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Interactive effects between phosphorus (P) placement and watering regimes on wheat grain yield

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Key findings

- Increase in wheat grain yield is attributed to the higher P rates rather than the placement strategies.
- Shallow P was as effective or more effective than dual P placement.
- P placement did not interact with watering regimes for wheat grain yield.
- Placing P deeper in the soil profile might not be a reliable way of improving crop performance in southern NSW.

Keywords Phosphorus placement, deep banded P, shallow P, dual P, rainout shelter

Introduction

Recent GRDC-invested research in the summer rainfall-dominated northern growing region of Australia has shown that grain yield can be increased by 6–40% by placing P ~20 cm deep and at 50 cm spacing instead of current farming practice, i.e. 5–10 kg P/ha applied in or around the seed row (Lester et al. 2022; Sands et al. 2022).

In contrast to the north, cropping in the southern growing region is dominated by winter rainfall. However, there are still periods of prolonged dry topsoils, particularly in drier years. These conditions, in addition to highly stratified surface P and low P reserves below the cultivated layer, led researchers to predict that dual P banding would be more efficient than current P placement strategies in or around the sowing rows.

In 2020, GRDC invested in a new project (Maximising the uptake of phosphorus by crops to optimise profit in central and southern NSW, Victoria and South Australia; DPI2001-033RTX) to investigate the effectiveness of dual placed P on crop performance. Prevailing wet conditions over the past 3 years have limited the incidence of favourable soil moisture conditions for deep P responses (i.e. dry surface with wet subsoil; Verburg et al. 2022). Therefore, a new experiment was established in 2022 at Tootool southern NSW, to impose a dry surface condition by excluding rain events greater than 5 mm using rainout shelters.

This paper reports experiment findings investigating the interactions between P placement strategies and watering regimes on grain yield of winter wheat.

Site details

Location	Tootool, southern NSW
Soil type	Red sodosol
Design	• Split-plot design with P treatment as the main plots and watering regimes as sub-plots • Replications: 4

Sowing	• Species: wheat (cv. Sunblade CL Plus(ϕ)) • Seed rate: 71 kg/ha • Sowing date: 19 May 2022 • Spacing: 25 cm
Fertiliser	• Urea at 60 kg/ha at sowing to balance the P fertiliser applied as mono-ammonium phosphate (MAP) • Urea at 100 kg/ha at tillering
Rainfall	• Fallow (November 2021 – March 2022): 445 mm; long-term average = 195 mm • In-crop (April–October 2022): 583 mm; long-term average = 325 mm
Harvest date	16 December 2022 (header harvested)

Treatments

P treatments

Four P treatments: 5/0, 5/60, 20/0, and 20/60 (shallow/deep P kg/ha).

Phosphorus was either applied as a dual placement strategy or shallow only:

- dual placement – some under every seed row (shallow band) and some banded at approximately 20 cm below the surface in 50 cm spacings (deep band)
- shallow only – all placed under every seed row.

These 2 strategies are described as dual P (e.g. 5/60 and 20/60; shallow/deep P kg/ha) or shallow P (e.g. 5/0 and 20/0; shallow/deep P kg/ha), respectively.

All treatments (even where no deep P was applied for example 5/0 and 20/0) were disturbed to ~20 cm deep to account for any apparent ripping effect.

Watering regimes

Two watering regimes:

- control (rain-fed)
- dry conditions (using rainout shelters).

A custom-built rainout shelter (Figure 1) was used to create a contrasting watering regime to the rain-fed condition by excluding rain events (>5 mm). The cover of the rainout shelter was put on when >5 mm of rain was forecast but removed after the rain event to minimise shading effects. The rainout shelters were used from the second week of July until maturity.

Results

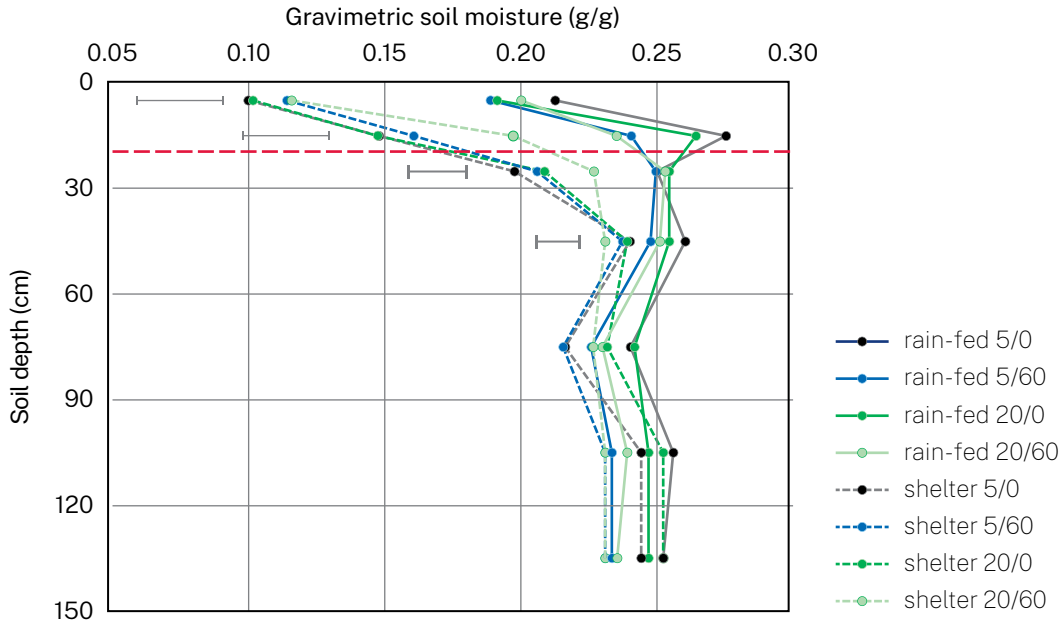
Growing conditions

The soil at the experiment site had stratified P. Colwell P was 26 mg/kg at the soil surface (0–10 cm) and 2.9 mg/kg in the subsoil (10–30 cm deep). The site had a potential alkaline sodicity constraint at depth (starting at 30–60 cm). Soil profile water content at sowing (up to 150 cm deep) was 605 mm indicating very high summer fallow rainfall. The site received well above average annual rainfall of 946 mm with 583 mm falling during the growing season (April–October).

Figure 1 Portable rainout shelters covering wheat plots to exclude rainwater at Tootool, southern NSW. Photos taken at anthesis showing wetter surface soil in the rain-fed plot (top right) compared to the plot with rainout shelter (bottom right).

Soil moisture content at anthesis

The gravimetric moisture content at different soil depths was determined by destructive soil coring at anthesis. The rainout shelters were effective at excluding rainwater and resulted in a significantly lower soil moisture content especially in the upper soil layers than in the rain-fed plots (Figure 2). The difference in surface soil moisture condition between the rain-fed and rainout shelter plots was also visible from the photos taken during soil coring at anthesis (Figure 1 top and bottom right). However, deeper in the soil profile (i.e. >60 cm deep) gravimetric soil moisture content did not significantly differ between the rain-fed and rainout shelter plots.

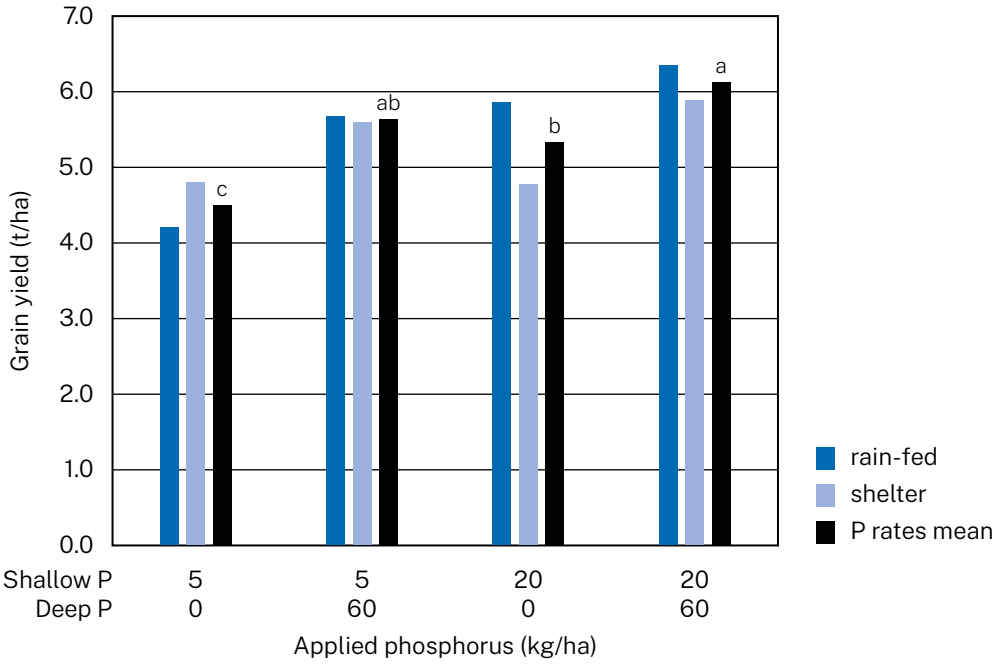


The horizontal dashed line (red) indicates deep P banding depth. All treatments had been disturbed to ~20 cm deep at 50 cm spacing at sowing in 2022 as part of the deep P application. At different soil depths, significant differences ($P<0.05$) between the watering regimes are indicated by horizontal lines. Gravimetric soil moisture content did not significantly differ ($P>0.05$) between the P placement strategies.

Figure 2 The effect of P placement strategy and watering regimes on gravimetric soil moisture content during wheat anthesis (cv. Sunblade CL Plus$^{(\phi)}$) at Tootool, southern NSW in 2022.

Grain yield

Wheat grain yield was significantly (P<0.001) affected by the P placement strategy, but the effect of watering regimes was not significant (P>0.05). With a low rate of shallow P (i.e. 5 kg P/ha), deep banded 60 kg P/ha increased grain yield by 25%, whereas with a moderate rate of shallow P (i.e. 20 kg P/ha), the increase in grain yield was only 15% (Figure 3). A similar yield response between a total of 65 kg P/ha dual banded P (i.e. 5/60 shallow/deep kg P/ha) and only 20 kg P/ha shallow banded P (i.e. 20/0 shallow/deep kg P/ha) indicates that shallow P was more effective than dual P.



All treatments had been disturbed to ~20 cm deep at 50 cm spacing at sowing in 2022 as part of the deep P application. Each data point is a mean value of n = 4. Significantly different (P<0.05) wheat grain yield between P placement strategies (l.s.d. = 0.7 t/ha) is annotated by different letters.

Figure 3 The effect of shallow and dual banded P (kg/ha) on wheat (cv. Sunblade CL Plus(ϕ)) grain yield at Tootool, southern NSW in 2022.

Summary

Deep banding P has produced consistent grain yield in the northern growing region (Lester et al. 2022; Sands et al. 2022), but there is very limited evidence of an advantage of dual banded P over shallow banded P in the southern growing region (Uddin et al. 2023). Consistent with earlier findings from the southern growing region, the results from this experiment also support shallow banded P as a more effective strategy than dual P placement.

This experiment aimed to create favourable soil moisture conditions for deep P responses (dry surface soil at shallow banded P depth and wet subsurface soil at deep banded P depth) using rainout shelters. Soil moisture at anthesis showed that excessively using rainout shelters resulted in dry conditions both at shallow and deep banded P depths, thereby creating unfavourable soil moisture conditions for deep P responses. However, this once-off soil moisture measurement was unable to represent all growing season scenarios, as wheat grain yield still benefited from the higher rates of deep banded P. This highlights the importance of periodic soil moisture measurements.

The effectiveness of the shallow banded P compared with dual P placement under contrasting watering regimes indicates that placing P deeper in the profile might not be a reliable strategy to improve crop performance in southern NSW.

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