Long-term phosphorus (P) trial and evaluation of the DGT soil phosphorus test

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Take home messages

- **after nine years, applying more than 5kg P/ha had no impact on grain yield in 2011**
- **consistently applying 5kg P/ha has been the most productive and profitable rate used**
- **the DGT soil P test will undergo commercial testing at CSBP laboratories in 2012**

Background

The long-term phosphorus trial was established at the BCG Farming Systems Site in 2003 on a Mallee clay loam with subsoil limitations. The trial focuses on the longer term value of increasing rates of phosphorus (P) fertiliser on production and profitability. After two years of favourable seasons, substantial amounts of P have been removed. The question remained: did P rates need to increase to reflect the removal in those years?

As P fertiliser represents a significant up-front cost to farmers and deficiencies are difficult to correct post-sowing, it is important to know what P is available in the soil. Measuring the amount of available soil P through soil tests has been found to be extremely valuable to determine if P is required (Mason and Craig 2008). The study showed that Colwell P (with PBI) predicted 70% of paddock responses, whilst the new soil P test Diffusive-Gradient in Thin Films (DGT) predicted 90% of paddock responses. DGT is a relatively new test, at least to the commercial world, which offers growers a more accurate measurement of soil-available P compared with Colwell P, Olsen P and resin tests. Unlike current soil tests for P, DGT results are not influenced by soil type and extract only available forms of P. DGT is promising as a test for wheat, barley, canola and peas and is continuing to be assessed for its commercial viability.

Aim

- to assess the long-term impact of a range of P fertiliser rates on crop yield and economic returns
- to evaluate the DGT soil test as a measurement for soil available P

Method

Two trials were set up at Jil Jil, 22km north of Birchip.

Trial 1: Long term phosphorus

Six rates of P (0, 5, 10, 15, 20 and 25kg P/ha) were applied annually to the same plots from 2003 to 2011. Each year, a base rate (5kg P/ha) of mono-ammonium phosphate, MAP (N10:P22:K0:S1), was applied to all treatments except the nil P rate. Triple Superphosphate, TSP (N0:P20:K0:S1), was then applied to vary the P rate without adding further N. To ensure N rate was the same for all treatments, urea was applied at 5kg/ha to the nil P treatment.

The trial began in 2003 after two years of fallow on a paddock with a strong fertiliser history and since then has followed a typical Mallee rotation for this soil type (Table 1).

Table 1. Crop rotation and growing season rainfall (GSR) at the Long term P trial site (note: average GSR for the site is 235mm)

Year	Rotation	GSR (mm)
2003	Yitpi wheat	200
2004	Vic Sloop barley	155
2005	Targa oats (hay)	198
2006	Medic/fallow	103
2007	Yitpi wheat	142
2008	Wyalkatchem wheat	113
2009	Morgan peas (hay)	186
2010	Correll wheat	350
2011	Hindmarsh barley	169

Location: BCG Farming Systems Site, Jil Jil

Replicates: 4

Sowing date: 11 June 2011

Sowing rate: 70kg/ha

Crop type: Hindmarsh barley

Herbicide: 8 June 2011 2L/ha Roundup PowerMAX, 75ml/ha Goal, 2L/ha TriflurX, 2.5L/ha Boxer Gold

Seeding equipment: no-till, narrow points, press wheels, 30cm row spacing

Soil samples have been taken annually, except in 2004, from each treatment for soil Colwell P measurement. Soil DGT measurements were taken in 2010 and 2011. Ten samples per treatment were collected randomly, using a 2.5 cm diameter soil corer to a depth of 10cm.

Based on annual fertiliser and hay or grain prices, net income after P expenditure and the accumulated income over the period have been calculated.

Trial 2: Evaluation of the DGT soil P test

Four rates of P (0, 5.5, 11, 16.5kg P/ha) were applied at three site. A base rate of 20kg urea/ha was applied to all treatments. MAP was then applied to vary the P rate.

Location: Jil Jil

Replicates: 3 paddocks (Landers, Bishes and Caldoes), each trial with 3 replicates

Sowing date: 30 June 2011

Sowing rate: 40kg/ha

Herbicide: 30 June 2011 TriflurX 1.5L/ha, Roundup 1.5L/ha

Seeding equipment: no-till, narrow points, press wheels, 30cm row spacing

Table 2. Cropping history, trial crop and sowing rate for the three sites

Site	Cropping history			Trial	
	2008	2009	2010	Crop	Sowing rate (kg/ha)
Landers	Pasture oats	Wheat	Barley	Correll wheat	40
Bishes	Lentils	Wheat	Wheat	Hindmarsh barley	40
Caldoes	Wheat	Wheat	Pasture oats	Hindmarsh barley	40

Soil samples were taken from each site and measured for soil Colwell P, PBI and DGT. Six samples were collected randomly, using a 2.5 cm diameter soil corer to a depth of 10cm. Note, soil samples were collected across each paddock and a trial was then established within that paddock.

The accuracy of soil tests was evaluated by comparing the predicted response to P fertiliser application with yield at different P fertiliser rates.

Results

Trial 1-Long Term P

Increasing rates of P fertiliser for the duration of the trial raised Colwell P levels of treatments 10P to 25P above 40mg/kg (P<0.01, LSD 6.9, CV. 10.4) (Table 3). The soil PBI (phosphorus buffering index) was 160, indicating that a soil Colwell P of below 35mg/kg should be P fertiliser responsive. Therefore, 0P and 5P treatments should be marginally responsive.

Table 3. Soil Colwell P and DGT for the six rates of P since 2003

Fertiliser P (kg/ha)	Colwell P (mg/kg)								DGT (µg/kg)	
	2003	2005	2006	2007	2008	2009	2010	2011	2010	2011
0	41	18	15	27	33	33	35	37	62	27
5	44	18	21	34	35	35	38	39	61	30
10	49	25	23	29	47	47	63	46	84	41
15	65	30	22	35	49	49	54	44	86	51
20	71	47	44	26	42	42	66	49	99	54
25	68	41	31	29	54	54	66	53	106	57
Sig. diff.	**P<0.01**	**P<0.05**		**NS**	**NS**	**NS**		**P<0.001**		**P<0.001**
LSD(p=<0.05)	**17**	**18**	**N/A**				**N/A**	**6**	**N/A**	**12**
CV%	**20**	**12**						**10**		**18**

Note: *Critical Colwell P at this site 35mg/kg (with PBI). PBI is calibrated for use with wheat and should be treated with caution when predicting critical values for barley. DGT thresholds are: low 18-47C_{DGT}µg/kg, marginal 47-60C_{DGT} µg/kg, high >60C_{DGT}µg/kg.*

With the exception of 2005, the trial site was in severe drought or had below growing season rainfall from 2003 to 2009. 2010 was very wet (Decile 10). The crop yields achieved in these years reflect the seasonal conditions. The 2011 season was low in GSR (Decile 1) but a full soil moisture profile following record summer rainfall contributed to yield.

There was significant increase in barley grain yield (P<0.1) and biomass production at GS65 (P<0.05) with the application of P fertiliser (Table 4).

Table 4. Crop and hay yield for P fertiliser treatments from 2003 (note: the site was medic fallow in 2006)

Fertiliser P (kg/ha)	Crop production yields (t/ha)							
	2003 Wheat	2004 Barley	2005 Oats (hay)	2007 Wheat	2008 Wheat	2009 Pea (hay)	2010 Wheat	2011 Barley
0	3.0	0.6	1.6	0.7	0.2	2.4	3.2	3.0
5	3.3	0.9	1.7	0.7	0.2	2.1	4.0	4.5
10	3.2	0.9	1.5	0.6	0.2	2.2	3.9	4.4
15	3.3	1.0	1.6	0.6	0.2	2.2	4.1	4.3
20	3.5	0.9	1.5	0.5	0.3	2.2	4.1	4.1
25	3.4	0.9	1.9	0.6	0.2	2.3	4.2	4.4
Sig. diff.	**NS**	**P<0.05**	**NS**	**NS**	**NS**	**NS**	**P<0.001**	**P<0.001***
LSD (P=<0.05)		**0.2**					**0.4**	**1.0**
CV%		**8.8**					**5.2**	**17**

** Significant difference at 90% confidence level.*

Grain protein was high given the season, with the mean of all treatments above 14%. This suggests that nitrogen was not limiting in 2011. Other grain quality parameters were measured, for all treatments screenings were <5% and retention 88%. Test weight on average was low (mean for all treatments <65kg/hl). The test weight and protein put the grain outside malt classification (maximum 12.8% protein and minimum 65kg/hl test weight) and subsequently, all treatments were downgraded to Feed 1 (F1). None of these parameters improved with higher rates of P.

After eight years of applying variable rates of P fertiliser, the most profitable rate, 5kg P/ha, resulted in 9kg P/ha being exported from the soil. Although P balance is also influenced by P soil reserves and the rate of mineralisation, this indicates that the 5kg P/ha treatment was closest to a maintenance rate and to achieving a neutral P balance.

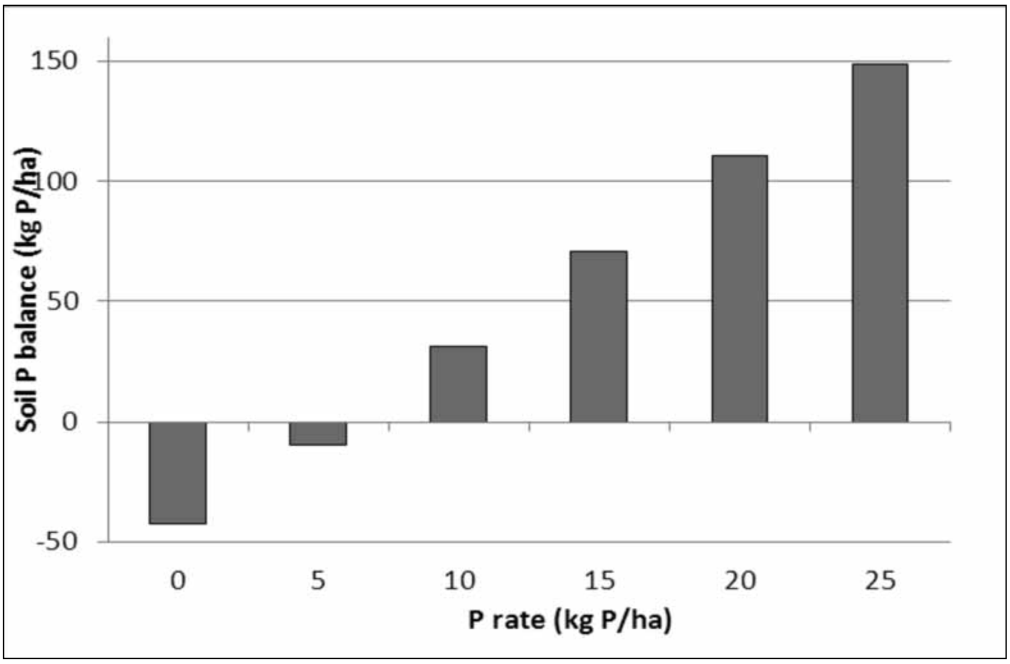

Figure 1. Soil P balance, comparing P applied with P removed in the grain, after eight years (2003-2011) of application of variable rates of P fertiliser

Net income on an annual and cumulative basis (2003-2011) was calculated, based on the price of grain (at harvest each year) and the price of MAP in that year. In 2011 the price for F1 was $154.25/t delivered Birchip (3 December) and the price of MAP was $780/t.

Table 5. Annual net income and cumulative net income, 2003-2011*

Fertiliser P (kg/ha)	Net income after P expenditure ($/ha)								
	2003	2004	2005	2007	2008	2009	2010	2011	Cumulative 2003-2011
0	555	69	205	254	64	440	710	478	2775
5	545	113	195	241	40	419	867	676	3096
10	535	109	185	228	16	398	824	643	2938
15	525	105	174	215	-8	377	848	609	2845
20	515	101	164	143	-32	356	827	561	2635
25	505	97	156	188	-56	335	828	589	2642

**Net income was calculated using treatment yields averaged across the replicates.*

Trial 2- Evaluation of soil P test DGT

Soil test predictions

All three sites were predicted as responsive to P fertiliser by DGT testing and responsive by Colwell P testing at one site (Table 6). For a Mallee sandy clay loam, Colwell P values of 20-25mg/kg are considered optimal and across all soil types DGT 47-60C_{DGT} µg/L is marginal and 18-47C_{DGT} µg/L is low.

Table 6. Soil Colwell P, PBI and DGT measurements and the predicted responsiveness of crop yield to P fertiliser application at each site

Site	Colwell P			DGT	
	mg/kg	PBI	Prediction	C_{DGT} µg/L	Prediction
Landers	23	160	Responsive	18	Responsive
Bishes	30	107	Not responsive	52	Marginal
Caldoes	30	65	Not responsive	20	Responsive

Yield

One paddock, Landers, was responsive to P fertiliser (Table 7). Crop yield in Landers increased incrementally with P-rate. There was a 2t/ha yield increase in applying 75kg/ha MAP. This response was in line with that predicted by both DGT and Colwell P (with PBI). If PBI were not used with Colwell P, then the value of 23mg/kg would have indicated P was adequate, assuming a threshold of 15mg/kg.

To determine whether the response to P application was due to the extra N applied in the MAP the contribution of N and P was separated. The simulated yield difference between nil MAP and 75kg MAP/ha was 200kg/ha. As yield difference between nil and 25-75kg MAP/ha was far greater than 200kg, it is thought that the majority of this yield increase can be attributed to P.

Table 7. Grain yield for three phosphorus rates

Fertiliser application		Grain yield (t/ha)		
MAP* kg/ha	P kg/ha	Landers	Bishes	Caldoes
0	0	2.6	2.1	1.0
25	5.5	3.4	2.9	1.0
50	11	4.2	2.6	1.2
75	16.5	4.5	3.1	1.0
	Sig. diff.	**P<0.001**		
	LSD (P=<0.05)	**0.5**	**NS**	**NS**
	CV %	**5.9**		

At Landers, grain protein was higher for treatments with MAP applied as compared with no MAP applied ($P<0.05$). However, there was no increase in grain protein with increasing rates of MAP. This also implies that the response in yield was due to P rather than N.

Interpretation

Trial 1-Long Term P

After eight years of applying increasing rates of P fertiliser, the nil and 5kg P/ha rates had a negative to neutral long term P-balance (by comparing P applied to P removed in the grain). There was a yield increase when some P was applied (5kg P/ha or more) but only at the 90% confidence level.

On a Mallee Clay Loam with subsoil limitations, not applying P fertiliser during the drought years had the highest return. However, when the better cropping years of 2010 and 2011 are included, applying 5kg P/ha at sowing every year was the most profitable.

Although 5kg P/ha has the highest returns in this trial, a range of factors must be considered when deciding what P rate is required to achieve a good yield, including soil type, soil P levels, root disease, sowing date, crop type and paddock history.

Trial 2-Evaluation of soil P test DGT

Landers

Landers was responsive to the application of P fertiliser. All treatments with MAP applied yielded significantly higher than nil MAP. The 50kg and 75kg MAP/ha treatments also yielded significantly higher than nil MAP and 25kg MAP/ha treatments. The Colwell P test (with PBI) and the DGT test correctly predicted a P response at this site.

Bishes and Caldoes

For Bishes and Caldoes there was no significant response to P fertiliser, indicating that there were other more limiting factors. At Bishes, problems with rabbit damage and uneven weed competition across the trial contributed to its being highly variable and unresponsive to the application of fertiliser. Caldoes was water-limited due to cereal crop regrowth over the summer using stored soil moisture.

Trials across southern Australia have demonstrated that the DGT method is producing more consistent response predictions than the Colwell P test across soil types. It is hoped that the test can incorporate seasonal variation as well.

Future research will also focus on the influence of lower soil moisture, as when growers dry sow paddocks. The DGT test should be commercially available and provide farmers with a more accurate soil P test, which can help to improve P efficiency (Mason 2010).

In the meantime, for farmers uncertain about the current soil P status of their paddocks, the best on-farm test is to leave a strip in the paddock where no P is applied and to closely monitor crop growth and yield. For most soils in the southern Mallee, a Colwell P greater than 30mg/kg is likely to be adequate for P. Applying a low rate (5-6kg P/ha), will allow you to capitalise on better seasons, whilst maintaining soil P reserves at minimal risk.

Commercial practice: what this means for the farmer

- on a Mallee clay loam with subsoil limitations, the yearly application of 5kg P/ha provided the highest return in an eight year trial. Farmers should also consider paddock and fertiliser history, soil P levels and financial constraints when deciding on a P fertiliser rate
- Colwell P combined with PBI testing is at times unreliable. It hoped that, in the near future, farmers will have access to the more accurate DGT soil P test. In the interim, farmers who are unsure about the P levels of their paddock can leave a control strip where no P is applied to the crop.

References

Mason S and Craig S (2008), 'Performance of DGT and Colwell P in predicting phosphorus responses in the Wimmera Mallee,' *BCG 2008 Season Research Results*, pp. 45-49.

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