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Phosphate fertiliser source—Gunningbland NSW 2009 to 2012

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Introduction

This experiment evaluated the effectiveness, profitability and residual benefit of various phosphate fertiliser sources over a four-year period from 2009 to 2012.

Due to the combination of drought and highly volatile fertiliser prices many growers in southern NSW have started to explore the use of alternative P sources and nutritional programs.

Traditionally in southern NSW growers have banded all their granular high-analysis fertiliser at sowing with fungicide-treated seed. It is generally accepted that approximately 20%–30% of fertiliser P banded at sowing is available in the first year and the residual amount becomes available in subsequent crops (*Price, 2006*).

The exact ratio of how much P gets locked up will vary depending on soil characteristics such as soil texture, soil acidity/alkalinity and availability of aluminium, iron and calcium.

The potential of a soil to lock up P is estimated by the phosphorus buffer index (PBI). The majority of soil types in southern NSW have low PBI values indicating that much of the applied P will become plant available over time.

The combination of paddock history, crop type (root morphology and arbuscular mycorrhizal fungi), sowing date (early or late sown) and soil test results have proven to be beneficial tools in predicting individual paddock responsiveness to freshly applied fertiliser P.

Growers and advisors are now being challenged by new hypotheses that claim further fertiliser efficiencies can be gained for southern NSW.

Some biological advocates promote the use of rock phosphate products in conjunction with 'microbe-friendly' seed treatments and 'biological inoculants'. It is claimed that the improved biological health of the soil will unlock some of the tied up P and enhance the effectiveness of applied fertiliser P.

Conventional understanding of rock phosphate suggests it is only appropriate for slow-growing grass or tree crops and is only successful on acidic soils (*White, 1979*) with high rainfall (*Bolland, 2007*).

Interest in liquid P fertilisers is also developing due to the increased efficiencies of liquid P over granular P on the alkaline calcareous soils of South Australia (*McBeath, 2005*). These efficiencies are yet to be proven in the common soil types of southern NSW as the presence of topsoil limestone is not considered regionally significant.

Key findings

- High-analysis granular fertiliser (MAP) was the most profitable P source.
- Liquid forms of P performed well, but high purchase price reduced profitability.
- Rock phosphate did not improve grain yield (averaged over three years) or residual soil P.
- Additional biological inoculants applied to rock phosphate did not significantly improve response greater than MAP.
- Consider long-term implication of P fertiliser source and application rate. If P rates are reduced, the residual soil P benefit will also be reduced.
- Growing season rainfall will impact crop response to freshly applied P.
- Growers must consider fertiliser effectiveness and cost ($ per unit of P) when considering P fertiliser source.
- It was more profitable to apply no fertiliser than apply rock phosphate.

Site details

Location	35 km north-west of Forbes, central NSW
Trial design	randomised complete block (4 replicates) laid out as a single row
Soil type	grey vertosol
Colwell P	15 mg/kg
PBI	106 mg/kg
Total inorganic P	62 mg/kg
Total P	252 mg/kg
Organic P	190 mg/kg
pH_{Ca}	7.6
Free lime present	Yes[a]

[a] Free lime present within topsoil, estimated between 1%–5%.

Treatments

From 2009 to 2011 a range of phosphorus fertiliser products (*Table 2*) were applied over the same plot (1.8 m x 20 m) for three consecutive winter crop seasons. The fourth season relied on residual P, with no fertiliser P applied in 2012. The plots were sown to wheat in 2009 and 2010, canola in 2011 and wheat again in 2012.

Table 1: Rainfall data for the experiment site.

	Rainfall (mm)			
Year	**2009**	**2010**	**2011**	**2012**
Stored PAW mm[a]	84	140	202	147
In-crop rainfall	154	300	199	203
Effective rainfall	238	440	401	350

[a] Stored moisture measured at sowing via five gravimetric soil cores.

Table 2: Fertiliser source/product details.

Phosphorus source	P %	$/tonne	$/kgP
Hi-analysis MAP (granular)	22	950	4.32
Rock phosphate (granular)	12	775	6.46
Phosphoric acid (liquid)	16	2231	13.94
Polyphosphate (liquid)	23	3214	13.98

Note: basal applications of nitrogen applied as urea to balance all treatments. Fertiliser costs derived from 2009 prices.

Phosphorus rates: 0 kg P/ha, 5 kg P/ha, 10 kg P/ha and 20 kg P/ha.

An additional 'systems' experiment was conducted to evaluate the impact of 'microbe-friendly' seed treatments, 'biological' inoculants and rock phosphate fertiliser (*Table 3*).

Results

Refer to *Tables 4* and *5* for wheat and canola grain yield and gross margin results for individual years from 2009–12.

Grain yield response

On average, grain yield was significantly affected by fertiliser source (P<0.001) and rate (P=0.001). The average combined grain yield over the three-year period was 2.65 t/ha. The highest average yield of 3 t/ha was achieved by MAP at 20 kg P/ha (*Figure 1*).

Grain yield responded positively with increasing application of MAP and both forms of liquid (Ezy NP and Polyphos) with similar response curves (*Figure 1*). For example, the MAP fertiliser treatment at 5 kg, 10 kg and 20 kg P/ha increased grain yield on average by 0.33 t/ha, 0.47 t/ha and 0.63 t/ha respectively.

There was no significant yield benefit of rock phosphate fertiliser when averaged across three years. However, in one season (2011) the 10 kg P/ha and 20 kg P/ha rates did significantly increase yield by 0.35 t/ha and 0.49 t/ha over the nil P treatment (*Table 4*). This grain yield benefit was not carried over into the following year (2012).

The addition of biological inoculants (*Table 3*) did not improve the rock phosphate response greater than MAP in this experiment (*Figure 2*).

Table 4 illustrates the impact of seasonal conditions on P response. Grain yield at the high P rate responded by 0% in 2009 (drought year), 22% in 2010 (high in-crop

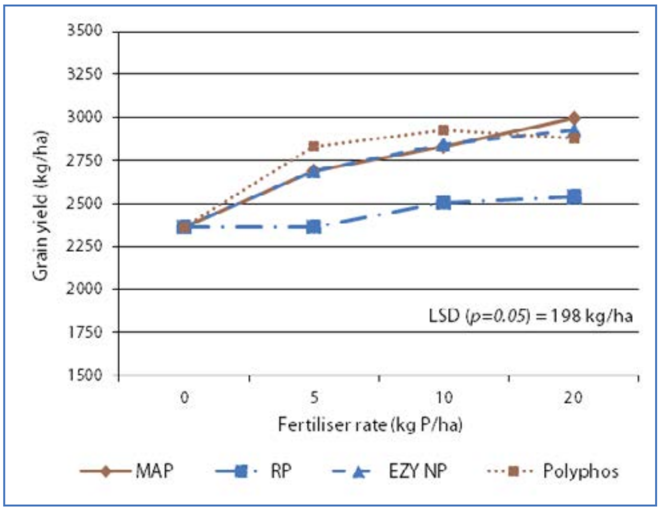

Figure 1: Averaged grain yield response of fertiliser treatments over a three-year period.

Table 3: Additional products used in 'systems' experiment.

Fertiliser treatment	Additional product applied	Application details			Key aim of product
		Seed or foliar	Rate	Cost $/ha	
Rock phosphate	Broad-spectrum inoculum of compost microbes	seed	5 L/t	0.91	Re-inoculate rhizosphere with a broad-spectrum inoculum to improve the soil's natural organic cycle with beneficial fungi and bacteria
	Broad-spectrum inoculum of compost microbes	foliar	5 L/ha	18.49	Re-inoculate the phyllosphere (leaf surface) with a broad-spectrum inoculum to maximise flower bloom, flower retention and harvest yield
Hi-analysis granular (MAP)	Raxil	seed	1 L/ha	1.58	Control bunts and smuts

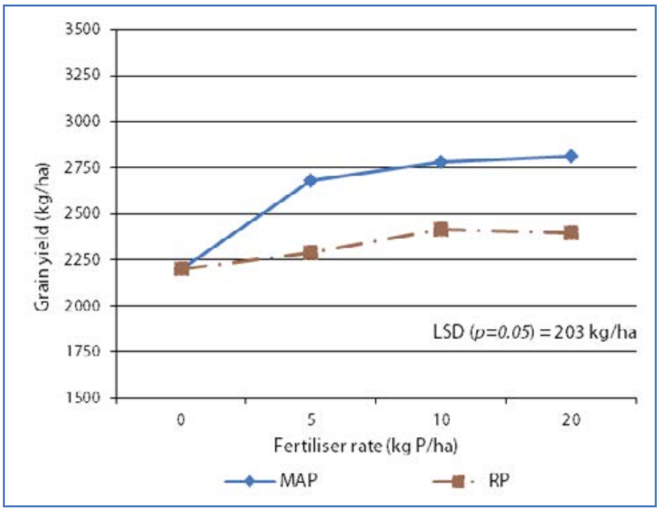

Figure 2: Averaged grain yield response over the three-year period comparing MAP with rock phosphate + biological inoculants.

rainfall), 72% in 2011 (average in-crop rainfall) and 14% in 2012 (no P applied to any treatment in 2012).

Residual P build-up

Residual P benefit was measured by soil testing after two crops, following the 2010 wheat crop (*Figure 3*) and also by measuring grain yield in 2012 (*Table 4*) as no fertiliser P was applied to that wheat crop.

Residual soil P (Colwell)

- Residual soil P levels ranged from 14.7 mg/kg to 22.7 mg/kg and differed significantly with fertiliser source (P<0.001), rate (P<0.001) and interaction between fertiliser source and rate (P=0.02).
- The greatest residual benefit was from the high P rate (20 kg P/ha) of Polyphos and MAP, with a respective increase of 7.9 mg/kg and 6.2 mg/kg over the nil P treatment (*Figure 3*).
- Residual P levels following MAP application increased as the rate increased. The 5 kg P/ha, 10 kg P/ha and 20 kg P/ha treatments increased residual P levels by 1.8 mg/kg, 2.6 mg/kg and 6.2 mg/kg respectively.
- Rock phosphate did not increase soil P levels.
- Both liquids (Ezy NP and Polyphos) had residual responses similar to the MAP treatment. However, Polyphos (20 kg P/ha) did have a significant (P<0.001) residual benefit of 3.3 mg/kg over the 20 kg P/ha Ezy NP treatment (*Figure 3*).

Residual grain yield (2012)

- The 2012 grain yield was significantly affected by the fertiliser source (P<0.001) and rate (P<0.001) for the previous three seasons.
- The highest grain yield in 2012 was achieved where MAP was applied at 20 kg P/ha for the previous three seasons. The yield was 0.57 t/ha higher than the nil P treatment.

Table 4: Grain yield and Colwell P soil test results.

Fertiliser treatment kg P/ha	Wheat yield 2009 (t/ha)	Wheat yield 2010			Canola yield 2011			Wheat yield 2012			Colwell P 2011		
		(t/ha)	(% Nil P)		(t/ha)	(% Nil P)		(t/ha)	(% Nil P)		(mg/kg)	(% Nil P)	
Nil P	1.65 a	4.15	100	a	1.38	100	a	4.22	100	a	14.7	100	a b
MAP 5	1.43 a	4.56	110	b c	2.03	147	c d e f	4.57	108	c d e	16.5	112	b c d
MAP 10	1.52 a	4.72	114	b c d	2.18	158	e f g	4.54	107	b c d	17.3	118	c d e
MAP 20	1.50 a	5.06	122	d	2.37	172	g	4.80	114	e	20.9	142	f g
RP 5	1.53 a	3.99	96	a	1.56	113	a b	4.15	98	a	15.5	105	a b c
RP 10	1.64 a	4.09	99	a	1.73	125	b c	4.31	102	a b	13.4	91	a
RP 20	1.58 a	4.17	100	a	1.87	136	c d	4.21	100	a	15.0	102	a b
Ezy NP 5	1.681 a	4.33	104	a b	2.04	148	d e	4.20	99	a	15.9	108	b c d
Ezy NP 10	1.608 a	4.60	111	b c	2.30	167	e f g	4.32	102	a b c	17.5	119	c d e
Ezy NP 20	1.551 a	4.85	117	c d	2.35	170	f g	4.63	110	d e	19.3	131	e f
Polyphos 5	1.72 a	4.58	110	b c	2.20	159	e f g	4.34	103	a b c	18.1	123	d e
Polyphos 10	1.67 a	4.75	114	c d	2.32	168	e f g	4.61	109	d e	18.9	129	e f
Polyphos 20	1.52 a	4.79	115	c d	2.32	169	f g	4.58	108	d e	22.6	154	g
CV	14%	5.8%			8.9%			3.8%			9.4%		
LSD (P=0.05)	0.32	0.40			0.29			0.25			2.3		

Notes:
* All seed was treated with either Raxil on wheat or Jockey + Gaucho on canola.
* No fertiliser was applied in the 2012 wheat experiment to measure impact of residual P.
* Values that do not have the same letter within a column are significantly different at LSD (P=0.05).

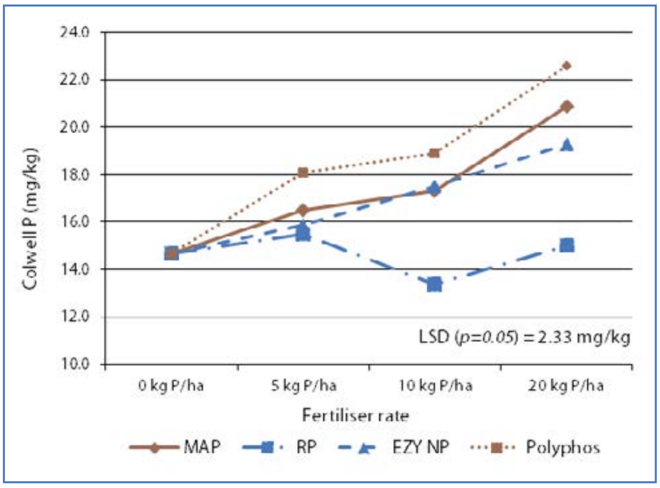

Figure 3: Residual soil phosphorus after the first two wheat crops.

- The 5 kg P/ha, 10 kg P/ha and 20 kg P/ha rates of MAP produced a yield benefit of 0.35 t/ha, 0.31 t/ha and 0.57 t/ha respectively over the nil P treatment.
- There was no significant yield benefit (above nil P) in 2012 where rock phosphate had been applied in the previous three seasons.
- Both liquid products produced similar yield responses to MAP fertiliser. However, Ezy NP at 5 kg P/ha did produce a yield reduction of 0.37 t/ha when compared with MAP at 5 kg P/ha, and a 0.14 t/ha yield reduction when compared with Polyphos.

Profitability

- Profitability was affected by fertiliser source and application rate, and ranged from –$182 to $519/ha (*Figure 4*).
- Cost ($/kg P) of the various fertiliser sources were $4.32 kg/P for MAP, $6.46 kg/P for rock phosphate, $13.94 kg/P for Ezy NP and $13.98 kg/P for Polyphos (*Table 2*).
- The most profitable treatment over the four-year period was 20 kg P/ha of MAP, with a total benefit of $519/ha over the nil P treatment.
- MAP produced a positive economic return across all three rates and grain yield increased as fertiliser rate increased. The 5 kg P/ha, 10 kg P/ha and 20 kg P/ha rates increased profitability (over three years) by $380/ha, $430/ha and $510/ha respectively.
- Rock phosphate treatments produced a negative economic return across all three rates. The 5 kg P/ha, 10 kg P/ha and 20 kg P/ha rates reduced profitability by –$81/ha, –$14/ha and –$156/ha respectively. It was more profitable to apply no fertiliser than to apply rock phosphate.
- Both forms of liquid phosphate (Ezy NP and Polyphos) produced a positive economic return at the lower rates of 5 kg P/ha and 10 kg P/ha and a negative economic return at the higher rate of 20 kg P/ha (–$140/ha and –$182/ha respectively).
- Polyphosphate was more profitable at 5 kg P/ha and 10 kg P/ha than Ezy NP, with a benefit of $166/ha and $114/ha above Ezy NP.

Table 5: Gross margin analysis for fertiliser treatments.

Fertiliser type and rate kg P/ha	Gross margin ($/ha)					Benefit over Nil P ($/ha)
	Year 1 Wheat	Year 2 Wheat	Year 3 Canola	Year 4 Wheat	Total	
Nil P	90	591	319	732	1732	
MAP 5	25	651	622	811	2109	378
MAP 10	21	661	674	803	2160	428
MAP 20	–26	685	728	864	2251	519
RP 5	34	526	376	714	1651	–81
RP 10	23	514	428	752	1717	–14
RP 20	–54	464	437	729	1576	–156
Ezy NP 5	27	557	581	726	1890	159
Ezy NP 10	–58	540	643	754	1879	148
Ezy NP 20	–209	451	524	824	1591	–140
Polyphos 5	35	606	658	758	2057	325
Polyphos 10	–46	571	648	821	1993	262
Polyphos 20	–215	438	513	814	1550	–182

Notes:
Variable costs (not including fertiliser) used for 2009 wheat = $240/ha, 2010 wheat = $240/ha, 2011 canola = $370/ha and 2012 wheat = $240/ha.
Refer to Table 1 for various fertiliser costs.
Grain price received for 2009 wheat = $200/t, 2010 wheat = $200/t, 2011 canola = $500/t and 2012 wheat = $230/t.

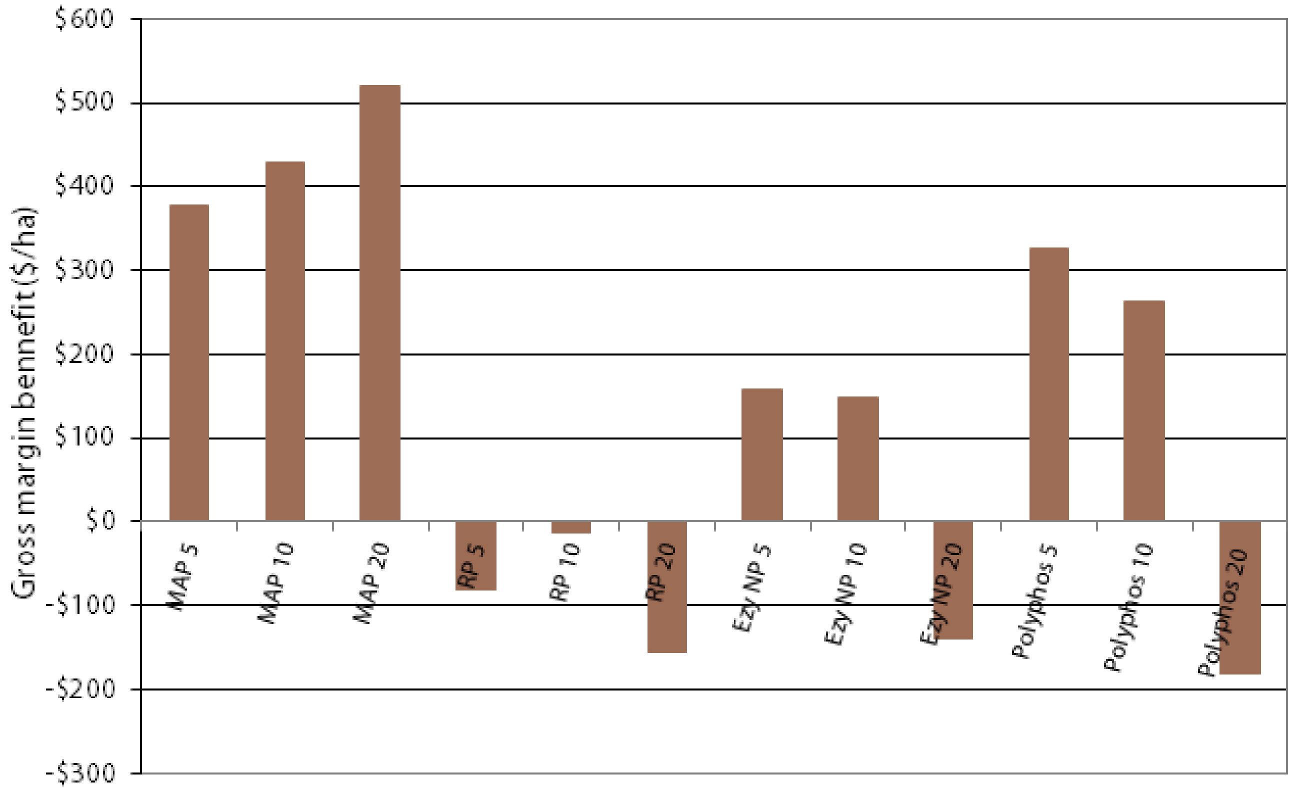

Figure 4: Gross margin benefit ($/ha) of fertiliser treatments over the nil P treatment over four years.

These results do not consider the additional cost associated to convert machinery for liquid P application, or the additional freight cost required for less concentrated P sources. For example, rock phosphate would need approximately twice the quantity of product to provide the same quantity of P as MAP.

Summary

These results highlight a number of important factors to consider when making phosphate fertiliser decisions.

1. Phosphate fertiliser selection

Growers must consider cost per kg of P compared with cost per tonne of product as this greatly influenced profitability in this experiment. MAP and both forms of liquids had similar response curves; however, MAP was significantly more profitable due to lower cost per unit of P.

The fertiliser source needs to become plant available to be effective. These results indicate that high-analysis granular fertiliser and both forms of liquid P respond positively and similarly, whilst rock phosphate was unresponsive and not available for plant uptake. Therefore, rock phosphate fertiliser was both ineffective and expensive in the four years that it was evaluated in this experiment. The addition of biological inoculants did not improve rock phosphate response greater than MAP in this experiment.

Another consideration is the relationship between freight costs and P concentration within a fertiliser. For example, MAP fertiliser contains 22% P and will therefore require less tonnes/freight cost than rock phosphate that contains 12% P.

2. Long-term implications

Fertiliser source and rate would have had an impact on the 2013 season as well as future years.

An advantage of purchasing cheap and effective P is that you can buy more P for the same dollar value, which allows greater flexibility in future years. As residual P increases, rates can safely be reduced with knowledge of the local P calibration curve.

Residual P benefit will decline if fertiliser rates are reduced to allow for more expensive forms of P to be used (i.e. liquids). If crop removal of P is greater than fertiliser P input, soil P will decline until crop P removal is equal to the rate of mineralisation of organic P.

Rock phosphate did not have any residual benefit in either soil P (Colwell) or grain yield (2012) at the 5 kg P/ha, 10 kg P/ha or 20 kg P/ha rates.

3. Seasonal factors and P response
The combination of a soil test result, local P calibration curve, paddock and crop rotation history and sowing date can greatly assist in determining paddock responsiveness to additional fertiliser P.

As demonstrated by this experiment, seasonal factors will influence crop response to freshly applied P. Other studies in South Australia have demonstrated that P uptake is largely from residual soil P in wetter years (crop roots can forage in nutrient-rich topsoil), and from freshly applied P in average seasons. Therefore, the response from freshly applied P will vary from year to year.

Whilst we cannot control the season, we can control how much we invest in the crop. Selecting the appropriate fertiliser source will allow yield to be maximised when seasons allow, and reduce risk when seasonal factors produce low yields. In this experiment, the high-analysis granular fertiliser MAP maximised yield potential whilst also requiring the lowest breakeven yield to cover fertiliser cost, hence reducing financial risk in low-yielding seasons.

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