GOA trial site report

Validation of the benefits of deep placement of phosphorus fertiliser in CW NSW

Grain Orana Alliance

Trial code:	GONU014-3
Season/year:	2018-2024
Location:	Gin Gin Station, Trangie
Trial partners:	James Austin
Trial establishment date:	24/04/2018

Keywords

GANU014, phosphorous, nutrition, Colwell, deep placement, stratification, nutrition, Trangie

Take home messages

- Applying phosphorus (P) at or close to the soil surface achieved yields as good as or better than deep placed P.
- Positive results to deep placement of P in Queensland were not consistently achieved in these trials.
- There were no instances where a combination of deep plus annual P applications was better than an annual application only.
- There was no yield or economic advantage from deep P application. The deep P application was at an economic disadvantage due to the costs of deep application

Background

Research from Queensland has shown that deep application of P fertilisers has improved yields of grain crops in some situations. Stemming from this research, several guidelines have been developed which aim to predict responsiveness to applied deep P. Validation of these responses in the central west (CW) NSW has been limited.

Soil testing undertaken by Grain Orana Alliance (GOA) during their existing trial program identified paddocks that would be predicted to respond to applied deep P based on these guidelines. Recent work by other organisation's has identified similar circumstances where P concentrations appear to be stratified close to the soil surface, with limited P availability at depth.

Overlaying this is the consideration as to whether our environment, in particular rainfall patterns, could impact the relative responsiveness of soils that have demonstrated responses in Queensland and Northern NSW.

To expand on this hypothesis, the frequency of winter rainfall within a growing season increases from north to south in eastern Australia's cropping areas. When moving south, the reliance on deep moisture, stored from outside the growing season decreases. Theoretically, in the central and southern regions, the shallower soil P, close to where it is applied or accumulating, should be more accessible (in frequency and duration) than in the northern environment. This could lead to decreased responses to deep applied P, despite there being little P at depth and the crop being P responsive.

Aims

To validate crop responsiveness in CW NSW to deep applied P where soils are P deficient and to compare this response to traditional P applications at 2-8 cm.

Methodology

Trial design	
Type	Small plot (~12 m x 2 m)
Design	Randomized split plot
Replications	3
Analysis	ASREML
Confidence interval	95%

Site selection:

This site was selected because it should be responsive. Soil testing from this site (Table 1) showed that the topsoil (0-10 cm) had modest Colwell P levels which declined to very low levels deeper in the profile.

Research on vertosols in the Queensland grain growing areas predicted that yield responses to subsoil P application are more likely where the Colwell and BSES P is less than 10 mg/kg and 30 mg/kg respectively (in the 10-30 cm soil layer). This site meets those criteria.

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

Location	Analyte/assay	Unit	0-10 cm	10-30 cm	30-60 cm	60-90 cm
Trangie	Phosphorus (Colwell)	mg/kg	29	7	<5	<5
Trangie	Phosphorus (BSES)	mg/kg	36	8	<5	<5
Trangie	Phosphorus Buffer Index		50	69	98	120

Rainfall:

There has been a range of seasonal conditions since trial establishment, 2018 and 2019 were dry to very dry, 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 *2*.

Table 2. Monthly rainfall[2] (mm) and long-term average (LTA) at the trial site

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2018	38	7	10	2	10	18	1	25	8	55	56	48	**278**
2019	43	27	14	1	12	5	6	3	4	6	20	2	**143**
2020	9	103	98	114	17	20	68	32	41	51	11	92	**656**
2021	43	119	207	1	20	78	60	42	44	36	107	59	**816**
2022	65	27	44	173	65	8	10	93	102	107	67	16	**777**
2023	43	63	35	50	2	34	25	11	1	17	67	71	**419**
2024	59	57	48	59	92	40	39	44	8	36	79	53	**614**
LTA	54	51	44	40	39	40	36	34	35	44	45	45	**507**

Treatments

Note that in this trial the nitrogen (N) component of the MAP was balanced with urea to assess if the N component of the MAP might have any bearing on the trial outcomes. Three additional treatments were included where the N was not balanced with no difference in the results to where the same amount of P was applied. This data is not presented.

Deep applied P as MAP was applied in the Autumn of 2018 using grower machinery, a deep ripper with an air cart and fertiliser boots. The machinery had the capacity to apply 0, 100 or 200 kg/ha MAP. All treatments, even those with 0 MAP, were deep ripped to remove any possibility of a ripping effect.

Deep P as MAP applied at the establishment of the project (2018):

- depth: 40 cm
- spacing: 50 cm
- rates: 0, 100 and 200 kg/ha.

Annual P as MAP applied with every crop at sowing:

- depth: 4-6 cm (sowing depth for wheat, banded below canola seed)
- spacing: 25.0 cm
- dates 2018-20: 0, 50, 100 and 200 kg/ha
- rates 2021-24: 0, 20, 40 and 80 kg/ha.

The trial was established in 2018 with crops harvested from 2020-2024. The treatment and crop history at the site are detailed in Table 3.

Table 3. Trial cropping and treatment history.

Year	Crop	Phosphorous	MAP Rates (kg/ha)
2018	Trial initiation	Deep	0, 100, 200
2018	Wheat (not harvested)	Annual	0, 50, 100, 200
2019	Fallow (drought)	None (drought)	0
2020	Canola (trophy)	Annual	0, 50, 100, 200
2021	Wheat (lancer)	Annual	0, 20, 40, 80
2022	Wheat (hellfire)	Annual	0, 20, 40, 80
2023	Canola (45Y95)	Annual	0, 20, 40, 80
2024	Wheat (lancer)	Annual	0, 20, 40, 80

The trial was designed using a full factorial structure. The full treatment list is outlined in Table 4 and includes the cumulative MAP and P applied to each treatment.

Table 4. Treatments and cumulative application rates (kg/ha).

		Annual MAP Rate								
Deep (initial)	**Annual**	**2018**	**2020**	**2021**	**2022**	**2023**	**2024**	**Total annual MAP**	**Total MAP**	**Total P**
0	Nil	0	0	0	0	0	0	0	0	0
	Low	50	50	20	20	20	20	180	180	39
	Medium	100	100	40	40	40	40	360	360	79
	High	200	200	80	80	80	80	720	720	158
100	Nil	0	0	0	0	0	0	0	100	22
	Low	50	50	20	20	20	20	180	280	61
	Medium	100	100	40	40	40	40	360	460	101
	High	200	200	80	80	80	80	720	820	180
200	Nil	0	0	0	0	0	0	0	200	44
	Low	50	50	20	20	20	20	180	380	83
	Medium	100	100	40	40	40	40	360	560	123
	high	200	200	80	80	80	80	720	920	201

Results

Yield

- The 2020 canola crop was high yielding; the average site yield was 2.9 t/ha and oil was 41% (Figure 1).
- Similarly, 2021, 2022, and 2024 wheat yields were very high, 6.7, 3.8, and 5.4 t/ha respectively.
- The 2023 canola crop had an average yield of 1.5 t/ha.

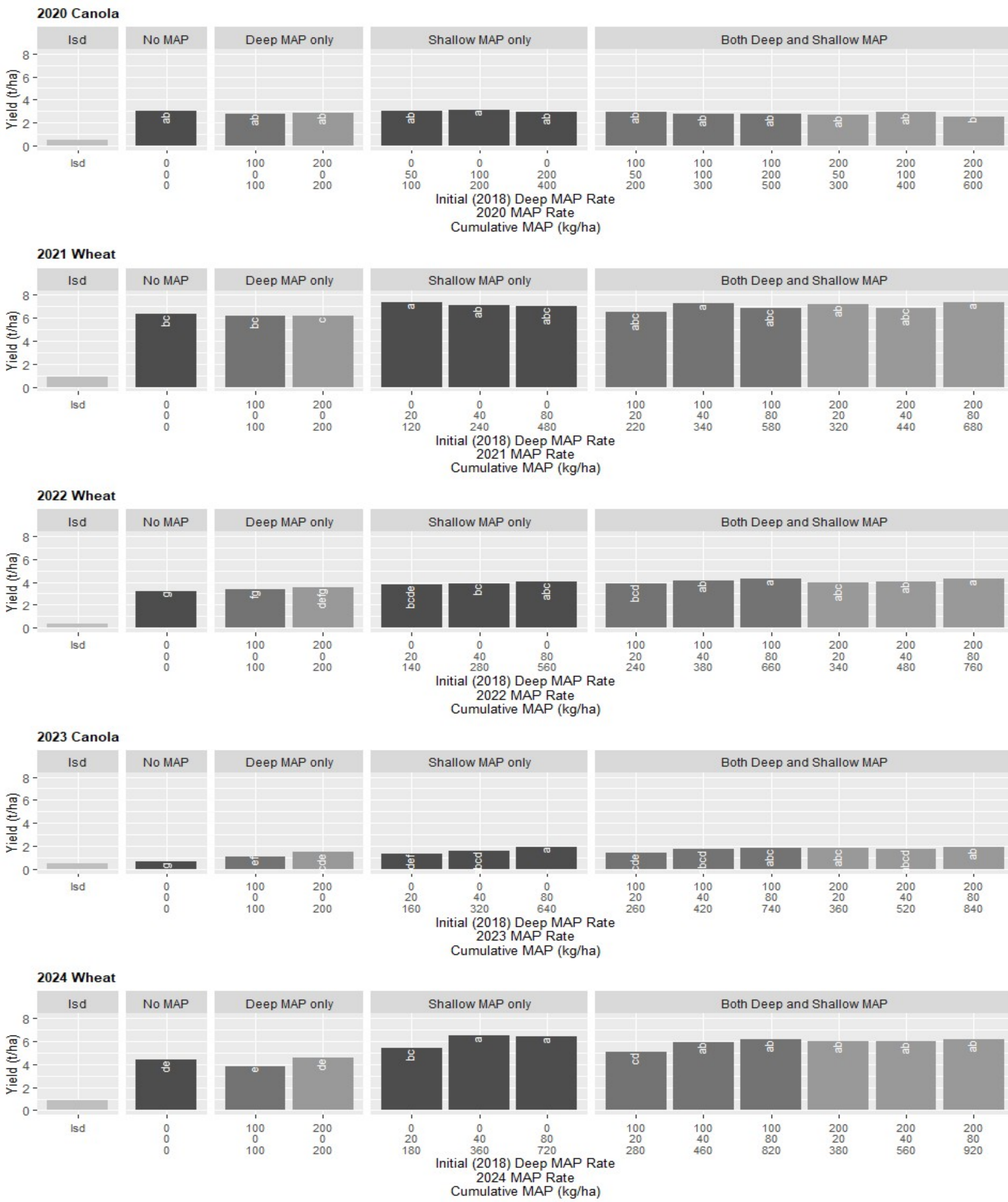

Figure 1. Yield (t/ha) by year and crop. Treatments with the same letter are not significantly different.

There was no MAP response for either yield or oil in the 2020 crop, regardless of its timing or placement when compared to 0P.

In 2021, there was a response to applied MAP to the lowest rate as an annual application, compared with the 0P and the deep P placement treatments. There was an overall trend to higher yields in the annual treatments.

In 2022, there were significant responses to applied P. Where 0P was applied, yields were not different to deep applied P (with no additional annual applications). The highest yields were achieved with the highest rates of P, regardless of whether it was an annual only application or annual + deep initial application.

In 2023, there were significant responses to applied P. Where 0P was applied, the yield was the lowest in the trial. Where deep P only was applied at 100 kg/ha, yields were better than the no P and as good as where the lowest rate of P was applied annually only, but not as good as 200 deep. The highest yields were achieved where a cumulative amount of 360 kg MAP/ha had been applied.

In 2024, there were no differences between the deep only applications and the 0P treatments. Where no deep P was applied, yields were higher at the 40 and 80 than the 20 kg/ha rate. Where deep P was applied, an initial rate of 100 plus an annual rate of 20 kg/ha had lower yields than the remaining deep and annual combinations.

Oil and protein:

Oil and protein levels are outlined in Figure 2.

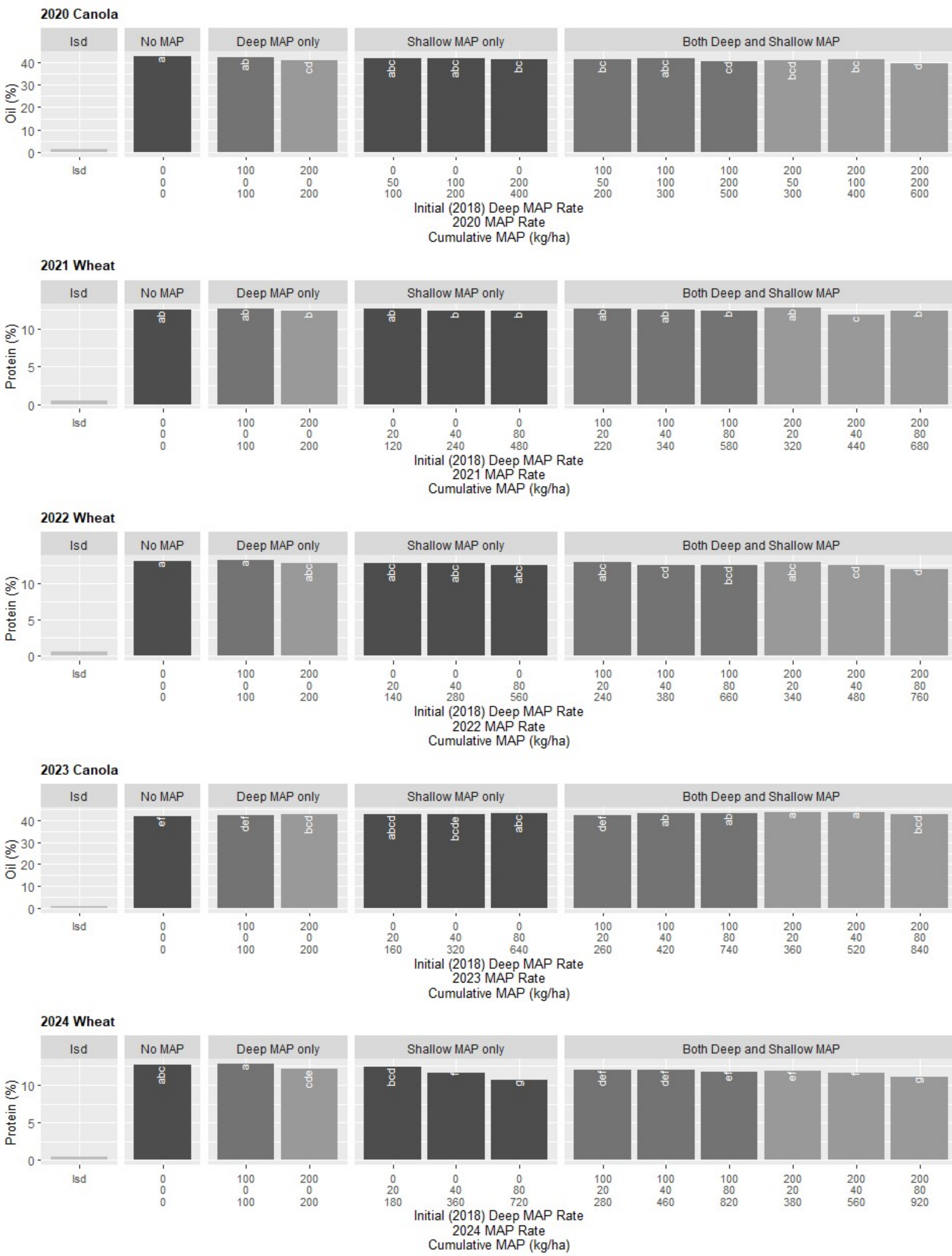

Figure 2. Oil or protein (%) by year and crop. Treatments with the same letter are not significantly different.

Phosphorous balance:

The calculated P removal[1] varied from ~55 to 74 kg/ha summed for the 5 crops, while the P application varied from 0 to 200 kg/ha (Figure *3).*

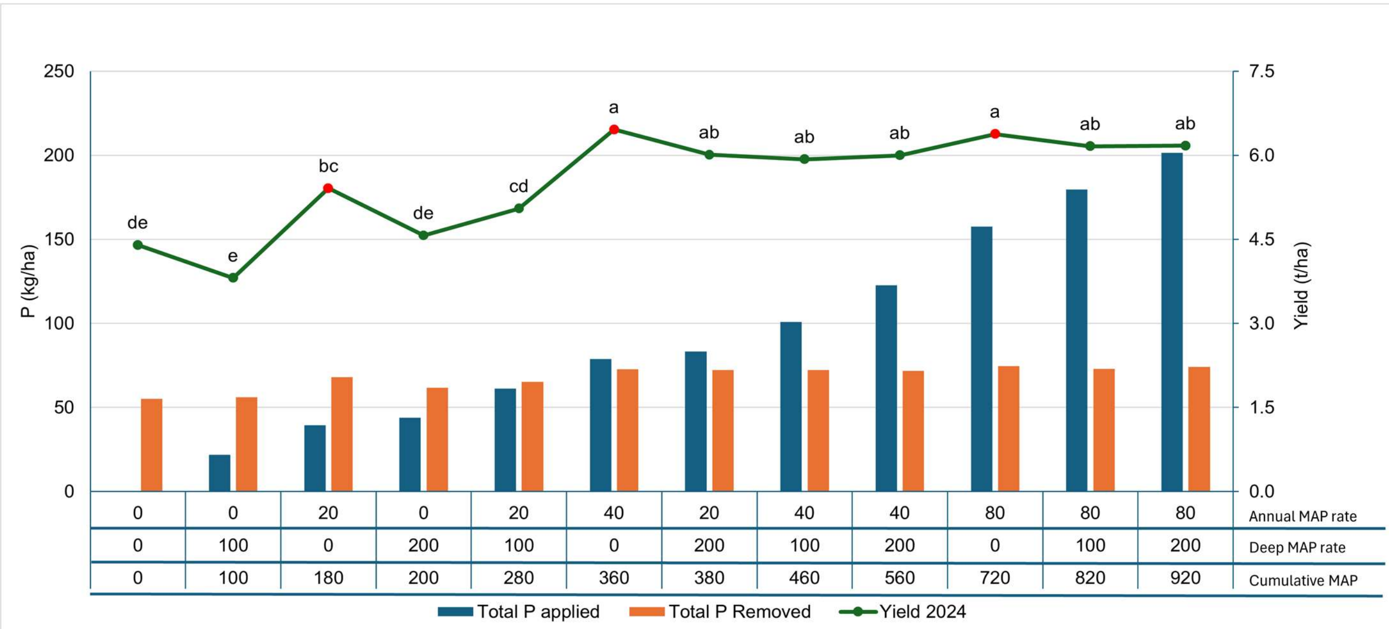

Figure 3. Total phosphorous applied and removed (kg/ha) and 2024 yields (t/ha). Values with the same letter are not significantly different.

Residual soil P:

Selected treatments were tested for residual P levels in 2025. Where 360 kg of MAP or less was applied in total over the lifetime of the project, the residual Colwell P levels were less than 22 mg/kg, in contrast, where 720 kg MAP was applied, the Colwell P was 33 mg/kg (Figure 4).

[1] (calculated assuming 3 and 7 kg/t P for wheat and canola respectively)

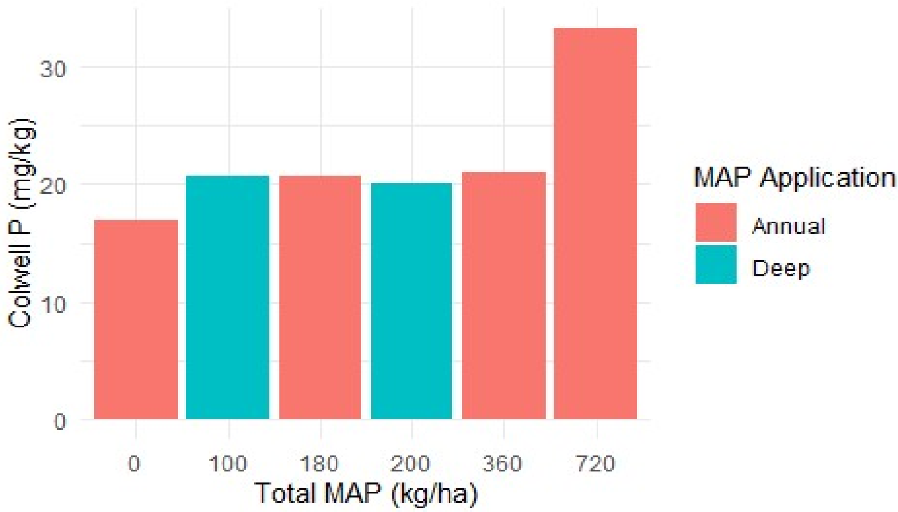

Figure 4. Colwell P (mg/kg) for selected treatments that received only annual or deep MAP.

Discussion

The ripping and deep application of P went into very dry soil, bringing up large and very hard clods. Subsequently, these took a long time to break down under the very dry conditions, and the seedbed was far from an ideal at sowing in 2018, despite this a crop was established. In September, both the trial and the surrounding crop were sprayed out due to a lack of moisture. While the effect on stored fallow moisture of the ripping did not make a difference to the outcomes for trial compared with the unripped paddock, it is likely that the working required to apply deep P and the to establish a seedbed would make a difference to the performance of the subsequent crop, and should be taken into consideration when deciding to deep apply P.

The drought broke in 2020, resulting in a wetter year where there was little or no response in the canola crop to P applied. Similar yields were obtained to where no P was applied and the higher rates of P, regardless of when or how it was applied.

The starting levels of P would have suggested that very high yields achieved in both 2020 and 2021 should have been limiting however this does was not the case.

This is possibly due to a combination of:

- a reasonable background soil P (2018 background Colwell P of 29 ppm)
- mineralization that occurred in the previous 2018/2019 drought
- that canola's "deep root system that can penetrate soil faster (~2 cm/day) and for longer than wheat"[2].

As the trial progressed, yield differences became more pronounced. By 2024, there were no differences in yields between where 0P and both the Deep P (100 and 200 kg/ha MAP) only treatments (see P balance discussion

[2] Canola's deep roots - agronomy to capture benefits and manage legacies - GRDC

below). The best treatments yielded ~2 t/ha more than where 0P was applied and plateaued where a total of 360 kg/ha MAP was applied over the trial period (~72 kg/ha/year MAP).

Where P was applied annually, the rate of 20 kg/ha MAP was sufficient to maximise yields for the first 3 years, but it was not enough in 2023 and 2024. A rate of 40 kg/ha MAP was, however, enough to optimise yields over the 5-year cropping period.

The 2023 season had a dryer finish, and arguably the best year for testing deep applied P applicability. It was evident that the crop was accessing the deep applied P, as where only deep P was applied; yields were higher than the 0P treatment. However, deep applied P was not better than applying 40 kg/ha or more annually, which was also as good as or better than any combination of deep and annual applied P.

When looking at P application and removal in grain only, the balance occurred where between 280 and 360 kg/ha was applied (equivalent to between 12-16 kg/ha P annually). When looking at the results over the 5 years, optimal yields were achieved where 40 kg/ha MAP was applied annually (for a total of 360 kg MAP). When considering P, the 5 harvested crops and the P applied to the failed 2019 crop, this equates to 15-16 kg/ha P removed annually. However, at these rates soil testing suggests that this is enough to build soil Colwell P (notwithstanding the limitations of soil testing for P in controlled traffic situations). A much higher P rate might be required if a grower was looking to build soil fertility.

It is likely that the concentrations of P are now high in the plant row for treatments with a positive P balance and very high in the highest MAP treatments which have received 560 kg/ha MAP (from instigation). While it is unlikely that growers would have used rates as high as tested in this trial, there may be ramifications for canola establishment, which is known to be sensitive to P.

Conclusions

- Deep applied P is not any better than surface applications in wetter than average seasons.
- Canola was able to access P from the soil surface in a year with a relatively dry finish, with the deep P offered no advantage.
- A replacement strategy for P management may be sufficient for optimising yields, though there could be some advantage to building P initially in paddocks with very low background P levels.

Acknowledgements

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DISCLAIMER — TECHNICAL

Appendix

Results

Table 5: Results 2020 (canola)

Phosphorous rates Deep (initial)	Annual (Kg/ha)	Cumulative	Yield (T/ha)		Oil (%)		Protein (%)		Admix (%)	
0	0	0	3.0	Ab	42.7	A	20.0	Fg	1.0	Ab
	50	100	3.0	Ab	41.7	Abc	21.6	Bcde	0.9	Ab
	100	200	3.1	A	41.8	Abc	20.9	Efg	0.7	B
	200	400	2.9	Ab	41.2	Bc	21.6	Abcde	0.9	Ab
100	0	100	2.8	Ab	42.1	Ab	21.4	Bcdef	0.8	Ab
	50	200	2.9	Ab	41.1	Bc	22.2	Abcde	1.1	A
	100	300	2.8	Ab	41.6	Abc	22.2	Abcde	1.2	A
	200	500	2.7	Ab	40.5	Cd	22.8	Ab	1.2	A
200	0	200	2.9	Ab	40.6	Cd	23.0	A	1.2	A
	50	300	2.7	Ab	40.9	Bcd	22.4	Abcd	1.2	A
	100	400	2.9	Ab	41.3	Bc	21.8	Abcde	1.1	Ab
	200	600	2.5	B	39.7	D	22.6	Abc	0.9	Ab
lsd	lsd	lsd	0.5		1.4		1.4		0.4	

Table 6: Results 2021 (wheat)

Phosphorous rates Deep (initial)	Annual (kg/ha)	Cumulative	Yield (t/ha)		Protein (%)		Screenings (%)		Test weight (%)	
0	0	0	6.3	bc	12.5	ab	1.7	ab	79.7	ab
	20	120	7.3	a	12.7	ab	1.5	abc	79.4	b
	40	240	7.1	ab	12.4	b	1.3	c	79.1	bc
	80	480	7.0	abc	12.4	b	1.9	a	78.6	c
100	0	100	6.2	bc	12.7	ab	1.6	abc	79.6	ab
	20	220	6.5	abc	12.7	ab	1.3	c	79.5	ab
	40	340	7.2	a	12.5	ab	1.5	bc	79.4	b
	80	580	6.8	abc	12.4	b	1.6	abc	79.5	ab
200	0	200	6.2	c	12.4	b	1.7	ab	79.6	ab
	20	320	7.2	ab	12.8	ab	1.4	bc	79.6	ab
	40	440	6.9	abc	11.8	c	1.7	abc	79.4	ab
	80	680	7.3	a	12.4	b	1.6	abc	79.4	ab
lsd	lsd	lsd	0.9		0.5		0.4		0.6	

Table 7: Results 2022 (wheat)

Phosphorous rates										
Deep (initial)	Annual (kg/ha)	Cumulative	Yield (t/ha)		Protein (%)		Screenings (%)		Test weight (%)	
0	0	0	3.2	g	13.0	a	4.1	ab	78.7	ab
	20	140	3.8	bcde	12.8	abc	4.1	ab	78.6	ab
	40	280	3.9	bc	12.7	abc	3.6	b	79.9	a
	80	560	4.0	abc	12.5	abc	4.2	ab	78.6	b
100	0	100	3.3	fg	13.1	a	4.8	ab	78.2	b
	20	240	3.9	bcd	12.8	abc	4.1	ab	78.3	b
	40	380	4.2	ab	12.4	cd	3.9	ab	78.5	b
	80	660	4.3	a	12.5	bcd	4.5	ab	78.3	b
200	0	200	3.5	defg	12.8	abc	4.6	ab	78.5	b
	20	340	4.0	abc	12.9	abc	3.8	ab	79.2	ab
	40	480	4.1	ab	12.4	cd	4.3	ab	78.2	b
	80	760	4.3	a	11.9	d	4.7	ab	78.8	ab
lsd	lsd	lsd	0.4		0.6		1.3		1.2	

Table 8: Results 2023 (canola)

Phosphorous rates										
Deep (initial)	Annual (kg/ha)	Cumulative	Yield (t/ha)		Oil (%)		Protein (%)		Test weight (kg/hl)	
0	0	0	0.6	g	41.8	ef	23.4	a	65.6	abc
	20	160	1.3	def	43.1	abcd	22.3	abcd	65.6	abc
	40	320	1.6	abcd	42.7	bcde	22.5	abcd	65.0	de
	80	640	1.9	a	43.2	abc	22.0	cd	65.1	cde
100	0	100	1.1	ef	42.3	def	23.1	abc	65.7	ab
	20	260	1.4	cde	42.3	def	22.2	bcd	65.3	bcde
	40	420	1.7	abcd	43.3	ab	21.7	d	65.3	bcde
	80	740	1.8	abc	43.4	ab	21.7	d	64.9	e
200	0	200	1.5	bcde	42.9	bcd	22.4	abcd	65.3	bcde
	20	360	1.8	abc	43.9	a	21.9	cd	65.3	bcde
	40	520	1.8	abcd	44.0	a	21.4	d	65.0	de
	80	840	1.9	ab	43.0	bcd	21.4	d	65.1	cde
lsd	lsd	lsd	0.5		1.0		1.2		0.5	

Table 9: Results 2024 (wheat)

Phosphorous rates								
Deep (initial)	Annual	Cumulative	Yield		Protein		Test weight	
(kg/ha)			(t/ha)		(%)		(kg/hl)	
0	0	0	4.40	de	12.61	abc	77.28	abcd
	20	180	5.41	bc	12.34	bcd	77.24	abcd
	40	360	6.46	a	11.60	f	77.46	ab
	80	720	6.38	a	10.71	g	77.09	cd
100	0	100	3.81	e	12.78	a	77.31	abcd
	20	280	5.05	cd	11.96	def	77.52	a
	40	460	5.93	ab	12.01	def	77.28	abcd
	80	820	6.16	ab	11.73	ef	76.98	d
200	0	200	4.57	de	12.17	cde	77.35	abc
	20	380	6.01	ab	11.81	ef	77.37	abc
	40	560	6.00	ab	11.56	f	77.32	abcd
	80	920	6.17	ab	11.09	g	77.09	bd
lsd	lsd	lsd	0.86		0.42		0.36	

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