Long-term phosphorus

Fiona Best *(BCG)*

Take home messages

- *In a Morgan pea hay crop, there were no dry matter differences between any of the phosphorus (P) fertiliser rates in 2009.*
- *The most profitable application rate of P on average between 2003 and 2009 has been zero kg P/ha on a site with a strong fertiliser history and initial soil P Colwell of 41mg/kg.*
- *A rate of 5kg P/ha/yr produced the second highest net income with the least amount of risk.*

Background

The long-term phosphorus (P) trial began at the BCG farming systems site in 2003 and focused on the impact on yield of increasing rates of P fertiliser on a heavy southern Mallee soil type. Since the trial commenced, the region has experienced several years of drought and below average rainfall. This has resulted in reduced crop performance and low grain yields, however the trial has still provided some interesting information to support farmers' P fertiliser decisions.

Aim

To assess the implications of different P fertiliser rates on crop growth and profitability over time.

Method

Six rates of P (0, 5, 10, 15, 20 and 25kg P/ha) were applied annually to the same plots from 2003 to 2009.

Each year a base rate of 23kg/ha MAP (mono-ammonium phosphate) was applied (this is the equivalent rate to 5kg P/ha) to all treatments except the nil. Triple-superphosphate (TSP) was then applied to change the rate of P for the various treatments without adding extra nitrogen. The control treatment did not receive any phosphorus between 2003 and 2009 but nitrogen was applied to ensure it was at the same rate as had been applied with the MAP.

Herbicide and non-P fertiliser inputs were applied throughout the life of the trial as required according to district practice.

The trial began in 2003 after 2 years of chemical fallow. A typical Mallee rotation was followed throughout the trial (Table 1).

Table 1. Crop rotation at the trial site, 2001 – 2009.

Year	Crop rotation
2001	Chemical fallow
2002	Chemical fallow
2003	Yitpi wheat
2004	Vic Sloop barley
2005	Targa oats
2006	Medic/fallow
2007	Yitpi wheat
2008	Wyalkatchem wheat
2009	Morgan peas

Location: BCG Farming Systems site, Jil Jil

Replicates: 4

Sowing date: 16 June 2009

Seeding density: 80kg/ha

Crop type/s: Morgan field peas

Seeding equipment: BCG cone seeder (no-till, narrow points, press wheels, 30cm row spacing)

Soil samples were taken at the end of each season (except for 2004) and analysed to record track changes in Colwell P through the rotation. Ten cores were taken from each plot using a 2.5cm wide soil corer to a depth of 10cm. In 2006, the samples of all replicates were bulked together before analysis and subsequently, statistical analysis could not be completed.

In early 2009, the Phosphorus Buffering Index (PBI) for the site was also measured. PBI is a measure of a soil's ability to 'hold onto' P. A high PBI soil will quickly bind up P and make it unavailable for plant uptake. A low PBI soil will have more phosphorus available to the plant for longer.

More recently, BCG has also been supporting research into a new test DGT (Diffusive Gradient Thin film) to predict P responsiveness. At the start of 2009, BCG measured the plots using DGT to compare the new test to Colwell P. Currently the DGT test has only limited data for the responsiveness in crops other than wheat, hence in 2009 the DGT could not be used to predict the responsiveness of peas to P.

With intended hay production in 2009, dry matter cuts to determine hay yield were taken on 30 October 2009. In other years, crops have been taken through to a grain yield, apart from 2005 (oaten hay) and 2006 (medic fallow).

Based on a typical fertiliser price in each year and grain price at harvest, net income (after P expenditure) and the cumulated income over the period were calculated. Unless a statistically significant difference in yield was found, the site mean yield was used (Table 5). A P balance audit was also undertaken, measuring P added minus P removed through grain or hay (based on typical figures for field crops).

Table 2. Nutrients removed with harvested grain and hay.

Crop	Phosphorus removed per tonne (kg P/t/ha)
Cereals	3 – 4
Cereal hay	2
Cereal straw	1
Pulses	6
Canola	6 – 9
Oats	2.5
Pea hay	3

Results

Increasing rates of P fertiliser lifted Colwell P values in the early years of the trial but these differences reduced with time until there were no substantial differences by the end of the 2008 season (Table 3). This was despite 6-years of different P rates. In 2009, the PBI at the site was measured as 160, which is high and indicates that P is bound quickly in this soil. The site mean Colwell P was 43mg/kg, indicating high reserves of plant available P, despite the high PBI.

However, DGT readings showed differences between a number of the treatments in 2008.

Table 3. Colwell P (ppm) measurements taken at the end of each season (0 – 10cm depth) and 2008 DGT readings.

Treatment (kg/ha)	Colwell P (ppm)					DGT
	2003	2005	2006	2007	2008	2008
0	41	18	15	27	33	466
5	44	18	21	34	35	464
10	49	25	23	29	47	753
15	65	30	22	35	49	1077
20	71	47	44	26	42	1105
25	68	41	31	29	54	1317
Sig. diff.	**P<0.01**	**P<0.05**		**NS**	**NS**	**P< 0.003**
LSD (P<0.05)	**17**	**18**	**N/A**			**437**
CV (%)	**20**	**12**		**20**	**48**	**14.2**

Note: Colwell P from 2006 was not replicated and statistical interpretation could not be performed.

Over this 6-year period, yields have been limited due to low rainfall. There were differences in grain or hay yield between treatments in 2004, but no difference in any other year (Table 4).

In 2009, annual rainfall was 330mm and growing season rainfall was 207mm. There were no differences in dry matter between any of the treatments (Table 4).

Table 4. Yield for P fertiliser treatments, 2003 – 2008.

P applied (kg P/ha)	Yield (t/ha)					
	2003 wheat	2004 barley	2005 oats (hay)	2007 wheat	2008 wheat	2009 peas (hay)
0	3.0	0.6	1.6	0.7	0.16	2.4
5	3.3	0.9	1.7	0.7	0.24	2.1
10	3.2	0.9	1.5	0.6	0.24	2.2
15	3.3	1.0	1.6	0.6	0.23	2.2
20	3.5	0.9	1.5	0.5	0.27	2.2
25	3.4	0.9	1.9	0.6	0.24	2.3
Sig. diff.	**NS**	**P < 0.05**	**NS**	**NS**	**NS**	**NS**
LSD (P<0.05)		**0.2**				
CV (%)		**8.8**		**18**	**26.3**	**13.5**

Note: 2006 was medic pasture hence no P was applied and no yield results obtained.

The most profitable rate of P was 0kg/ha with a cumulative net income of $1587/ha achieved over the 6-year period (Table 5). The 6-year P balance highlighted a negative P balance in the 0 and 5kg P/ha treatments and a positive P balance for all other treatments.

Table 5. Cumulated income after P expenditure, 2003 – 2008.

P applied (kg P/ha)	Net income after P expenditure ($/ha)						Cumulated income after P expenditure ($/ha)	6-year P balance (kg P/ha)
	2003	2004	2005	2007	2008	2009	2003 – 2009	2003 – 09
0	$555	$69*	$205	$254	$64	$440	$1587	-23
5	$545	$113	$195	$241	$40	$419	$1553	-1.
10	$535	$109	$185	$228	$16	$398	$1471	+32
15	$525	$105	$174	$215	-$7.7	$377	$1388	+62
20	$515	$101	$164	$143*	-$32	$356	$1247	+91
25	$505	$97	$156	$188	-$56	$335	$1225	+123

** Indicates the treatment yielded significantly less than the other treatments and income has changed accordingly.*

Note: Costings were based on average grain and hay receival prices and fertiliser costs for each year. For practical means, the expenditure on fertiliser was only calculated using MAP prices. Other costs for growing each crop have not been included. In 2003, wheat averaged $170/t and MAP $425/t; in 2004 barley $130/t and MAP $170/t; in 2005 oaten hay $130/t and MAP $430/t; in 2007 wheat $390/t and MAP $550/t; in 2008 wheat $254/t and MAP $1,047/t, in 2009 pea hay valued at $200/t and MAP $924t/ha. P balance was calculated using the estimated nutrient removal values; removal for wheat 3.5kg P/t, barley 2.7kg P/t, oaten hay 2kg P/t and pea hay 3kg P/t).

Interpretation

With only a slight decrease in grain yield in some years over the six-year period (Table 4) this trial has shown that, at this site, the most profitable P rate was 0kg/ha (Table 5), although not applying any P over this period has meant 23kg P/ha has been exported from the soil reserve. Subsequent crops may therefore respond positively to P in following years based on the theoretical P balance. The P balance may not be a true indication of the amount of P removed as it will also depend on the total P store and the mineralisation rate of P on this soil. However, it still provides an estimate of what has been taken up during the seasons.

Applying a maintenance rate of 5kg P/ha produced a similar net income yet had the benefit of maintaining a relatively neutral P balance. The higher rates of P have resulted in a surplus of unused P in excessive amounts (>54kg P/ha).

In drier years, P responses are more difficult to predict, with responses often depending on the season (eg dry/wet start or dry/wet finish etc), time of sowing and the P reserve.

P is relatively immobile in alkaline soils and subsequently, the majority of P is held within the top 10cm of the soil. Previous BCG trials have shown responses to P are minimal when: (i) soil P reserves are adequate (Colwell P>15mg/kg), and (ii) there has been a strong history of fertiliser application. Colwell P is the best test currently available to farmers to measure the P levels in alkaline soils. The Colwell test is sensitive to soil type and has its limitations. It has since been accompanied by the Phosphorus Buffering Index (PBI) which has improved its predictive ability. The PBI at this site is relatively high (170) suggesting that P is held strongly by the soil and that the critical Colwell P should be 33mg/kg not 15mg/kg. Therefore, for P to be adequate, the Colwell P value needs to be greater than 33 mg/kg.

As has been the case in recent years, southern Mallee fertiliser decisions in 2010 will again be constrained by limits on input expenditure. This trial, and other BCG work, has shown no economic return on investment from applying P at greater than maintenance rates on a paddock with a strong fertiliser history. While at this site the most profitable decision was to apply no P fertiliser from 2003 to 2009, every paddock and farm is different. Ensure soil P levels, crop P removal and previous P fertiliser history is taken into account when making P decisions.

If using low rates (less than 6kg P/ha) in 2010, be mindful of the timing of the break and conditions at sowing time. Sowing into cold soils (eg late sowing) with a low soil P reserve will mean less P mineralisation. Therefore crop response to applied P is more likely. Responses are less likely when soil P reserves are high with early sowing into warm, moist soils.

Row spacing can also have an effect. Lower P rates (3 – 5kg P/ha) can be a problem on wider row spacing, as granule distribution is so sparse.

When deciding on 2010 fertiliser rates, tools such as soil tests and P balances are a useful guide to support your decision.

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