Evaluation of soil phosphorus tests for making fertiliser decisions

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Take home messages

- *In this survey, 76% of the paddocks had a Colwell P greater than 20mg/kg.*
- *DGT correctly predicted 79% of crop responses in 2009, while Colwell P plus PBI predicted 64%. A relationship between crop responses and Colwell P alone was unable to be derived.*
- *Optimal P rate can now be determined using DGT and PBI.*

Background

Diffusive Gradients in Thin-Films (DGT) technology has been recently modified for the assessment of available phosphorus (P) and micro-nutrients in Australian agricultural soils. Field validation of DGT for predicting wheat responses to P has demonstrated that DGT is more accurate than other soil tests (Colwell P, Olsen P and resin) for assessing available P. One reason for this is that the DGT test is said to mimic a plant root by only measuring the P available to the plant. For a brief description on the method please refer to the *2008 BCG Season Research Results* page 45.

During 2008, a farmer survey was undertaken in order to obtain an idea of the current P levels in paddocks in the Mallee region. A comparison was made between 2 different soil P tests, DGT and Colwell P (including Phosphorus Buffering Index (PBI)), for predicting crop responses. Farmers were asked to leave a control strip (no P, seeders width) in their paddock by turning off their fertiliser input. Colwell P alone failed to show any relationship with the crop responses. When used with PBI, Colwell P correctly predicted a response in 54% of cases. However, Colwell + PBI still failed to predict the most responsive site (>40% yield increase).

The PBI soil test provides a good indication of the ability of an individual soil to fix P. Higher PBI values indicate an increased ability of the soil to tie up P, decreasing P fertiliser efficiency. This survey highlighted 2 important outcomes: that soil testing can reduce the risk associated with P decisions and that DGT has the potential to improve the accuracy of soil testing for P response in our region.

A small scale survey undertaken by John Stuchbery and Associates found that DGT correctly predicted 82% of crop responses.

BCG repeated the 2008 survey in 2009 to support findings.

Aim

To compare soil P tests (DGT, Colwell P, Colwell P plus PBI) for predicting crop responses on a paddock scale.

Table 1. 2009 sites surveyed, associated yield responses to P and soil test values.

Site	Crop type	% Relative yield ~GS30	% Relative yield - Grain	Colwell P mg/kg	PBI	*Critical Colwell P mg/kg	DGT (C_E) µmg/L
Berriwillock	Wheat	62	NA	29	103	28	2490
Boort A1	Wheat	70	NA	30	96	28	2065
Boort B	Wheat	NA	94	44	92	27	1119
Charlton	Wheat	53	NA	30	100	28	1234
Culgoa 1	Wheat	64	100	20	161	34	301
Culgoa 2	Wheat	87	106	34	91	27	1254
Culgoa 3	Wheat	79	NA	27	136	32	589
Curyo A1	Wheat	67	110	30	122	30	1625
Curyo B1	Wheat	56	111	27	97	28	1672
Curyo B2	Wheat	110	114	34	128	31	1988
Curyo C1	Wheat	123	88	36	119	30	895
Donald	Wheat	87	99	34	79	26	1339
Jil Jil A1	Wheat	54	112	28	99	28	1710
Jil Jil A2	Wheat	107	113	29	156	33	589
Jil Jil A3	Wheat	73	99	22	157	34	342
Jil Jil A4	Wheat	104	104	26	70	24	1234
Jil Jil A5	Wheat	84	116	18	94	27	914
Jil Jil B1	Wheat	38	NA	20	175	35	463
Jil Jil B2	Wheat	52	117	22	56	22	1885
Jil Jil B3	Wheat	64	101	32	23	16	2479
Kooloonong 1	Wheat	75	96	19	14	13	4015
Kooloonong 2	Wheat	79	NA	8	14	13	1590
Kooloonong 3	Wheat	78	NA	13	11	12	2734
Nullawil A1	Wheat	71	101	25	174	35	737
Nullawil B3	Wheat	72	91	20	124	31	1055
Sheep Hills A	Wheat	123	NA	42	49	21	4239
St Arnaud	Wheat	110	93	50	40	20	1139
Swan Corack	Wheat	93	80	37	16	14	2359
Warracknabeal 1	Wheat	85	98	36	56	22	1680
Woomelang	Wheat	72	103	25	52	22	2587
Birchip	Barley	NA	NA	22	48	21	306
Boort A2	Barley	81	NA	20	66	24	491
Curyo A2	Barley	60	84	29	105	29	1186
Curyo C2	Barley	NA	101	19	10	11	5050
Curyo C3	Barley	NA	100	34	9	11	5929
Nullawil B1	Barley	78	100	35	34	18	3710
Nullawil B2	Barley	89	100	30	76	25	2221
Nullawil A2	Barley	34	87	7	158	34	212
Rupanyup	Barley	64	NA	37	91	27	792
Sheep Hills B	Barley	85	NA	24	128	31	634
Warracknabeal 2	Barley	65	NA	25	111	29	623

**Critical Colwell P was calculated as performed by Moody 2007. NA = not available at time of writing.*

Method

The survey was conducted in 40 paddocks on 27 different properties across the Wimmera Mallee region. The survey involved growers not applying P for one pass of the seeder over a number of soil types representative of their property. Soil samples (0 – 10cm) were taken prior to or at the time of sowing. The soil collected was then analysed for Colwell P, PBI and DGT. The strips were compared to the adjacent crop. This allowed a simple comparison using a nearest neighbour design. The sites are described in Table 1 (following page) using results from the soil analysis taken at sowing.

Early dry matter responses were measured at the end of tillering (GS30) in the control strip and the adjacent strips by taking 4 x 1m random plant cuts in each strip. Grain yields in each strip were determined from yield monitors (>10 readings in each strip) and averaged. Where the farmer was without yield monitors, grain yields were obtained by hand harvest using the same method as the early dry matter analysis. Samples were then threshed to calculate grain yield.

Soil test values were plotted against relative yield (%) obtained with the fertiliser input to determine the effectiveness of each test in determining plant available P as assessed by plant response.

% Relative yield = Yield (control strip) / Yield (applied P) x 100

If a soil is deficient in P then relative yield will be <90%. The lower the relative yield, the higher the deficiency in P. If a soil is sufficient in P then the relative yield will be 100 % ± 10 % (sampling variation).

Results

Soil test results

Comparison of P levels as measured by Colwell P and DGT between 2008 and 2009 revealed discrepancies between the 2 tests. Sites were segregated into 5 different categories depending on their soil test values. Table 2 presents the current soil P values of the sites surveyed. Overall, Colwell P levels from the 2009 sites were lower compared to 2008. In 2008, 39% of sites had Colwell P values below 30mg/kg while in 2009, 68% of sites had Colwell P values below 30mg/kg. This might suggest overall P levels decreased from 2008; however the discrepancy between 2008 and 2009 could be simply due to random site location and the relatively small sample size (eg number of sites). In comparison the distribution of DGT values between 2008 and 2009 were quite similar and it is not uncommon to obtain large differences between the 2 tests. In 2008, 68% of sites had DGT values below 2000 µg/L compared to 70% for 2009.

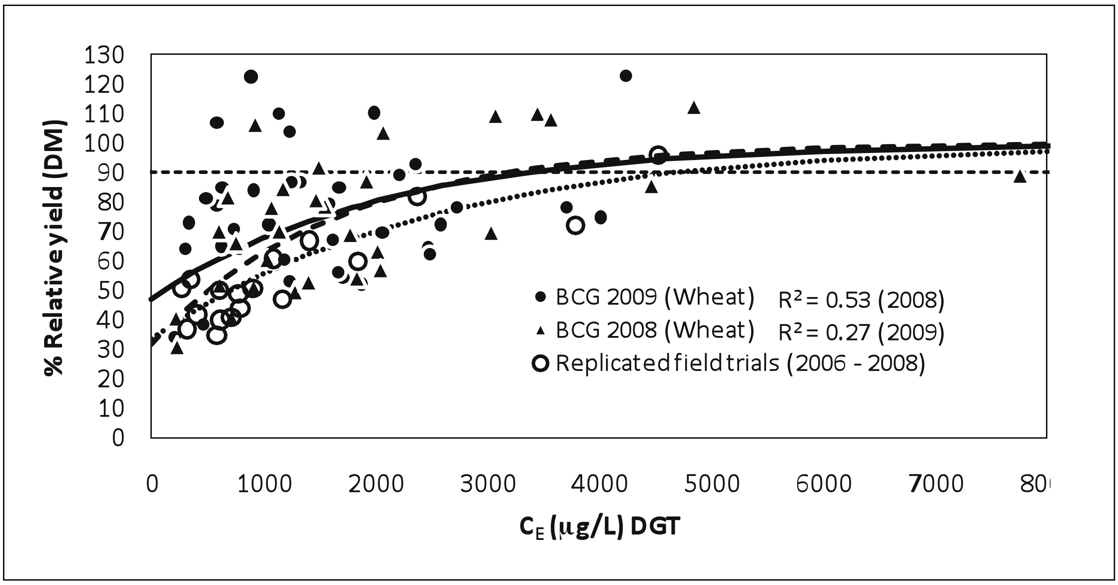
Table 2. Current soil P levels in the Wimmera Mallee (as a percentage of paddocks tested).

Year	Colwell P (mg/kg)				
	1 – 10	**11 – 20**	**21 – 30**	**31 – 40**	**>41**
2008	0%	10%	29%	26%	35%
2009	5%	19%	44%	23%	9%
	DGT CE (µg/L)				
	1 – 1000	**1001 – 2000**	**2001 – 3000**	**3001 – 4000**	**>4001**
2008	29%	39%	10%	13%	10%
2009	33%	37%	19%	2%	9%
	PBI				
	1 – 50	**51 – 100**	**101 – 150**	**151 – 200**	**>201**
2008	13%	42%	16%	19%	2%
2009	28%	37%	21%	14%	0%

Early dry matter (~GS30)

Early dry matter responses (<90% relative yield) to fertiliser were observed in 30 of the 37 (81%) paddocks (wheat (76%) and barley (100%). The percentage of responses to fertiliser was slightly higher than the corresponding survey in 2008 (72%). Relating the 2 soil tests (DGT and Colwell P) to dry matter response from 2009 and combining the results from 2008, found that DGT was still an improvement on Colwell P. The relationship has weakened from that obtained in 2008 (R^2 = 0.53 to 0.27) (Figure 1). No relationship could be obtained using Colwell P.

a)



b)

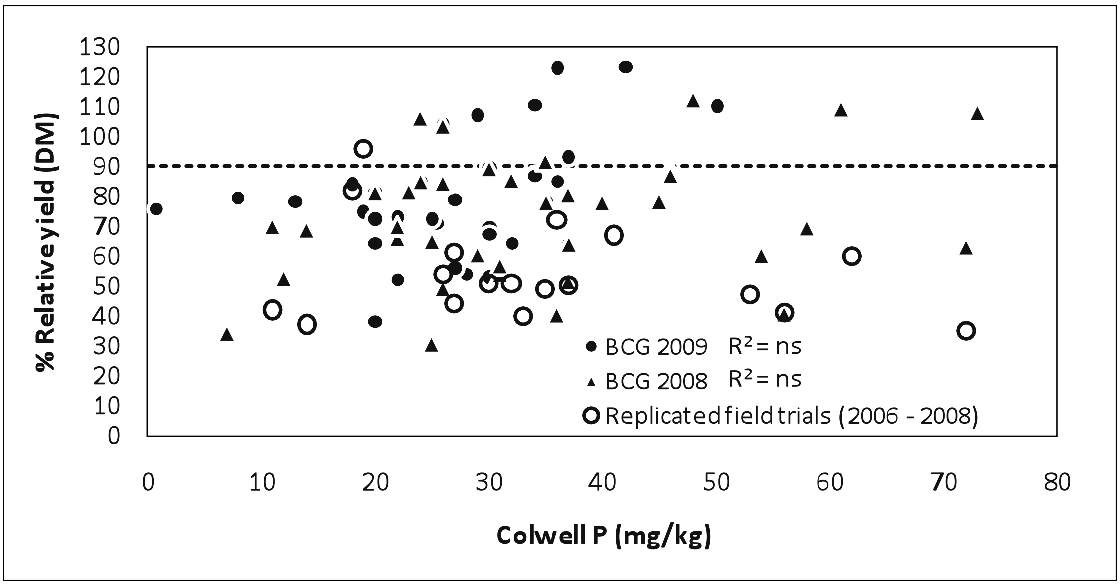


Figure 1. Relationship between wheat dry matter yields taken at mid-late tillering (expressed as percentage of relative yield) for the BCG farmer strips 2008 and 2009 with soil available P test value measured using a) DGT and b) Colwell P. The dashed line represents the relationship with replicated field trials. The larger dashed line represents the relationship with replicated field trials plus 2008 survey. The solid line represents the 2008 and 2009 relationship combined with replicated field trials. NS = not significant ($p \leq 0.05$).

Predicting required rates of P

The DGT method has been validated across numerous replicated field trials, accurately predicting both dry matter and grain responses. DGT can accurately predict if a soil is P-deficient or adequate and therefore provides confidence in reducing rates if the soil has adequate P. While DGT identifies if the soil is P deficient and the extent of this deficiency, it cannot specify at what P rate yield would be maximised. The required amount is governed by other factors in the soil, most importantly the ability of the soil to lock up additional sources of P. With the use of the PBI in combination with DGT, the P rate required to maximise dry matter during early growth stages (GS30) can be determined (Figure 2).

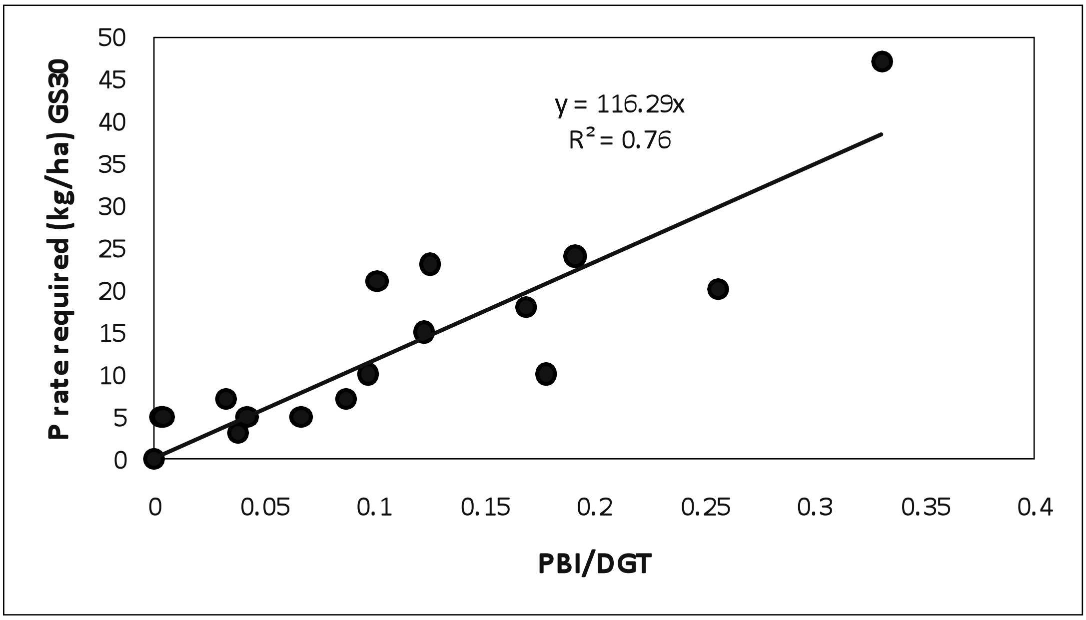


Figure 2. Relationship between combined PBI and DGT values with P application rate required to maximise yields at GS30 from replicated field trials (2006 – 2008).

Are current P rates sufficient?

Most farmers have reduced P rates overtime due to significant financial pressure. The aim of any system is to ensure yields are maximised and that an optimal return on P investment is achieved. Using data obtained from replicated field trials (see above) we can calculate approximate P rates required to maximise dry matter at GS30 for the survey sites by using PBI and DGT values. The survey found that 18 sites required rates of between 0 – 5kg/ha P to maximise dry matter, 10 sites required between 6 – 10kg/ha P, 6 sites required between 11 – 20kg/ha P and 9 sites required > 20kg/ha P. It should be noted that maximising dry matter at GS30 may not be economical as grain response to P is normally less than that obtained at GS30 and critical soil P levels for grain deficiency are lower than the corresponding growth stage at GS30 (refer to *2008 BCG Season Research Results* page 45).

It is highly likely that farmer application rates in 2009 would have been below 10kg P/ha and therefore a major proportion of sites would not have maximised their dry matter and a smaller portion would not have maximised grain yields. These sites have diverged off the relationship from replicated field trials (Figure 1) where it is known that dry matter has been maximised at GS30. This indicates why relationships between DGT and crop response have decreased from 2008 and 2009. Generally sites with low DGT values had high PBI values (>150) and therefore the rate of fertiliser used was not sufficient and yield responses were negligible. Maximum yield must be reached for the validation of any soil test.

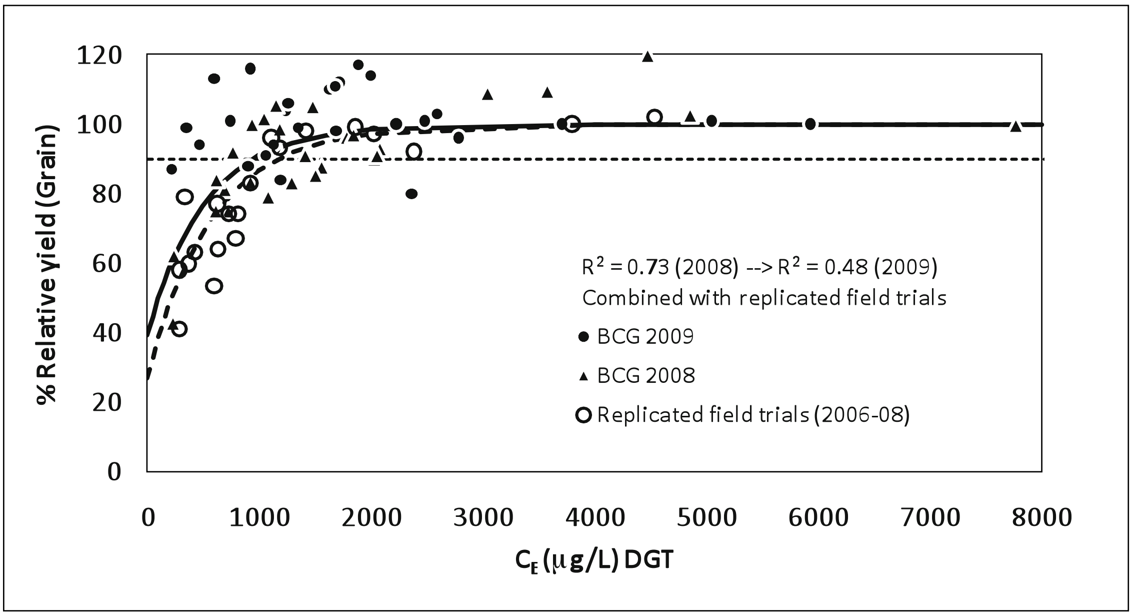
Grain

Grain responses (<90% increase in yield) to fertiliser were observed in 4 of the 28 (14%) paddocks using results available at the time of writing. The percentage of responses to fertiliser in 2009 was lower than 2008 (44%). DGT accuracy in predicted grain responses was again superior to Colwell P but relationships have decreased possibly due to insufficient rates used on particular soils (high PBI). No significant relationship could be obtained between Colwell P values and grain response to P (Figure 2). Determining the Critical Colwell P from the PBI measurements from each site (Moody et al. 2007) (assuming barley has similar response to P as wheat) did improve the grain response prediction (Table 1). Out of the 28 sites the critical Colwell P and actual Colwell P measurements correctly predicted the grain response for 18 sites (64%).

Using deficiency thresholds obtained by DGT from replicated field trials the DGT method correctly predicted the response from 22 of the 28 sites (79%). 4 of the 6 sites incorrectly predicted by DGT showed no response to fertiliser where DGT suggests P levels in the soil were deficient outlining again that rates used where not adequate in maximising grain yields in some cases.

The overall success rates for each soil test in predicting grain responses combining 2008 and 2009 results are 59% for Colwell P and 80% for DGT. Some findings of this survey need to be considered when determining the effectiveness of soil tests. The control strips were not replicated and in the majority of cases the farmer did not have the ability to balance N inputs. Outliers that showed a greater response than expected could be contributed to the added N application, therefore potentially reducing the relationship with DGT – particularly during early crop growth stages. It is also unclear whether the amount of P the farmer applied as their standard rate was enough to maximise yields especially on sites that have higher PBI values as described above.

a)



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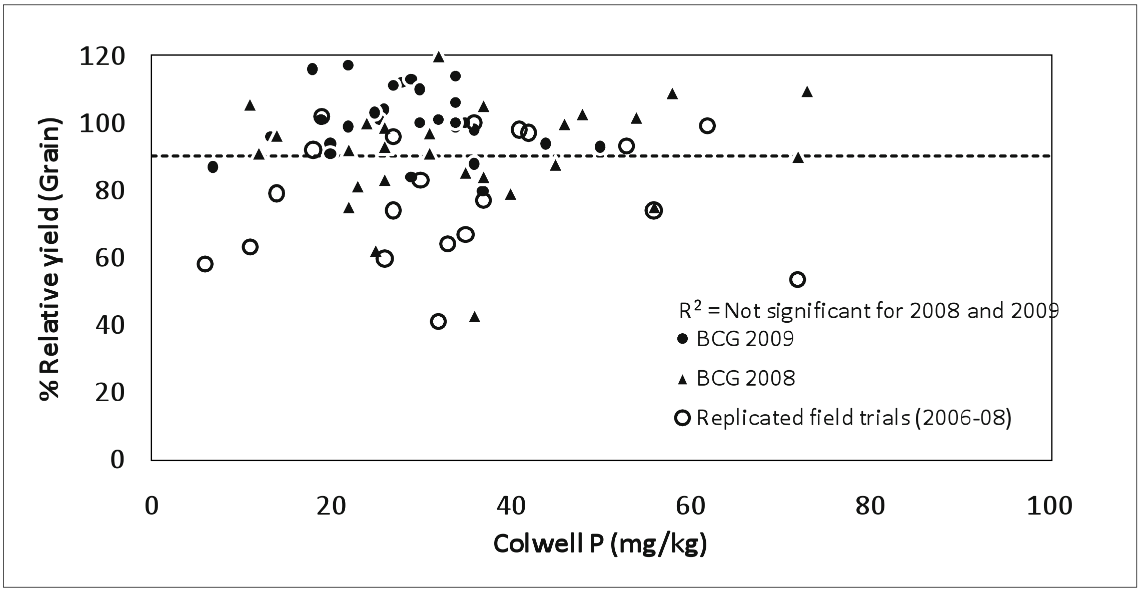

Figure 3. Relationship between wheat grain yields (expressed as percentage relative yield) for the BCG farmer strips 2008 and 2009 with soil available P test value measured using a) Colwell P and b) DGT. The dashed line represents the relationship for the 2008 survey; the solid line represents the 2008 and 2009 relationship combined.

Interpretation

Both surveys in 2008 and 2009 have demonstrated the potential benefits of DGT as a predictive tool for crop response to applied P and to improve fertiliser decisions. In both years, DGT has outperformed the commonly used Colwell P test. It is well documented that the methodology of Colwell P means its results can be misleading depending on soil chemistry as has been shown in this survey. The PBI test improves the Colwell P method to a degree where a predicted success rate can be achieved.

Utilising DGT, PBI and combining information from replicated field trials we can estimate the amounts of P fertiliser required to maximise yields. By using this method, decisions could be made regarding soils that have a high PBI and low P status and therefore whether the required rate of P will be economical or not.

Despite these findings, DGT is not yet commercially available and will not be until 2012. Subsequently, using Colwell P and PBI together is currently the best tool available. Given Colwell P and PBI can account for 50 – 60% of responses, it tells us that decisions should not be made on these values alone. Paddock history and P-balances would further improve the decision process and allow fertiliser rates to be refined.

Acknowledgments

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References

Moody, P. W. (2007) Interpretation of a single-point P buffering index for adjusting critical levels of the Colwell soil P test. *Australian Journal of Soil Research*, **45**, 55-62.

Notes: