Deep phosphorous in central west NSW

Ben O'Brien[1] & Maurie Street[1]

[1] Grain Orana Alliance

Key words

phosphorous, nutrition, Colwell P, Deep Placement, stratification, nutrition

GRDC code

GOA2006-001RTX

Take home messages

Applying phosphorus (P) at or close to the soil surface:

- achieves yields as good as or better than deep placed P
- has a higher net income than deep P.

Deep P may be an option if you have low soil Colwell P and you are:

- deep ripping to ameliorate another soil constraint
- moisture seeking to sow chickpeas
- BUT: Growers need to continue to apply shallow P fertiliser to optimise yields!

Background

Phosphorus (P) is an essential nutrient for crop growth, and although crop demand for P varies between species and across growth stages, plants can only take up P when it is present in the soil solution as phosphate ions. Many of our farming soils are naturally low in P and are depleting further. P fertilisers are mostly applied with the seed at 2-5cm of depth but crops are constantly cycling this P and other deeper sources (5-30cm) of P to the soil surface. Some P is removed in grain or crop tops with the balance returning to soil surface as crop residues. The combination of these factors has resulted in a concentrated or stratified P band at, or close to, the soil surface with the subsoils becoming P depleted. Research conducted in Central West NSW (CW NSW) by (McMaster, 2014) and reviews conducted by (Sandral *et al.,* 2019) demonstrated that it is very common for P concentrations to be stratified close to the soil surface, with limited P availability at depth in CW NSW.

Queensland and northern NSW grain growing areas have a summer dominated rainfall pattern and growing crops generally rely more on stored soil water. As such, crops grow on subsoil water and rely on P sources deeper in the profile. Accumulated P at the soil surface becomes unavailable as the surface dries and if the subsoil is also depleted, deficiencies can occur.

Research from these areas has shown that deep application of P fertiliser improved crop yields in some situations. Stemming from this research, several guidelines have been developed which aim to predict responsiveness to applied deep P, including the development of an online Deep P calculator (Gentry *et al.,* 2017).

Previous studies conducted in southern NSW found no crop responses from deep applied P compared with surface applied P (Brunton *et al.,* 2025). It is recommended that maintaining adequate soil P levels in the surface remains the best management option for the south. The research concluded that the reason for the lack of response to deep P was that the 'scenarios in which surface P availability may be restricted due to soil drying is likely to occur relatively infrequently' (Brunton *et al.,* 2025).

In summary deep applied P is recommended in the northern NSW and Queensland cropping regions but not recommended for southern NSW, however research in CW NSW has been limited to only 2 documented NSW DPIRD trials conducted in 2018 and 2019, which were inconclusive due to drought conditions (Mugerwa *et al.,* 2019b, 2019a).

In considering the potential responsiveness to deep applied P in CW NSW, GOA reviewed their database of approximately 90 local soil tests. Using the critical thresholds of Colwell P <10 mg/kg and BSES P <30 mg/kg in the 10–30 cm soil layer, indications are that 80% would respond to deep applied P. However, like the reasons suggested in southern NSW, it is questioned whether the rainfall patterns and frequency of soil drying periods justify the application of deep P.

What did we do?

In the fallow of 2017/18 GOA established 3 trials comparing P application depth, rate and spacing.

Trials were conducted in growers' fields that had a history of response to applied P, which was confirmed by soil testing (Table 1). All 3 sites had very low levels of both Colwell P and BSES in the deeper soil layers (10–90 cm) meeting the suggested thresholds for responsiveness to deep applied P.

Two trials were established using GOA's trialling equipment and the third was established using the grower's machinery (a deep ripper with fertiliser boxes). Phosphorous was applied as MAP and nitrogen rate balanced for each treatment with urea.

Table 1. Soil phosphorus prior to application of fertiliser treatments in 2018.

			Soil depth			
Location	**Analyte**	**Unit**	**0–10 cm**	**10–30 cm**	**30–60 cm**	**60–90 cm**
Trangie	Phosphorus (Colwell)	mg/kg	29	7	<5	<5
	Phosphorus (BSES)	mg/kg	36	8	<5	<5
	Phosphorus Buffer Index		50	69	98	120
Narromine	Phosphorus (Colwell)	mg/kg	22	<5	<5	<5
	Phosphorus (BSES)	mg/kg	28	6	8	
	Phosphorus Buffer Index		100	100	100	
Geurie	Phosphorus (Colwell)	mg/kg	14	<5	<5	<5
	Phosphorus (BSES)	mg/kg	27	5	<5	9
	Phosphorus Buffer Index		120	200	210	160

The trials were small plot, randomised, complete block design with 4 replicates. Results were analysed using ANOVA for the analysis of variance and results compared by using a least significant difference (LSD) method with a 95% confidence interval. Any references to differences between treatments should be assumed to be statistically different unless otherwise stated.

Table 2. Treatments applied at the trial establishment at each of the 3 sites in 2018.

	Trangie	**Narromine**	**Geurie**
P rates – deep (kg P/ha)	0, 22 and 44	0, 25 and 50	0, 25 and 50
P application depth	35–40 cm	18–20 cm	18–20 cm
P application spacing	50 cm	25 and 50 cm	25 and 50 cm
P application orientation (to sowing rows)	Perpendicular	Parallel	Parallel
Machinery	Grower deep ripper	GOA trialling equipment	GOA trialling equipment

Table 3. Treatments applied every year at sowing at each of the 3 sites.

	Trangie	**Narromine**	**Geurie**
P rates at sowing (kg P/ha)	0, 11, and 22 (2020) 0, 4 and 9 (2021–24)	0, 11, 12.5, 25	0, 11, 12.5, 25
Depth	2–5 cm	2–5 cm	2–5 cm
Sowing spacing	22.5 cm	22.5 cm	22.5 cm

In 2018 trials were sown, however were abandoned as a combination of the drought and the aggressive tillage associated with deep ripping (to apply the P) resulted in crop failures. Crops were also not harvested from the surrounding paddocks. The drought continued into 2019 and trials were not sown.

The following crops were sown on each of the sites:

Table 4. Trial crop sequence at each of the 3 sites, 2020 to 2024.

Year	**Trangie**	**Narromine**	**Geurie**
2020	Canola (HyTTec® Trophy)	Faba beans (PBA Nasmaⓑ)	Canola (44Y90CL)
2021	Wheat (LRPB Lancerⓑ)	Wheat (LRPB Lancerⓑ)	Wheat (Beckomⓑ)
2022	Wheat (LRPB Hellfireⓑ)	-	Wheat (Beckomⓑ)
2023	Canola (45Y95CL)	-	-
2024	Wheat (LRPB Lancerⓑ)	-	-

There has been a range of seasonal conditions since trial establishment; 2018 and 2019 were drought years, and no crop was harvested either year. The 2020, 2021, 2022, and 2024 seasons had above average rainfall, while 2023 was below average with a dry, seasonal finish. Rainfall details are in Table 5.

Table 5. Annual rainfall in each season at each of the 3 sites and the long-term average (LTA) 2018 to 2024

Month	Trangie	Narromine	Geurie
2018	278	245	339
2019	143	174	260
2020	656	628	822
2021	816	793	874
2022	777		1030
2023	419		
2024	614		
LTA	507	502	591

The Narromine and Geurie sites were abandoned at the end of 2022 and 2021 due to paddock renovations and shifting to a pasture phase respectively. The Trangie site was abandoned in 2024 as it was becoming evident that the deep applied P in some treatments was completely depleted.

What did we find out?

This report summarises the findings of this research. Full details of the trials referenced in this paper can be found at www.grainorana.com.au.

Narromine (2020–2021)

- There was no response to applied P at Narromine for the 2 crops grown (data not shown) irrespective of application depth or rates applied.

Geurie (2020–2022)

- The site was responsive to applied P at Geurie in each of the 3 years (Figure 1).
- In 2020, even though there was a yield response to deep applied P (compared to 0P), higher yields were achieved where either shallow placed, annual only or both deep and annual P was applied.
- In 2021, there was no difference between the 0P and the two rates of deep applied P. The best yields were achieved in the annual only or both deep and annual P treatments. The higher rate of annual only P had a lower yield than where 50 kg P/ha was applied deep and 12.5 kg P/ha annually.
- In 2022, both deep P rates yielded better than the 0P control and there was no difference between any of the annual only and the deep plus annual treatments.
- Across all years there were no cases where deep applied P achieved higher yields than those where the same rate of annual P was applied (shallow- at seed depth)

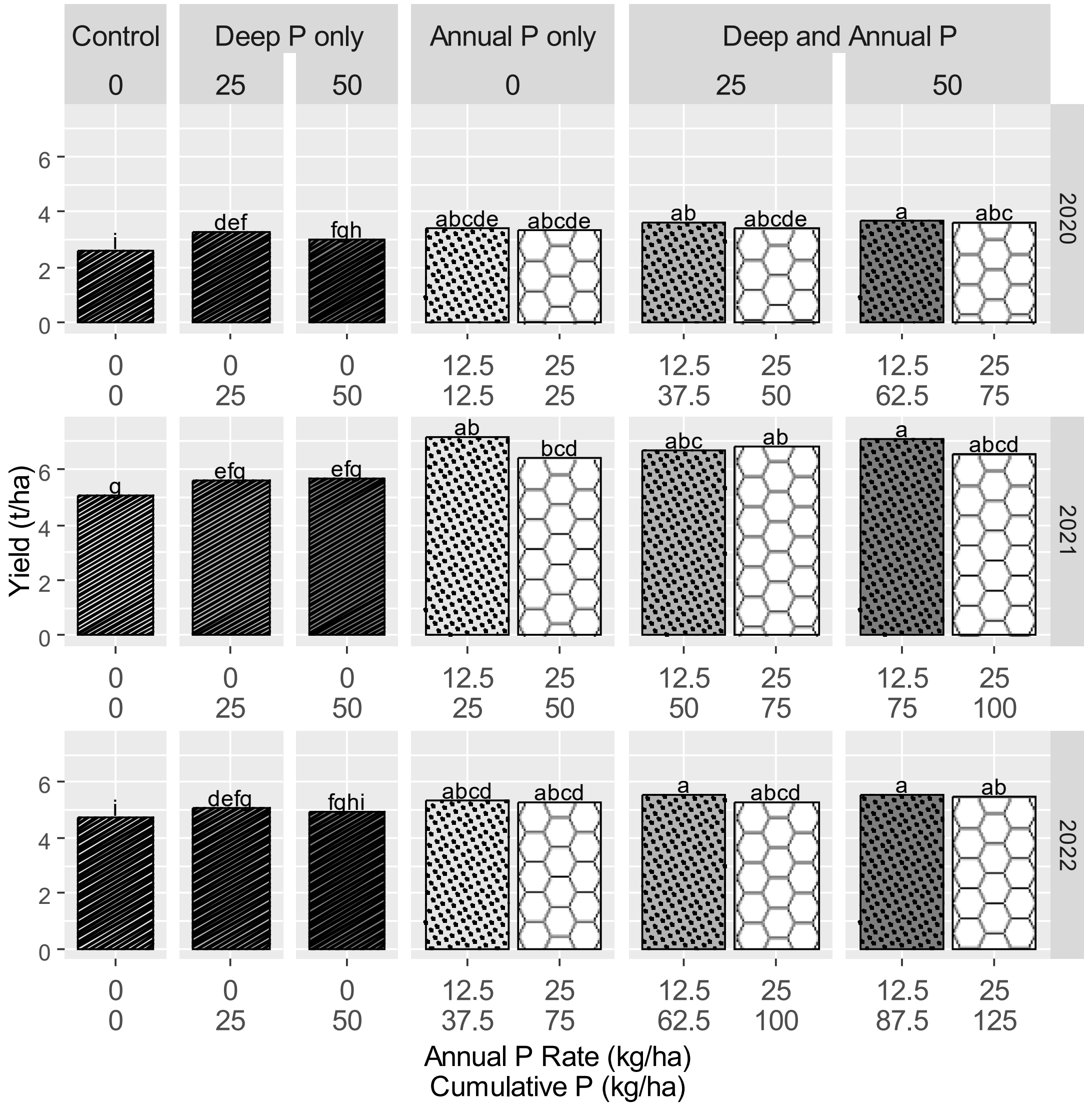

Figure 1. Yield (t/ha) for different P treatments in each crop year (2020 canola, 2021 wheat, 2022 wheat), Geurie. Treatments with the same letter within a year are not significantly different.

Trangie (2020–2024)

- 2020: No response in yield or oil content to applied P, regardless of timing or placement compared to 0P (Figure 2).
- 2021: Deep applied P with no annual applications achieved yields no more than 0P. Yields improved with the application of the lowest shallow placed annual P rate of 4 kg/ha in 2021 when compared to the 0P, with no further increase from doubling of annual P to 8 kg/ha.
- 2022: Deep applied P with no annual applications achieved yields no more than 0P. Yields increased with the application of 4 kg/ha of P applied shallow in 2022 with no further increase even when doubling the P rate in 2022.
- 2023: Applying 22 kg P/ha, applied deep only, resulted in increased yields compared to 0P. But no further increases achieved by increasing the rate to 44 kg P/ha. Applying the lowest rate of 4 kg/ha of annual P in 2023 matched the best deep applied only treatment with no

improvement from further annual increases. Except in one case where 4 kg/ha annual P was better when following deep application of 44 kg P/ha when the trial was established.

- 2024: Deep applied P achieved no better yields than 0P. Annual applications of 4 kg/ha and 9 kg/ha of shallow applied P achieved consecutive increases in yields. However no further increases where achieved with the addition of deep applied P at similar P rates.
- Across all years, with the exception of one case, deep applied P offered no higher yields than could be achieved with (similar) annual (shallow) applications only.

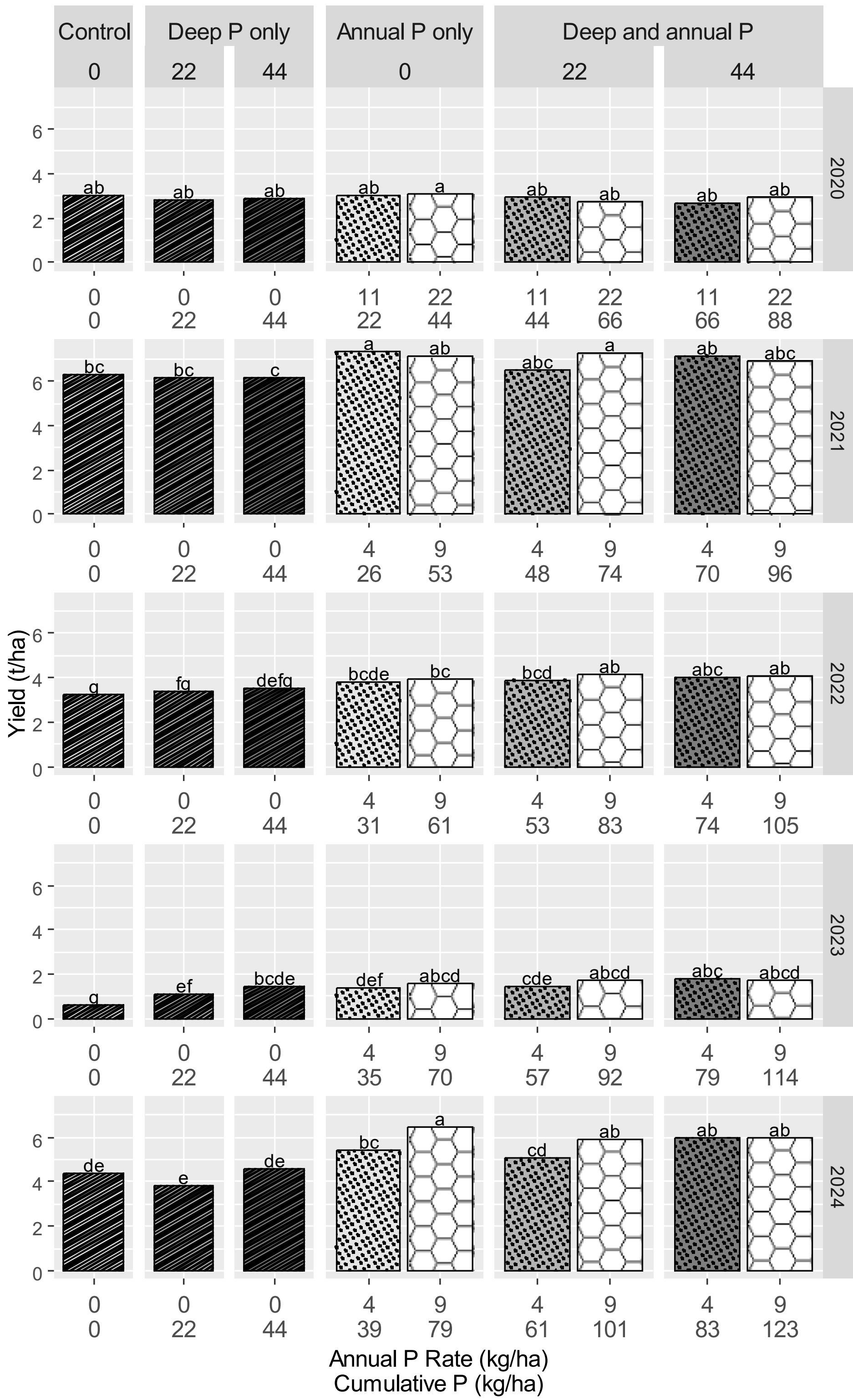

Figure 2. Yield (t/ha) for different P treatments in each crop year (2020 canola, 2021 wheat, 2022 wheat, 2023 canola, 2024 wheat), Trangie. Treatments with the same letter within a year are not significantly different.

Average net income and fertiliser cost

Average annual net income is calculated as gross income less the fertiliser cost. Costs were assumed to be $1500/t for MAP and grain prices of $350/t for wheat and $750/t for canola.

Geurie

The lowest average annual net income was in the control where 0P was applied, which was at least $150 less than where P was applied (regardless of P rate or placement). However, applying 12 kg P/ha annually added over $400/ha/year, regardless of rate or placement. Applying deep P (in addition to annual P) reduced average annual net income by $20/ha/year (before application costs are considered).

The cumulative effect over the 3 years of this trial compared to the 0P treatment is illustrated in Figure 3 below. The additional fertiliser and application costs when applying deep P significantly reduce the net income benefits when compared to annual only P. Note; application cost is estimated to be $150/ha.

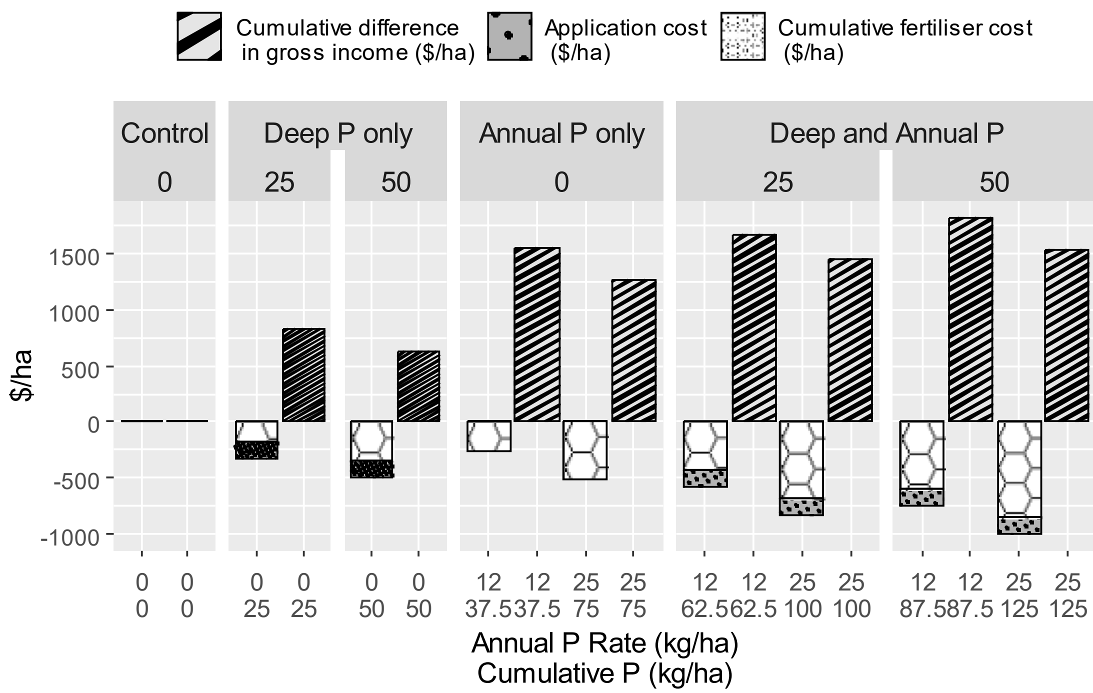

Figure 3. Cumulative difference (to the control) in gross income, cumulative fertiliser costs and estimated deep fertiliser application cost over 3 crops, Geurie 2020–22.

Trangie

The lowest average annual net income was in the control where 0P was applied, which was at least $20 less than where P was applied (regardless of P rate or placement). However, applying 4 kg P/ha annually added over $220/ha/year, increasing to 9 kg P/ha added over $290/ha/year. Applying deep P (in addition to annual P) reduced average annual net income by $50 and $80/ha/year respectively (before application costs are considered).

The cumulative effect over the 5 years of this trial compared to the 0P treatment is illustrated in Figure 4 below. The additional fertiliser and application costs when applying deep P significantly reduce the net income benefits when compared to annual only P. Note; application cost is estimated to be $150/ha.

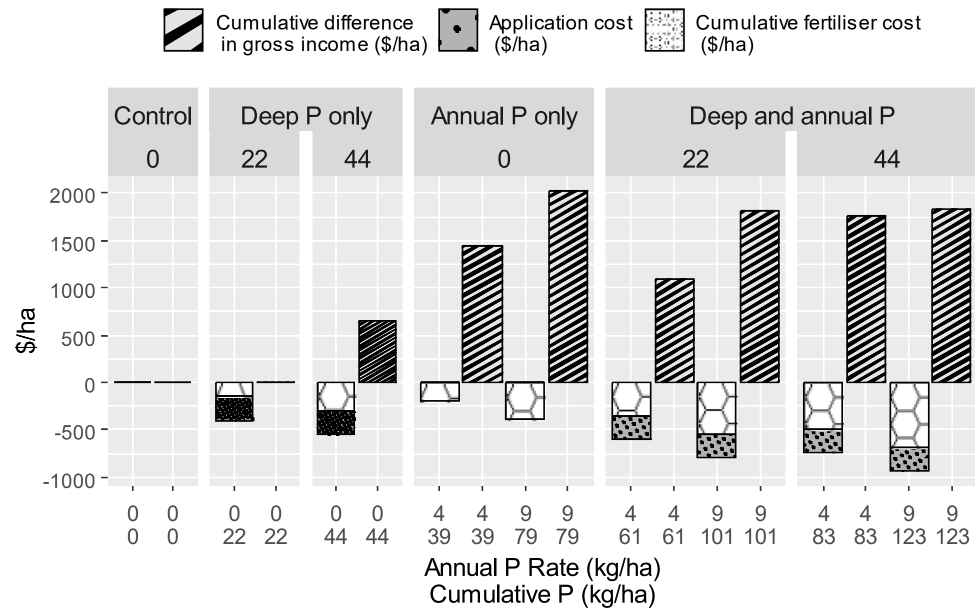

Figure 4. Cumulative difference (to the control) in gross income, cumulative fertiliser costs and estimated deep fertiliser application cost over 5 crops, Trangie 2020–24.

Discussion

These trials demonstrate that crops can access deep applied P, however there were no instances where a combination of deep plus annual P applications were better than an annual application only (when comparing equivalent application rates).

There was no yield or economic advantage from deep P application, and in fact deep P application would come at an economic disadvantage due to the costs of deep application. This is partially driven by a combination of slightly lower yields and the added fertiliser cost.

The structure of the trial treatments does not allow comparison of the effects and costs of ripping to apply P with not ripping. Ripping would come at a significant financial cost, coupled with an opportunity cost, particularly as ripping in the summer fallow will cause moisture loss and reduction in the fallow efficiency (due to a lack of stubble cover). The follow-on effects may cause establishment issues and reduce yields in the subsequent crop.

There are few summer crops grown in CW NSW, which is an indicator that our soils tend not to have the storage capacity to produce a crop on stored moisture alone, coupled with the unreliability of summer rain. This is a key difference to regions further north where crops can be commonly grown on stored soil moisture, and as such deep P availability becomes important. When conditions get dry in CW NSW and surface P becomes positionally unavailable, the overall lack of moisture will more commonly be the yield limiting factor.

The frequency of climatic conditions that may lead to a positive deep P response in CW NSW are likely to be far fewer than in the summer rainfall dominated cropping areas of QLD and northern NSW but maybe more than experienced in southern NSW. Modelling of this frequency by Verburg *et al.*, 2024 has shed some light on the potentially responsiveness across the cropping regions of Australia, finding a reduced likelihood of favourable D/W conditions in CW NSW compared to regions to the north, reflecting what was found in these trials. At this point in time the application of deep P may generally not be warranted in the CW of NSW. However, if growers were conducting other practices that enabled deep P application, e.g., deep ripping to resolve a soil constraint or moisture seeking chickpeas at sowing, then it could be considered in paddocks with low P levels, particularly those that are stratified. Surface layer applied P would still be required.

There are also possibly learnings about how crops access deep P, in terms of depth, band width and orientation (to the sowing rows) that may increase its viability in the future.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the authors would like to thank them for their continued support.

References

Brunton O, Haling R, McCormick J, Condon J, Watts-Williams S, Uddin S (2025) Surface P fertility and crop type influence response to Deep P: is there a role for Deep P in southern NSW? in 2025 Dubbo GRDC grains research update. Grains Research and Development Corporation. Available at: https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2025/02/surface-p-fertility-and-crop-type-influence-response-to-deep-p-is-there-a-role-for-deep-p-in-southern-nsw (Accessed: January 14, 2026).

Gentry J, Cox H, Zull A, Brider J, Hagan J (2017) Developing and testing an analysis framework for long-term fertiliser decisions: Deep-P Calculator, Rural Extension & Innovation Systems Journal, 13(2), pp. 147–150.

McMaster C (2014) Phosphate fertiliser source—Gunningbland NSW 2009 to 2012, in Southern cropping region trial results 2014. NSW Department of Primary Industries, pp. 10–15.

Mugerwa TM, Brooke G, Graham R, Formann P (2019a) Crop response to deep placement of phosphorus – Gilgandra 2018. Northern NSW research results 2019. NSW DPI.

Mugerwa TM, Brooke G, Graham R, Formann P (2019b) Crop response to deep placement of phosphorus in a chromosol – Nyngan 2018. Northern NSW research results 2019. NSW DPI.

Sandral GA, Tavakkoli E, Armstrong R, Barati M, Pumpa R, Lester D, Mason S, Norton R and Bell M (2019) Phosphorus and phosphorus stratification, in 2019 Wagga Wagga GRDC grains research update. Grains Research and Development Corporation, pp. 203–212.

Verburg, K. Armstrong RD, Biggs JS, Wilhelm NS, Haling RE, Sandral G, Uddin S, Mason SD, McBeath TM (2024) Identifying soil and climate drivers of soil water conditions favourable for deep phosphorus placement for wheat in Australia using spatial modelling, Field Crops Research, 315, p. 109448. Available at: https://doi.org/10.1016/j.fcr.2024.109448

Contact details

Ben O’Brien
Grain Orana Alliance
Email ben.obrien@grainorana.com.au

Date published

February 2026