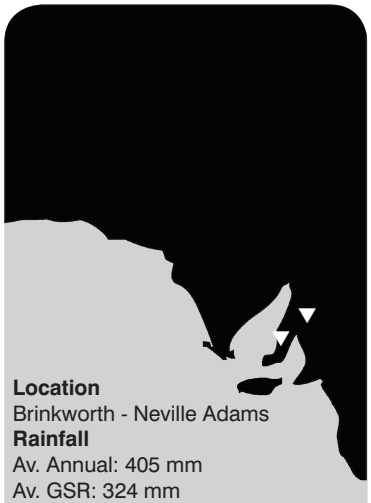
Pulse phosphorus requirements and resulting nitrogen fixation

Sean Mason[1], Liz Farquharson[2] and Lynette Schubert[2]
[1]Agronomy Solutions; [2]SARDI, Waite

RESEARCH



Location
Brinkworth - Neville Adams
Rainfall
Av. Annual: 405 mm
Av. GSR: 324 mm
2018 Total: 289 mm
2018 GSR: 251 mm
Yield
Potential yield: Not measured
Actual: 2.55 t/ha Mace wheat from adjacent trial
Soil Type
Red calcareous loam
Soil Test
See table 2
Plot Size
12 m x 1.41 m x 3 reps
Trial Design
Experimental: randomised complete block
Yield Limiting Factors
Frost - Slight, main part of the paddock affected was in a valley > 50m away.
Dry finish - Moderate, 34 mm for September and October meant early season potential was not fulfilled.
Wind - Moderate, significant late season wind events meant pulse crops had lodged and meant harvesting was extremely difficult.

Location
Urania - Ashley Wakefield
Rainfall
Av. Annual: 506 mm
Av. GSR: 421 mm
2018 Total: 334 mm
2018 GSR: 296 mm
Yield
Potential yield: Not measured
Actual: 5.15 t/ha Mace wheat from adjacent trial
Soil Type
Grey calcareous
Soil Test
See table 2

Key messages

- **Pulse phosphorus requirements for biomass growth is equal to or greater than cereals.**
- **Poor P nutrition will hinder pulse N fixation and soil N reserves.**
- **On P responsive soil types, pulse crop dry matter increases may occur with increasing P rates above district practice.**
- **Further research is needed to determine what the most efficient fertiliser type is to deliver adequate P inputs, but not hinder pulse N fixation through extra N applied via DAP/MAP.**

Why do the trial?

The aim of the trials was to determine optimal P rates for two pulse crops (lentil and chickpea) compared to wheat and assess the flow on effects of extra pulse biomass on nitrogen (N) fixation and yield. Growers are potentially missing out on returns due to inadequate phosphorus nutrition on pulse crops. Early data has shown that P requirements for important pulse crops grown in SA (e.g. lentil, chickpea) can be as high, if not higher, than that for cereals. Recent work (SAGIT funded projects AS216, UA115) has also shown that gross margins can be significantly lifted by increasing P rates on applicable soil types that have a moderate to high ability to fix P. Many of these soil types are in regions (Eyre Peninsula (EP), Yorke Peninsula (YP), mid-North) where pulse crops are often an important component of crop rotations.

How was it done?

Measurements:

- Starting soil P and N levels (Colwell P, PBI, DGT P and mineral N)
- Early biomass response - NDVI (GS30 for wheat)
- Nodulation counts (12 weeks after sowing)
- N fixation using 15N natural abundance technique
- Grain yields and quality
- Mineral N (0-10 cm) after harvest

What happened?

Pre-sowing phosphorus and nitrogen status

Both sites were low in P as measured by both DGT P and Colwell P. Background N levels were moderate at both sites (Table 2).

In-season measurements

NDVI biomass: Early biomass assessment was performed using a greenseeker when wheat was at the end of tillering (GS30). Responses to applied P were clear at both sites and similar trends were found between the three different crop types. Chickpeas and wheat had similar P response characteristics, but linear responses were found for lentils indicating P rates greater than 50 kg P/ha were required to maximise biomass at this growth stage (Table 3).

Plot Size
5 m x 1.6 m x 3 reps
Trial Design
Experimental: randomised complete block
Yield Limiting Factors
Wind - Moderate, significant late season wind events meant pulse crops had lodged and meant harvesting was extremely difficult.

Table 1 Trial details at Brinkworth and Urania in 2018

Trial details	Trial 1 Brinkworth (mid-North)	Trial 2 Urania (YP)
Crop (Variety)	Wheat (Mace), Chickpea (Genesis 090s), Lentil (Hurricane)	
Sowing date	25 May 2018	26 May 2018
Treatments	5 P rates (as Pasture King, no N), 0, 5, 10, 20, 50 kg P/ha N requirements for wheat met with Urea	
Harvest	5 December 2018	10 December 2018

Table 2 Starting soil P and N levels as measured by various soil tests at both trial sites. Critical values (wheat): DGT=48-60 ug/L, Colwell P=27 mg/kg and 30 mg/kg for Brinkworth and Urania respectively.

Site	DGT P (ug/L)	Colwell P (mg/kg)	PBI	Nitrate N (mg/kg)	Critical Colwell P (mg/kg)	Total N (kg/ha)
Brinkworth	13	18	90	19	27	50 (0-60 cm)
Urania	9	19	123	22	30	30

Table 3 Comparative early biomass responses of chickpea, lentil and wheat to applied P at both sites and the corresponding optimal P required to reach maximum yields. *Linear responses meant that higher rates of P addition would be needed to maximise plant growth.

Site	Crop	NDVI control @ 0 kg P/ha	NDVI max	Relative yield (%)	Optimal P (kg/ha)
Brinkworth	Chickpea	0.27	0.32	86	40
	Lentil	0.30	0.37*	72*	>50
	Wheat	0.33	0.44	75	26
Urania	Chickpea	0.32	0.38	85	50
	Lentil	0.38	0.45*	84*	>50
	Wheat	0.54	0.70	77	47

Nodulation counts

Twelve weeks after sowing (before flowering) nodulation counts were performed on three P treatments (0, 10 and 50 kg P/ha) at both sites. Significant ($p<0.05$) increases in both nodulation numbers (data not shown) and nodulation dry weight per gram of root were found in select cases by applying 10 kg P/ha compared to the control (0P). A further increase in most cases was found by increasing rates up to 50 kg P/ha (Figure 1).

Grain yields

Yield responses for both chickpea and lentil at both sites were erratic mainly due to the poor finish to the season and significant wind events which meant crops were flattened, reducing harvestability. Pulse yields at Brinkworth were very low and in combination with site variability responses to P were hard to interpret (Table 4). Pulse yields at Urania were also poor compared to the yields obtained for wheat. The significant delay between desiccation and harvest due to rainfall events may have contributed to the low pulse yields (Table 4).

Nitrogen fixation

Prior to harvest, shoot samples were collected at peak biomass to estimate the proportion of N that came from biological fixation. There was a significant difference in the total amount of N fixed between standard P rates (10 kg P/ha) and higher P rates for lentils at Urania, with approximately 40 kg/ha more fixed in the latter (data not shown). Trends showed that N fixation generally increased with P rate for Urania but less so for Brinkworth, where there were no significant treatment effects, possibly due to the poor finish.

There was a highly significant relationship between nodule number per plant early in the season (12 weeks) and the amount of N fixed at peak biomass. This highlights the importance of maximizing nodulation, in this case by optimising P nutrition particularly for the Urania site which had the higher nodule counts (Figure 2 - lentil only).

Soil mineral N post-harvest

All pulse plots from both sites were sampled (0-10 cm) and analysed for mineral N values post-harvest (Brinkworth – mid December, Urania – mid January). No significant differences ($p>0.05$) were obtained between treatments at both sites due to sample variability but significant correlations ($p<0.05$) between soil nitrate values and P rate were observed for chickpea and lentil at Urania (Figure 3). This sampling time would only have captured a fraction of the full mineralization potential of the pulse crops which can occur over several years and will be most prevalent in autumn and spring.

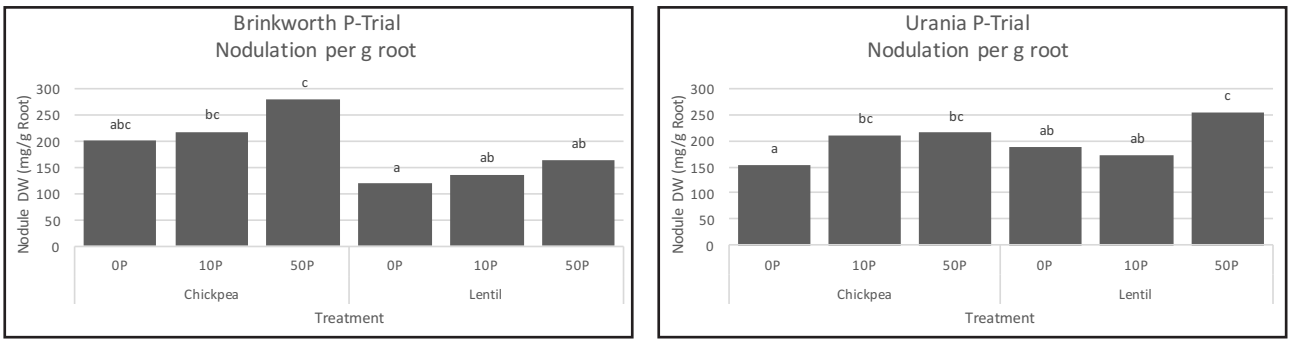


Figure 1 Effect of P nutrition (0P, 10P and 50P) on nodulation (dry weight per gram of root) of chickpea and lentils at Brinkworth and Urania in 2018. Different letters denote values are significantly different (p<0.05).

Table 4 Comparative grain responses of chickpea, lentil and wheat to applied P at both sites and the corresponding optimal P required to reach maximum yields. NR denotes not responsive.

Site	Crop	Grain yield control (t/ha)	Grain yield maximum (t/ha)	Relative yield (%)	Optimal P (kg/ha)
Brinkworth	Chickpea	0.339	0.498	68	5
	Lentil	0.088	0.121	72	5
	Wheat	1.570	1.770	89	NR
Urania	Chickpea	1.180	1.220	97	NR
	Lentil	0.809	0.927	87	5
	Wheat	4.264	5.147	83	16

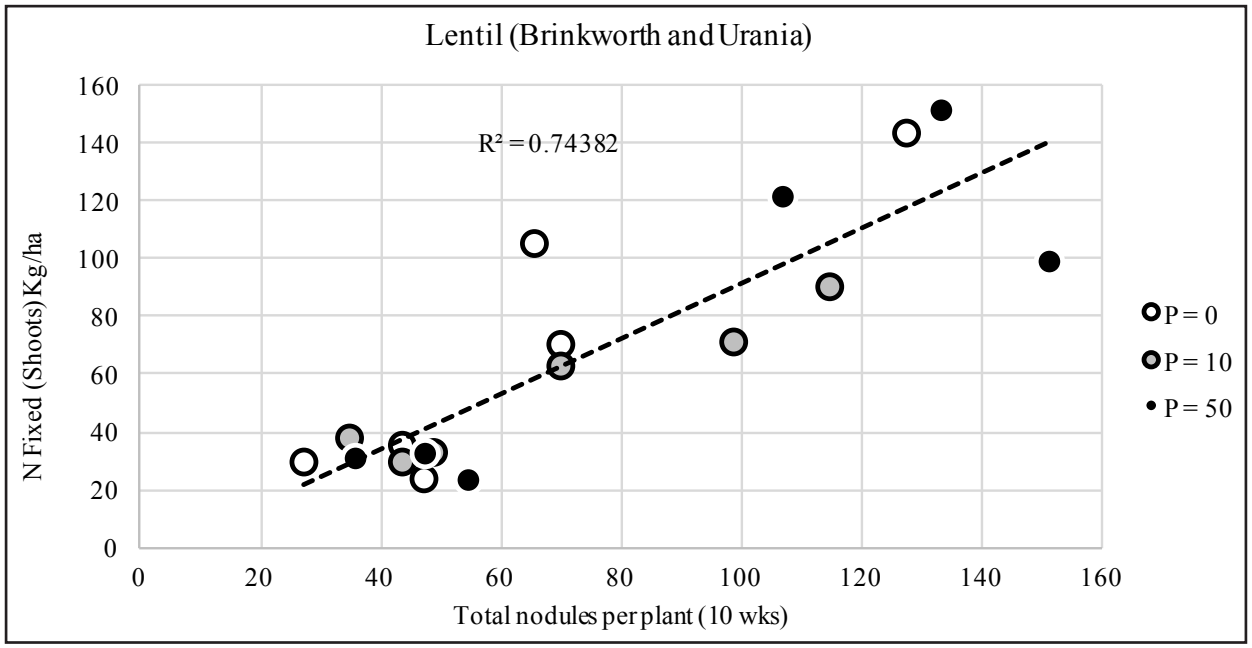


Figure 2 Relationship between nodule number per plant and the nitrogen fixed (shoot – kg/ha) for lentil grown at Brinkworth and Urania at three P rates (0P, 10P, 50P).

Soil mineral N post-harvest

All pulse plots from both sites were sampled (0-10 cm) and analysed for mineral N values post-harvest (Brinkworth - mid December, Urania - mid January). No significant differences ($p>0.05$) were obtained between treatments at both sites due to sample variability but significant correlations ($p<0.05$) between soil nitrate values and P rate were observed for chickpea and lentil at Urania (Figure 3). This sampling time would only have captured a fraction of the full mineralization potential of the pulse crops which can occur over several years and will be most prevalent in autumn and spring.

Form of phosphorus

There has been limited research into the best form of P and P+N combinations for optimal pulse production. High background N (from soil of fertilizer) can suppress nodulation and N fixation, and additional work is required to quantify this relationship with respect to starter fertilizer application on P responsive soils.

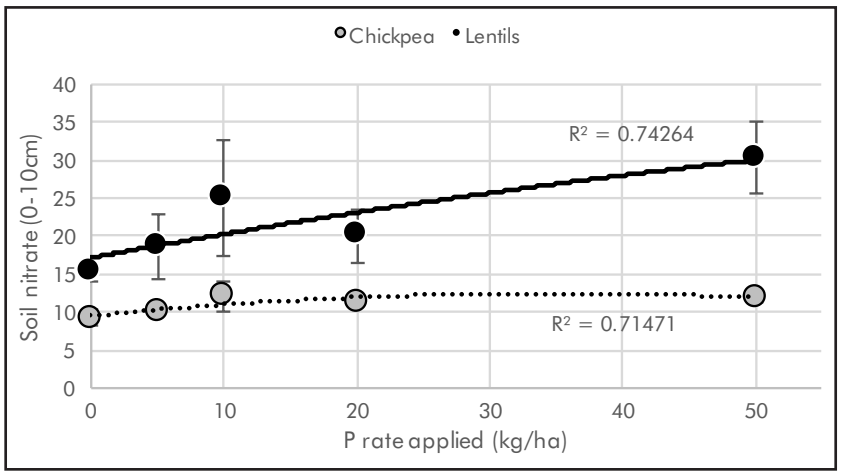


Figure 3 Soil nitrate levels (0-10 cm) with applied P sampled after harvest for both chickpea and lentils at Urania. Error bars represent standard errors from 3 replicates.

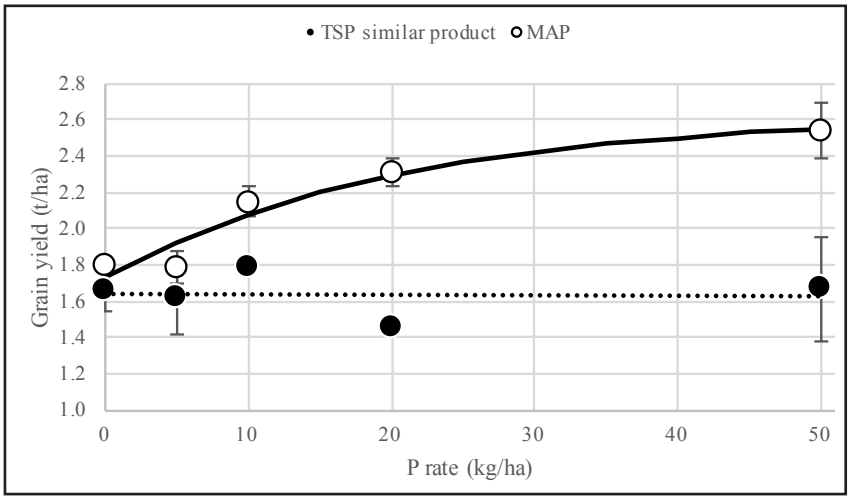


Figure 4 Comparison of wheat responses to P applied as MAP (TOS P trial) and Pasture King (Pulse trial) at Brinkworth. Error bars represent standard errors from 3 replicates.

Observations of an adjacent trial at Brinkworth show positive responses in wheat to MAP compared to a TSP (triple superphosphate equivalent) (Figure 4). It is known that TSP has an inferior performance at delivering P in highly calcareous soils, but it also appears to be limited in performance on moderate calcareous soils ($CaCO_3$ = 10%, PBI 90). This limits the choice of optimal P products available for growers as P deficiency coincides with moderate to high fixing soils driven by $CaCO_3$ soil levels.

Economics

Simple economic analyses for both pulse crops at both sites (2018) which include the cost of applied P treatments, income from corresponding grain yields, conversion of the amount of N fixed into a urea equivalent revealed that low P rates (5-10P) produced the highest gross margins for both crops at Brinkworth (data not shown). This was mainly due to the poor returns from low grain yields. At Urania, 10P produced the highest gross margin for chickpea but 20P was the highest gross margin treatment for lentil. It is important to consider that this economic analysis uses an initial estimate of the amount of N fixation and no consideration of the economics resulting from the performance of the next crop in rotation.

What does this mean?

- In season assessments showed higher P requirements for both pulse crops (particularly lentil) compared to wheat.
- The increase in pulse biomass with increasing P rates coincided with increases in both nodule number but also nodule weight per gram of root.
- Benefits from optimising pulse production occurred at P rates higher than what is considered district practice for these crops.
- Later season assessments (due to seasonal conditions) meant that the early season increases in biomass didn't translate to grain in 2018.
- Nitrogen fixation estimates were highly related to early season nodule nodulation, particularly for lentil.

Acknowledgements

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