More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints

Brian Dzoma[1], Nigel Wilhelm[1], Amanda Cook[1], Ian Richter[1] and Craig Standley[1]
[1]SARDI

Location
Minnipa
Minnipa Agriculture Centre
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2023 Total: 280 mm
2023 GSR: 169 mm
Paddock History
2021: Wheat
2022: Barley
2023: Pasture
Soil type
Mild calcareous sand
Soil test
High pH and carbonate, poor P reserves, high N reserves
Plot size
30 m x 2 m x 4 reps
Trial design
RCBD with 4 replicates
Yield limiting factors
Moisture, hostile subsoil

Location
Poochera - Gosling family
Rainfall
Av. Annual: 326 mm
Av. GSR: 247 mm
2023 Total: 207 mm
2023 GSR: 120 mm
Paddock History
2021: Barley
2022: Wheat
2023: Pasture
Soil type
Grey highly calcareous sandy loam
Soil test
Very high pH and carbonate, poor P reserves, high N reserves
Plot size
30 m x 2 m x 4 reps
Trial design
RCBD with 4 replicates
Yield limiting factors
Moisture, hostile subsoil

Key messages

- **Deep ripping as a physical intervention to manage subsoil compaction has not resulted in any significant difference to the control in all three years of these trials.**
- **Topsoil strategies showed the greatest benefits in productivity in the first 2 years; however, these responses did not carry through into the 3rd year, possibly due to less rainfall during Spring in the 2023 year.**
- **On very highly calcareous soils, improving the fertility of subsoils has the potential to improve grain yield, but responses only started showing in the third crop after application compared to the control.**

Why do the trial?

Highly calcareous soils are common in some areas of south-eastern Australia and challenge crop production with a range of constraints. The challenges limit the effectiveness of improved agronomic practices developed elsewhere. This collaborative project, which started in 2020, aimed to identify and overcome calcareous soil constraints in order to lift crop production on these difficult soils. Replicated field trials were conducted on the upper Eyre Peninsula from 2021 to 2023 to investigate impacts of subsoil and topsoil amelioration strategies. This article summarises results of topsoil and subsoil strategies from the third crop grown on these trials in 2023. For details of trial set up and past results, see the 2021 and 2022 EPFS Summary article titled: More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints.

How was it done?

Six replicated field trials were established in 2021 at Poochera, Port Kenny and Minnipa and were re-seeded in May 2023 with GIA Kastar field peas @ 100 kg/ha with 60 kg/ha of MAP. This variety is tolerant to imidazolinone herbicides but does not have improved tolerance to flumetsulam (Broadstrike®) or residual sulfonylurea herbicides. Fresh carbon-coated mineral (CCM) @ 500 kg/ha was applied in topsoil trials as the only new treatment for 2023. The rest of the treatments were the same as in previous years. For more treatment details, see article in EPFS Summary 2022 titled: More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints.

Measurements taken included crop establishment, flowering biomass, shoot nutrients at flowering, grain yield and soil penetration resistance of selected subsoil treatments. Statistical analysis of data was performed using standard ANOVA models in R.

Location
Port Kenny - Simon Guerin
Rainfall
Av. Annual: 349 mm
Av. GSR: 270 mm
2023 Total: 248 mm
2023 GSR: 171 mm
Paddock History
2021: Barley
2022: Pasture
2023: Wheat
Soil type
Grey very highly calcareous sandy loam
Soil test
Very high pH and carbonate, poor P reserves, high N reserves
Plot size
30 m x 2 m x 4 reps
Trial design
RCBD with 4 replicates
Yield limiting factors
Moisture, hostile subsoil

What happened?

Crop establishment was not affected by any of the topsoil and subsoil strategies at any site. Mean plant population was 46 plants/m^2 (Poochera), 43 plants/m^2 (Port Kenny) and 39 plants/m^2 at Minnipa.

Shoot biomass at flowering was not improved by subsoil strategies and trial site averages ranged from 2.1 t/ha (Port Kenny), 1.3 t/ha (Poochera) and 0.9 t/ha (Minnipa). At Minnipa and Poochera, none of the topsoil strategies improved biomass at flowering, however, at Port Kenny in 2023 applied CCM @ 500 kg/ha improved flowering biomass by 15% when compared to '*typical practice*' (2.45 t/ha).

Shoot nutrient analysis

After assessing flowering biomass, samples were sent to APAL for shoot nutrient analysis. Table 1 summarises ANOVA outputs for responses of key plant nutrient concentrations at flowering to topsoil and subsoil treatments at the three sites.

Subsoil

Shoot concentration of P at Minnipa and Port Kenny was not different from the control, however, at Poochera shoot P was significantly higher with CCM (0.22%) than typical practice (0.18%). Neutrog in the subsoil resulted in higher concentration of zinc in the plants at all 3 sites. Shoot zinc concentration with Neutrog was 17.5 mg/kg (Minnipa), 41.3 mg/kg (Poochera) and 25.1 mg/kg (Port Kenny). Shoot nitrogen (%) and manganese (mg/kg) was not affected by amendments and deep ripping at all 3 sites.

Table 1. Average nutrient concentrations across all treatments in flowering DM at Minnipa, Poochera and Port Kenny in 2023 and the significance of treatment differences.

SUBSOIL	Minnipa		Poochera		Port Kenny	
	p-value	mean	*p-value*	mean	*p-value*	mean
Nitrogen %	*ns*	2.45	*ns*	2.34	*ns*	2.65
Phosphorus %	*ns*	0.14	*0.003*	0.20	*ns*	0.22
Potassium %	*ns*	2.03	*<0.001*	2.16	*0.005*	2.21
Sulfur %	*ns*	0.12	*0.001*	0.19	*ns*	0.19
Copper (mg/kg)	*ns*	3.77	*ns*	6.13	*0.05*	3.33
Zinc (mg/kg)	*0.02*	14.5	*0.007*	34.2	*<0.001*	10.4
Manganese (mg/kg)	*ns*	29.4	*ns*	30.2	*ns*	20.8
TOPSOIL	**Minnipa**		**Poochera**		**Port Kenny**	
	p-value	mean	*p-value*	mean	*p-value*	mean
Nitrogen %	*ns*	2.44	*ns*	2.11	*ns*	2.24
Phosphorus %	*ns*	0.13	*ns*	0.18	*ns*	0.19
Potassium %	*ns*	2.03	*0.01*	2.06	*ns*	2.23
Sulfur %	*0.006*	0.13	*0.004*	0.17	*ns*	0.17
Copper (mg/kg)	*ns*	4.56	*0.01*	5.33	*<0.001*	3.83
Zinc (mg/kg)	*<0.001*	15.6	*ns*	27.4	*<0.001*	15.1
Manganese (mg/kg)	*ns*	29.9	*ns*	23.4	*ns*	19.3

Topsoil

Though adequate in controls, the combination strategy (fungicide + N + P + TEs) resulted in higher concentration of zinc in the plants at Minnipa (24.5 mg/kg) and Port Kenny (18.5 mg/kg). Shoot nitrogen (%), phosphorus (%) and manganese (%) were not affected by topsoil strategies at all 3 sites.

Grain yield

In 2023, a lack of moisture during late spring resulted in an early finish and generally very poor yields. Pod filling was poor at Minnipa and Poochera. The Minnipa site was not harvested, Poochera was harvested on 19 October, and Port Kenny on 18 October. Site mean for grain yield was 0.2 t/ha at Poochera and 1.1 t/ha at Port Kenny. Topsoil strategies did not improve grain yield at the 2 harvested sites. In the subsoil trial, deep ripping alone did not improve grain yield at both sites, however, all ripping with amendments improved grain yield at Port Kenny. Typical practice was 0.87 t/ha, and the two highest yielding treatments were deep ripping with inclusion plates and Neutrog (1.12 t/ha) and deep ripping with CCM (1.10 t/ha).

Soil strength

Measurements of penetration resistance were carried out using a cone penetrometer in December, after 72 mm of rain (Figure 1). Data from the unripped controls showed that soil strength is not severe in these soils with penetration resistance ranging between 500 - 2500 kPa. However, there were signs of re-compaction of the ripped treatments because penetration resistance was slightly higher in 2023 than in 2021 initial measurements. For example, in 2021 at 35 cm soil depth, penetration resistance was 524 kPa at Poochera and 964 kPa at Port Kenny, and at the same depths in 2023 it increased to 1216 kPa at Poochera and 1684 kPa at Port Kenny respectively.

2023 Deep rip means that soil penetration resistance measurements were taken in 2023 (after ripping in 2021).

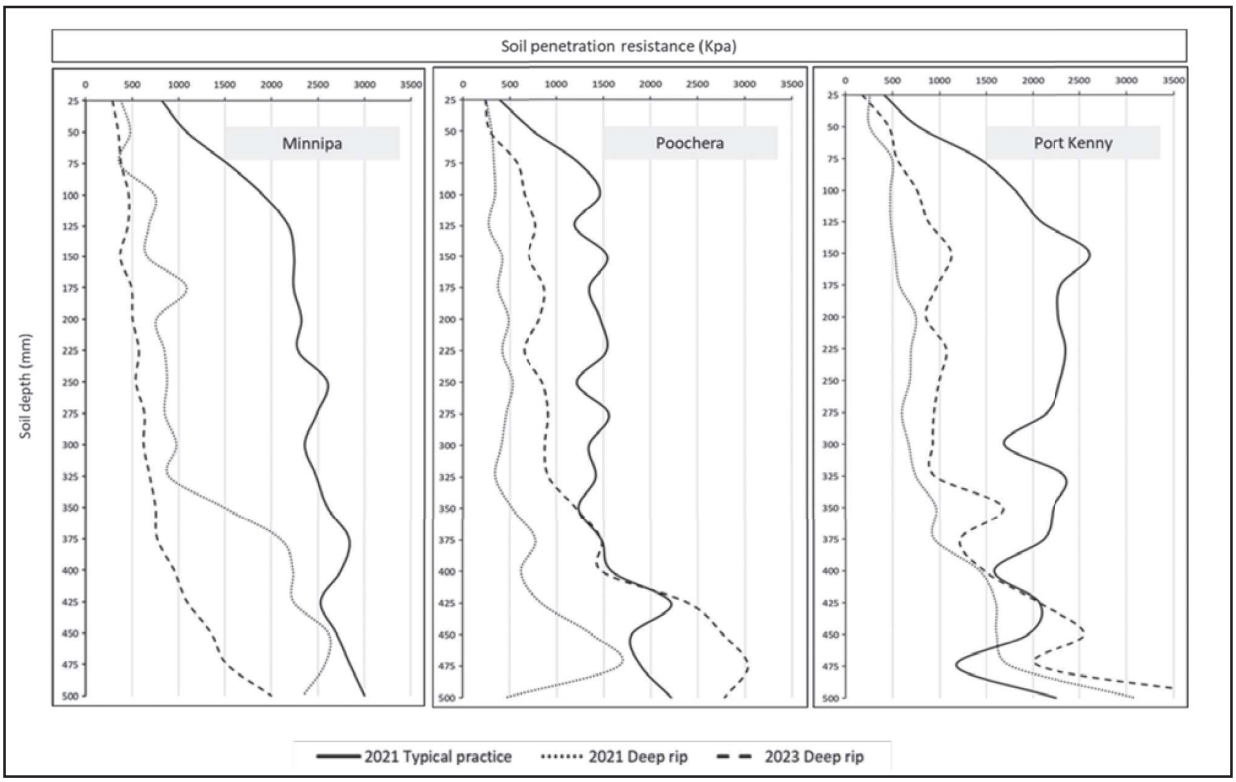

Figure 1. Soil penetration resistance (kPa) in 2021 or 2023 comparing deep ripping with unripped typical practice at Minnipa, Poochera, and Port Kenny.

What does this mean?

Our results have demonstrated that on very highly calcareous soils, while improving the fertility of the subsoil has potential to improve grain yield, the responses can take several years to appear and were quite modest in size compared to their cost. These modest responses might be a result of the poor finish in 2023 and the response of these interventions in the longer term under different growing season conditions is unknown. Deep ripping without amendments as a physical intervention to manage subsoil compaction has not improved grain yields in all three years of running these trials. This indicates that the constraints in these soils are more than just compaction, and therefore managing multiple constraints would be required to optimise crop production on these challenging soils. Topsoil interventions have showed strong benefits in the first two years of conducting the trials, however, in year 3, under poor growing conditions, they have not shown any residual benefits over and above typical practice.

CCM applied under seed rows resulted in the highest flowering biomass in all three seasons at Port Kenny. Even though it is not commercially available, follow up research is required to assess whether the knowledge gained from this work can be developed into a commercial option. This new research should focus phosphorus supply and uptake in calcareous soils using different formulations (e.g., liquid and pelletised CCM of different types), and an economic analysis to determine if these strategies can be financially attractive.

Acknowledgements

This project, "More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints", is supported by the Cooperative Research Centre for High Performance Soils, whose activities are funded by the Australian Government's Cooperative Research Centre Program. The project is co-funded by Grains Research and Development Corporation (GRDC). The authors would also like to thank the landholders and families involved in this project: Shard Gosling, Simon Guerin and the Minnipa Agricultural Centre.

Farzad Aslani and Craig Standley; SARDI, Gareth Scholz; SANTFA and Jack Desbiolles; University of South Australia visiting the Robust Ground Cover Seed Priming site at Minnipa (Scholz).