Department of Primary Industries

Improving grain yield by ameliorating sodic subsoil, Rand NSW

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Key findings

- Deep placement of organic and inorganic amendments increased grain yield by 20–40% for three successive years on a sodic subsoil at Rand.
- Deep placement of organic and inorganic amendments increased root growth and soil water use from the deeper clay layers during the grain filling-stage.
- Improvements in grain yield with deep placement of organic and inorganic amendments were associated with reduced subsoil pH and exchangeable sodium percentage, and increased microbial activity.

Introduction

In the Australian grain belt, soil constraints often result in lower water use efficiency (WUE) in grain production. Soil-constrained yields (<15 kg/mm/ha) are much lower than water limited yields (~24 kg/mm/ha). The difference between soil-constrained and potential yield is referred to as the yield gap. Among the various soil constraints, soil sodicity is associated with the largest yield gap, with an estimated yield loss of $A1,300 million per annum (Orton et al., 2018). The yield gap is caused by several physicochemical properties including:

- high exchangeable sodium (Na) concentrations
- dispersion
- poor structure
- waterlogging
- high soil strength
- and in some circumstances pH higher than 8.2 (H_2O).

In sodic subsoils these factors restrict crop rooting depth and subsequent water and nutrient extraction (Passioura and Angus, 2010) leading to significant yield penalties (Adcock et al., 2007).

Gypsum application has been the most widespread traditional approach to correcting subsoil sodicity, however, the problems with this have included:

- surface application when the problem is evident in the subsoil
- the large quantities of gypsum required to displace significant amounts of sodium
- gypsum's somewhat low solubility.

A new approach was required to consider a wider range of the physicochemical constraints associated with sodic subsoils that also better targeted the subsoil sodic layer. This approach also included providing the building blocks for soil colloid formation to improve structure.

This paper reports 2019 results from a subsoil amelioration experiment aimed at minimising the yield gap on sodic subsoils by treating them with various organic and inorganic amendments in pelletised form.

This research paper is an extract from the publication *Southern NSW Research Results 2020*, available at https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/southern-nsw-research-results

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Site details

Location	Rand, southern NSW
Soil type	Sodosol
Previous crop	Wheat
Design	Randomised complete block design (RCBD) with four replications
Sowing	• Sown with an air seeder spaced at 250 mm using a GPS auto-steer system (10 April 2019) • Seed rate: 4.4 kg/ha
Fertiliser	• 90 kg/ha mono-ammonium phosphate (MAP) (at sowing) • Urea 220 kg/ha (top dressed on 28 June 2019)
Rainfall	• Fallow rainfall (November 2018–March 2019): 196 mm • Fallow rainfall long-term average: 221 mm • In-crop rainfall (April 2019–October 2019): 215 mm • In-crop rainfall long-term average: 319 mm
Harvest date	30 October 2019

Treatments

Outlined in Table 1.

Table 1 Organic and inorganic amendments with their rate of application in February 2017.

Treatments	Organic/inorganic	Rates
Control	–	–
Deep gypsum	Inorganic	5 t/ha
Deep NPK (liquid nitrogen [N], phosphorus [P], potassium [K])	Inorganic	N to match chicken manure
Deep manure	Organic	8 t/ha
Deep pea straw	Organic	15 t/ha
Deep pea straw + gypsum + NPK	Organic + inorganic	15 t/ha, 5 t/ha, N to match chicken manure
Deep pea straw + NPK	Organic + inorganic	15 t/ha, N to match chicken manure
Deep wheat straw	Organic	15 t/ha
Deep wheat straw + NPK	Organic + inorganic	15 t/ha, N to match chicken manure
Rip only	–	–
Surface gypsum	Inorganic	5 t/ha
Surface manure	Organic	8 t/ha
Surface pea straw	Organic	15 t/ha

Surface amendments were applied on the soil surface; deep amendments were incorporated at 20–40 cm depth in 50 cm bands.

Results

Growing conditions

A field experiment was established on-farm near the township of Rand in southern NSW during February 2017. Treatments and physicochemical properties are detailed in tables 1 and 2, respectively. Paddock history was a cereal–canola rotation for decades.

The soil is a sodosol (Isbell, 2002), with a texture–contrast profile increasing in clay content at depth. The increasing levels of exchangeable sodium relative to calcium and/or magnesium in subsoil results in decreased soil structural stability and increased dispersion potential. The high clay content in this subsoil layer has a bulk density of 1.55 g/cm^3 that restricts water movement and consequently the saturated hydraulic conductivity value is low at 0.03 cm/hr.

The site received less summer rainfall (196 mm) and less growing season rainfall (215 mm) compared with their respective long-term averages (summer 221 mm, growing season 319 mm May to November).

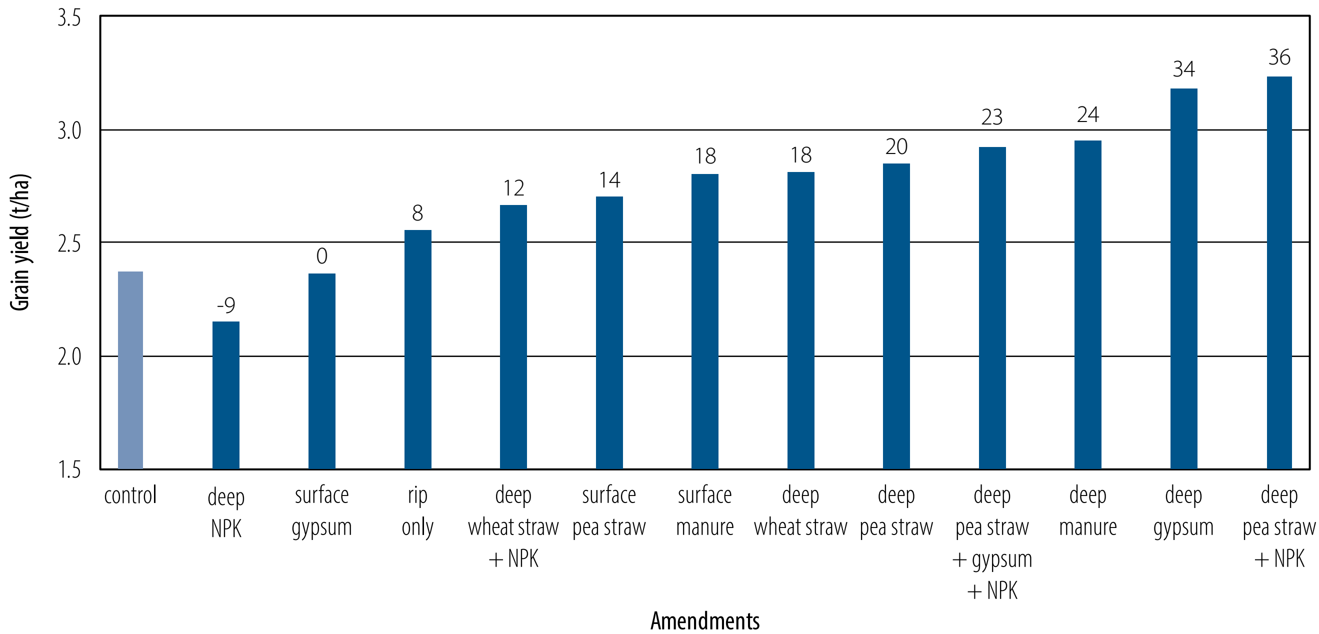
Table 2 Chemical properties at different soil profile depths at the Rand experiment site.

Soil depths (cm)	$pH_{1:5\ water}$	EC (µs/cm)	ESP (%)
0–10	6.6	132.1	3.8
10–20	7.8	104.0	7.3
20–40	9.0	201.5	12.5
40–45	9.4	300.5	18.1
50–60	9.5	401.3	21.8
60–100	9.4	645.0	26.4

Values are means (n = 4).
EC: electrical conductivity; ESP: exchangeable sodium percentage.

Grain yield

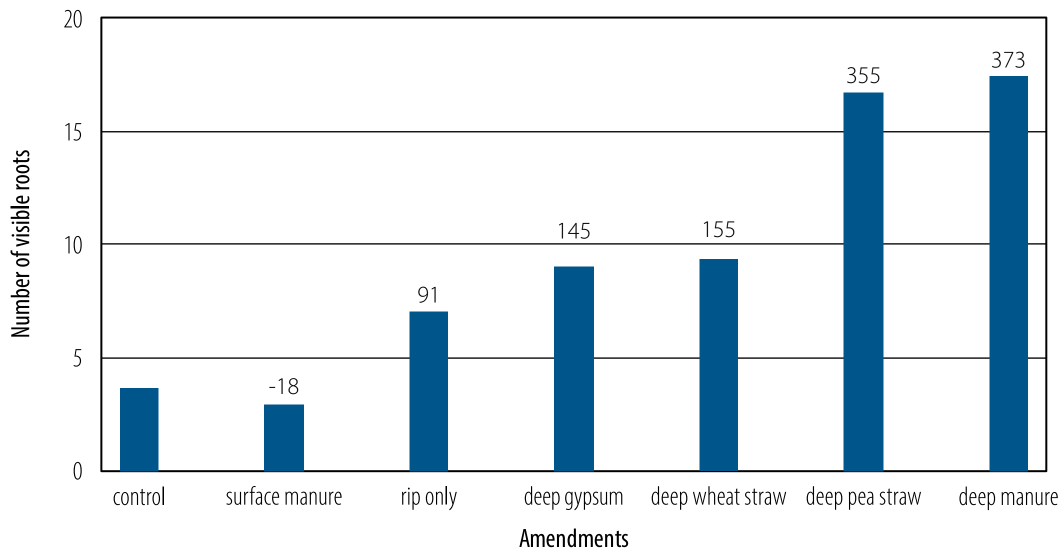
In 2019, canola grain yield was significantly (*P*<0.001) increased following amendments applied in 2017 (Figure 1). The highest increase was observed for deep placement of pea straw + NPK and followed by deep gypsum. Deep nutrients alone did not improve grain yield compared with the control, consequently it can be concluded that the grain yield increases were due to improving soil characteristics and not due to improved nutritional conditions.



Values on the top of each bar represent percent change of grain yield compared with the control.
Each data point is mean value of n = 4.
l.s.d. (P = 0.05) = 0.45 t/ha.

Figure 1 The mean effect of surface or deep-placed amendments on canola (cv. Pioneer® 45Y91 (CL)) grain yield grown in alkaline sodic subsoil in Rand, southern NSW in 2019.

Different amendments also significantly affected ($P<0.05$) the number of visible roots in the amended sodic subsoil (20–40 cm depth) (Figure 2). Deep placement of both manure and pea straw increased the number of visible roots by more than three-fold compared with the control. Neutron probe readings taken during flowering also indicated that the highest root counts were associated with improved water extraction. Compared with the control, deep placement of gypsum reduced the soil pH by 0.7 units (8.8 to 8.1) at 20–40 cm depth.



Values on the top of each bar represent percent change of visible roots compared with the control.
Each data point is mean value of n = 3.
l.s.d. ($P = 0.05$) = 8.8.

Figure 2 The mean effect of surface or deep-placed amendments on the number of visible roots at 30 cm at late flowering of canola (cv. Pioneer® 45Y91 (CL)) grown in alkaline sodic subsoil in Rand, southern NSW in 2019.

Conclusion

The marked increase in the grain yield that occurred at Rand with the deep placement of both organic and inorganic amendments indicates the potential of this approach in reducing the yield gap associated with sodic subsoils in major cropping regions of Australia. Placement of the amendments in the study site in 2017 resulted in three consecutive years with significant yield improvement, indicating the residual effects of this approach on the yields for following crops (Gill et al., 2008).

There was no positive yield response to deep placement of nutrients, and this supports other evidence that the responses at Rand are not due to nutritional factors. In a year of intensive drought such as in 2019, the grain yield improvements at Rand could be attributed to the additional root growth in the amended subsoil layer (Figure 2), which facilitated the use of extra subsoil water (Uddin et al., 2020). Under dryland conditions, water captured by roots in the subsoil layer is extremely valuable as its availability can coincide with the grain filling period and has a very high conversion efficiency into grain yield (Kirkegaard et al., 2007).

This experiment also provides significant indications of how the deep placement of both organic and inorganic amendments can improve soil physicochemical properties. Reductions in extremely high soil pH and ESP at 20–40 cm depth (amended layers) were reported within 14 months following deep placement treatments (Tavakkoli et al., 2019). Furthermore, improvement in soil chemical properties were also associated with increasing soil porosity, infiltration rate and microbial activity (data not shown), which leads to improved soil aggregation and ultimately improved soil structure (Uddin et al., 2020).

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