Improved phosphorus prescription maps – beyond phosphorus replacement

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Key Findings

- At phosphorus responsive sites, fertiliser rates above 20 kg P/ha were able to increase crop early vigour measured as NDVI.
- For three of the four sites where there was a high predicted response to P fertiliser the highest partial gross margin was achieved at 32 – 40 kg P/ha.
- At three of the four sites where there was a low or moderate predicted P response there was no benefit to the partial gross margin from applying any P fertiliser.

Why do the trial?

The aim of this project is to increase the profitability derived from phosphorus (P) fertiliser application. This will be achieved through increasing P fertiliser use efficiency through a better understanding of the spatial variability in P availability, demand and P response.

Map data layers that can infer spatial information on P uptake, soil tie up and response are becoming increasingly available, such as grain yield, soil pH, soil EC and NDVI. However, the best methodology for integrating this data for improving P rate calculations is unknown. The aim of this project is to better understand how these data layers can be integrated to produce variable rate P prescription maps that optimise P rates across variable paddocks.

This will be achieved by analysing data layers (yield, soil pH, soil EC, NDVI) to identify the range in likely P response. This information will be used to locate a series of P rate trials, in two paddocks per year in 2019 and 2020 in the Mid North and YP regions. The yield responses observed in these trials will be used to determine the relative importance or weighting that each data layer has on the rate calculation and inform the best method for integrating these data layers for calculating optimal P rates.

How was it done?

Predicted P response was estimated through analysis of historical grain yield, NDVI and Veris pH data for two paddocks (Figure 1). Based on these estimates, eight sites were selected to cover the range of expected P response, with four in a paddock near Bute and four in a paddock near Koolunga.

The eight trials were established using knife points and press wheels and had three replicates. Treatments included P rates of 0, 5, 10, 20, 30 and 50 kg P/ha. Fertiliser was applied using MAP and nitrogen rates were matched between treatments using adjusted rates of urea. An additional treatment of 2.5 t/ha chicken litter was also included at each site. Analysis of the chicken litter showed a P content of 0.8%, equating to 20 kg P/ha applied. For application rates of MAP and matched urea see Table 1.

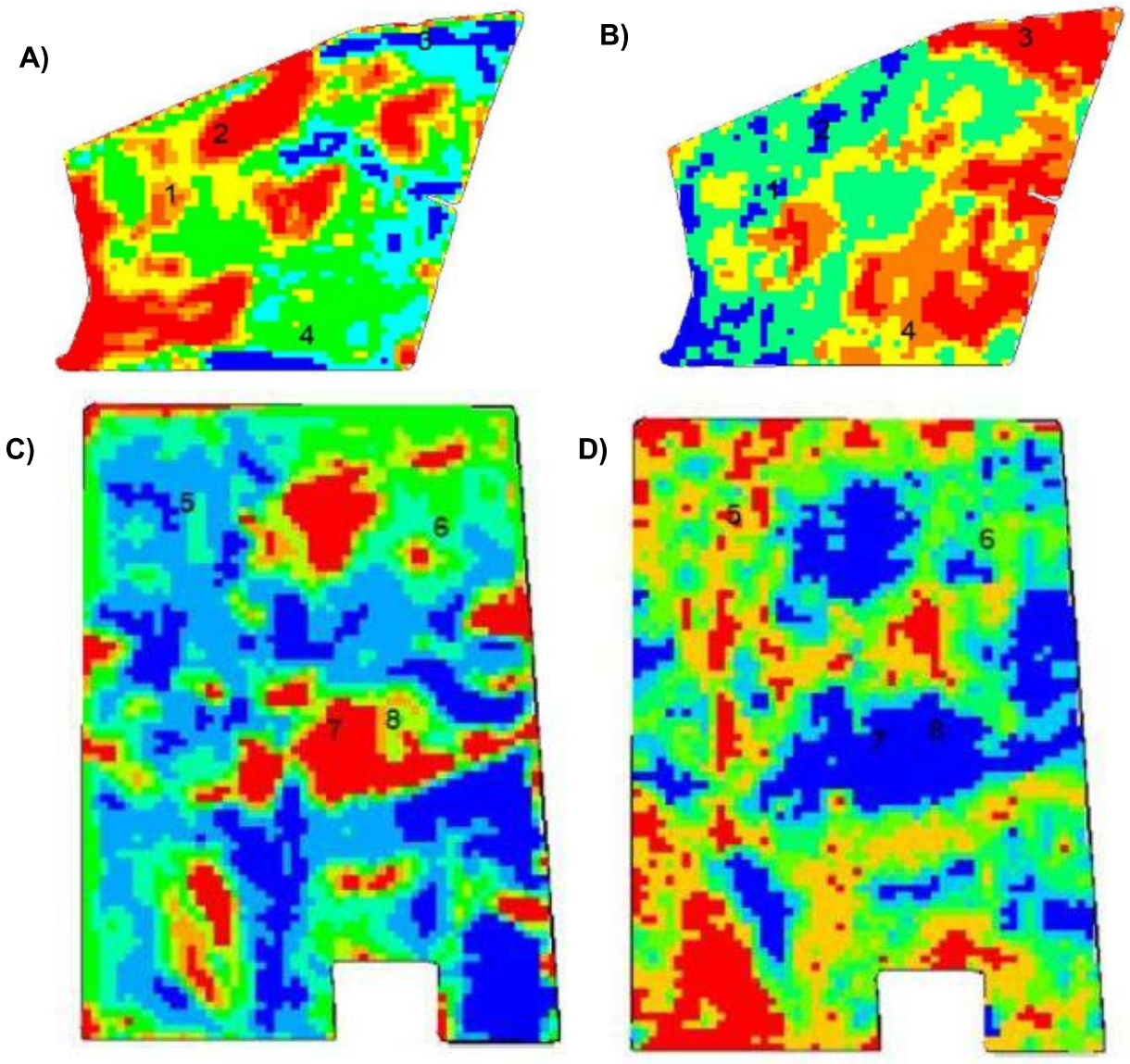

Figure 1. The two maps on the left are Landsat NDVI (2018) and on the right are soil pH (red = low, blue = high) for the trial paddocks at Koolunga, A) and B), and Bute, C) and D), respectively. Numbers within the maps show where P trials were established.

Table 1. Treatment list and application rates of MAP and urea for the eight P trials in 2019.

Treatment	P rate (kg/ha)	MAP (kg/ha)	Urea (kg/ha)
1	0	0	49.4
2	5	22.7	44.5
3	10	45.5	39.5
4	20	90.9	29.7
5	30	136.4	19.8
6	50	227.3	0.0
7	Chicken litter 2.5t	0	0

Sowing date: 23rd May 2019 Bute and Koolunga

Varieties: Bute – Compass barley, Koolunga – Scepter wheat

Measurements throughout the season included GreenSeeker NDVI, grain yield and grain quality on all treatments. Crop biomass, leaf tissue nutrient concentration, and grain nutrient concentration for selected treatments.

2019 Site descriptions and soil test results

Table 2. Historical yield, satellite NDVI and Veris pH and the predicted P response for each of the eight P trial sites in 2019.

Paddock	Site	Historical yield	Historical NDVI	Veris pH	Expected P response
Koolunga	**1**	High	Moderate	Alkaline	High
	2	Low-Mod	Low	Alkaline	High
	3	Reliable 3.5t	High	Acid	Low
	4	Variable	Moderate	Neutral	Moderate
Bute	**5**	High	Mod-High	Acid	Low
	6	Variable	Moderate	Neutral	Moderate
	7	Low	Low	Alkaline	High
	8	Moderate	Low	Alkaline	High

Table 3. Soil test analysis for each of the eight P trial sites in 2019.

Paddock	Site	Colwell P (mg/kg)	PBI	DGT-P	pH $CaCl_2$	Organic Carbon % (W&B)	Colwell K (mg/kg)
Koolunga	**1**	24	121	12	7.55	1.64	640
	2	35	131	21	7.48	2.11	480
	3	33	51	56	6.97	1.09	240
	4	62	77	62	6.61	1.57	430
Bute	**5**	27	20	103	5.46	0.48	150
	6	63	50	106	6.04	1.36	510
	7	20	71	22	7.68	0.92	270
	8	19	51	38	7.72	0.86	340

Results and Discussion

NDVI and biomass

NDVI measurements were taken in both paddocks in July (early tillering) and August at Bute (head emergence) and September at Koolunga (post flowering).

The NDVI data recorded in July (early tillering) gives a good indication of how the plots were visually responding to P fertiliser (Figure 2). Sites 3 and 4 at Koolunga and sites 5 and 6 at Bute were predicted to have a low or moderate response to the application of P. At Koolunga the response for these sites (3 and 4) flatten out at 10 kg P/ha (Figure 2). For the non-responsive sites at Bute (Sites 5 and 6) there was a low level of response, with little response beyond 5 kg P/ha.

In contrast, Sites 1 and 2 at Koolunga and 7 and 8 at Bute were predicted to be highly responsive and a greater response to P fertiliser was observed.

Later in the season (prior to flowering) NDVI showed a similar trend at Bute (Figure 2d). At the Koolunga sites the second NDVI reading was not taken until mid-grain fill and senescence had started to occur, the relationships here are not consistent with the earlier timing (Figure 2c). The NDVI at this timing did not represent the actual crop biomass and should be interpreted with caution.

Crop biomass was assessed in one replicate at each site in July and had a strong correlation with the NDVI taken at the same time. Biomass cuts were taken at flowering from two replicates, to estimate hay yield. As the biomass samples were not fully replicated, treatment differences could not be determined at individual sites. When the high P responsive sites were averaged (Sites 1, 2, 7 and 8) an increase in biomass was identified. Phosphorus rates of 20 and 50 kg/ha increased biomass by an average of 30% compared to the control.

Table 4. Crop dry matter (t/ha) production taken at flowering averaged across high P responsive trial sites 1, 2, 7 and 8.

P rate (kg/ha)	Flowering dry matter (t/ha) (sites 1,2,7,8)	Flowering dry matter (% of 0 kg P/ha)
0	4.9	0%
5	5.5	12%
10	5.7	16%
20	6.2	27%
50	6.5	33%
LSD (0.05)	1.7	

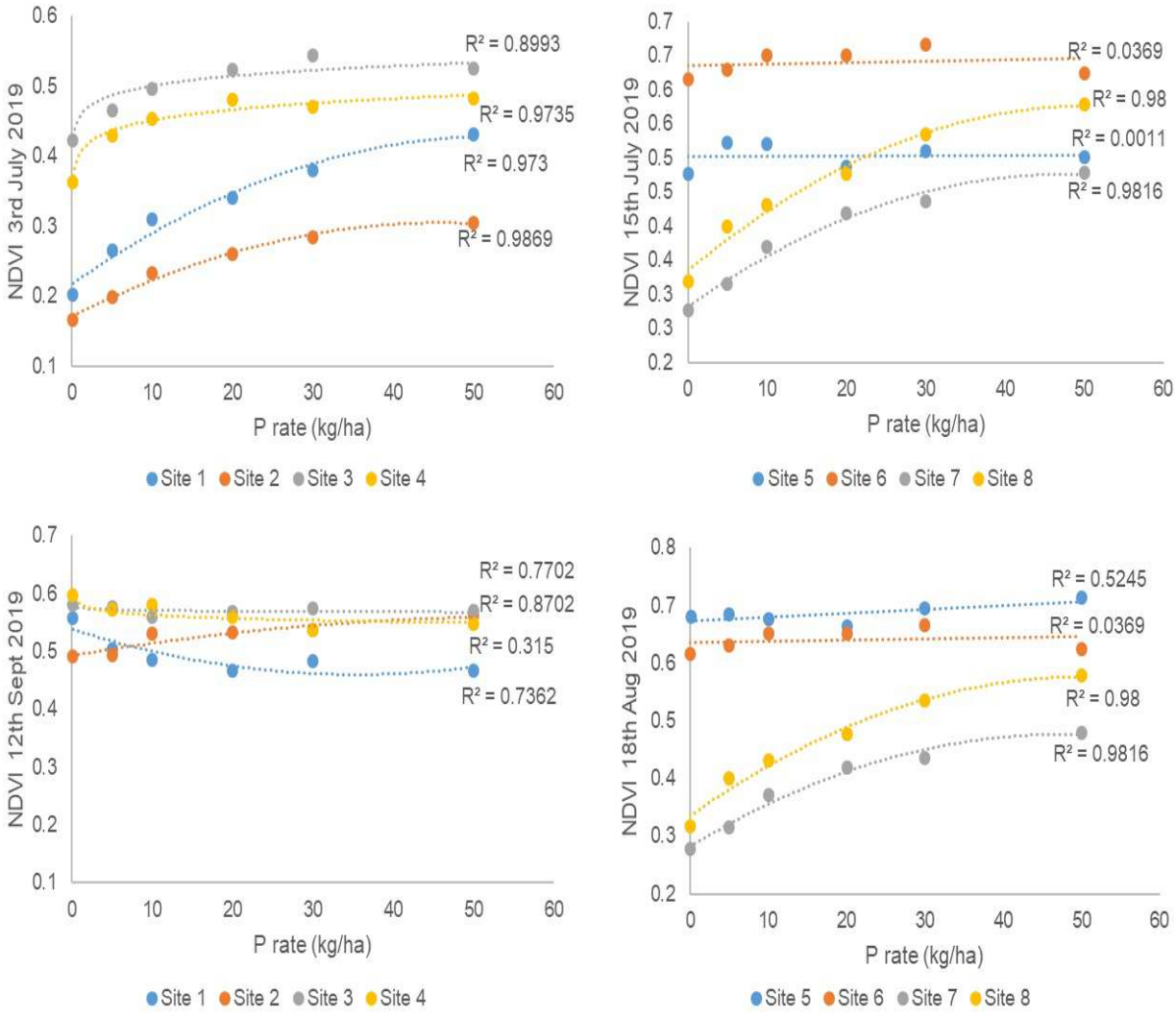

Figure 2. Green Seeker NDVI a) July 3 Koolunga, b) July 15 Bute, c) September 12 Koolunga and d) August 18 Bute for P trials 2019.

Grain yield

Grain yield was not affected by phosphorus rate at three of the eight sites (3, 5 and 6) indicating nil P fertiliser was needed to achieve maximum yield. These three sites along with one other (Site 4) were predicted to have a low or moderate response to P fertiliser. Site 4 was predicted to have moderate P response and grain yield was increased with the application of 30 or 50 kg P/ha by an average of 8.5% compared to the control. Lower rates of P fertiliser at this site did not increase grain yield compared to the nil.

At high P responsive sites (Sites 1, 2, 7 and 8) there were much larger grain yield responses. At Sites 1, 2 and 7, 50 kg P/ha was the highest yielding treatment producing an average 45% yield increase over the nil. At Site 8, 30 kg P/ha was able to achieve the same grain yield as 50 kg P/ha, producing a 27% increase over the nil.

Table 7. Wheat grain yield (t/ha) for P agronomy trials at Koolunga in 2019. Grain yield values appended by a different letter within a column are significantly different.

Koolunga			**Wheat grain yield (t/ha)**			
Treatment	**MAP (kg/ha)**	**Urea (kg/ha)**	**Site 1**	**Site 2**	**Site 3**	**Site 4**
0	0	49	1.71^{d}	2.05^{e}	3.01	2.59^{cd}
5	23	44	1.91^{c}	2.30^{d}	3.14	2.59^{bcd}
10	45	40	2.14^{b}	2.67^{c}	3.02	2.63^{bc}
20	91	30	2.15^{b}	2.72^{bc}	3.10	2.75^{abc}
30	136	20	2.25^{b}	2.86^{b}	3.30	2.77^{ab}
50	227	0	2.46^{a}	3.05^{a}	3.15	2.82^{a}
Chicken Litter			*1.87^{cd}*	*2.22^{d}*	*3.02*	*2.42^{d}*
LSD (P≤0.05)			*0.18*	*0.17*	*ns*	*0.18*

Table 8. Barley grain yield (t/ha) for P agronomy trials at Bute in 2019. Grain yield values appended by a different letter within a column are significantly different.

Bute			**Barley grain yield (t/ha)**			
Treatment	**kg MAP**	**kg Urea**	**Site 5**	**Site 6**	**Site 7**	**Site 8**
0	0	49	4.98	4.58	3.35^{e}	4.21^{c}
5	23	44	4.95	4.49	3.62^{de}	4.76^{b}
10	45	40	5.07	4.54	4.07^{c}	4.95^{b}
20	91	30	5.05	4.66	4.29^{bc}	5.07^{ab}
30	136	20	5.26	4.71	4.48^{ab}	5.35^{a}
50	227	0	5.17	4.67	4.78^{a}	5.35^{a}
Chicken Litter			*5.12*	*4.81*	*3.97^{cd}*	*4.77^{b}*
LSD (P≤0.05)			*ns*	*ns*	*0.39*	*0.39*

Partial gross margin

Partial gross margins (PGM) were calculated to assess the economic return on the rates of fertiliser applied. Gross margins are sensitive to commodity prices and therefore price assumptions must be made. For these trials the partial gross margins are based on 2019 prices and are as follows; Wheat - $300/t, Barley - $270/t, MAP - $650/t, Urea - $500/t.

At three of the four low or moderate P responsive sites there was little or no grain yield response to application of P fertiliser. Therefore, not applying any P fertiliser produced the best PGM for that season.

Polynomial curves were fitted to the PGM data to identify the rate producing the maximum PGM. At the highly responsive sites 1 and 2 the maximum PGM was achieved at 35 kg P/ha and at sites 7 and 8 the maximum PGM was 40 kg P/ha and 32 kg P/ha respectively.

Increasing P rates from a typical rate of 15 kg P/ha to the maximum partial gross margin could result in an increased profit of between $29/ha and $101/ha for areas of the paddock that are responsive. Potential savings of the cost of P fertiliser being applied where it is not required are also significant.

Response to chicken litter

The chicken litter treatment was implemented by spreading 2.5 t/ha chicken litter on the surface of the plots prior to seeding. No additional fertiliser was applied with the seed. The results show chicken litter applied to the surface was not as effective as a fertiliser for the crop compared to banding the synthetic fertiliser with the seed. At the low and moderate responsive Sites 3, 4, 5 and 6 there was no significant positive response to chicken litter compared to the control.

At the sites where the predicted response was high, there was generally a positive response to chicken litter for NDVI recorded in July, August and September. There was an increase in grain yield of 13% and 19% at Sites 7 and 8 respectively at Bute. At Koolunga, application of chicken litter increased grain yield by 8% at site 1 however, no response was observed at Site 2. This response to chicken litter at Site 2, 7 and 8 was equivalent to applying 2.3, 11.5 and 8.4 kg P/ha as MAP, respectively. Chicken litter applied at 2.5 t/ha supplied 20 kg P/ha (a mixture of both plant available and unavailable P). The efficiency of P applied as chicken litter in the year of application ranged from 12 – 58%.

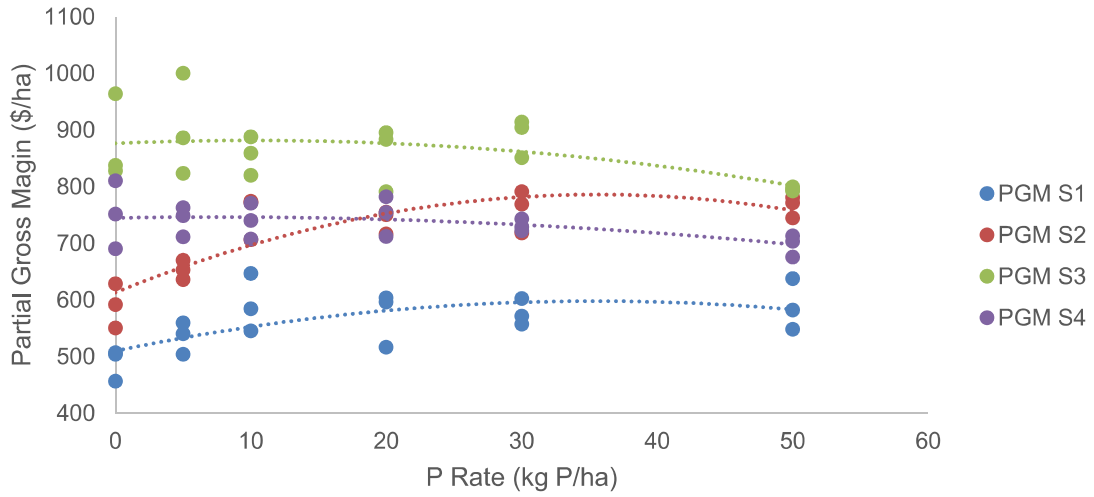

Figure 3. Koolunga P agronomy trials (Sites 1 – 4) partial gross margins, price assumptions, Wheat - $300/t, MAP - $650/t, Urea - $500/t. Polynomial functions for Sites 1, 2 and 3 are, $y = -0.0702x^2 + 4.98096x + 509.679$, $R^2 = 0.4497$, P-val = 0.01717, $y = -0.13533x^2 + 9.6654x + 613.27432$, $R^2 = 0.6963$, P-val = <0.001 an $y = -0.04981x^2 + 1.00197x + 843.37685$, $R^2 = 0.4351$, P-val = 0.02 respectively. Function for Site 4 was not significant.

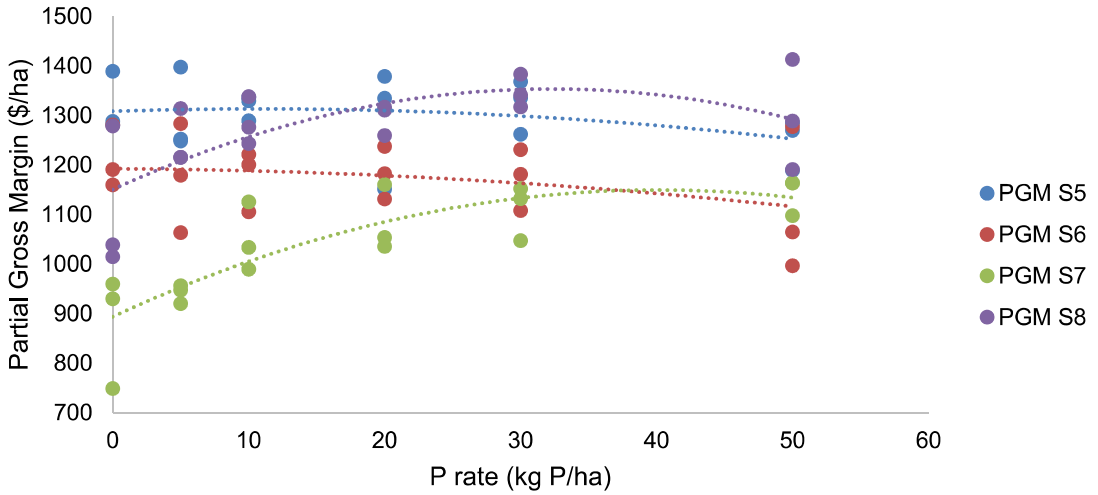

Figure 4. Bute P agronomy trials (Sites 5 – 8) partial gross margins, price assumptions, Barley - $270/t, MAP - $650/t, Urea - $500/t. Polynomial functions for Sites 7 and 8 are, $y = -0.15937x^2 + 12.78033x + 893.40713$, $R^2 = 0.6609$, P-val = <0.001 and $y = -0.19493x^2 + 12.58356x + 1150.44279$, $R^2 = 0.3938$, P-val = 0.009 respectively. Functions for Sites 5 and 6 were not significant.

Acknowledgements

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