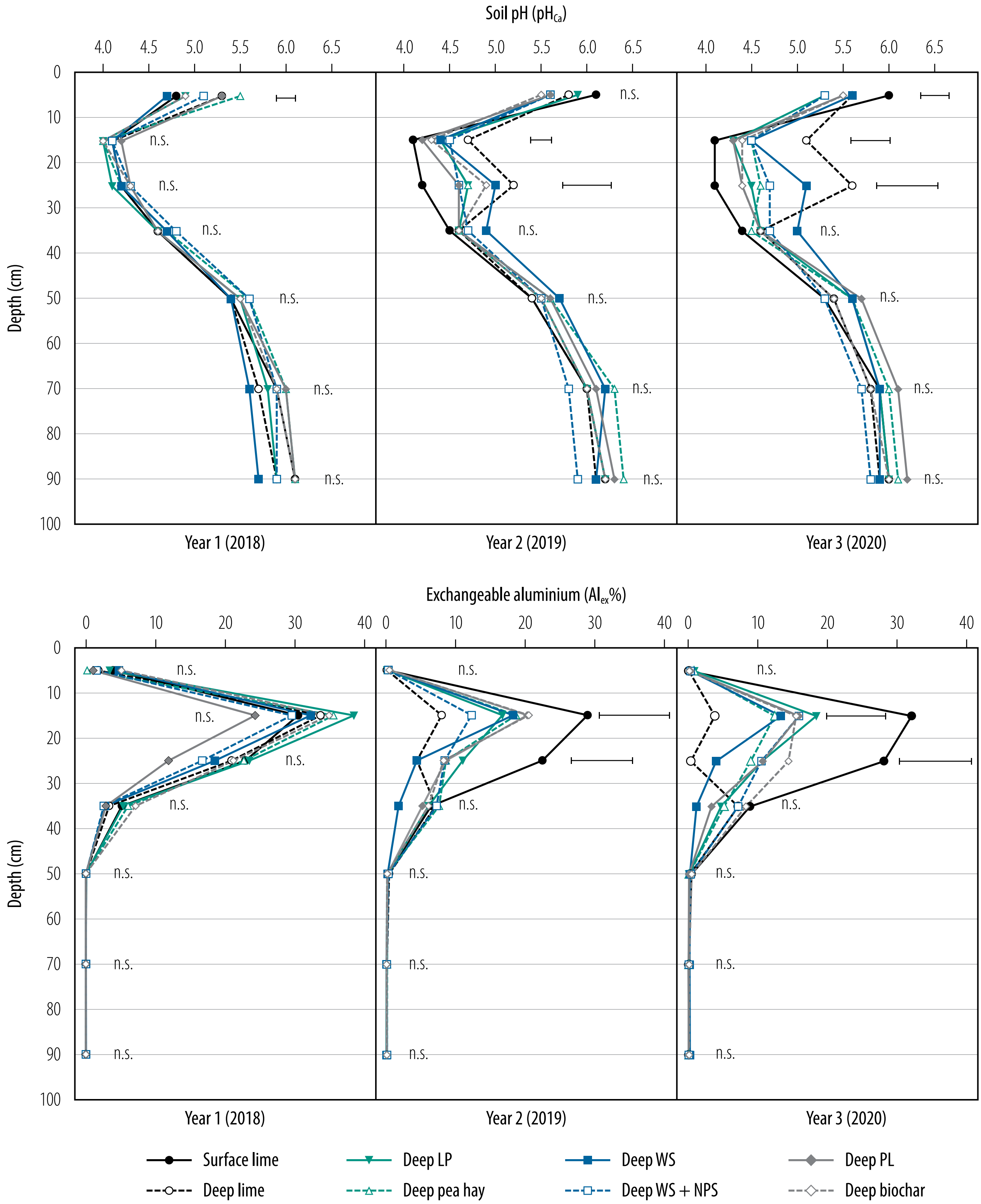


Figure 1 Monthly rainfall and long-term average rainfall at Holbrook, NSW.

Lime plus organic amendments

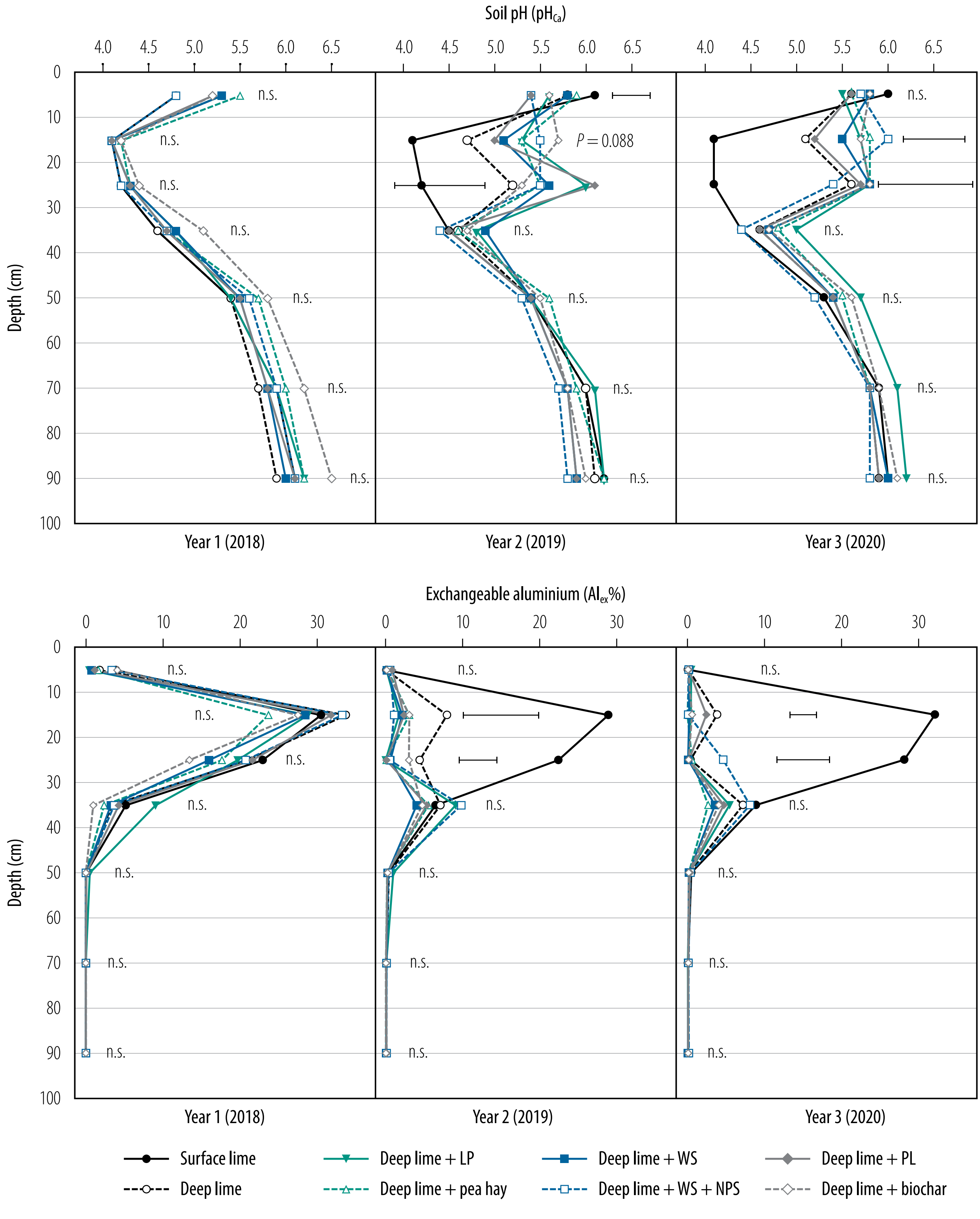
Adding lime to organic amendments increased soil pH in the 10–20 cm depth at $P = 0.09$ and 20–30 cm depth at $P<0.05$, and reduced Al_{ex}% significantly at both depths ($P<0.01$) compared with the surface lime treatment (Figure 3). There were no significant differences in soil pH and Al_{ex}% between deep lime only and deep lime combined with organic amendments, indicating that it was the lime rather than organic amendments that played the major role in ameliorating soil acidity. A number of soil column experiments demonstrated that adding lime with plant residues can facilitate alkalinity moving below the amended depth (Butterly et al. 2021). However, there was no evidence to show alkalinity movement down the soil profile in the field experiment (Figure 3).



LP, lucerne hay pellets; WS, wheat straw pellets; NPS, 5N:2P:1.3S; PL, poultry litter pellets.

Horizontal bars represent l.s.d. at $P = 0.05$; n.s. = not significant.

Figure 2 Soil pH (pH_{Ca}) (top row) and exchangeable aluminium percentage (Al_{ex}%) (bottom row) under various organic ameliorants in years 1–3 at the Holbrook site, NSW.



LP, lucerne hay pellets; WS, wheat straw pellets; NPS, 5N:2P:1.3S; PL, poultry litter pellets.

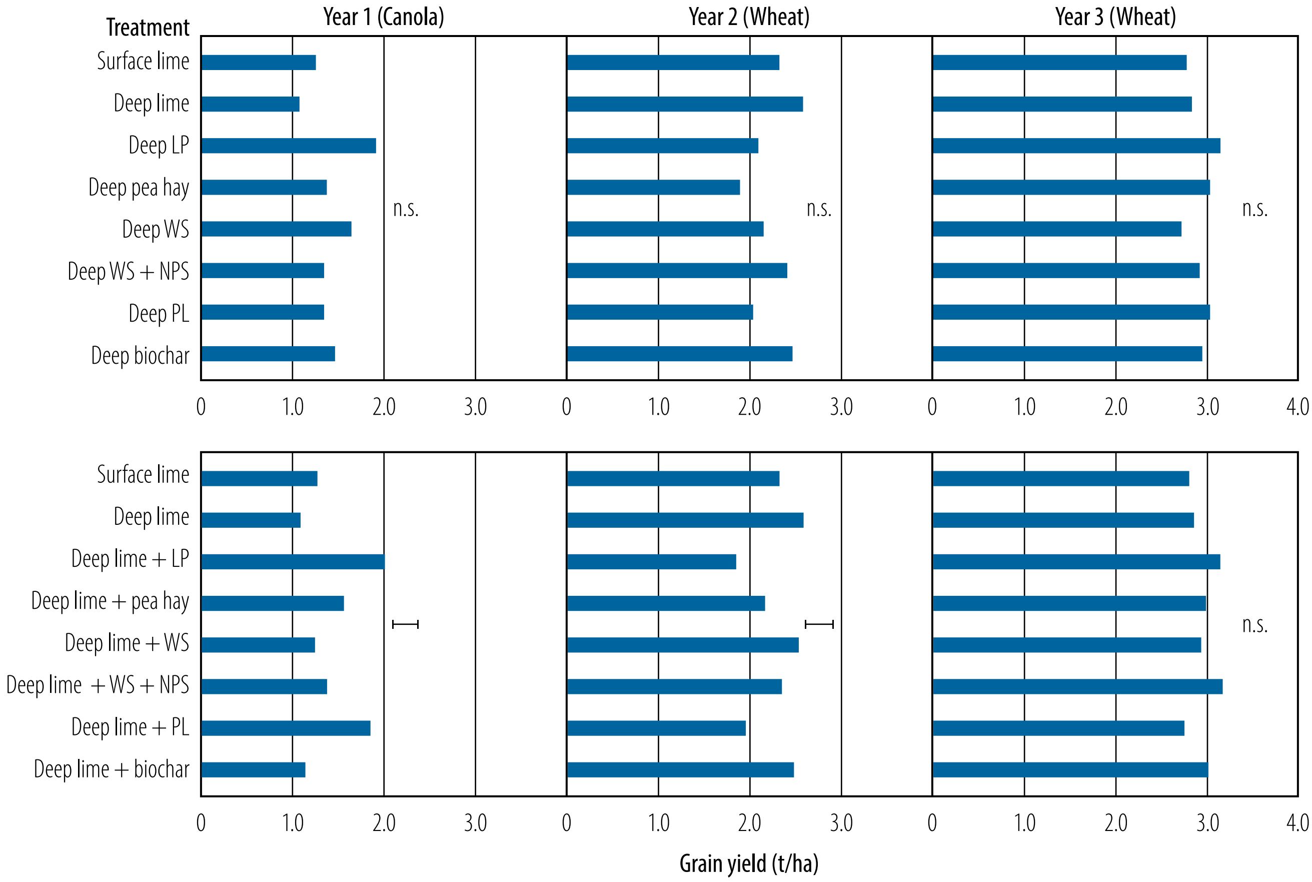
Horizontal bars represent l.s.d. at $P = 0.05$; n.s. = not significant.

Figure 3 Soil pH (pH$_{Ca}$) (top row) and exchangeable aluminium percentage (Al$_{ex}$%) (bottom row) under various organic ameliorants with lime in years 1–3 at the Holbrook site, NSW.

Grain yield

The drought in 2018 and 2019 (Figure 1) greatly suppressed grain yield. The canola grain yield was less than 2.0 t/ha in 2018 and the wheat grain yield was under 2.6 t/ha in 2019 (Figure 4). In contrast, wheat yield was up to 3.2 t/ha in 2020 – a wet year (Figure 4).

In the first year, 2018, the deep lucerne hay pellet treatments with and without lime had the highest yield, followed by the deep poultry litter treatment with lime (Figure 4), probably due to nutrient effect rather than ameliorating soil acidity. Those treatments with higher grain yield in 2018 tended to have low yields in 2019 due to severe drought. For example, both the lucerne hay pellet and poultry litter with added lime treatments had lower grain yield compared with other organic amendments in 2019. This is probably related to soil water dynamics. In 2020, a wet year, no difference in grain yield was found between treatments at the site. It appeared that the effect of soil acidity on root function was much less when soil water was not a limiting factor.



LP, lucerne hay pellets; WS, wheat straw pellets; NPS, 5N:2P:1.3S; PL, poultry litter pellets.

⊢⊣ Horizontal bars represent l.s.d. at $P = 0.05$; n.s. = not significant.

Figure 4 Grain yield (kg/ha) under organic amendments (top row) and lime plus organic amendments (bottom row) in years 1–3 at the Holbrook site, NSW.

Conclusions

Deep lime increased soil pH and decreased Al_{ex}% significantly in the 10–20 cm and 20–30 cm depths in 2019 and 2020. Organic amendments could increase pH, but were not as effective as lime, however, organic amendment decreased Al_{ex}% significantly. Crop yields responded more to nutrients than to ameliorated soil acidity in the first year (2018). However, the nutrient effect under organic amendment treatments was suppressed by lack of soil moisture in the second year (2019). The long-term effect of organic amendments on crop yield needs further investigation.

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