# Characterising water limited yield potential in calcareous soils of upper Eyre Peninsula

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**Location**
Minnipa (Condada)
**Rainfall**
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm
**Paddock history**
2019: Scepter wheat
2018: Volga vetch
2017: Fathom barley
**Soil type**
Red sandy loam
**Plot size**
12 m x 2 m x 3 reps

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**Location**
Streaky Bay
**Rainfall**
Av. Annual: 377 mm
Av. GSR: 303 mm
2019 Total: 278 mm
2019 GSR: 262 mm
**Paddock history**
2019: Mace wheat
2018: Medic pasture
2017: Compass barley
**Soil type**
Grey calcareous sandy loam
**Plot size**
12 m x 2 m x 3 reps

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**Location**
Cungena
**Rainfall**
Av. Annual: 284 mm
Av. GSR: 239 mm
2019 Total: 208 mm
2019 GSR: 185 mm
**Paddock history**
2019: Scepter wheat
2018: Medic pasture
2017: Mace wheat
**Soil type**
Grey calcareous sandy loam
**Plot size**
12 m x 2 m x 3 reps

## Key messages

- **Current standard practices of 50 kg/ha DAP or 50 kg/ha MAP balanced with urea below the seed provides adequate P nutrition.**
- **With adequate soil moisture, no large differences in grain yield were observed in 2019 at Streaky Bay with different granular fertiliser treatments.**

## Why do the trial?

On the upper Eyre Peninsula (UEP), highly calcareous soils constitute a high proportion (more than 1 million hectares) of soils used for agricultural production (Bertrand *et al*. 2000, Bertrand *et al*. 2003). The website 'Yield Gap Australia' (http://yieldgapaustralia.com.au/maps/) identifies that the average grain yield on Western Eyre Peninsula (WEP) and UEP is between 41 and 45% of the water limited yield potential (1.5 t/ha for WEP and 1.8 t/ha for UEP). Closing the grain yield gap for wheat on UEP presents a challenge to growers, particularly on highly calcareous soils where nutrient deficiencies are common (Holloway *et al*. 2001). The production of insoluble minerals through the interaction of soil calcium carbonate with soluble nutrients such as phosphorous and trace elements (Holloway *et al*. 2001), combined with low soil moisture conditions prevents these nutrients from being readily available to the plant (Lombi *et al*. 2004). Holloway *et al*. (1999-2003) demonstrated the possibility of providing phosphorus (P) to the plant in an available form by applying fluid P fertilisers instead of granular fertilisers at seeding.

The majority of landholders in Australia, including the western and upper Eyre Peninsula currently use granular fertilisers which require good soil moisture conditions to enable uptake of nutrients by crops. Growers and advisors have noted that highly calcareous top soils dry out quickly after rainfall events, which may contribute to poor water use and nutrient extraction efficiency, and may also be a reason why diseases such as *Rhizoctonia solani* have greater impact in these soils. In addition, as a risk management strategy, growers often apply lower rates of nutrients than required to achieve the water limiting yield potential (Sadras and Roget 2004, Monjardino *et al*. 2013). A better understanding of soil moisture, root disease and factors which influence nutrient availability and the efficacy of fertilisers are needed to increase the water limited yield potential of the highly calcareous soils (McLaughlin *et al*. 2013).

Field trials were conducted in 2019 to investigate these factors on the nutrition of wheat on highly calcareous soils.

## How was it done?

***Trial 1: Fertiliser Trial***

In trial 1, a randomised block design fertiliser trial was sown at three sites to test the effects of soil moisture on nutrient uptake and yield of wheat. The trials were located at Streaky Bay and Cungena on grey calcareous soils with differing calcium carbonate levels, and Minnipa, a red loam with low calcium carbonate. The treatments applied to Scepter wheat sown at 60 kg/ha were:

- Nil fertiliser (control)
- Nil fertiliser with a high seeding rate of 80 kg/ha
- 50 kg/ha DAP (di-ammonium phosphate)
- 50 kg/ha MAP (mono-ammonium phosphate) balanced with urea
- 50 kg/ha DAP with fluid trace elements (TE) (Zn Cu, Mn)
- 50 kg/ha DAP with a high seeding rate of 80 kg/ha
- 50 kg/ha MAP balanced with urea and fluid TE (Zn Cu, Mn)
- 5 kg P/ha as fluid fertiliser (phosphoric acid) with fluid TE (Zn Cu, Mn)
- 100 kg/ha DAP
- 100 kg/ha MAP balanced with urea
- 200 kg/ha MAP balanced with urea
- 200 kg/ha DAP with a high seeding rate of 80 kg/ha.

***Trial 2: Phosphorus and Nitrogen Interaction Trial***

A factorial trial was conducted to evaluate the interaction between phosphorous and nitrogen at Streaky Bay, Cungena and Minnipa (Table 1), and was used to interpret the response of commercial fertilisers in Trial 1. In this trial, Scepter wheat was sown at 60 kg/ha.

At each site, twenty plants per plot were randomly sampled to estimate root dry weight and rhizoctonia on roots within the top 10 cm soil layer at 6 weeks and 12 weeks after sowing. Root rhizoctonia disease measurements consisted of 1) counting the number of seminal roots and 2) calculating a percentage of infected crown roots.

Gravimetric soil moisture was measured in increments to 100 cm depth at sowing for each replicate, and for each plot at maturity. Soil fertility was also measured before sowing . Volumetric soil water was estimated using bulk density from the nearest APSOIL sites. Statistical analyses were performed using R software and the R package ASREML to estimate treatment variability and adjust for spatial trends in the trials. Tukey's tests were applied to assess differences between treatments.

## What happened?

***Soil water and fertility at sowing***

Cungena and Streaky Bay had higher soil moisture (65 and 77 mm) to 100 cm than Minnipa (Table 2). Although all three sites had pasture as a previous crop, Minnipa had the lowest mineral N, organic C and Colwell P of the three sites (Table 2). Cungena and Streaky Bay sites had moderate phosphorus buffer index (PBI) values but high Colwell P (Table 2). The organic carbon levels measured at Streaky Bay and Cungena could have been due to the presence of higher calcium carbonate levels affecting the measurements (Table 2).

***Table 1. Treatment details and application time (Trial 2) at Streaky Bay, Cungena and Minnipa in 2019.***

| Timing of treatment | Treatment details |
|---|---|
| Seeding | Phosphoric acid (water rate of 80 L/ha): 0, 5, 10 and 40 P kg/ha |
| Emergence | Granular urea: 0, 10, 30, and 60 kg N/ha |

***Table 2 Soil N, P, organic C content and soil moisture at sowing, sowing date and growing season rainfall. Plant available water capacity (PAWC) information taken from Hancock et al., 2007.***

| Trials 2019 | Mineral N 0-100 cm (kg/ha) | Colwell P 0-10 cm (mg/kg) | PBI 0-10 cm | Soil moisture 0-100 cm (mm) | Organic carbon 0-10 cm (%) | Sowing date | Growing season rainfall (Apr-Oct) (mm) | PAWC (mm) |
|---|---|---|---|---|---|---|---|---|
| Minnipa (Condada) | 44 | 22 | 76* | 41 | 0.61 | 6 May | 234 | 126 |
| Cungena | 86 | 49 | 127 | 65 | 0.96 | 7 May | 185 | 38 |
| Streaky Bay | 65 | 52 | 184 | 77 | 2.28 | 8 May | 262 | 96 |

**Data collected in the neighbouring paddock next to a soil moisture probe*

*Water limited grain yield (Trial 2)*

The phosphorus and nitrogen interaction fluid fertiliser trials showed grain yield increases were associated with 40 kg/ha of P at Minnipa and Cungena (Figure 1). Minnipa and Cungena had the highest increases compared to the nil treatment with 11 and 12% increase in grain yield compared to the nil respectively (Figure a-b). Streaky Bay had no yield difference across treatments (Figure c). These results may be explained by the higher solubility of P and other nutrients due to the higher growing season rainfall (Table 2) with 262 mm at Streaky Bay compared to Minnipa (234 mm) and Cungena (185 mm).

*Water limited grain yield (Trial 1)*

The granular trials performed similarly to the fluid trials in terms of average grain yield (Figures 1-2). Minnipa had 200 kg/ha of MAP balanced with urea and DAP with high seeding rate as the best fertiliser treatments with 16-18 % increase in grain yield compared to the nil (Figure 2a). However, similar grain yields were also achieved with growers' standard practices such as: 50 kg/ha of DAP or MAP balanced with urea at seeding (Figure 2a).

At Cungena, 200 kg/ha of MAP balanced with urea was also the best treatment, with a grain yield increase of 22% compared to the nil with high seeding rate, and 50 kg/ha of DAP with trace elements (Figure 2b). Although 200 kg/ha of MAP balanced with urea had the highest increase in grain yield, similar grain yields were found for the nil fertiliser with normal seeding rate and growers' standard practice of 50 kg/ha DAP at Cungena (Figure 2b). This result may be due to low soil moisture at Cungena (Table 2) that affected soil P availability and uptake.

At Streaky Bay, there were no significant differences in grain yield responses to fertiliser treatments applied at sowing (Figure 2c). The high growing season rainfall, and increased soil nutrient availability at sowing (Table 2) may have reduced the responsiveness of Streaky Bay soil to fertiliser rates.

Although Trial 2 results supported the grain yield responses to 40 units of P at Trial 1 (Figure 1 and 2), no drastic grain yield increases have been detected that justified replacing standard practices of 50 kg/ha of DAP or MAP balanced with urea.

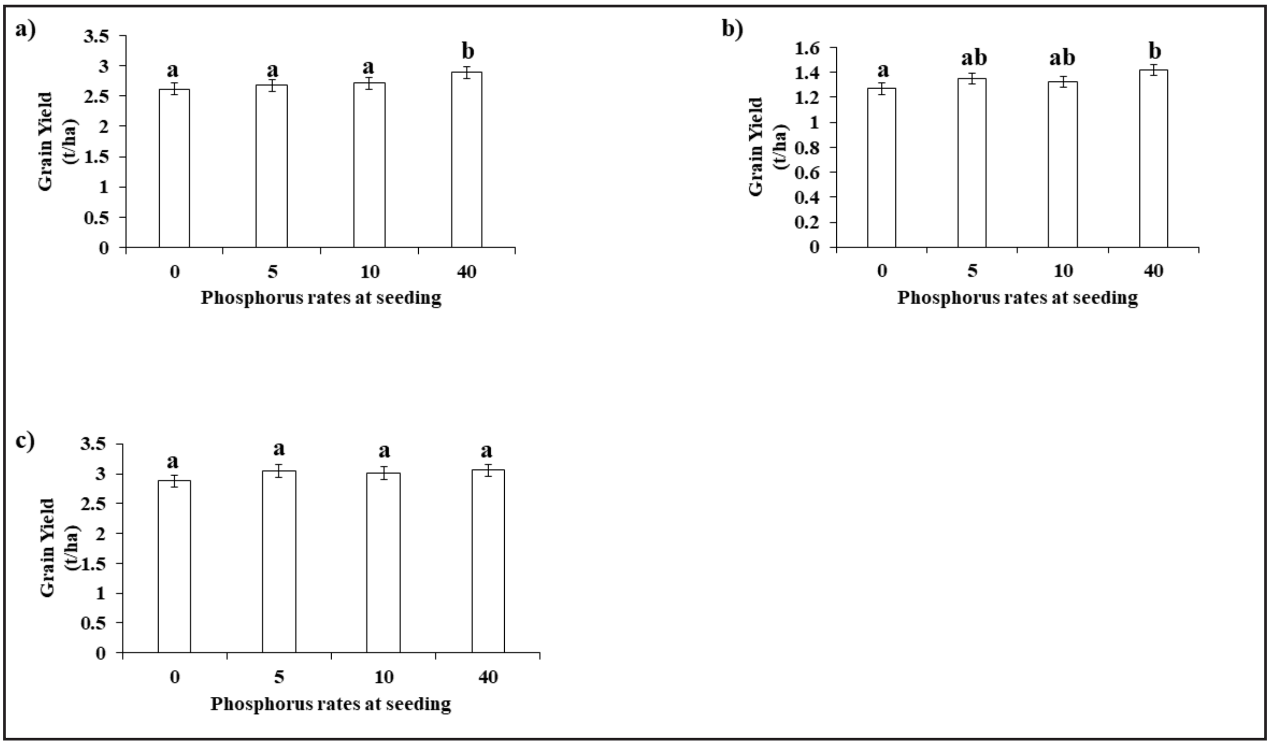


*Figure 1. Grain yield (t/ha) across fluid fertiliser trials at Minnipa (Condada (a), Cungena (b) and Streaky Bay (c).*

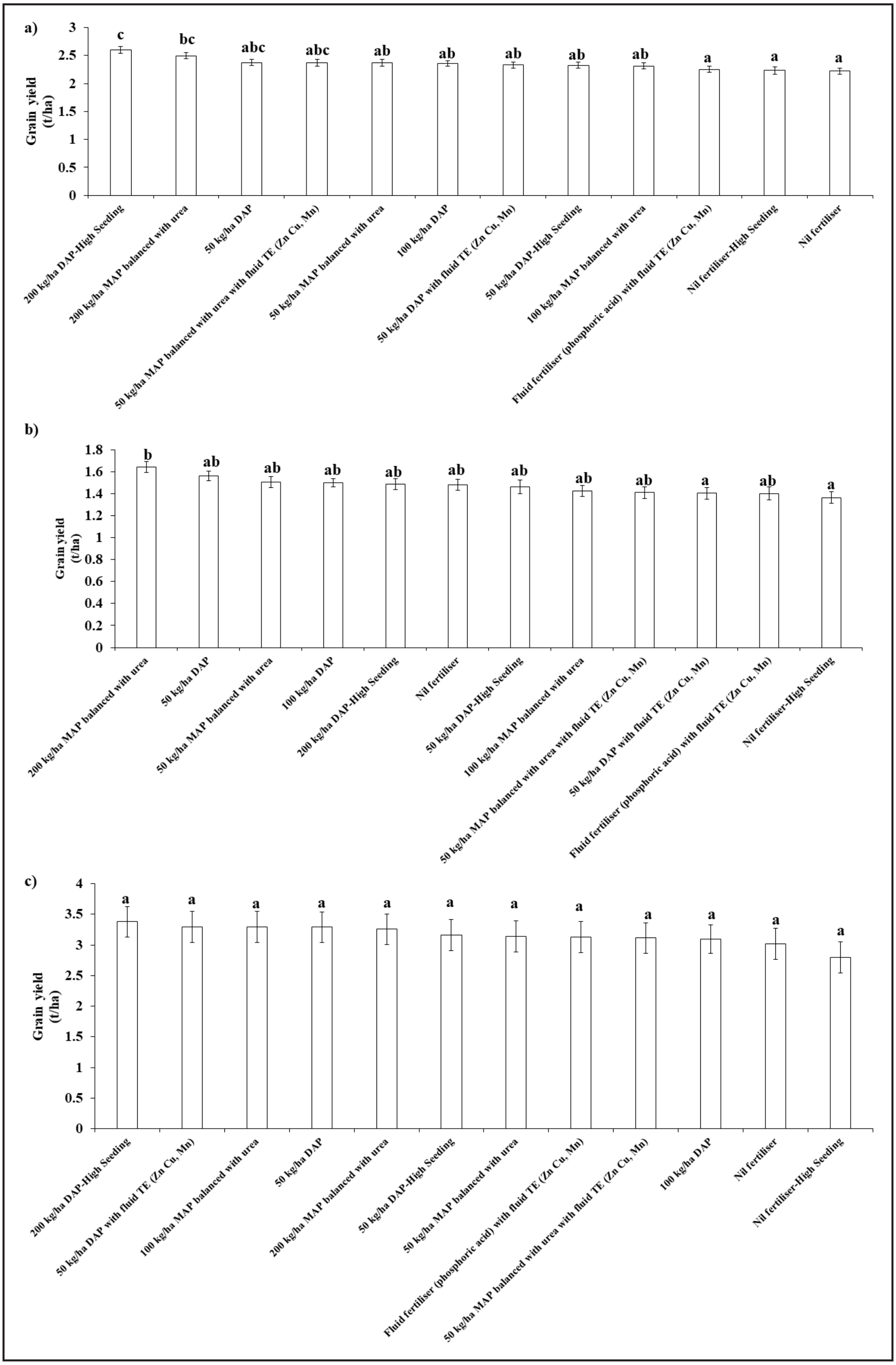


***Figure 2. Grain yield (t/ha) across granular fertiliser trials at Minnipa (Condada, a), Cungena (b) and Streaky Bay (c).***

***Rhizoctonia infection of crown roots (Trial 2)***

At Cungena and Minnipa, there were differences in rhizoctonia infection of crown roots between treatments at both sampling times (data not shown). Interactions of N and P rates were detected in response to rhizoctonia incidence. The delay in the application of N (at emergence) compared to P (at sowing) may have been responsible for an increase in rhizoctonia incidence in crown root infection across treatments.

## What does this mean?

In 2019, our findings suggest:

1. 0.3-0.4 t/ha increases in grain yield compared to nil fertiliser were observed across higher input fertiliser treatments in 2019. No improved fertiliser strategies have been found to replace the current standard practices of 50 kg/ha of DAP or MAP balanced with urea below the seed applied at seeding.
2. Soil moisture and P dynamics contributed to increase grain yield of wheat in dryland farming systems. This research confirmed the findings of McBeath *et al*. 2012 where P fertiliser use efficiency was strongly affected by water input (soil moisture and growing season rainfall). The combination of soil moisture, seasonally applied P and N fertiliser inputs at Streaky Bay and Minnipa favoured high levels of grain yield.
3. Rhizoctonia crown root infection was triggered by an interaction between N and P treatments. This may have been due to soil nutrient deficiencies caused by the delayed N application (after emergence instead of at seeding). These results supported the conclusions from Cook *et al*. 2009, where nitrogen deficiencies at seeding increased Rhizoctonia incidence. Additionally, reduced rhizoctonia incidence across high input treatments in good seasons was also observed by Cook *et al*. 2011 at Streaky Bay.

Future research should focus on the soil chemistry and the development of new fertiliser formulations to unlock the soil P already fixed in calcareous soils.

## Acknowledgements

This project was part of the strategic partnership between SARDI and GRDC (scoping study DAS00157). Special thanks to Matthew Cook, Myles Tomney and Phil Wheaton and families for providing the field trial sites. Thank you to Katrina Brands, Steve Jeffs and Bradley Hutchings for their collaboration with field activities. Thank you to Nigel Wilhelm and Amanda Cook for feedback and suggestions throughout the season.

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