Grower-scale strip trials evaluating strategies for P & K nutrition

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Key words

phosphorus, potassium, participatory action research, strip trial

GRDC code

DAQ2404-008BGX, DAQ2303-011BGX

Take home messages

- Grower-scale strip trials are being used to assess subsurface (deep) placement of phosphorus (P) and potassium (K) across multiple collaborative projects
- Grain yield responses to deep P across southern Queensland (SQ) ranged from 0 up to 10% across 31 site years. We hypothesise that this variability may be related to fertiliser band direction as we have observed biomass responses more often when P was applied at 90° to the crop rows compared with the same direction as the rows (0°).
- Grain yield responses to deep K across SQ were observed at one site with an exchangeable K value of 0.18 cmol/kg in the 10–30 cm soil layer. No yield responses to deep K have been observed with exchangeable K >0.35 cmol/kg in the 10–30 cm soil layer. A national K project will implement further strip trials to better define critical K values and crop responses.

Introduction

The current phase of immobile nutrient research across southern Queensland employs a range of on-farm, grower-scale strip trials across RiskWi$e (the National Risk Management Initiative) and National Grower Network (NGN) investments. Broadly, these trials aim to assess phosphorus (P) and potassium (K) strategies building upon the outcomes from small-plot research. These strip trials aim specifically to increase grower participation in this research process.

Trial design

As part of the natural capital theme within RiskWi$e, several trials are being conducted to investigate crop responses to deep placement of P and K fertiliser, with emphasis on managing declining soil fertility. Specifically, these trials draw upon participatory action research methodology. Collaborating growers and consultants have identified that investing in deep P and K are challenging or risky decisions within their farm businesses. In these trials, growers and their consultants are directly involved in the formulation of research questions, trial design and implementation, data collection and results interrogation. Treatments for these trials are listed in Table 1. A number of these trials are also assessing various nitrogen (N) strategies (see Gentry *et al.,* 2025). These trials will be monitored for four years.

Table 1. Deep P and K treatments implemented in the RiskWi$e trials. Not all treatments have been implemented at all sites. MAP (N 10, P 22, K 0); MOP (muriate of potash, N 0, P 0, K 50); urea (N 46, P 0, K 0).

Treatment	P rate (kg/ha)	K rate (kg/ha)	MAP cost ($/ha)	MOP cost ($/ha)	Urea cost ($/ha)	Ripping cost ($/ha)	Treatment cost ($/ha)
Untreated control (UTC)	0	0	0	0	0	0	0
Rip only	0	0	0	0	0	60	60
Rip + 30P	30	0	150	0	0	60	210
Rip + 30P + 50K	30	50	150	70	0	60	280
Rip + 60N + 30P	30	0	150	0	75	60	285
Rip + 60N + 30P + 50K	30	50	150	70	75	60	355

The second collection of strip trials are part of the Deep P in Southwest Queensland National Grower Network (NGN) project. These trials complement several small-plot sites to collectively investigate the combined effects of ripping, N and P management strategies on productivity (Table 2). These trials have been monitored for two years.

Table 2. Treatments implemented in the deep P trials. Not all treatments have been implemented at all sites. MAP (N 10, P 22, K 0); urea (N 46, P 0, K 0). P and K were both applied in subsurface bands approximately 20cm deep, and N was spread.

Treatment	P rate (kg/ha)	N rate (kg/ha)	MAP cost ($/ha)	Urea cost ($/ha)	Ripping cost ($/ha)	Treatment cost ($/ha)
UTC	0	0	0	0	0	0
Rip only	0	0	0	0	60	60
Rip + 60N	0	60	0	98	60	158
Rip + 60N + 30P	30	60	150	75	60	285
Rip + 60N +60P	60	60	300	53	60	413

Soil P and K values for each site prior to implementing treatments are listed in Table 3. Almost all trials have Colwell P values which suggest that crop responses to P fertiliser are likely (Bell and Lester, 2023). Exchangeable K (Ex. K) values in the 10–30 cm soil layer range from 0.18 cmol/kg at the Brigalow site to 1.1 cmol/kg at the Dirranbandi site (Table 3).

Table 3. Soil characterisation of trial sites prior to treatment implementation.

Site	Colwell P 0–10cm (mg P/kg)	BSES P 0–10 cm (mg P/kg)	Colwell P 10–30 cm (mg P/kg)	BSES P 10–30 cm (mg P/kg)	Ex. K 0–10cm (cmol/kg)	Ex. K 10–30cm (cmol/kg)	ECEC 10–30cm (cmol/kg)
Brigalow	18	41	5	15	0.31	0.18	37
Warra	12	16	4	4	0.25	0.19	33
Tara	13	37	5	63	0.78	0.29	28.1
Glenmorgan	24	33	4	8	0.91	0.51	29.1
Surat RiskWi$e	12	26	4	18	0.67	0.41	42.9
Surat NGN	17	54	3	29	1.06	0.66	51.6
Wallumbilla Nth	17	24	5	5	0.63	0.34	28.9
Wallumbilla Sth	22	35	9	11	1.1	0.5	11.4
Roma	9	12	4	6	0.46	0.34	38.3
Dirranbandi	28	203	14	215	1.49	1.12	38.7
Nindigully	10	39	5	20	1.01	0.74	26.2
Daymar Sth	12	17	8	6	1.08	0.53	10.0
Daymar Nth	20	32	4	12	1.62	1.11	27.0
Thallon	19	39	6	2	1.28	0.77	28.8
Morialta Junction	10	103	6	95	1.47	0.85	33.0
Weemelah	23	95	7	56	1.30	0.88	31.1

Deep P and K were either applied across the crop row (90°) or in the same direction as the crop row (0°) at 0.5 m band spacings and roughly 20–25 cm deep. This reflects the experimental design of each trial and equipment used to implement them. Treatments were either implemented using small plot research equipment (a TTQ ripper), or by the growers themselves with tyne planters.

All trials were implemented from mid-2023 to early 2024 and have had 1 to 3 grain crops grown since. Grain yield responses were measured through analysis of yield maps supplied by the participating growers. Biomass responses were assessed through a combination of satellite NDVI imagery and destructive biomass sampling at physiological maturity.

Note: Statistical analyses of spatial data are yet to be finalised, hence only trends are reported in this paper.

Phosphorus

Yield responses to deep P

Crop responses to deep P have been measured in a total of 31 grain crops across 16 sites so far. Crops grown were mostly wheat (13) and chickpea (11), but also included barley (4), mungbean (2), and sorghum (1). Yield responses ranged from no response to 10% in wheat at both the

Wallumbilla North and Wallumbilla South sites in winter 2024 (Table 4). Overall, 8 out of the 31 crops grown so far have produced additional grain in response to deep P application (Table 4, Table 5). These 8 yield responses were observed across 7 sites, with a further 9 sites yet to produce a clear yield response to deep P.

Table 4. Grain yield at sites where a yield response to deep P was observed. Values in brackets represent yield relative (%) to the untreated control treatment (UTC).

Treatment	Grain yield (t/ha (Rel%))												
	Warra			Brigalow		Thallon		Daymar Nth		Wallumbilla Nth	Wallumbilla Sth		Roma	
	Mungbean 2023-4	Wheat 2024	Barley 2025	Sorghum 2023-4	Wheat 2024	Wheat 2024	Chickpea 2025	Wheat 2024	Wheat 2024	Wheat 2024	Wheat 2024	Chickpea 2025	Chickpea 2024	Barley 2025
UTC	2.3	4.6	6.4	4.8	1.4	4.8	1.4	2.0	4.0	2.7	2.7	1.6	1.6	4.5
Rip Only	2.4 (+1)	4.6 (0)	6.4 (0)	4.9 (+1)	1.4 (+2)	4.8 (0)	1.4 (0)	2.2 (+10)	4.0 (0)	-	-	-	-	-
Rip + 60N	2.5 (+7)	4.3 (-7)	6.4 (0)	5.4 (+11)	1.4 (+5)	4.9 (+2)	1.4 (0)	2.1 (+5)	4.3 (+5)	-	-	-	-	-
Rip + 60N + 30P	2.6 (+12)	4.6 (0)	6.9 (+8)	5.1 (+6)	1.5 (+8)	5.3 (+12)	1.4 (0)	2.2 (+10)	4.6 (+13)	-	-	-	-	-
Rip + 60N + 60P	-	-	-	-	-	5.3 (+12)	1.4 (0)	2.1 (+5)	4.6 (+13)	-	-	-	-	-
Rip + 60 N + 30P + 50K	2.6 (+12)	4.7 (+1)	6.9 (+8)	5.5 (+13)	1.7 (+22)	-	-	-	-	-	-	-	-	-
Rip + 30P	-	-	-	-	-	-	-	-	-	3.0 (+10)	3.0 (+10)	1.6 (0)	1.7 (+6)	4.9 (+9)
Rip + 30P + 50K	-	-	-	-	-	-	-	-	-	-	2.9 (+7)	1.6 (0)	1.7 (+6)	4.7 (+5)

Table 5. Instances of grain yield and biomass response to deep P across the 16 strip trials, 2023–2025.

Site	Crop 1	Yield response to deep P	Biomass response to deep P*	Crop 2	Yield response to deep P	Biomass response to deep P*	Crop 3	Yield response to deep P	Biomass response to deep P*
Brigalow	Sorghum	N	N	Chickpea	Y	Y	-	-	-
Warra	Mungbean	Y	Y	Wheat	N	N	Barley	Y	Y
Tara	Barley	N	N	Barley	N	N	-	-	-
Glenmorgan	Wheat	N	N	Wheat	N	Y	-	-	-
Surat RiskWi$e	Wheat	N	Y	Chickpea	N	Y	-	-	-
Surat NGN	Wheat	N	N	Chickpea	N	N	-	-	-
Wallumbilla Nth	Wheat	Y	Y	Sorghum	N/A**	Y	-	-	-
Wallumbilla Sth	Wheat	Y	Y	Chickpea	N	Y	-	-	-
Roma	Chickpea	N	Y	Barley	Y	Y	-	-	-
Dirranbandi	Wheat	N	N	Mungbean	N	N	-	-	-
Nindigully	Wheat	N	N	Chickpea	N	Y	-	-	-
Daymar Sth	Wheat	N	N	Chickpea	N	N	-	-	-
Daymar Nth	Chickpea	N	Y	Wheat	Y	Y	-	-	-
Thallon	Wheat	Y	Y	Chickpea	N	N	-	-	-
Morialta Junction	Chickpea	N/A***	N	-	-	-	-	-	-
Weemelah	Wheat	N	N	-	-	-	-	-	-

*Determined either through satellite NDVI and/or maturity dry matter sampling. **This crop was cut for hay, so no grain yield data has been included in this analysis.
*** This yield map is yet to be analysed, but the lack of biomass response suggests a yield response is unlikely.

Of the seven sites where there have been yield responses to deep P, there is only one site (Warra) where the cost of deep P has been paid off, with profit now being generated (Table 6). At this site, a 12% (280 kg/ha) yield response in a good yielding mungbean crop paid off the cost of the Rip+30N+60P treatment in the first season following application. A further 8% (490 kg/ha) response to this treatment in the 2025 barley crop has generated an additional $157/ha profit since (Table 6). This is despite the lack of clear yield response to deep P in the 2024 wheat crop, highlighting that yield responses are not required every season to profit from applying deep P.

Table 6. Economics for select deep P and K treatments at sites where a yield response has been observed, 2023–2025.

Treatment	Treatment cost ($/ha)*	Economic balance (gains** – treatment costs) ($/ha)						
		Warra	Brigalow	Thallon	Daymar Nth	Wallumbilla Nth	Wallumbilla Sth	Roma
Rip + 30P	240	-	-	-	-	-154	-150	-132
Rip + 60N + 30P	285	+ 157	-127	-106	-185	-	-	-
Rip + 60N + 60P	413	-	-	-316	-313	-	-	-
Rip + 60 N +30P +50K	355	+87	+255	-	-	-	-	-

**using input costs of $60/ha for ripping, $750/t for urea and $1100/t for MAP-Zn.*

*** using crop prices of 300/t for wheat, barley and sorghum, $680/t for chickpea, and $1000/t for mungbean*

The other six responsive sites are yet to pay back the cost of deep P application (Table 6). However, one responsive crop at each of these sites has paid back between 45–63% of the cost of the 30P treatments (Table 4, Table 6). Given that deep P can produce grain yield responses for at least 10 years following application (Hunter *et al.,* 2025), it is therefore probable that the deep P at these sites will eventually generate profit.

What remains unclear is whether we will see any future yield responses to deep P at the sites where we are yet to see a yield response, and how consistently and for how long we will continue to see responses at sites where responses are currently being observed. More broadly, we are yet to understand why we are seeing such variability in deep P responses despite the subsoil profiles being generally low in crop available P.

One working hypothesis for this variability in deep P responses is that the direction at which deep P is applied relative to the crop row may affect the ability for crops to access and respond to it. A long-term deep P collaborator has recently implemented a large-scale trial to investigate the effects of band direction on yield responses to deep P, applying deep P either in the same direction as the crop row or at 45°. This trial is currently in its first crop (sorghum), so we are still waiting on yield results.

Potassium

Of the seven strip trials investigating crop responses to deep K within RiskWi$e, yield responses have only been measured in one chickpea crop at the Brigalow site, which has an exchangeable K value of 0.18 cmol/kg in the 10–30 cm soil layer (Table 3). At this site, applying deep K in conjunction with deep P increased chickpea yield by 22% (300 kg/ha) compared to the untreated control, and 13% (200 kg/ha) compared to deep P without deep K (Table 4).

Consequently, treatment costs have been recovered in the Rip + 60N + 30P + 50K treatment, which has generated $255/ha of profit so far.

No clear yield responses to deep K have been observed in the sites further west, where the exchangeable K values in the 10–30cm layer are all greater than 0.35 cmol/kg (Table 3, Table 5). One objective of the new national K project (UOQ2503-008RTX) led by UQ is to explore soil test crop responses for K fertiliser to provide improved critical K values. Queensland DPI will be implementing several grower-scale strip trials across southern and central Queensland to achieve this.

Conclusion

Monitoring deep P responses in 31 crops across 16 grower-scale strip trials over 3 years has revealed variability in yield responses to deep P, ranging from no response to 10% increase. Moreover, this research has raised questions as to whether further finetuning of immobile nutrient strategies is required to optimise crop access to fertiliser.

Yield responses to deep K have been observed when the exchangeable K value in the 10–30 cm layer is 0.18 cmol/kg, but not when it is greater than 0.35 cmol/kg. Implementation of new grower-scale strip trials as part of the new national K project aim to better identify critical K values and will aid in the interpretation of these current findings.

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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 author would like to thank them for their continued support.

The delivery of these experiments would not be possible without the dedication of the team of technical and operational staff in DPI at Kingaroy, Goondiwindi and Toowoomba who make this happen. The authors appreciate the efforts of our staff to deliver these experiments.

RiskWi$e is conducted in partnership with grower groups, 6 action research groups, research/extension partners, CSIRO and the Grains Research and Development Corporation (GRDC). The Queensland Department of Primary Industries is leading the RiskWi$e initiative on various topics across Queensland in collaboration with JB Ag Services and Iker Ag Consulting.

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Date published

March 2026