

# Final Technical Results Report

## 2024

### Phosphorus Response Curves for Pulses in the Esperance and Albany Port Zones

**Project code:** KAL2104-001SAX

**Prepared by:** Sean Mason and Barrett Sinclair

[bsinclair@kalyx.com.au](mailto:bsinclair@kalyx.com.au)

[sean@agronomysolutions.com.au](mailto:sean@agronomysolutions.com.au)

Kalyx Australia and Agronomy  
Solutions

**Date  
submitted to  
GRDC:** 7 May 2024

## REPORT SENSITIVITY

Does the report have any of the following sensitivities?

Intended for journal publication YES  NO

Results are incomplete YES  NO

Commercial/IP concerns YES  NO

Embargo date YES  NO

If Yes, Date: <Choose date>

## Contents

<b>Final Technical Results Report</b>	<b>1</b>
ABSTRACT	3
EXECUTIVE SUMMARY	4
BACKGROUND	5
PROJECT OBJECTIVES	6
METHODOLOGY	7
LOCATION	8
RESULTS	9
DISCUSSION OF RESULTS	14
CONCLUSION	15
IMPLICATIONS	16
RECOMMENDATIONS	17
APPENDIX A: Survey	18
GLOSSARY AND ACRONYMS	19

## ABSTRACT

Phosphorus requirements of pulse crops grown in the Albany and Esperance port zones are unknown and current decisions are based on cereal response trial databases. Phosphorus response trials performed between 2021 and 2023 comparing crop response to applied P have revealed that relative responses are generally larger for pulse crops compared to wheat, but overall yield increases were lower. P requirements to maximize pulse yields and gross margins were generally higher than wheat. Therefore, recommendations based on wheat datasets are still applicable but should be used as a minimum. Alleviating pulse P deficiency through sufficient P inputs can generate significant partial gross margin returns that are competitive with wheat. Additional benefits of maximizing pulse biomass through extra N fixation are not factored into these gross margin calculations but are an important consideration.

Soil testing is an important tool for highlighting soil types that are prone to P deficiency and where the maximum ROI of P inputs for both pulses and cereals will occur. Soil characteristics need to be considered before increasing P rates with pulses for seed and fertilizer safety.

## EXECUTIVE SUMMARY

Phosphorus is the main fertiliser input for pulses grown in the Albany and Esperance port zones yet very little information is available to inform growers of pulse P requirements and decisions are currently made using cereal response databases.

It was the objective of this investment to validate the correlation of the current wheat P response curves and the P requirement of pulses, by conducting a series of field trials within the Esperance and Albany Port Zone. The trials were conducted with P response treatments using two to three of the most adapted pulse varieties grown in the regions and wheat was included as the control crop.

This project developed a P response trial dataset consisting of four trial sites across three seasons (2021-2023) with a combination of 2-3 pulse crops in addition to wheat used as the benchmark. The dataset has outlined that using all response parameters, addressing P deficiency for all pulse crops is important to maximise gross margins. Relative response to P and P requirements of pulses are either in line with wheat or greater suggesting that current soil testing guidelines for wheat are appropriate for pulse crops and if there needs to be a shift it would be slightly higher than what is currently used for cereals. In line with recent GRDC investment assessing current crop response to applied P across broad acre cropping regions of WA this project supplements these findings and by expanding the messaging to pulses in rotation.

Importantly maximising pulse grain yields increases partial gross margins in P deficient soils and benefits can be higher than the corresponding wheat phase. Yield potentials for pulse crops are generally lower than that of wheat but the higher grain price of pulse crops offsets the lower overall yield gains obtained by addressing P deficiency.

Alleviating P deficiency of pulse crops generated not only increases in grain yields but also increases in early season biomass through NDVI readings. Increasing pulse above ground biomass translates to increased nodulation and N fixation which has the potential flow on effect to the next cereal crop and potentially lowering N requirements.

Growers and advisors with the use of this trial set should have greater confidence in managing P requirements for pulse crops in soil types that are prone to P deficiency. P inputs should not decrease in the pulse phase, but considerations are potentially required for pulse seed and fertiliser safety with placement.

These results should be applicable to the wider broad acre cropping region of WA with consideration of economics associated with lower yield potentials in other regions and therefore lower relative grain yield increases by alleviating P deficiency. Pulse P requirements compared to wheat found in this study is in line with research performed both nationally and internationally.

## BACKGROUND

Phosphorus is the main fertiliser input required to successfully grow pulse crops, and local growers have expressed a desire for improved information to achieve the most profitable results when applying this nutrient.

This investment aims to address this 'knowledge gap' by conducting field trials in Western Australia's Albany and Esperance port zones.

The two-year project will investigate the response of field pea, faba bean and lentil crops to different phosphorus (P) treatments.

It is believed that guidelines for P application for pulse crops in WA's southern cropping areas are currently based on cereal crop P 'response curves' (predicted yield responses to applied P).

GRDC Grower Network meetings have highlighted that these P response curves for cereals are used for pulse crops as there is perceived to be a lack of local data about P requirements in pulses in WA's southern regions.

Previous research, nationally and internationally, has demonstrated a correlation between cereals and pulses and their P use efficiency (how much of the applied nutrient is used by the crop), but pulses appear to be less efficient in taking up P than cereals.

The objective of the new investment is to validate – through field trials that include wheat as a control crop – the correlation of wheat P response curves with the P requirement of pulses.

This is expected to lead to more accurate P fertiliser recommendations that will allow growers to grow pulses more profitably.

This information is important as pulses are an important 'break crop' and can add diversity to crop rotations. Improving pulse agronomy knowledge may also increase grower confidence to grow more of these crops."

To increase knowledge on current pulse nutrition practices and to help guide the research, Albany and Esperance port zone growers were encouraged to complete a survey and a summary of answers are provided in the appendix of this report.

## PROJECT OBJECTIVES

Determine the P requirements for different pulse crops in two different climatic x soil type scenarios using wheat as the benchmark crop.

Currently P recommendations are calculated off response curve data and soil test interpretation for wheat, therefore it is important to gain information on pulse P requirements in comparison.

It is the objective of this investment to validate the correlation of the current wheat P response curves and the P requirement of pulses, by conducting a series of field trials within the Esperance and Albany Port Zone. The trials will be conducted with P response treatments using two of the most adapted pulse varieties grown in the region and will include wheat as a control crop. This information will provide confidence to growers of the use of P fertiliser inputs and identify any further gaps in nutritional knowledge for further investment. This investment will consist of two trial sites being implemented annually over two growing seasons, and will trial P rates x pulse species, to understand the accuracy of the current nutrition advice.

Outcome By March 2023 (extended to 2024), growers in the Western region will have access to more accurate phosphorus fertiliser recommendations for the profitable production of pulses.

Output 1 By April 2021, conduct a review of local growers to quantify their decision-making process around nutrient budgeting for their pulse crops. Details: Survey questions to include, but not limited to: where do growers obtain their pulse nutrient budgets information, what are the assumptions of those budgets.

Output 2 By December 2022, delivery of at least two small plot field sites, annually for two growing seasons, located in the Esperance and Albany Port Zone trialling at least two locally important pulse species.

## METHODOLOGY

Total of four phosphorus responsive trials were designed and located in Albany (Kojonup) and Esperance (Scaddan) port zones between 2021-2023. At all sites crop responses to applied P was assessed using 5 P rates which included 0, 5, 10, 20 and 40 kg P/ha as MAP. With each incremental increase in P rate with MAP there was a complementary increase in N rate. To ensure any difference in crop performance was attributed to P only, applied N with MAP was balanced with urea.

At most sites the response to wheat to applied P was compared to pulses including Faba Bean, Field Pea, and Lentil. Field Peas are not suitable to the Esperance growing zone so were not included and Lentils were not grown at Kojonup in 2021 but included in 2023.

Trial designs were performed by SAGI West in the form of randomised block design. Each crop was kept as a block and P rates randomised with the crop block.

Trial maintenance.

All plots received non-P basal maintenance requirements specific to crop type and as per standard grower practice. Legumes were inoculated prior to sowing.

Statistical analysis and calculation of P requirements

Grain yield and grain P uptake results were statistically analysed using a general two-way ANOVA with crop and P rate as the two factors using software package Genstat (22<sup>nd</sup> edition). Significance at the 95% confidence level ( $p < 0.05$ ) of the interaction between crop type and P rate was also assessed. NDVI readings during the season were evaluated but results are not presented in this report.

Response parameters between the different crops were determined using a Mitschlich fitted response to max curve function in the form  $Y = Y_0 + a(1 - \exp(-b \cdot x))$  with  $Y_0$  calculated as yield at 0P,  $a =$  yield response, resulting in  $Y_0 + a =$  maximum yield,  $b =$  response curvature and  $x =$  P rate.

Overall response to applied P was expressed as relative yield (%) =  $Y_0/Y_{max} * 100$

Optimal P rate for either grain response or grain P uptake was calculated at the intercept of yield corresponding to the 90% of response level =  $(0.9 \cdot a) + Y_0$ .

Phosphorus use efficiency (PUE%) was calculated at each applied P level for each crop type by measuring the increase in grain P uptake for each P level in kg/ha over the control as a percentage of the total amount of P applied.

Partial Gross Margins (PGM) were calculated for each crop type at each site when yields were maximised with applied P by subtracting the fertiliser cost at the optimal P rate from increased returns associated with yield gains for each respective crop type and price.

## LOCATION

Where field trials have been conducted, provide the following location details in the table below: latitude and longitude, or nearest town. (Add additional rows as required.)

Site #	Latitude (decimal degrees)	Longitude (decimal degrees)	Nearest town
Trial Site #1	-33.20266	121.57895	Grass Patch
Trial Site #2	-33.88312	116.73294	Kojonup
Trial Site #3	-33.43468	121.74158	Grass Patch
Trial Site #4	-33.88861	116.78271	Kojonup

If the research results are applicable to a specific GRDC region/s (e.g. North/South/West) or [GRDC agro-ecological zone/s](#), indicate which in the table below:

Research	Benefiting GRDC region (select up to three)	Benefiting GRDC agro-ecological zone	
Phosphorus Response Curves for Pulses in the Esperance and Albany Port Zones	Western Region Choose an item. Choose an item.	<input type="checkbox"/> Qld Central <input type="checkbox"/> NSW NE/Qld SE <input type="checkbox"/> NSW Vic Slopes <input type="checkbox"/> Tas Grain <input type="checkbox"/> SA Midnorth-Lower Yorke Eyre <input checked="" type="checkbox"/> WA Northern <input checked="" type="checkbox"/> WA Eastern <input checked="" type="checkbox"/> WA Mallee	<input type="checkbox"/> NSW Central <input type="checkbox"/> NSW NW/Qld SW <input type="checkbox"/> Vic High Rainfall <input type="checkbox"/> SA Vic Mallee <input type="checkbox"/> SA Vic Bordertown-Wimmera <input checked="" type="checkbox"/> WA Central <input checked="" type="checkbox"/> WA Sandplain

## RESULTS

To compare P requirements and responses of pulse crops compared to wheat as the benchmark it is important to establish field trials on soil types with low starting P availability. Soil P characteristic from each site is displayed in table 1 and outlines expected P responsiveness at three of the four field sites with low Colwell P for the associated high PBI value and very low DGT P levels (target 66 ug/L – wheat). The outlier was Grass Patch in 2021 where the Colwell P value of 43 might be sufficient at a PBI level of 89. Unfortunately, we didn't receive confirmation of P status via DGT at this site. Recent GRDC project work has outlined the superior performance of DGT over Colwell P in predicting crop response to P when soil types present PBI values greater than 50.

Table 1: Soil salinity and phosphorus status of each of the four trial sites used in this project. Target DGT P levels for wheat is 66 ug/L.

Trial No.	Site	Year	EC 1:5 dS/m	ECe dS/m	Colwell P mg/kg	PBI	DGT P ug/L	Colwell P/ PBI
1	Grass Patch	2021	0.350	3.150	43	89	N/A	0.48
2	Kojonup	2021	0.130	1.170	38	147	17	0.26
3	Grass Patch	2022	0.240	2.160	8	111	17	0.07
4	Kojonup	2023	0.060	0.720	27	216	15	0.13

Statistical summary of the four field sites reported significant responses ( $p < 0.05$ ) to applied P at three of the four sites with the 2021 site at Grass Patch the outlier. These responses are in line with starting P levels reported in table 1. As expected, the mean yields of each crop type were significantly different but there was no crop type x applied P interaction at any of the sites. The lack of significant interaction suggests that the behaviour of the different crops to applied P is similar regardless of the crop yield potential. Calculated response parameters between yield and applied P will be important in completing the project objectives.

Table 2: Summary of statistical output of the four trial sites using a two-way ANOVA with crop and P rate the main factors and their interaction included. NS = not significant ( $p > 0.05$ ).

Site	Factor	P value	LSD
Grass Patch 2021	Crop	<.001	245
	P rate	0.966	NS
	Crop x P rate	0.925	NS
Kojonup 2021	Crop	<.001	322
	P rate	0.003	415
	Crop x P rate	0.816	NS
Grass Patch 2022	Crop	<.001	0.2524
	P rate	0.024	0.3259
	Crop x P rate	0.056	NS
Kojonup 2023	Crop	<.001	0.219
	Prate	<.001	0.245
	Crop x Prate	0.69	NS

Summary of the response curve fitting parameters are presented in table 3 which displays the full field trial data set.

Table 3: Response parameters for each crop at the four trial sites including yield control, calculated yield maximum, response correlation, overall response as relative yield, optimal P required for 90% response and average PUE across the 4 applied P rates. PGM was calculated using the following pricing: MAP = \$1000/t, Faba Bean = \$450/t, Field Peas = \$500/t, Lentil = \$800/t, Wheat = \$350/t.

Trial No.	Crop	Site	Year	Yield (Control)	Yield Max	R <sup>2</sup>	% Relative	Optimal P	Average PUE	PGM return
				kg/ha	kg/ha (predicted)		yield (grain)	kg/ha	%	\$/ha
1	Faba Bean	Grass Patch	2021	2230	2163	NA	103	0	0	Negative
2	Faba Bean	Kojonup	2021	2541	4103	1	62	40	4.2	521
3	Faba Bean	Grass Patch	2022	1397	2146	1	65	10	5	292
4	Faba Bean	Kojonup	2023	593	1359	0.97	44	50	2.3	117
2	Field Peas	Kojonup	2021	1034	1873	0.96	55	25	9.8	306
4	Field Peas	Kojonup	2023	1274	2523	0.99	51	49	8	402
1	Lentil	Grass Patch	2021	2076	1914	NA	108	0	0	Negative
3	Lentil	Grass Patch	2022	1444	1219	NA	100	0	0	Negative
4	Lentil	Kojonup	2023	520	1210	0.97	43	50	7.2	325
1	Wheat	Grass Patch	2021	6372	6609	NA	96	5	1.2	Negative
2	Wheat	Kojonup	2021	1071	1673	0.99	64	32	6.8	65
3	Wheat	Grass Patch	2022	2469	3372	0.93	73	4	16	298
4	Wheat	Kojonup	2023	2256	3345	0.88	66	25	11.5	268
	Frosted						Linear response	Linear response		

Using the overall relative response of each pulse crop type to P applications compared to that of wheat by using the yield obtained at nil P input as a % of the maximum yield obtained when P deficiency was corrected is presented in figure 1. There was one notable outlier with the lentils at grass patch 2022 not responding to applied P when both faba bean and wheat responded strongly. All other pulse crop x field site combinations had either the same or greater relative response to applied P than that for wheat outlining the importance

of P nutrition for all crops grown in both port zones and potentially elsewhere in WA and nationally.



Figure 1: Overall response of each pulse to applied P calculated as relative yield compared to the baseline response of wheat for each field site. The solid line represents the 1:1 relationship.

Another parameter to assess the P efficiency and requirements of pulses compared to wheat as the benchmark is to calculate the optimal P required to reach maximum yields when P deficiency is alleviated. This data set is potentially not as comprehensive but suggests that on most occasions P requirements for pulses were equal to or greater than that for wheat. The Kojonup 2023 site revealed the largest deviation with all three pulse crops requiring at least 40 kg P/ha compared to wheat which required 25 kg P/ha. The response function for these three pulse crops at this site was linear and generates some uncertainty around relative yields and optimal P requirements.



Figure 2: Phosphorus requirements for each pulse crop to meet 90% of the overall response compared to wheat for each field site. The solid line represents the 1:1 relationship.

Phosphorus use efficiency (PUE) of applied P sources can be used to support overall relative response and optimal P requirements. PUE will generally be highest at the lower P rates and decrease when higher P rates are applied generating a reduced P deficiency. Mean PUE values across the four P rates are presented in table 1 and figure 3. For all responsive P sites, pulse PUE was comparatively lower than wheat apart from field peas grown at Kojonup in 2021. Generally, the order of PUE from this dataset was wheat > field pea >= lentil > faba bean.



Figure 3: Phosphorus Use Efficiency (PUE) averaged cross the four P application rates for each pulse crop compared to wheat at the four field sites. The solid line represents the 1:1 relationship.

Grain P concentrations for pulses are generally higher than wheat and in the range of 0.25-0.28% (table 4). This is an important consideration when factoring in P balances for subsequent crops in rotations. Overall P removal was still dominated by wheat and controlled by yield potential of each crop type but P removals can be significant if large pulse grain yields are obtained.

Table 4: Grain P concentrations and subsequent grain P uptake for each crop type and trial location for the control (0P) and maximum yield through optimal P applications.

Trial No.	Crop	Site	Year	Grain P (Control)	Grain P uptake/Removal	Grain P (Max)	Grain P uptake/Removal
				%	kg/ha (control)	%	kg/ha (max)
1	Faba Bean	Grass Patch	2021	0.32	7.01	0.33	6.96
1	Lentil	Grass Patch	2021	0.25	5.22	0.27	5.53
1	Wheat	Grass Patch	2021	0.26	16.23	0.25	16.53
2	Faba Bean	Kojonup	2021	0.22	5.81	0.23	8.13
2	Field Peas	Kojonup	2021	0.29	3.04	0.3	5.29
2	Wheat	Kojonup	2021	0.35	2.59	0.37	4.18
3	Faba Bean	Grass Patch	2022	0.235	3.29	0.253	5.43
3	Lentil	Grass Patch	2022	0.248	3.58	0.293	3.69
3	Wheat	Grass Patch	2022	0.155	3.84	0.168	5.99
4	Faba Bean	Kojonup	2023	0.225	1.3	0.273	3.34
4	Field Peas	Kojonup	2023	0.238	3.04	0.24	5.61
4	Lentil	Kojonup	2023	0.22	1.14	0.278	3.25
4	Wheat	Kojonup	2023	0.19	4.16	0.203	6.65
	Frosted						

Table 5: Partial gross margins (PGM) for crop yield obtained at each P rate subtracting off the cost of applied P as MAP using fertiliser and grain price reflective of 2023 for the Kojonup site.

Partial Gross Margins (\$/ha)				
Prate	Faba Beans	Field Peas	Lentils	Wheat
0	267	640	416	774
5	196	742	527	939
10	275	889	588	1056
20	345	979	654	1002
40	572	1128	928	1161
MAP	\$1000/t			
Faba Beans	\$450/t			
Field Peas	\$500/t			
Lentils	\$800/t			
Wheat	\$350/t			

## DISCUSSION OF RESULTS

This trial dataset has outlined that using all response parameters addressing P deficiency for all pulse crops is important to maximise gross margins. Relative response and P requirements are either in line with wheat or greater suggesting that current soil testing guidelines for wheat are appropriate for pulse crops as well and if there needs to be a shift it would be slightly higher than what is currently used for cereals. In line with recent GRDC investment assessing current crop response to applied P across broad acre cropping regions of WA this project supplements these findings and by expanding the messaging to pulses in rotation.

Importantly maximising pulse grain yields increases partial gross margins in P deficient soils and benefits can be higher than the corresponding wheat phase (table 1, table 4). Yield potentials for pulse crops are generally lower than that of wheat but the increases in grain price of pulse crops offsets the lower overall yield gains obtained by addressing P deficiency.

Alleviating P deficiency of pulse crops not only generated increases in grain yields but also increases in early season biomass through NDVI readings were also obtained (data not shown). Increasing pulse above ground biomass translates to increased nodulation and N fixation which has the potential flow on effect to the next cereal crop and potentially lowering N requirements.

Identification of soil types or zones within paddocks that are prone to P deficiency (high PBI) is therefore vital in terms of maximising profits throughout a crop rotation. Importance of soil testing and using the current P guidelines for wheat is applicable for the pulse rotation.

An importance consideration for pulse emergence and early growth under low soil P conditions is fertiliser and seed safety. Increasing fertiliser rates when placed near pulse seeds can have a negative impact on crop emergence and early seedling growth through increases in soil salinity levels near the seed. It appears that lentil seeds are more sensitive to soil salinity compared to other pulse crops and wheat. Impacts of fertiliser toxicity will be seasonal and controlled by inherent soil salinity and soil moisture levels.

## CONCLUSION

This project has compared pulse P requirements with Wheat on four sites across three seasons (2021, 2022, 2023). Phosphorus responses have varied from high with associated high P requirements (Kojonup 21/23) to medium (Grass Patch 22) and non-responsive (Grass Patch 21). Across both responsive sites the P requirements and response of pulses including Faba Bean, Field Peas, Lentils are inline or slightly greater than Wheat. Responses and P requirements are not reflective of greater demand set up by higher grain yields as pulses on most occasions yielded significantly less than the Wheat. It appears the mechanism of matching or greater P requirement of pulses is due to lower PUE of the applied P.

Maximizing pulse yields through adequate P in P deficient soils translates to significant increases in PGM at current prices and therefore P inputs should not be lowered for crop rotations when in the pulse phase. Soil monitoring is essential for outlining current soil P status and P requirements for all crops as outlined in previous recent GRDC investment into current responses to applied P in WA across a range of soil types.

There are however occasions where application of relatively high rates of applied P with pulse seeds might not be favourable. Lentils have a greater sensitivity to soil salt levels for emergence and early growth and these conditions might be amplified with the introduction of further salt through high analysis fertilisers.

## IMPLICATIONS

This project is one of the first that has directly assessed pulse requirements compared to wheat on WA soil types and quantified the P requirements in terms of relative response, optimal P levels and measured PUE.

As pulse crops become more common in current rotations there is minimal trial data to support fertiliser requirements and therefore decisions to maximise gross margins. To establish new, well defined soil P test calibration datasets for each relatively new crop type requires significant amounts of time and investment. Using current well-established datasets for wheat and baselining P requirements of pulses by using wheat as the baseline can provide valuable information as seen in this project and report.

Inclusion of pulse crops in current rotations have proven to be profitable through numerous overall benefits. This project has outlined P as one of them and under low soil P availability, adequate P inputs are vital to maximise partial gross margins. Through higher grain prices of pulses, relatively smaller grain yield gains by alleviating P deficiency of pulses can increase PGM to be comparable to cereal phases. This observation should not be just restricted to the Albany and Esperance port zones of WA but nationally where other soil types drive P deficiency which can be hard to managed. Fertiliser management and seed safety is an important consideration for other soil types where other constraints might be present.

Maximising pulse production by alleviating P deficiency has other profitable flow on effects through increased nodulation and N fixation and greater retained stubble loads.

## RECOMMENDATIONS

Identification of P deficiency through soil testing, P balances or plant tissue testing is vital for maximising profit through increased pulse grain yields.

Current guidelines for soil P testing developed for wheat which has been improved through recent GRDC investments can be used as a benchmark for other pulse crops.

Phosphorus management strategies for your pulse phase is just as important as cereal phase and recommendations wouldn't be to reduce P inputs in your pulse phase.

## **APPENDIX:** Pulse P Response Survey 2021



20211022045437-Ka  
lyx Pulse P Response

## GLOSSARY AND ACRONYMS

Below is a sample abbreviations and acronyms list. Be sure to include all abbreviations and acronyms that appear in the report.

DGT	Diffusive Gradients in Thin films
PBI	Phosphorus Buffering Index
MAP	Monoammonium Phosphate
PGM	Partial Gross Margins