PHOSPHORUS FERTILISER EVALUATION TRIAL

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Key Words
Liquid P, Hi-analysis granular, Rock Phosphate

GRDC code
CWF00013

Take home message

- Hi-analysis granular fertiliser required the smallest yield to breakeven in 2009
- Hi-analysis granular P and liquid P had a similar response curve and both types of products performed well
- Rock Phosphate product had a very flat response which slightly improved when 30% DAP was added
- The addition of biological additives to the Rock Phosphate did not produce a fertiliser response curve greater than Hi-analysis granular
- Growers must consider the effectiveness of various fertiliser sources (e.g. what does the fertiliser response curve look like) and cost per unit of P each year before deciding on fertiliser type/form

Background

Due to the combination of drought and highly volatile fertiliser prices many growers within the Central West have started to explore the use of alternative fertiliser sources and nutritional programs.

Traditionally in the Central West growers have banded all their granular Hi-analysis P fertiliser (such as MAP and DAP) upfront with seed that has been treated with a fungicide to control diseases such as bunts, smuts and stripe rust etc. It is generally accepted that approximately 20-30% of fertiliser P banded at sowing is available for the current seasons crop, 20-30% becomes available over the next 3-5 years and the remaining 50% is locked up (sorbed) for the long term. The exact ratio of how much P gets locked up will vary depending on soil characteristics such as texture, pH, Al, Fe and Ca.

The potential of a soil to lock up P is estimated by the phosphorus buffer index (PBI). The majority of soil types within the Central West have low PBI values indicating that much of the applied P will become plant available over time. The combination of paddock history, sowing date (early or late sown) and soil test results (interpreted with local calibration results) have proven to be beneficial tools in predicting individual paddock responsiveness to fertiliser P.

As a result of the continuous drought many intensive cropping paddocks across the Central West have high P levels (>50ppm Colwell) due to fertiliser inputs exceeding outputs. This has enabled a safe reduction in fertiliser rates as these soils are comfortably above the local benchmark of 35ppm (Colwell).

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

Some biological advocates promote the use of Rock Phosphate products in conjunction with "microbe friendly" seed treatments and "biological inoculants". The overall aim is to enhance biological health and hence improve nutrient cycling. It is claimed that the improved biological health of the soil will unlock some of the tied up P (sorbed P) and enhance the effectiveness of applied P fertiliser. Research suggests that the effectiveness of Rock Phosphate fertilisers are dependant on acid soil (ph<4.5), high rainfall (>600mm), P-sorption, texture and plant species.

Significant interest in liquid fertilisers is also developing due to the increased efficiencies of liquid P over granular P on the alkaline calcareous soils (containing free lime - $CaCO_3$) of Southern Australia. These efficiencies are yet to be proven amongst the common soil types of Central West NSW as the presence of topsoil lime ($CaCO_3$) is not considered regionally significant. The other suggested benefit of liquid P products is the potential to apply P at various stages throughout the year.

The aim of this trial was to evaluate the effectiveness of the various sources of phosphorus (P) fertiliser programs including liquids, Hi-analysis granular and Biological Rock Phosphate products. Specific questions to address were:

1. Can fertiliser rates be reduced when using liquid P
2. Do liquid fertilisers allow growers to split fertiliser P applications
3. Do Rock Phosphate fertilisers release enough P to provide for crop requirements
4. How important is it to use "microbe friendly" seed treatments and "biological inoculants" when using Rock Phosphate fertilisers or other Biological programs
5. Which form of P was most cost effective

Methods

Two sites (Table 1) were selected for fertiliser "Product" trials (Table 2) in the Central West representing differences in soil type and their potential to be responsive to additional phosphorus. The Gunningbland site is considered one of the higher "P- sorption" sites of the region ($CaCO_3$ present in topsoil) whilst the Peak Hill site represented a far more common soil type with lower P-sorption characteristics (as indicated by PBI – Table 1). Colwell P values (Table 1) indicate that both sites should be responsive to additional P.

At each site a second "Systems" trial was conducted to evaluate if fertiliser efficiency was improved by adopting a "full nutritional program" (additional seed/ foliar treatments) compared to only applying the specific fertiliser product. Each trial was designed as a randomised complete block (4 replicates) and laid out as a single row.

Product trial: Fertiliser product/source (Table 2) + Seed treated with Raxill

Systems trial: Fertiliser product/source (Table 2) + recommended seed/foliar treatment (Table 3). *Note: The Hi-analysis granular fertiliser and Phosphoric liquid fertiliser had no additional seed treatments or foliar sprays as this is not recommended to enhance fertiliser efficiency. Therefore the systems trial was designed to compare the benefits of adopting a full biological system or liquid system over current district practise of Hi-analysis granular fertiliser.*

Table 1: Site location and details

Location	Variety	Sowing date	Soil type	Free lime present	Colwell P (mg/kg)	PBI (mg/kg)	Total inorganic P (mg/kg)	Total P (mg/kg)	Organic P (mg/kg)	pH (CaCl)
Peak Hill	Livingston	15 June	Red Dermosol	No	25 [a]	58	43	240	196	5.5
Gunningbland	Ventura	16 June	Grey Vertosol	Yes [c]	15 [b]	106	62	252	190	7.6

[a] Moderate response expected from additional P
[b] High response expected from additional P
[c] Free lime percentage yet to be analysed

Table 2: Fertiliser product details

Phosphorus Source	Form	Cost	Phosphorus		$ % of MAP
			P%	$/kg P	
Hi-analysis (MAP)	Granular	$950/t	22	4.32	100%
Rock phosphate (RP) [a]	Granular	$775/t	12	6.46	150%
Rock phosphate +30% DAP (RP+30% DAP) [a]	Granular	$786/t	8	9.83	228%
Phosphoric acid	Liquid	$2231/t	16	13.94	323%
Polyphosphate	Liquid	$3214/t	23	13.98	324%

Prices at Feb/Mar 09
[a] Rock Phosphate products are biologically activated (inoculated) with microbes to further solubilise P

Fertiliser
Trace Elements

Table 3: Seed/foliar treatments used in systems trial

Fertiliser treatment	Additional product applied	Application details: Seed/Foliar	Application details: Rate	$/ha	Key claim of product
Polyphosphate (liquid)	Seaweed extract	Seed	1 lt/t	0.75	Root hormone to promote root growth
	Zn seed treatment	Seed	4 lt/t	1.40	Enhance root growth and disease resistance overcomming any zinc deficiencies either induced or inherent
	NPK (14-15-11)	Foliar [a]	2 lt/ha	5.40	Enhance nutrient uptake and supply additional nutrients at key growth stages
	Raxill	Seed	1 lt/t	1.58	Control bunts and smuts
Rock Phosphate and Rock Phosphate + 30% DAP	Broad spectrum inoculmn of compost microbes	Seed	5 lt/t	0.91	Re-inoculate the rhizosphere with a broad spectrum inoculmn to improve the soils natural organic cycle with benneficial fungi and bacteria
	Broad spectrum inoculmn of compost microbes	Foliar [a]	5 lt/ha	18.49	Re-inoculate the phyllosphere (leaf surface) with a broad spectrum inoculmn to maximise flower boom, flower retention and harvest yield.
Hi-analysis granular and Phosphoric acid liquid	Raxill	Seed	1 lt/ha	1.58	Control bunts and smuts

Prices at Feb/Mar 09

[a] Foliar sprays applied at head emergence

All fertiliser products were applied at 5 kg P/ha, 10kg P/ha and 20kg P/ha. An additional Polyphosphate treatment (liquid P) was included where half the P rate was applied at sowing and half applied at early booting. Fertiliser treatments were balanced with urea to ensure even rates of nitrogen (N) were applied. Basal application of N as urea was applied to the Nil P fertiliser treatment at the same rate as the other treatments.

At each site an early vigour score was conducted at mid tillering to identify any visual differences between treatments. The Gunningbland site was assessed by 7 agronomists and 2 growers whilst the Peak Hill site was assessed by 22 growers and 3 agronomists. To ensure no bias occurred the scoring was conducted without knowledge of trial plan/layout. All individuals scored each plot using a value between 1 (poor crop growth/vigour) and 10 (high crop growth/vigour) in regards to visual crop health and vigour. It could be assumed that the early vigour score is an indication of dry matter production

Other data collected from the trial sites include plant establishment, tiller counts, heads at harvest, yield, protein, screenings, soil moisture at sowing and monthly rainfall.

Results and Discussion

Refer to Appendix for results table

Break even yield to cover fertiliser investment

To determine which fertiliser product to use the costs relative to response need to be investigated. Figures 1 and 2 illustrate the breakeven yields required to cover the various fertiliser costs in 2009. For example approx 0.5t/ha of grain yield would cover the cost for:

- 21 kgP/ha of MAP
- 14 kgP/ha of Rock phosphate
- 9 kgP/ha of Rock phosphate + 30% DAP
- 7 kgP/ha of liquid.

Therefore if growers allocate $10,000 for fertiliser budget in 2009, they had the option to purchase either

- 2315 kgP via MAP
- 1548 kgP via Rock phosphate
- 1017kgP via RP+30% DAP
- 715 kgP via liquid.

If the decision is to buy less P for the same $ value, growers need to be sure that the crop is more responsive to P from a particular product compared to the alternative fertiliser sources. Factors such as P-sorption and the presence of free lime need to be considered. Growers also need to be aware that there will be less residual P for following seasons.

Figure 1: Yield threshold to cover fertiliser costs in Product trial (assumes grain value of $185/t)

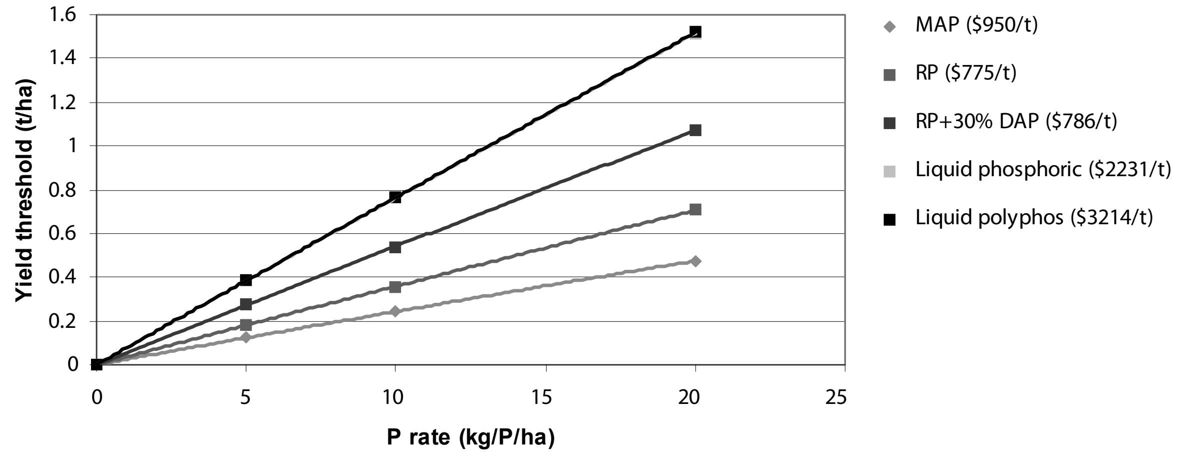
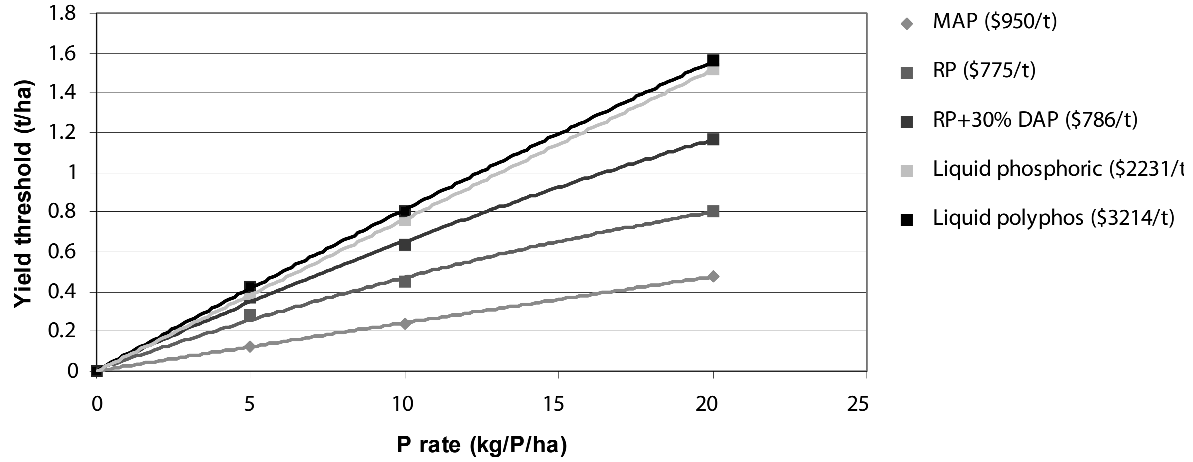


Figure 2: Yield threshold to cover fertiliser costs in Systems trial (assumes grain value of $185/t)



Seasonal conditions

The combination of good rainfall, follow up rain events and adequate weed control during the summer fallow period helped to penetrate moisture into the safety of the sub-soil at Gunningbland. Consequently 30% (84mm) of summer rain was retained for the following wheat crop. A combination of adequate sub-soil moisture at sowing and a wet June (decile 9) provided a good start for early crop growth and development. However as the season progressed (Table 4) moisture became extremely limiting during critical growth stages such as flowering and grain fill. Consequently yields were severely water limited in 2009.

In comparison the Peak Hill site had much less significant rainfall with little follow up rain events over the summer fallow. Much of the moisture was retained near the surface where evaporation losses are highest, leaving zero moisture at sowing. Whilst growing conditions improved due to a wet June (decile 9.8), yield penalties started to occur much earlier than the Gunningbland site. However a relatively mild spring and some timely rain toward the end of the season resulted in grain yield at this site.

These sites highlight the difference between the benefits of stored moisture at sowing (Gunningbland had 84mm) compared to zero moisture at sowing but an additional 79mm of incrop rainfall (Peak Hill site). Table 4 shows that both sites received the same effective rainfall (stored moisture +incrop rainfall) despite the dissimilar rainfall distribution

Fertiliser
Trace Elements

Table 4: Seasonal overview

Trial location	Monthly rainfall (mm)												Fallow period (Nov 08-May 09)			Incrop rainfall (May-Oct) mm	Total rainfall (Nov 08 - Oct 09) mm	Effective Rainfall (mm)
	Nov (08)	Dec (08)	Jan (09)	Feb (09)	Mar (09)	Apr (09)	May (09)	Jun (09)	Jul (09)	Aug (09)	Sep (09)	Oct (09)	Rainfall mm	moisture @1st May [a]	Fallow efficiency			
Peak Hill	68	17	15	55	3	21	12.5	98	18	9	38	54	179	0	0.0%	229.5	408.5	229.5
Decile [b]	*8.1*	*3.2*	*3.9*	*7.6*	*0.2*	*2.9*	*1.6*	*9.8*	*2.5*	*1.8*	*5.7*	*7.1*						
Gunningbland	101	25	48	48	27	35	4	80	18	11	21	16	284	84	29.6%	150	434	234
Decile [b]	*8.8*	*4.4*	*6*	*6.6*	*4.9*	*5.9*	*0.7*	*9.2*	*2.1*	*0.9*	*3.1*	*1.4*						

[a] Moisture at 1st of May was measured by gravimetric moisture (5 soil cores) to a depth of 1.2m
[b] Monthly decile figures can be used to compare monthly rainfall with historical data. For example in Nov 2008, Peak Hill received decile 2.1 rainfall. This means that historically only 2 out of 10 seasons have received less than 8mm in Nov - therefore considered a more drier than normal November.

Gunningbland site (Appendix Table 1)
Was the site responsive to additional P?

Yes - The early vigour score's (Fig 1 and 2) indicate that visual responses to additional P were evident. There were up to 50% more tillers and heads at harvest where P products were compared with the Nil P.

Figure 3: Gunningbland Product trial - Early Vigor Score
Conducted by 7 local agronomists and 2 growers

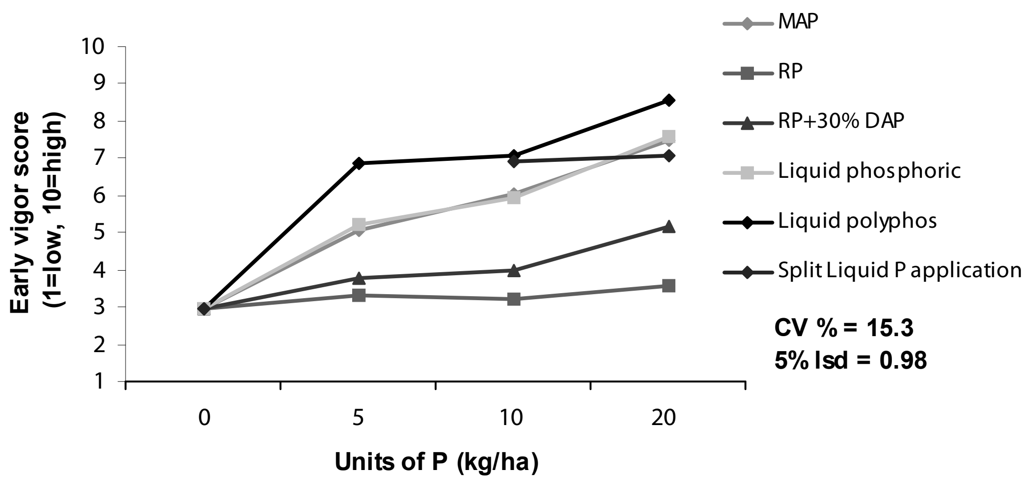


Figure 4: Gunningbland Product trial - Early Vigor Score
Conducted by 7 local agronomists and 2 growers

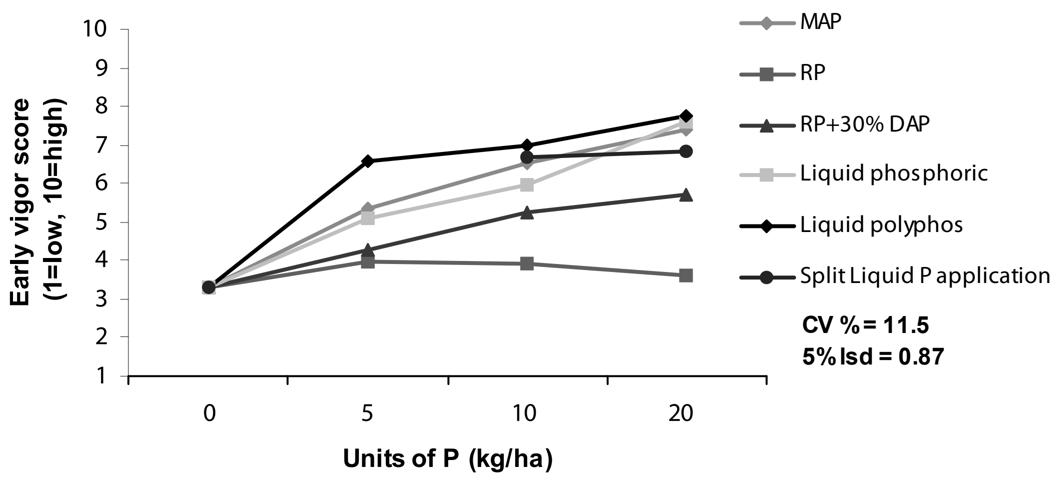


Figure 5: Gunningbland Product trial - Tillers counts
(5% lsd=24.3, CV%= 9.89)

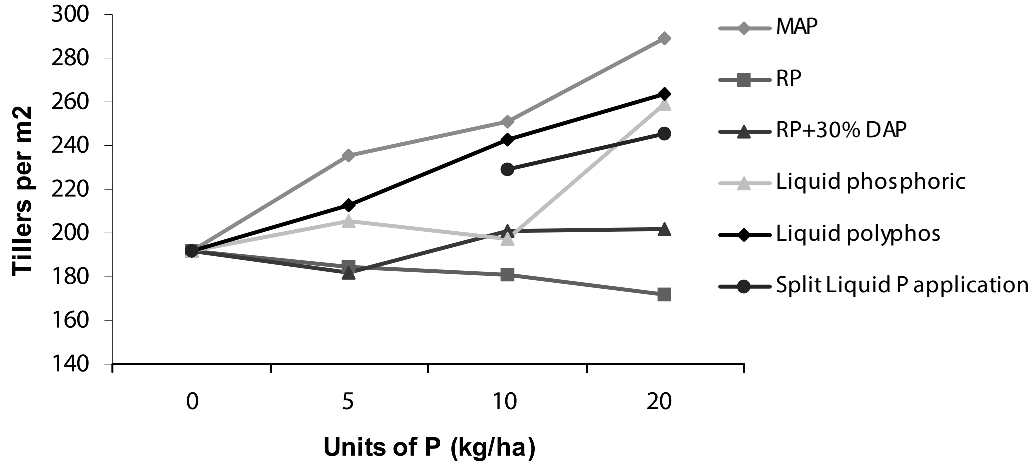
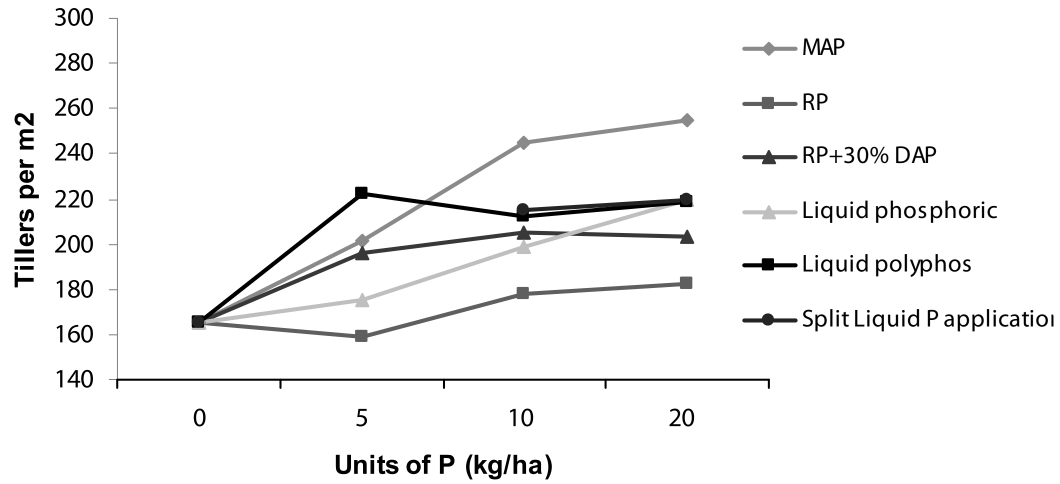


Figure 6: Gunningbland Systems trial - Tillers counts
(5% lsd=30.2, CV%= 11)



Did the various fertilisers respond differently?

Yes – The early vigour score indicates that the Rock Phosphate treatments were visually undistinguishable from the Nil P, and there was no difference between the number of tillers per m^2. A small visual response and a 25% increase in tiller numbers was evident when 30% DAP was added to the Rock Phosphate (when applied at the higher rates of 20 kgP/ha). Applying the various seed dressings and biological inoculants did not improve the Rock Phosphate fertiliser response above conventional Hi-analysis granular.

The Polyphosphate liquid gave the most impressive visual response which was followed closely by the Hi-analysis granular and Phosphoric liquid. The greatest tiller response (50% above Nil P) was achieved with 20 kgP/ha of Hi-analysis granular which was closely followed by approximately 35% more tillers from the other liquid P products (polyphosphate and phosphoric)

There was no significant yield difference between fertiliser sources in the product trial. However there was an increase in yield of approximately 30% in the systems trial for the Hi-analysis granular (20 kgP/ha) and 38% for the split Polyphosphate treatments (10 kgP/ha at sowing and another 10kgP/ha at mid booting). This raised the question regarding the possibility of splitting P applications throughout the year - was the yield increase due to better P absorption or was it from the water required (1000l/ha) to apply the additional 10kgP/ha at mid booting? The Rock Phosphate treatments gave no yield advantage over the Nil P treatment, however when 30% DAP was added approximately 16% yield increase occurred when applied at the higher Rock Phosphate rates.

There was considered to be no practical significance between the various fertilisers in protein or screenings as they all fit into the same grade of APH1

Figure 7: Gunningbland Systems - Yield
(5% lsd=0.159, CV%= 9.47)

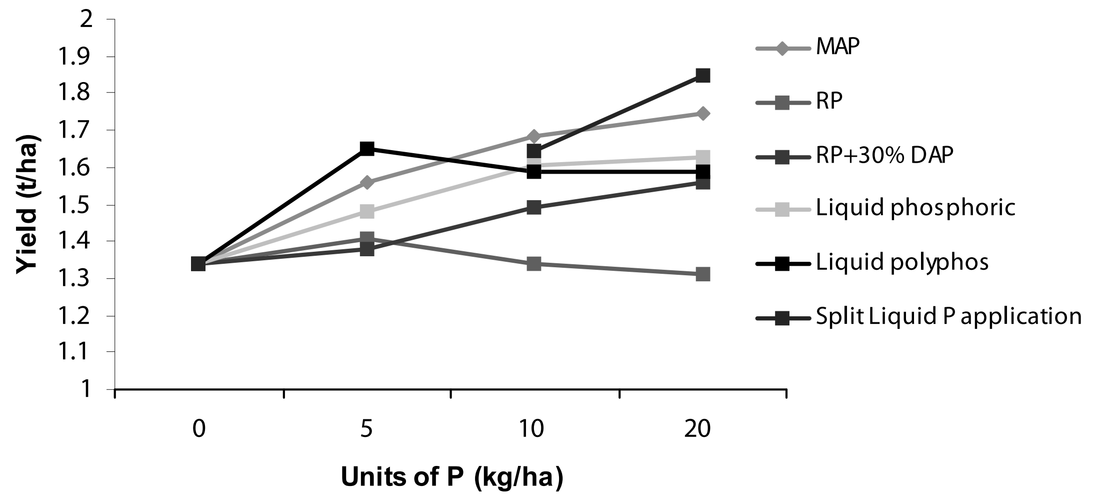


Figure 8: Peak Hill Product trial - Early Vigor Score
Conducted by 22 growers and 3 agronomists

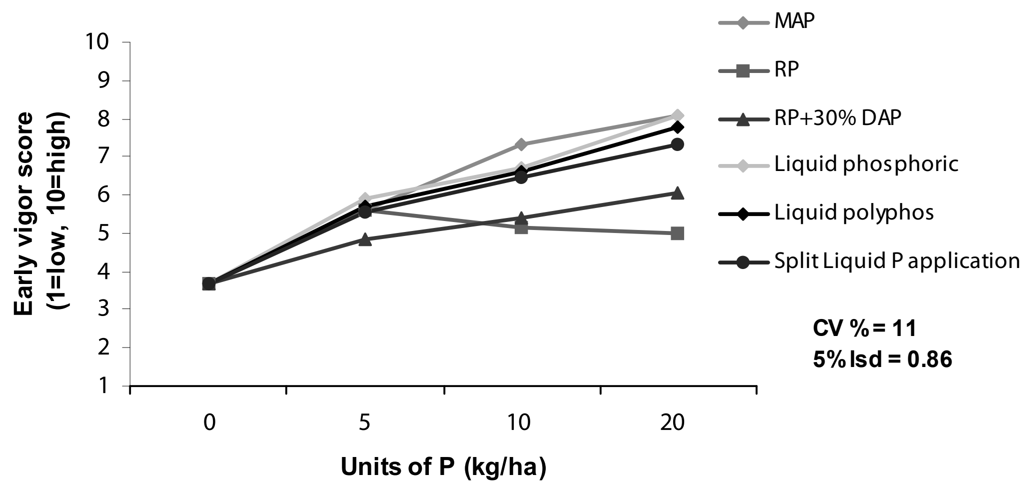


Figure 9: Peak Hill Systems trial - Early Vigor Score
Conducted by 22 growers and 3 agronomists

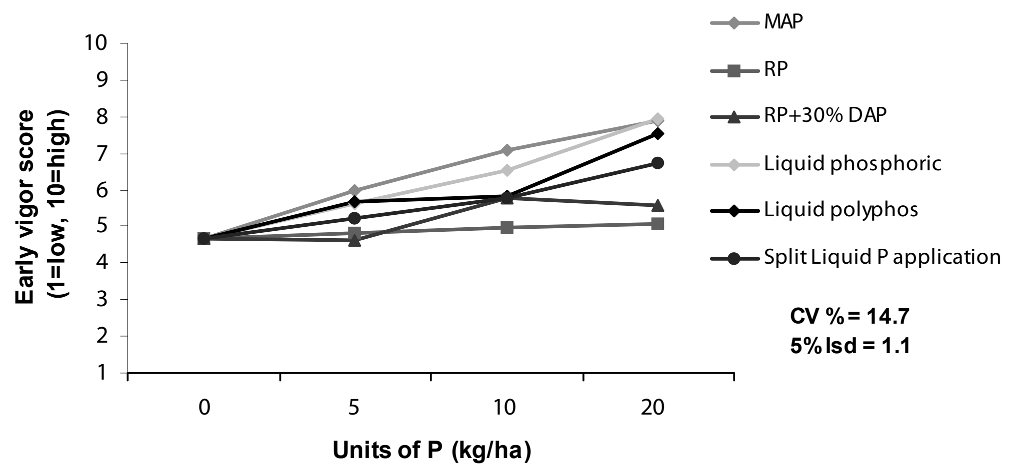


Figure 10: Peak Hill Product trial - Tillers counts
(5% lsd=20.3, CV%=10.3)

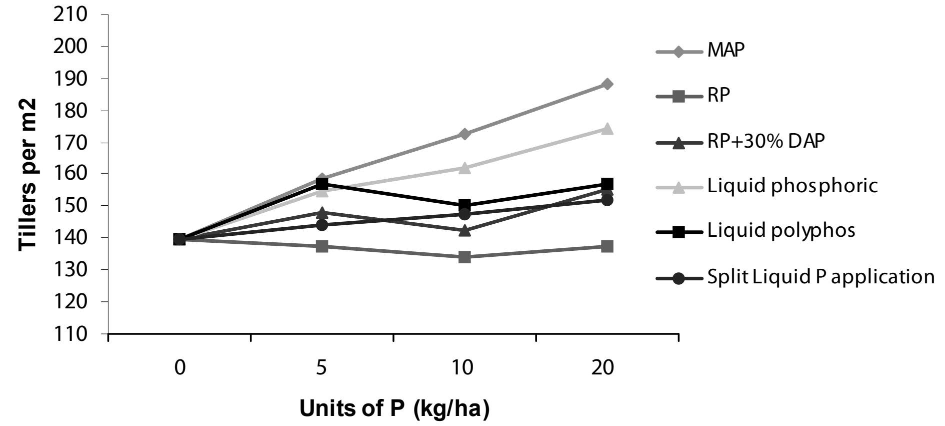
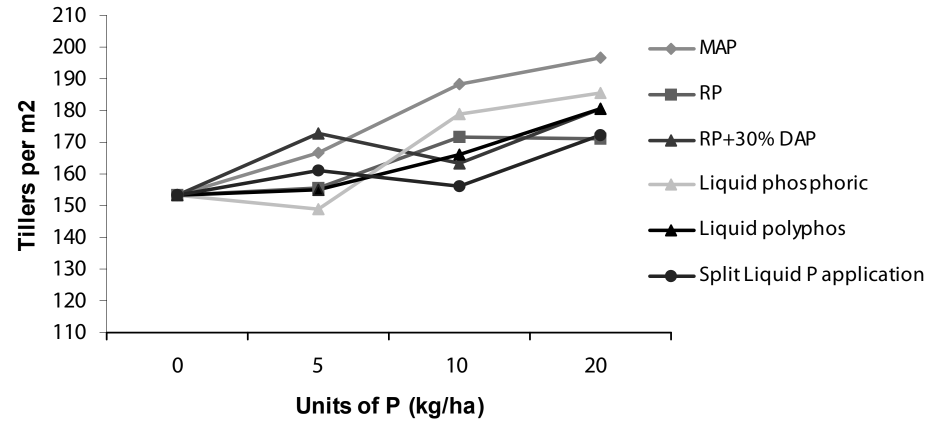


Figure 11: Peak Hill Systems trial - Tillers counts
(5% lsd=22.3, CV%=9.88)



Peak Hill site (Appendix Table 2)

Was the site responsive to additional P?

Yes – The early vigour scores indicated a visual response to additional P and there were up to 35% more tillers per m^2 where treatments were compared with the Nil P treatment.

Did the fertiliser treatments respond differently?

Yes – The Rock Phosphate treatments were visually similar to the Nil P treatment and there was no significant difference in tillers per m^2. Again small visual responses and tiller numbers increased (by up to 18%) when DAP was included with the higher P rates of Rock Phosphate. Applying the various seed dressings and biological inoculants did not improve the Rock Phosphate fertiliser response curve above the conventional Hi-analysis granular.

The early vigour scores indicated that the Hi-analysis granular and liquids performed strongly with no visual differences between these products. The Hi-analysis granular product produced the greatest tiller numbers increase of 35% when compared to the Nil P treatment.

Due to severe moisture stress there was no practical significant difference in yield (approx 1.47t/ha) and grain quality (APH2). Interestingly there was no significant yield decrease by the treatments that produced more bulk earlier in the season.

Conclusion

Conclusive judgements regarding the various fertiliser sources/forms need to be reserved for when more favourable seasons return. However these results are a reminder regarding the importance of selecting a fertiliser that responds effectively whilst also requiring the lowest breakeven yield to cover the cost of investment.

P response curves (based on early vigour scores, tillers and head numbers at harvest) were similar for liquids and Hi-analysis granular, whilst the Rock Phosphate products were much less effective. Additional seed treatments and biological inoculants did not increase the Rock Phosphate fertiliser efficiency above the Hi-analysis granular P.

The Hi-analysis granular fertiliser required the lowest break even yield in 2009

As prices for the various forms of phosphorus fertilisers can fluctuate from year to year it is recommended that growers consider the effectiveness (what does the response curve look like) and the cost per unit of P before making a decision.

Similar yields occurred across the two trial sites regardless of major differences in rainfall distribution. Despite the Gunningbland site receiving 79mm less incrop rainfall it was able to utilise the 84mm subsoil moisture to produce similar yields. This highlights the value of moisture conservation over the summer fallow period.

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Appendix

Table 1: Gunningbland results

Gunningbland Product trial

Treatment	Units of P (kg/P/ha)	Plants (m^2)			Early vigor score		Tillers (m^2)			Heads at harvest (m^2)			Yield (t/ha)			Protein		Screenings	
Nil	0	110	100%	abcd	3.0	a	192	100%	abcd	127	100%	abc	1.66	100%	ab	13.5	a	3.3	abc
Hi analysis granular	5	123	112%	cd	5.1	c	235	122%	fgh	145	115%	cdef	1.39	83%	a	13.5	a	3.1	ab
Hi analysis granular	10	110	100%	abc	6.0	cde	251	131%	ghi	161	127%	fgh	1.48	89%	ab	13.5	a	3.2	ab
Hi analysis granular	20	103	94%	ab	7.5	g	289	150%	j	187	148%	j	1.47	88%	ab	13.5	a	3.5	abc
RP	5	124	113%	cd	3.3	ab	185	96%	abc	124	98%	ab	1.54	92%	ab	13.5	a	3.4	abc
RP	10	116	105%	abcd	3.2	ab	181	94%	ab	121	96%	ab	1.61	97%	ab	13.4	a	3.7	bc
RP	20	128	116%	cd	3.6	ab	172	90%	a	116	92%	a	1.56	94%	ab	13.6	a	2.9	ab
RP+30% DAP	5	118	107%	abcd	3.8	ab	182	95%	abc	136	107%	bcd	1.44	86%	ab	13.4	a	3.5	abc
RP+30% DAP	10	118	107%	abcd	4.0	b	201	105%	bcd	143	113%	cdef	1.56	94%	ab	13.4	a	3.5	abc
RP+30% DAP	20	129	117%	d	5.1	c	202	105%	bcd	151	119%	defg	1.40	84%	a	13.5	a	3.7	bc
Liquid (phosphoric)	5	116	105%	abcd	5.2	c	206	107%	cde	147	116%	defg	1.65	99%	ab	13.5	a	3.2	ab
Liquid (phosphoric)	10	110	100%	abc	5.9	cd	198	103%	bcd	139	110%	bcde	1.61	97%	ab	13.4	a	3.7	bc
Liquid (phosphoric)	20	125	114%	cd	7.6	gh	259	135%	hi	175	138%	hij	1.53	92%	ab	13.4	a	2.8	a
Liquid (polyphosphos)	5	120	109%	bcd	6.8	defg	213	111%	def	164	130%	ghi	1.71	103%	b	13.5	a	3.5	abc
Liquid (polyphosphos)	10	115	105%	abcd	7.1	fg	242	126%	ghi	183	144%	ij	1.61	97%	ab	13.5	a	4.1	c
Liquid (polyphosphos)	20	101	92%	a	8.5	h	263	137%	i	174	138%	hij	1.46	88%	ab	13.6	a	2.7	a
Liquid split [a]	7.5	113	103%	abcd	6.3	def	228	118%	efg	161	127%	fgh	1.48	89%	ab	13.6	a	3.2	ab
Liquid split	10	113	103%	abcd	6.9	efg	229	119%	efg	157	124%	efgh	1.57	94%	ab	13.4	a	3.1	ab
Liquid split	20	120	109%	abcd	7.1	fg	246	128%	ghi	148	117%	defg	1.59	95%	ab	13.5	a	3.1	ab
Average CV%		11.6			15.3		9.9			9.0			14.4			1.8		20.6	
Average 5% LSD		18.3			0.983		24.3			18.9			0.3			0.3		0.8	
P < 0.05		0.19			<0.001		<0.001			0.00			0.71			0.99		0.15	

Gunningbland Systems trial

Treatment	Units of P (kg/P/ha)	Plants (m^2)			Early vigor score		Tillers (m^2)			Heads at harvest (m^2)			Yield (t/ha)			Protein		Screenings	
Nil	0	97	100%	a	3.3	a	166	100%	a	123	100%	a	1.34	100%	ab	13.8	g	2.9	abcde
Hi analysis granular	5	111	114%	ab	5.3	de	202	122%	bcde	154	124%	def	1.56	117%	cdef	13.3	abc	2.7	abc
Hi analysis granular	10	117	120%	ab	6.5	fgh	245	148%	fg	155	126%	ef	1.68	126%	fg	13.4	abc	3.2	cdefg
Hi analysis granular	20	127	130%	b	7.4	ijk	254	154%	g	177	144%	g	1.74	130%	gh	13.5	cdef	4.3	i
RP	5	113	116%	ab	4.0	ab	159	96%	a	130	105%	abc	1.41	105%	abc	13.6	defg	3.1	bcdef
RP	10	108	111%	ab	3.9	ab	178	108%	abc	127	103%	ab	1.34	100%	ab	13.6	efg	2.6	ab
RP	20	121	124%	b	3.6	ab	183	110%	abcd	136	110%	abcde	1.31	98%	a	13.7	fg	2.4	a
RP+30% DAP	5	121	124%	b	4.3	bc	196	118%	bcde	134	108%	abcd	1.38	103%	ab	13.7	efg	2.4	a
RP+30% DAP	10	124	128%	b	5.2	de	205	124%	cde	146	119%	bcdef	1.49	112%	bcde	13.6	defg	2.4	a
RP+30% DAP	20	116	119%	ab	5.7	def	203	123%	bcde	150	122%	def	1.56	116%	cdef	13.4	abc	2.8	abcd
Liquid (phosphoric)	5	126	130%	b	5.1	cd	175	106%	ab	146	118%	bcdef	1.48	111%	bcd	13.4	bcde	2.7	abcd
Liquid (phosphoric)	10	107	110%	ab	6.0	efg	199	120%	bcde	147	119%	cdef	1.61	120%	defg	13.4	abc	2.9	abcde
Liquid (phosphoric)	20	111	114%	ab	7.6	jk	220	133%	ef	161	131%	fg	1.63	122%	defg	13.5	bcde	3.6	gh
Liquid (polyphosphos)	5	126	130%	b	6.6	ghi	222	134%	ef	150	121%	cdef	1.65	123%	efg	13.2	ab	3.3	cdefg
Liquid (polyphosphos)	10	121	125%	b	7.0	hijk	212	128%	de	159	129%	fg	1.59	119%	defg	13.4	abcd	3.3	defg
Liquid (polyphosphos)	20	113	116%	ab	7.8	k	219	132%	ef	155	126%	ef	1.59	119%	defg	13.3	abc	4.2	hi
Liquid split [a]	7.5	121	124%	b	6.8	hij	218	132%	ef	157	127%	fg	1.64	123%	efg	13.2	a	3.3	cdefg
Liquid split	10	97	100%	a	6.7	ghi	215	130%	ef	149	121%	cdef	1.65	123%	efg	13.3	abc	3.6	fgh
Liquid split	20	106	109%	ab	6.8	ghij	220	133%	ef	164	133%	fg	1.85	138%	h	13.2	a	3.5	efg
Average CV%		13.3			11.5		11.0			10.7			9.5			1.5		14.9	
Average 5% LSD		21.6			0.9		30.2			20.4			0.2			0.2		0.6	
P < 0.05		0.18			0.00		0.00			<0.001			<0.001			0.00		<0.001	

Percentages are expressed as % from the Nil P Treatment

[a] Application rates where applied at 5kgP/ha at sowing and additional 2.5kgP/ha at mid-booting. This gave a total P application of 7.5kg/P/ha rather than 5gP/ha

Table 2: Peak Hill results

Peak Hill Product trial

Treatment	Units of P (kg/P/ha)	Plants (m^2)			Early vigor score		Tillers (m^2)			Heads at harvest (m^2)			Yield (t/ha)			Protein		Screenings	
Nil	0	73	100%	ab	3.7	a	140	100%	abc	123	100%	abc	1.41	100%	ab	14.3	a	3.7	ab
Hi analysis granular	5	72	99%	ab	5.6	bcde	159	113%	cde	129	105%	abc	1.39	99%	ab	14.4	a	3.8	ab
Hi analysis granular	10	87	119%	abcde	7.3	gh	172	123%	ef	160	130%	ef	1.44	102%	ab	14.7	b	3.4	a
Hi analysis granular	20	97	133%	e	8.1	h	188	135%	f	173	141%	f	1.42	100%	ab	14.4	a	3.7	ab
RP	5	88	121%	bcde	5.6	bcde	137	98%	ab	116	95%	a	1.40	99%	ab	14.4	a	3.8	ab
RP	10	96	132%	e	5.2	bc	134	96%	a	126	103%	abc	1.38	98%	ab	14.4	a	3.5	a
RP	20	84	116%	abcde	5.0	b	137	98%	ab	131	107%	abc	1.42	101%	ab	14.4	a	4.0	ab
RP +30% DAP	5	96	132%	de	4.9	b	148	106%	abcd	120	98%	ab	1.45	103%	ab	14.3	a	3.7	ab
RP +30% DAP	10	85	117%	abcde	5.4	bcd	142	102%	abcd	127	103%	abc	1.38	98%	ab	14.4	a	4.2	b
RP +30% DAP	20	71	97%	a	6.0	def	155	111%	bcde	130	106%	abc	1.46	104%	ab	14.4	a	3.3	a
Liquid (phosphoric)	5	82	113%	abcde	5.9	cdef	155	111%	bcde	133	109%	bc	1.37	97%	ab	14.4	a	3.3	a
Liquid (phosphoric)	10	74	102%	ab	6.7	fg	162	116%	de	156	127%	e	1.45	103%	ab	14.3	a	3.9	ab
Liquid (phosphoric)	20	76	105%	abc	8.1	h	174	125%	ef	156	127%	e	1.45	102%	ab	14.3	a	3.7	ab
Liquid (polyphosphos)	5	80	109%	abcd	5.7	bcde	157	112%	bcde	126	103%	abc	1.41	100%	ab	14.4	ab	3.5	ab
Liquid (polyphosphos)	10	79	109%	abc	6.6	fg	150	107%	abcd	151	123%	de	1.36	97%	a	14.4	ab	3.9	ab
Liquid (polyphosphos)	20	91	125%	cde	7.8	h	157	112%	bcde	151	124%	de	1.44	102%	ab	14.4	a	3.7	ab
Liquid split	5	79	109%	abc	5.6	bcd	144	103%	abcd	136	111%	bcd	1.40	100%	ab	14.3	a	3.6	ab
Liquid split	10	78	107%	abc	6.5	efg	148	106%	abcd	138	113%	cd	1.48	105%	b	14.3	a	3.5	a
Liquid split	20	88	121%	bcde	7.3	gh	152	109%	abcd	138	113%	cd	1.47	104%	ab	14.2	a	3.7	ab
Average CV %		14.5			11.0		10.3			9.7			9.5			2.8		13.7	
Average 5% LSD		16.4			0.9		20.3			16.2			0.1			0.3		0.7	
P < 0.05		0.03			0.00		<0.001			0.00			0.67			0.59		0.54	

Peak Hill Systems trial

Treatment	Units of P (kg/P/ha)	Plants (m^2)			Early vigor score		Tillers (m^2)			Heads at harvest (m^2)			Yield (t/ha)			Protein		Screenings	
Nil	0	83	100%	abc	4.7	a	153	100%	ab	128	100%	ab	1.48	100%	abc	14.2	ab	4.1	bcd
Hi analysis granular	5	90	108%	bcd	6.0	cde	167	109%	abcde	142	112%	abcde	1.49	100%	abc	14.2	ab	3.5	abc
Hi analysis granular	10	97	116%	cd	7.1	fg	188	123%	ef	147	115%	bcde	1.55	105%	abc	14.3	ab	3.8	abcd
Hi analysis granular	20	106	127%	d	7.9	g	197	128%	f	150	118%	de	1.59	107%	c	14.0	a	3.2	a
RP	5	85	101%	abc	4.8	ab	156	101%	ab	125	98%	a	1.54	104%	abc	14.2	ab	3.5	abc
RP	10	93	112%	cd	5.0	abc	172	112%	bcde	129	101%	abc	1.46	98%	ab	14.3	b	4.2	cd
RP	20	83	99%	abc	5.1	abc	171	112%	bcde	148	116%	cde	1.57	106%	bc	14.4	b	3.5	abc
RP +30% DAP	5	83	99%	abc	4.6	a	173	113%	bcde	123	96%	a	1.46	99%	abc	14.2	ab	3.9	abcd
RP +30% DAP	10	95	113%	cd	5.8	bcde	163	107%	abcd	138	108%	abcd	1.56	106%	abc	14.3	ab	3.5	abc
RP +30% DAP	20	101	121%	cd	5.6	abcd	180	118%	cdef	145	113%	bcde	1.46	98%	ab	14.3	ab	3.8	abcd
Liquid (phosphoric)	5	72	86%	ab	5.6	abcd	149	97%	a	133	104%	abcd	1.50	101%	abc	14.3	ab	4.3	d
Liquid (phosphoric)	10	72	86%	ab	6.5	def	179	117%	cdef	137	107%	abcd	1.57	106%	abc	14.3	ab	3.4	ab
Liquid (phosphoric)	20	84	101%	abc	7.9	g	185	121%	def	159	125%	e	1.57	106%	abc	14.2	ab	3.3	a
Liquid (polyphosphos)	5	88	105%	abcd	5.7	abcd	155	101%	ab	145	114%	bcde	1.44	97%	a	14.2	ab	3.7	abcd
Liquid (polyphosphos)	10	85	101%	abc	5.8	bcde	166	108%	abcde	139	109%	abcde	1.48	100%	abc	14.2	ab	4.0	bcd
Liquid (polyphosphos)	20	96	115%	cd	7.5	fg	181	118%	cdef	159	124%	e	1.56	106%	abc	14.1	ab	3.8	abcd
Liquid split	5	85	102%	abc	5.2	abc	161	105%	abc	130	102%	abc	1.54	104%	abc	14.2	ab	3.8	abcd
Liquid split	10	69	83%	a	5.8	bcde	156	102%	ab	135	106%	abcd	1.50	101%	abc	14.2	ab	3.8	abcd
Liquid split	20	87	105%	abcd	6.8	ef	172	112%	bcde	150	118%	de	1.54	104%	abc	14.3	ab	4.0	bcd
Average CV %		16.3			14.7		9.9			10.2			9.6			2.3		13.0	
Average 5% LSD		19.8			1.1		22.3			20.0			0.1			0.3		0.7	
P < 0.05		0.03			0.00		0.00			0.01			0.39			0.87		0.16	

Percentages are expressed as % from the Nil P Treatment