

Five years of grain production on deep placement treatments of phosphorus and potassium in scrub soils—Dysart



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RESEARCH QUESTION: Does the deep placement of phosphorus (P), potassium (K) and sulfur (S) have an impact on sorghum yields five years after the original deep applications?

Key findings

1. There was a 35% (970 kg/ha) grain yield response to the highest deep-P treatments in the 2018 sorghum crop.
2. There was no significant response to K in the 2018 sorghum crop.
3. Over 5 crops the deep-P treatments have produced between 2500-3000 kg/ha of extra grain over the zero P treatments.
4. After 5 crops the return on investment for 20 kg and 40 kg P/ha are 4.7 and 3.4 respectively.

Background

Over the last five years the UQ00063 project (Regional soil testing guidelines) has been monitoring a series of nutrition-based trial sites across Central Queensland (CQ). These trial sites were chosen based on soil testing evidence showing varying degrees of nutrient depletion in the surface and subsurface layers. This is particularly evident in the non-mobile nutrients of phosphorus (P) and potassium (K). In some established zero tillage production systems there is a marked difference between the nutrient concentration in the top 10 cm of the soil profile and the deeper layers (10–30 cm and 30–60 cm), that cannot be explained by natural stratification. It would seem that this pattern is becoming more evident across CQ, particularly in the brigalow scrub and open downs soil types.

This project is gathering data from these trial sites to ascertain whether the one-off application of either P, K or sulfur (S) placed in these deeper more depleted layers can provide a grain yield benefit and whether that benefit can be maintained over several years. These results can also be used to define the economic benefit of adding these non-mobile nutrients over successive cropping cycles.

What was done?

Initial soil testing was conducted (see Trial details) and the treatments were established in August 2013. Three successive sorghum crops were harvested from the site in 2014, 2015 and 2016; followed by a chickpea crop in 2017, before the site was planted to sorghum again, which was harvested on 21 June 2018.

Each of these crops was monitored for response to the original deep-placed fertiliser treatments, both in grain yield and dry matter production. Additionally, the dry matter samples and grain samples have had tissue analysis done to quantify the nutrient uptake by the crop.

Phosphorus (P)

There were seven unique treatments (Table 1; the 0P plots were doubled up to give eight plots per replicate), which included four P rates; 0, 10, 20, and 40 kg P/ha. These treatments had background fertiliser applied at the same time to negate any other potentially limiting nutrients. This background fertiliser included; 80 kg nitrogen (N), 50 kg K, 20 kg sulfur (S) and 0.5 kg zinc (Zn) per hectare. The next two treatments included 0P and 40P without background fertiliser except N and Zn (0P-KS, 40P-KS). The final treatment was a farmer reference (FR), which had nothing extra applied compared to normal commercial practice (Table 1).

Table 1. Summary of nutrient application rates (kg/ha) for all three trials.

Treatment	N	P	K	S	Zn
Phosphorus					
0P	80	0	50	20	0.5
10P	80	10	50	20	0.5
20P	80	20	50	20	0.5
40P	80	40	50	20	0.5
0P -KS	80	0	0	0	0.5
40P -KS	80	40	0	0	0.5
FR	0	0	0	0	0
Potassium					
0K	80	20	0	20	0.5
25K	80	20	25	20	0.5
50K	80	20	50	20	0.5
100K	80	20	100	20	0.5
0K -PS	80	0	0	0	0.5
100K -PS	80	0	100	0	0.5
FR	0	0	0	0	0
Sulfur					
0S	80	20	50	0	0.5
10S	80	20	50	10	0.5
20S	80	20	50	20	0.5
30S	80	20	50	30	0.5
0S -PK	80	0	0	0	0.5
30S -PK	80	0	0	30	0.5
FR	0	0	0	0	0

Treatments were applied using a fixed tyne implement which delivered the P and K at 20 cm depth and the N and S 10–15 cm deep. The bands of fertiliser were placed 50 cm apart in plots that were eight metres (m) wide by 32 m long. The bands were placed in the same direction as the old stubble rows. There were six replicates making a total of 48 plots for the trial.

The 2018 sorghum crop had 200 kg/ha of urea applied in the fallow, 6 weeks prior to planting. This rate is double the normal commercial practice for the rest of the farm. Starter fertiliser was applied at planting (10 L/ha polyphosphate plus 2.5 L/ha Foundation™) as a liquid injection with the seed. This starter rate was split in the P trial so that all treatments could have a ‘with’ and ‘without’ starter treatment. This effectively doubled the number of plots in the P trial from 48 to 96. The sorghum variety MR Bazley was planted at 50,000 seeds/ha on 14 February 2018. The crop received 159 mm of in-crop rainfall, with over 85% occurring within two weeks of planting.

Potassium (K)

There were seven unique treatments (Table 1; the 0K plots were doubled up to give eight plots per replicate) which included four K rates; 0, 25, 50, 100 kg K/ha. These treatments had background fertiliser applied at the same time to negate any other potentially limiting nutrients. This background fertiliser included; 80 kg N, 20 kg P, 20 kg S and 0.5 kg Zn per hectare. The next two treatments included 0K and 100K without any background fertiliser except N and Zn (0K-PS, 100K-PS). The final treatment was a farmer reference (FR), which had nothing extra applied compared to normal commercial practice (Table 1).

Applications were done in the same way as the phosphorous trial and the other trial details remain the same.

Sulfur (S)

There were seven unique treatments (Table 1; the 0S plots were doubled up to give eight plots per replicate) which included four S rates; 0, 10, 20, 30 kg S/ha. These treatments had background fertiliser applied at the same time to negate any other potentially limiting nutrients. This background fertiliser included; 80 kg N, 20 kg P, 50 kg K and next two treatments included 0S and 30S without any background fertiliser except N and Zn (0S-PK, 30S-PK). The final treatment was a farmer reference (FR), which had nothing extra applied compared to normal commercial practice (Table 1).

Results

Each trial's results are presented separately. The 2018 sorghum crop represents the fifth crop harvested off this site since the initial treatments were applied. Results include the cumulative mean yield data from all five crops.

Phosphorus

The P trial has shown a consistent significant yield response across the past four years to deep applied P. The sorghum crop in 2018 is no different with the 20P and 40P treatments showing a 25% to 35% yield increase (Table 2). This amounts to just under a 1 tonne/ha yield increase for the top P treatment, and during a year when sorghum prices ranged from \$300-350 per tonne this would have paid for the total application cost back in 2013. However

as this is the fifth crop since application the yield benefit is now going straight to profit as treatment costs were covered in the second year of production.

Table 2. Mean grain yield comparison across treatments in phosphorus trial for sorghum 2018.

Treatments	Mean grain yields (kg/ha)		Relative difference to '0P' plots (kg/ha) (%)	
FR	2349	a	-469	-16.6
0P -KS	2569	ab	-249	-8.8
0P	2817	b	0	0.0
10P	3349	c	532	18.9
20P	3548	cd	731	25.9
40P	3788	d	971	34.5
40P -KS	3481	cd	663	23.6

Letters indicate least significant difference (Lsd) P(0.05). Means with a common letter are not significantly different (Lsd = 342)

This site does have a high degree of variability in its nutritional status which is why the lsd of 342 kg/ha is relatively large and means there is no clear significant difference between the 20P and 40P treatments rates. This is despite the fact that there has been sizeable difference in grain yield between the 20P and 40P treatments in the last two crops (chickpea 2017, sorghum 2018).

The impact of starter fertiliser within the P trial was also significant (Table 3). Across all treatments the addition of starter fertiliser added an extra 504 kg/ha. Within each deep-P treatment the difference was consistently significant (Table 3). Despite this there was no significant interaction between Starter P and the deep-P treatments. This means the size of the response to deep-P (for example, difference between 0P and 40P was consistent in both starter P treatments.

Table 3. Mean grain yield results for plus and minus starter application at planting.

Deep-P treatments	Mean grain yields (kg/ha)		
	No Starter	Starter	Difference
FR	1942	2755	814
0P -KS	2260	2877	617
0P	2618	3016	397
10P	3123	3575	452
20P	3319	3777	458
40P	3502	4074	572
40P -KS	3320	3641	322
Mean difference			504

Lsd P(0.05) = 198

A comparison between all crops grown on the P trial site since 2014 (Figure 1) shows the response to the deep-P treatments has not diminished, with the best results recorded in the most recent seasons. It is particularly interesting that the performance of sorghum has improved from the 2015-16 sorghum season to the 2018 season, despite the fact that the 2015-16 sorghum crop received 43 mm more in-crop rainfall. Analysis of the yield and protein data of the two sorghum crops suggests that the nitrogen status of the site has likely played a part in the relative response to deep-P (Figure 2).

There is no significant differences in grain protein between the deep-P treatments but there is up to a 4% difference in protein between sorghum in 2015-16 and 2018 (Figure 2.) The 2018 sorghum crop has also produced 1 tonne more grain (averaged over P plots) with 43 mm less rainfall than 2015-16. The deep-P response in 2018 was 21% bigger in the 40P treatment and 11% bigger in the 20P treatment than in 2015-16 (Figure 1).

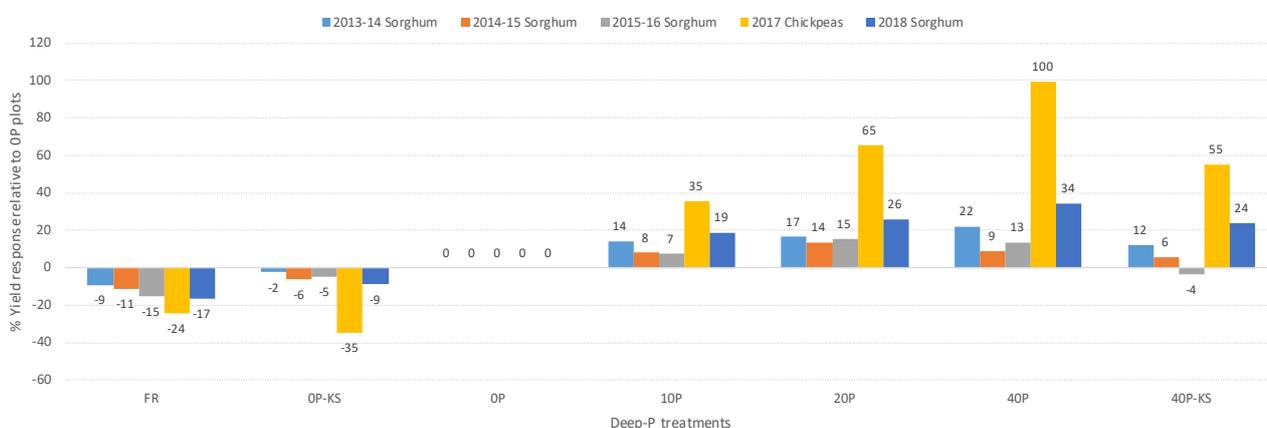


Figure 1. Relative response in grain yield as a percentage of 0P plots for all crops since first treatment.

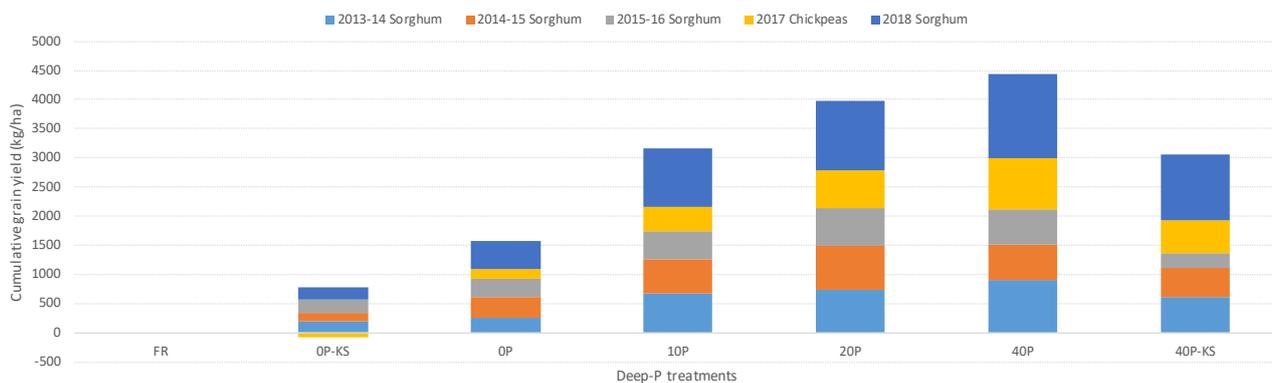


Figure 2. Comparative grain yield and grain protein for the 2015-16 and 2018 sorghum crops in the phosphorus trial site.

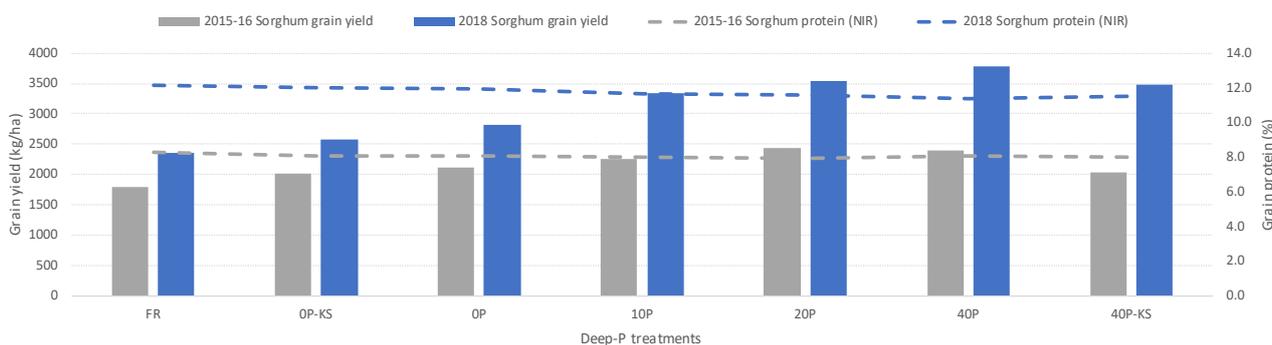


Figure 3. Comparison of the cumulative differences in grain yield (kg/ha) across all the deep-P treatments relative to the FR plots across all years.

The main management difference between the two sorghum crops has been the doubling of the nitrogen fertiliser applied to the site. The 2018 sorghum crop had 200 kg/ha of urea applied as a band in the top 5 cm, across the site prior to planting; whereas the 2015-16 crop had 100 kg/ha of urea side-dressed three weeks after planting.

This comparison of the two sorghum crops from 2015-16 and 2018 along with the large differences in chickpea performance measured

across the deep-P treatments (Figure 1) in 2017; suggests that with P and K constraints addressed, the nitrogen status of the site is once again having a strong influence on the relative yield responses to the deep-P treatments.

Data collected from this site has given the best indicator of the long term gains in yield and economic viability for the use of deep placement nutrition. One way of measuring this is by adding the differences in grain yield between the FR plots and the other deep-P treatments (Figure 3).



Same plots across different crops (2018 sorghum and 2017 chickpea); 40P plot on the left and oP plot on the right.

Table 4. Cumulative benefit (\$/ha) analysis across the five crops in the deep-P trial*.

P rate (kg/ha)	2014 Sorghum	2015 Sorghum	2016 Sorghum	2017 Chickpea	2018 Sorghum	ROI
FR	\$0	\$0	\$0	\$0	\$0	0.0
0	-\$96	-\$11	\$80	\$149	\$312	1.6
10	\$2	\$179	\$328	\$659	\$974	4.2
20	-\$10	\$219	\$419	\$915	\$1,278	4.7
40	-\$70	\$100	\$174	\$737	\$1,156	3.4
OP -KS	-\$42	\$4	\$73	\$15	\$89	0.9
40P -KS	-\$48	\$108	\$125	\$565	\$910	3.7

(Courtesy: Hagan, J., 2018) *Costs included additional background fertiliser that was used in the initial application of these treatments on this trial site.

The data demonstrates that the 40P application has produced 4500 kg/ha more grain than the FR plots over five crops whilst the 20P treatment generated 4000 kg/ha. A proportion of this difference could be attributed to deep ripping and additional N, however comparing the treatments to the OP rate shows 3000 kg/ha improvement for 40P and a 2500 kg/ha increase for the 20P.

These accumulated grain yield increases have generated significant economic benefits (Table 4). After five years of significant responses, it is worth noting that despite the 40P treatment giving the highest increase in cumulative yield, it is the 20P treatment that has given the best return on investment (ROI) at 4.7 due to lower upfront costs. If there is a continued difference in crop responses to the 40P and 20P treatments in future years then the ROI results may change.

Potassium

The differences in grain yield across the potassium trial are reasonably consistent with an 8% response (280 kg/ha) across all the K treatments that had background P and S applied in relation to the OK plots (Table 5).

Table 5. Mean sorghum grain yield comparison across treatments in the potassium trial 2018.

Treatments	Mean grain yields (kg/ha)		Relative difference to 'OK' plots	
	(kg/ha)		(kg/ha)	(%)
FR	3041	a	-483	-13.7
OK -PS	2964	a	-560	-15.9
OK	3524	b	0	0.0
25K	3815	b	291	8.3
50K	3808	b	283	8.0
100K	3799	b	275	7.8
100K -PS	3009	a	-515	-14.6

Letters indicate least significant difference (Lsd) P(0.05). Means with the same letters are not significantly different (Lsd = 405)

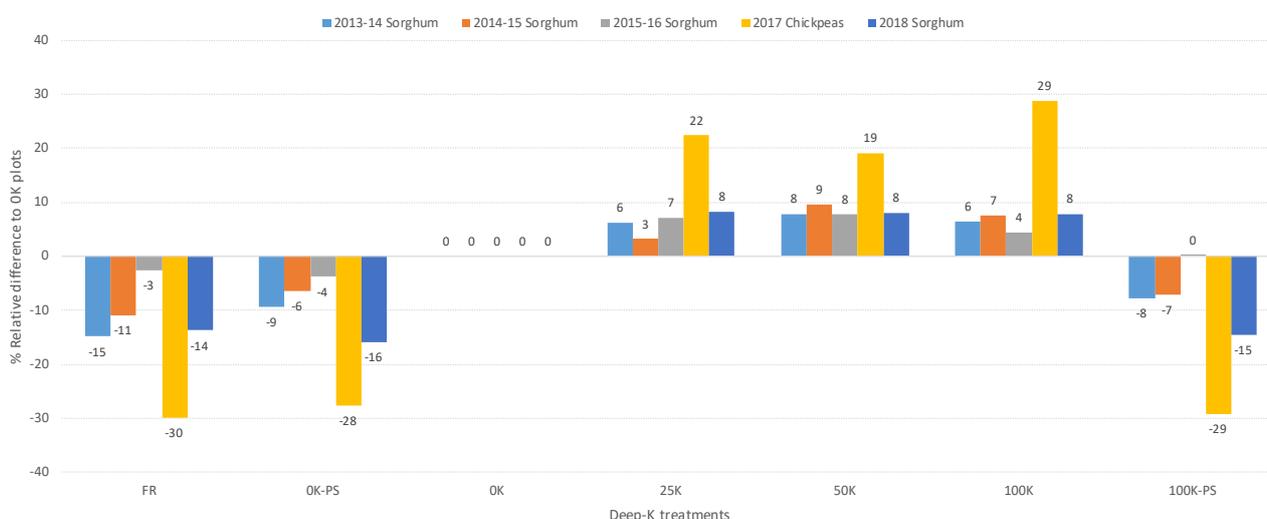


Figure 4. The relative difference in grain yield between deep-K treatments and the OK plots across all crops grown on-site.

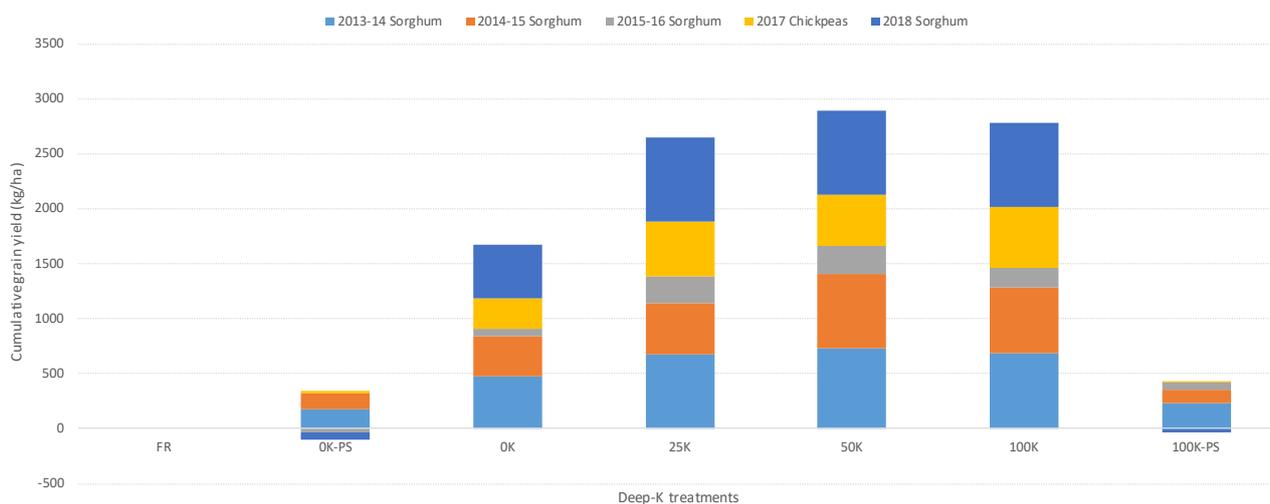


Figure 5. Comparison of the cumulative differences in grain yield (in kg/ha) across all the deep-K treatments relative to the FR plots across all years.

Table 6. Cumulative benefit (\$/ha) analysis across the 5 crops in the deep-K trial*.

K rate (kg/ha)	2014 Sorghum	2015 Sorghum	2016 Sorghum	2017 Chickpea	2018 Sorghum	ROI
0	-\$45	\$62	\$81	\$307	\$446	2.4
25	-\$11	\$128	\$201	\$595	\$820	3.8
50	-\$19	\$182	\$259	\$629	\$852	3.6
100	-\$84	\$97	\$149	\$592	\$811	2.8
OK - PS	-\$46	-\$3	\$12	\$12	-\$22	-0.2
100K - PS	-\$131	-\$94	-\$48	-\$59	-\$76	-0.4

(Courtesy: Hagan, J., 2018) *Costs included additional background fertiliser that was used in the initial application of these treatments on this trial site.

Any plot that had no P applied as a background nutrition had a 15% yield penalty. This K response is comparable to previous sorghum crop performance with most responses occurring between 6-9% over the past four crops. In the 2018 sorghum results, the statistical analysis has not been able to find any significant difference in the K treatments. The natural variability in the data has contributed to the lsd being too high for an equivalent 8% response in yield to be significant.

Sorghum responses in the K trial are consistent across the five year data set (Figure 4), whilst chickpea had a far more significant response. This may indicate differences between crop species in ability to forage for potassium down the soil profile.

It may also indicate that the potassium levels are not as limiting as P at this site. Once the P limitation is addressed then the K levels may be just approaching a deficient level leading to some small responses in those crop species that have a robust root system.

Over the long term, the cumulative improvement in grain yield over the FR plots is just under 3 t/ha (Figure 5). Approximately half of this increase can be attributable to background P with yields jumping from 242 kg/ha (OK-PS) to 1668 kg/ha (OK). Despite the increments in grain yield being modest in most seasons (Figure 4), after 5 successive crops the accumulated benefit is substantial with 50K providing an additional 1224 kg/ha over the OK treatment.

This is backed up in the economic analysis (Table 6) with the 50K treatment producing a ROI of 3.6 and payback occurred in the second crop harvested off this site. Interestingly the 25K treatment produced a slightly higher ROI (3.8) with a lower accumulated grain yield benefit which shows that when there are no significant differences between the different rates of K in terms of yield the economics favours the lower rate. However it would be expected responses to higher rates of K will last longer and improve in ROI over time.

Sulfur

The yield data from the sulfur trial shows no response to the main deep S treatments (Table 7), which has been consistent for every crop monitored in this trial.

As in previous crops there is a pattern where those treatments without background P have a much lower yield performance. In past trial data these differences have been statistically significant; however in the 2018 sorghum crop the statistical analysis has not shown this. The reason for this change from previous years is unknown.

There were no significant differences identified in the grain protein analysis from the samples taken at harvest.

Table 7. Mean grain yield comparison across treatments in the sulfur trial for 2018 sorghum.

Treatments	Mean grain yields (kg/ha)	Relative difference to 'OS' plots (kg/ha)	(%)
FR	3179	-514	-13.9
OS -PK	3326	-367	-9.9
OS	3693	0	0.0
10S	4031	339	9.2
20S	3706	13	0.4
30S	3863	170	4.6
30S -PK	3195	-498	-13.5

No significant differences across treatments.

Implications for growers

The results from the 2018 sorghum crop have shown another strong response to the deep banding of P and also a strong response to starter P. This site has been P responsive in every year however the size of the response has fluctuated from season to season. The 2018 sorghum crop has shown the strongest relative response (34.5%) out of the four sorghum crops grown at the site and this is unexpected given the first sorghum crop had the benefit of extra nitrogen and deep ripping in the first year. The 2018 sorghum crop also had the least amount of in-crop rainfall out of the four crops.

Starter P responses at this site have not always been consistent even though soil analysis shows that surface P is low (see 0-10 cm in Trial details). This may relate to how quickly the surface profile dries out after planting which then governs how long the plant gets access to

the starter P. In this case early in-crop rainfall (137 mm in first 10 days) may have extended the plant access to the starter P application and consequently improved grain yield.

This trial site has proven that deep placement of P at rates of 20 to 40 kg/ha can continue to provide economic responses for at least five consecutive crops over a period of five years. It is also clear that once subsoil P constraints are addressed that nitrogen may once again be the crop-limiting nutrient. The 2017 chickpea crop showed very high relative responses (60-100%) even though yields were restricted by seasonal conditions.

Defining the best rate of P is still not clear even though there has been a bigger spread of yields between the 20P and 40P rates over the last two crops. The statistical analysis cannot split the performance of the two rates so far and this may be a result of the inherent variability at the site. Economically the 20P rate is just ahead in return on investment, however there will be another crop monitored on this site before the end of the project and those results may change the long term analysis.

The deep placed potassium has once again shown a pattern of small responses to the deep band placements but not enough to be considered statistically significant in the 2018 sorghum crop. The long term grain response to potassium over the last five years has shown that the addition of K has been economically viable although at a lower ROI than the P trial.

This site is proving that the most limiting nutrient will always make the biggest difference to yield but once the nutrient has been lifted then other nutrients, particularly K and N, can have an impact on yield. While K has only contributed marginally to stronger yield performance it is an indicator that this nutrient could become limiting if nothing was done.

Nitrogen fertility has shown it has the capacity to strongly limit response to P and K, even though soil analysis would suggest that P should be the most limiting factor. The data collected at this trial site has been focused on crop response to P, K and S; however it is emerging from the variations between crops and seasons that N fertility at this site is playing a large role in the size of the response that is being achieved by deep placement of P and K.

Acknowledgements

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Trial details

Location: Dysart
Crop: Sorghum (MR Bazley)
Soil type: Grey Vertosol (Brigalow scrub) on minor slopes
In-crop rainfall: 159 mm
Fertiliser: Fallow-applied urea @ 200 kg/ha

Selected soil fertility characteristics:

Depth (cm)	Nitrates	Sulfur (KCl-40)	Col P	BSES P	Exc. K	ECEC
0-10	2	1.7	5	8	0.25	36
10-30	1	1.6	1	3	0.12	29
30-60	1	2.6	1	4	0.09	31