

# Responses to deep placement of phosphorus and potassium in chickpea—Clermont

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**RESEARCH QUESTION:** *What is the yield response in chickpea to the deep-banding application of phosphorus and potassium?*

## Key findings

1. Chickpea yields increased by over 900 kg/ha on deep banded phosphorus (P) applied at 40 kg P /ha; representing a 300 % increase over the zero P treatments.
2. Chickpea yields were not responsive to deep applied potassium bands.

## Background

Over the last four years the UQ00063 project (Regional soil testing guidelines) has been monitoring a series of nutrition 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. Subsurface depletion is particularly evident for the non-mobile nutrients 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 of soil analysis 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 a one-off application of either P, K or sulfur (S) that is 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 a crop rotation, rather than the conventional approach of assessing the profitability against the next crop to be sown.

Data from these sites is also contributing to the understanding of the pathways of macro nutrient uptake and how responses to deep-banded fertiliser can be impacted by seasonal constraints and differences in crop species.

## What was done?

This trial site was established in October 2015, then planted to sorghum in February 2016 and chickpea in May 2018. Based on the original soil characterisation tests (see Trial details), it was decided to locate three individual rate response trials at this site: one each for P, K and S. All trials contained a farmer reference (FR) treatment in which had nothing extra applied compared to normal commercial practice, benchmarking current production levels.

### Phosphorus (P)

There were seven unique treatments (Table 1a), which included 4 P rates of 0, 10, 20, and 40 kg P/ha (0P, 10P, 20P and 40P). The 0P plots were doubled up to make eight plots replicated six times. All treatments had background fertiliser applied at the same time to negate any other limiting nutrients. This basal fertiliser was 80 kg nitrogen (N)/ha, 50 kg K/ha, 20 kg S/ha and 1 kg zinc (Zn)/ha. Two contrasting treatments included 0P and 40P without any background K and S fertiliser (0P-KS, 40P-KS) to assess the impact of P only. Table 2 lists the commercial fertiliser products that were used to make up the treatments.

These treatments were applied using a fixed tyne implement which delivered the P and K 20 cm deep and the N and S 10–15 cm deep. The fertiliser bands were placed 50 cm apart in plots that were 8 m wide by 32 m long and in the same direction as the crop rows. Under normal conditions this trial would also have had three P-based starter fertiliser treatments (0, 15 and 30 kg/ha) applied with the seed at planting,

however, due to a lack of planting rain, the 2018 crop had to be deep planted with the co-operator's planter and consequently the different starter treatments could not be applied as they were for the previous sorghum crop in 2016. Instead, the trial had MAP (mono ammonium phosphate) starter fertiliser applied @ 20 kg/ha (equivalent to 3 kg/ha P) with Basis XC® applied with the MAP at 2 L/t across the entire site.

Chickpea (Kyabra<sup>®</sup>) was planted with a 24 m commercial planter with moisture-seeking capability on 27 May 2018 and harvested on 25 October. The crop was planted on 0.5 m rows at 20 cm deep into moisture and received a total of 51 mm of in-crop rainfall of which the crop received just 7.6 mm during the first 109 days.

### Potassium (K)

The potassium experiment explored application of K with/without P and S being present. There were seven unique treatments including 4 K rates: 0, 25, 50, and 100 kg K/ha with a background fertiliser of 80 kg N/ha, 20 kg P/ha, 20 kg S/ha and 1 kg Zn/ha. The OK plots were doubled up to make eight plots per replicate. Contrasting this are two treatments OK and 100K without PS fertiliser (OK-PS, 100K-PS).

Applications were done in the same way as the P trial and Table 1b gives a summary of the rates of nutrition used in each treatment. The K trial was planted in the same way as the P trial with the co-operators 24m planter. Plot dimensions remain the same as the P trial. Starter fertiliser was applied to the whole trial at planting.

### Sulfur (S)

There were seven unique treatments which included four S rates; 0, 10, 20, 30 kg S/ha. All treatments had background fertiliser applied at the same time to negate any other limiting nutrients. This background fertiliser included 80 kg N/ha, 20 kg P/ha, 50 kg K/ha and 1 kg Zn/ha.

The other treatments included OS and 30S without any background fertiliser except N and Zn (OS-PK, 30S-PK). Treatments were applied in the same way as the P and K trials; application rates are summarised in Table 1c. This trial was planted by the farmer co-operator in the same way as the K trial with starter fertiliser.

**Table 1a. Summary of nutrient application rates (kg/ha) for the phosphorus trial.**

Treatment	N	Starter P	P	K	S	Zn
OP	80	3	0	50	20	2
10P	80	3	10	50	20	2
20P	80	3	20	50	20	2
40P	80	3	40	50	20	2
40P-KS	80	3	40	0	0	2
OP -KS	80	3	0	0	0	2
FR	0	3	0	0	0	0

**Table 1b. Summary of nutrient application rates (kg/ha) for the potassium trial.**

Treatment	N	P	K	S	Zn
OK	80	20	0	20	2
25K	80	20	25	20	2
50K	80	20	50	20	2
100K	80	20	100	20	2
OK-PS	80	0	0	0	2
100K-PS	80	0	100	0	2
FR	0	0	0	0	0

**Table 1c. Summary of nutrient application rates (kg/ha) for the sulfur trial.**

Treatment	N	P	K	S	Zn
OS	80	20	50	0	2
10S	80	20	50	10	2
20S	80	20	50	20	2
30S	80	20	50	30	2
OS-PK	80	0	0	0	2
30S-PK	80	0	0	30	2
FR	0	0	0	0	0

**Table 2. Commercial products used in nutrient treatments.**

Nutrient	Product source of nutrient in applications
Nitrogen (N)	Urea (46%), MAP (10%), GranAm® (20%)
Phosphorus (P)	MAP (22%)
Potassium (K)	Muriate of potash (50%)
Sulfur (S)	GranAm® (24%)
Zinc (Zn)	Supa Zinc™ (Liq) (7.5% w/v)

For all three trials, data collection was done the same way. Plant counts, starting soil water and starting nitrogen (N) measurements were taken post emergence. Total dry matter measurements were taken at physiological maturity and yield measurements were taken with a plot harvester when commercial harvesting started in the same paddock. Two harvest samples were taken from each plot and a grain sample was kept from the

plot for nutrient analysis. Both the dry matter samples and the grain samples are ground down and subsampled for a wet chemistry analysis.

## Results

The results for each trial are presented separately. The 2018 chickpea crop represents the second crop grown at this site since the initial deep-banded treatments were applied. This section will also include data from the previous sorghum crop harvested in 2016.

### Phosphorus

Chickpea grain yields for the deep-P trial show a similar pattern to that produced by the sorghum crop two years ago (Figure 1). Although chickpea yields have been limited by very dry conditions, the relative increase in yields between the 0P treatment and the 40P treatment are of a much larger magnitude (304%) than the sorghum response (39%) in 2016. The sensitivity of the chickpea to the deep-banded P is clearly evident with each rate of P producing a significant increase in grain yield (Figure 1). This is slightly different to the sorghum pattern where any additional deep-P gave a significant increase in yield against the 0P rate) but there was no difference between the 10P and 20P rates. The 40P rate gave a significant increase in yield again over the lower rates by 384 kg/ha. This is slightly unusual as in other trial sites the 20P and 40P rates have given a similar responses in sorghum crops.

The magnitude of the response by the chickpea was evident at the site early in the crop development stages and continued right through to maturity. Plots with no additional P were barely harvestable.



Establishment: 40P (background) and 0P (foreground).

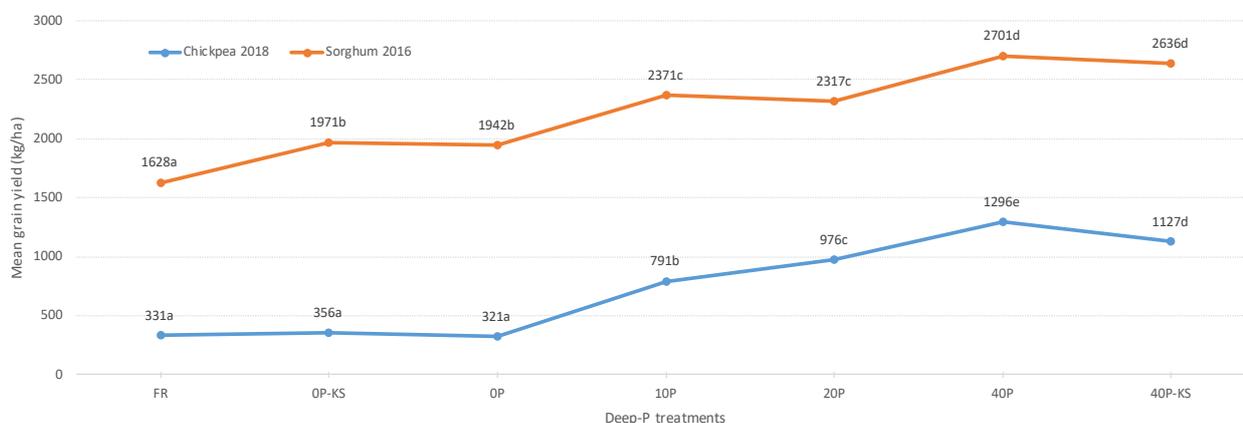


20P plot ready for harvest (right), next to untreated tramline buffer.

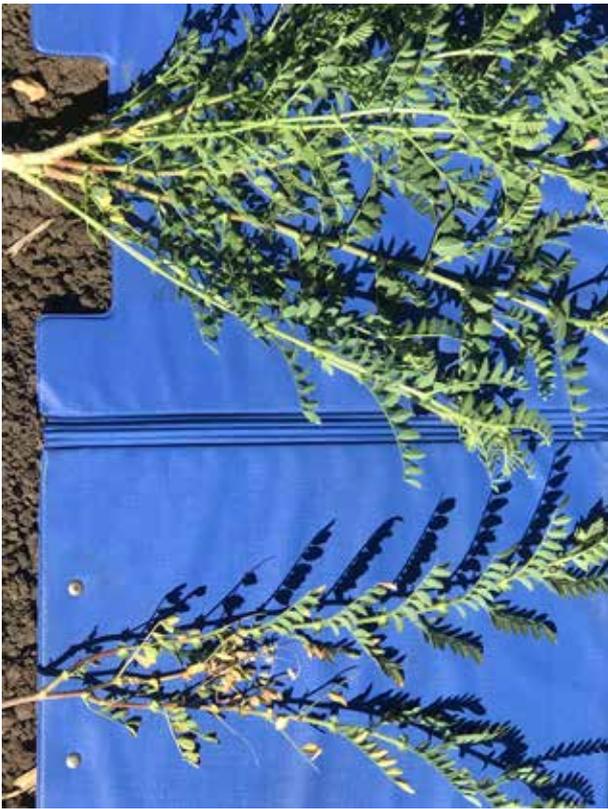
**Table 3. Summary of soil analysis data for phosphorus and potassium across the site (based on average of six replicates for each trial).**

Depth	Colwell P (mg/kg)	BSES P (mg/kg)	K (meq/100 g)
0-10 cm	7	39	0.81
10-30 cm	1*	37	0.32
30-60 cm	1*	34	0.22

\*Note: Laboratory analysis cannot read below 2 mg/kg. For ease of mean calculations a figure of <math>\leq 2</math> was represented by a numerical figure of 1.



**Figure 1. Mean grain yields from deep-P trial for 2016 sorghum and 2018 chickpea.**  
(Means with the same letters are not significantly different at the 5% level) Sorghum Lsd=146, Chickpea Lsd=104.



Comparison of plants starting to flower; top plant from additional P plot, bottom has no deep-P.

The most recent soil analysis of the site (Table 3) shows very low P levels in the subsurface layer (10-30 cm), in some cases not detectable for normal lab analysis. It should not be surprising that there is a very strong response to deep-P at this site, however what is surprising is the difference in response between species (pulses and cereals). There are a number of factors that could be at play to cause this result.

Firstly, chickpea (being a legume) is not constrained by nitrogen (N) fertility the same way as cereals such as sorghum can be. In this trial, N was backgrounded out at a rate of 80 kg N/ha prior to sorghum being planted in 2016, so it is unlikely the N status would have affected the P response in the sorghum.

Secondly, the structure of the root system and the plants' ability to forage for nutrients between cereals and pulses can be a factor. The foraging nature and depth of rooting by cereals such as sorghum can be an advantage in a nutrient-depleted environment. Banding P at a depth where moisture is prevalent for longer gives the chickpea plant better access to P than it normally would have if it had to rely on its tap-rooted system to explore the profile in order to extract enough P.

Thirdly, the deep banding of P creates an area of high concentration for the nutrient. This greatly assists in the uptake by the plant as it relies on diffusion and a concentration gradient to move the phosphate ion across the root membrane from an area of high concentration to low concentration. This may benefit the root structure of chickpea crops far more than sorghum crops.

Fourthly, there is a higher requirement for P in pulse crops, particularly in the amount of P that ends up in the grain in relation to cereal crops<sup>1</sup> (3 kg/t for chickpea, 1.9 kg/t for sorghum). This may give crops such as chickpea a higher sensitivity and therefore larger response to increasing levels of P fertility.

Lastly, in-crop rainfall is always a factor in the relative response to deep-P. The sorghum crop in 2016 had some useful in-crop rainfall 30 days after sowing whereas the 2018 chickpea crop had almost no growing season rainfall (Figure 2).

Based on the soil analysis (Table 3), some in-crop rainfall would have allowed the crop to access some of the P contained in the surface profile (0-10 cm). In the case of the chickpea crop there was so little in-crop rainfall that the surface P would have been largely unavailable, resulting in a much stronger reliance on the

<sup>1</sup>Based on a summary of plant analysis data collected across Southern Queensland nutrition sites (2013 to 2016).

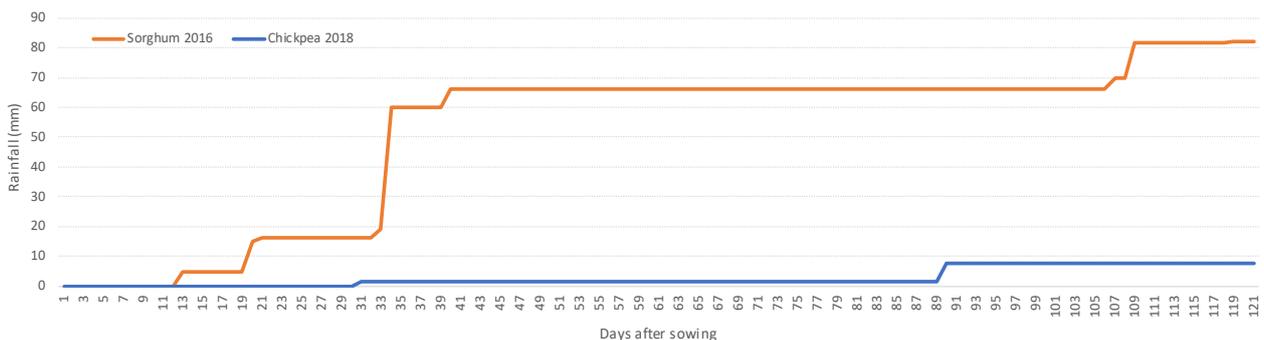
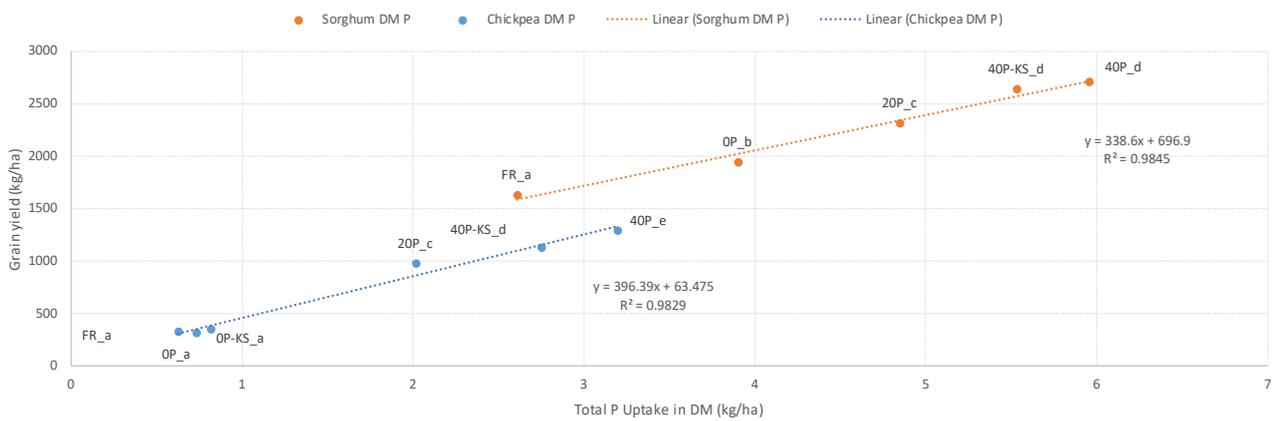


Figure 2. Accumulated in-crop rainfall totals for chickpea (2018) and sorghum (2016).



**Figure 3. Comparison of plant uptake rates in the P trial across species and treatments.**

Means with the same letters (lower case) are not significantly different.

P contained in the deep bands. In addition to this, the fact that the chickpea crop was deep sown (15cm) means the primary root system was established below the top 10 cm of the soil profile, effectively isolating any surface nutrients from the plant. Comparing the rates of P uptake across the two crops (Figure 3) illustrates this point.

The plots without any additional P (FR, OP, OP-KS) had to survive on what they could access from the soil profile. In the case of chickpea this was quite limited, as the root system only developed from the subsurface (10-30 cm) which we know had almost no P available (Table 3). These treatments were only able to acquire 0.6-0.8 kg P/ha in crop biomass (Figure 3), so the very low yields without deep-P bands were therefore not surprising.

In contrast, the sorghum had some in-crop rainfall early in the life cycle so those plots with no additional P would have been able to at least access some native P from the higher P concentrations in the surface profile (0-10cm) as well as what they could from the low P subsoil (Table 3). The sorghum crop was able to acquire 2.5 kg P/ha (FR plots), as opposed to the 0.6 kg P/ha (FR plots) in the chickpea. It is assumed most of this difference came from better access to the surface profile (0-10 cm).

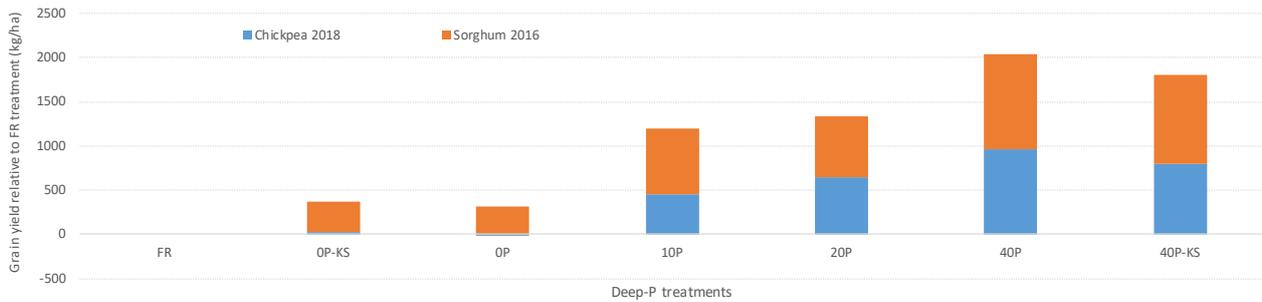
Interestingly, the estimated P acquisition from the deep-P bands (difference between 40P and OP treatments) was relatively similar for both crops – ca. 2.5 kg P/ha for the chickpea and 2.1 kg P/ha for the sorghum (Figure 3). The sorghum crop would have become reliant on the deep-P bands later in the crop life cycle as the surface soil dried out, but was still able to increase P content by 50% (Figure 3) and produce an additional tonne of grain yield (39% yield increase). While impressive, this

relative yield increase would have been a lot larger if the crop had not been able to acquire the 2.5 kg P/ha from the topsoil thanks to the in-crop rainfall; with that background soil P sufficient to produce yields of ca. 2 t/ha (Figure 1).

In the chickpea circumstances the additional 2.4 kg P acquired from the deep bands represented a five-fold increase in crop P uptake compared to the treatments with no deep-P applied (Figure 3). While this additional P uptake produced a similar 1 t/ha yield increase as recorded in the sorghum crop, the lower unfertilised crop yields (300-350 kg/ha) meant the additional yield represented an increase of 300% (Figure 1).

The chickpea crop was effectively almost totally dependent on the P it could acquire from the deep-placed bands, but given the very dry season, the chickpea may have only been able to access those deep bands for a limited time, meaning the crop may well have still been P-limited. Once the moisture had been extracted from around the P bands in the 10-30 cm part of the soil profile, further P acquisition would have been impossible.

While the difference in scale of response to deep-placed P by the two crops is intriguing, the main focus is still the quantity of extra grain that has been produced by the deep-P treatments. The scale of grain yield is dissimilar between the two crops, however when they are added together the differences that the deep-P has made to grain yield is stark (Figure 4) and provides a strong basis for good economic returns for the application of deep-P. In this trial site, the 40P rate has delivered over 2 t/ha more grain yield than the FR baseline and 1.7 t/ha more than the OP rate in just two crops.



**Figure 4. Accumulated grain production for each treatment in the P trial relative to the FR treatment.**

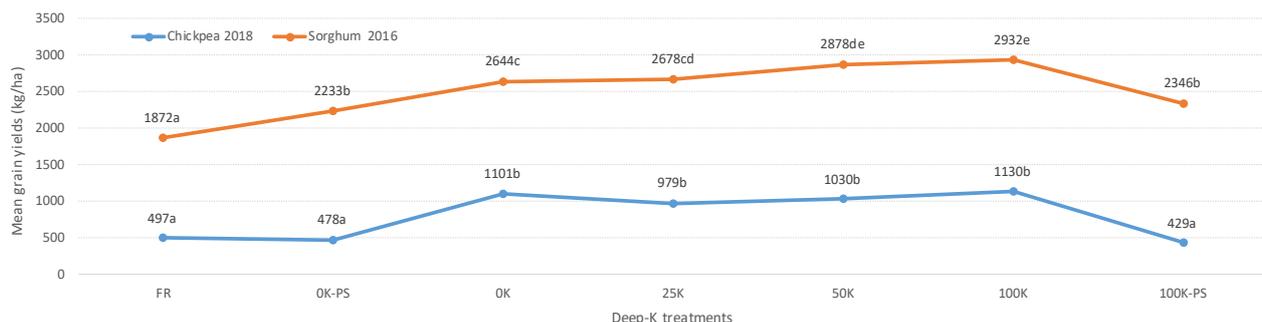
### Potassium

Whilst there were similarities in the P response between the sorghum and chickpea crops, the grain yield response to K shows a clear contrast (Figure 5). In 2016 the sorghum crop did show a small significant response to the two highest rates of K applied (50K, 100K). This response amounted to about 250 kg/ha of grain (9-10%) over the 0K treatment. However, the chickpea in 2018 showed no significant response to the deep-applied K treatments (Figure 5). The most significant observation from the chickpea yield data is the fact that the treatments with no background P applied (FR, 0K-PS, 100K-PS) showed a large drop in yield of over 600 kg/ha (55-60% relative difference) compared to treatments in which P was applied. This reinforces that crop performance at this site was primarily determined by the chronic P deficiency.

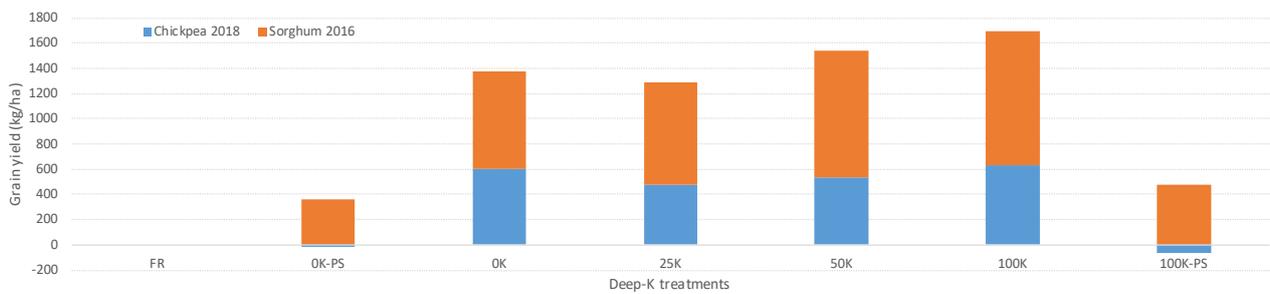
The soil analysis for this site (Table 3) indicates the K levels in both the 0-10 cm (0.81 meq/100 g) and 10-30 cm (0.32 meq/100 g) layers were reasonable and would not be categorized as K deficient. Therefore, the most surprising result is that the sorghum did have a small response to deep-K, rather than the chickpeas not responding at all.

Similar to the P trial, the K trial has highlighted some differences between crop species in their response to deep-applied fertiliser. Although it seems contradictory, differences in root structure may play a part in the response to deep-K. The sorghum plant may be able to develop more roots in and around the K band (with the help of accompanying background of 20 kg P/ha), thus increasing the surface area exposed to the high concentration of K in the fertiliser band. With enough root proliferation around the band, the root system of the sorghum plant has a good chance of taking up enough K out of the fertiliser band to make a difference to crop performance; especially as there was significant early season rain that would have kept those bands wetter for longer.

In contrast, chickpea crops have typically been slower to proliferate roots around a P band, and in the dry seasonal conditions where the band was never re-wet, the crop may not have had enough time or root density to acquire a significant amount of K from the band. While root activity by chickpea was sufficient for the crop to acquire 2.5 kg P/ha (Figure 3), plant tissue typically requires at least five times the K uptake per tonne of dry matter as it does P. With access to the bands limited in a very dry year, the chickpea crop may not have been able to acquire sufficient K from the bands to generate a yield response.



**Figure 5. Mean grain yields from deep-K trial for 2016 sorghum and 2018 chickpea.** Means with the same letters are not significantly different at the 5% level; sorghum lsd = 195, chickpea lsd = 244.



**Figure 6. Accumulated grain production (kg/ha) for treatments in the potassium trial relative to the FR treatment.**

Another possible confounding issue is that the background rate of P fertiliser used in the K trial was equivalent to the 20P rate used in the P trial. The yield data for the chickpea crop (Figure 1) shows similar yields in both the P and K trials when 20 kg P/ha was applied in deep bands – ca. 1100 kg/ha. However, the 40P rate in the P trial increased yield by another 30%, indicating that the plants' requirement could not be satisfied by the lower rate (20P). It is therefore possible that any additional K uptake by the chickpeas was not able to generate a yield response as P still represented the primary yield constraint.

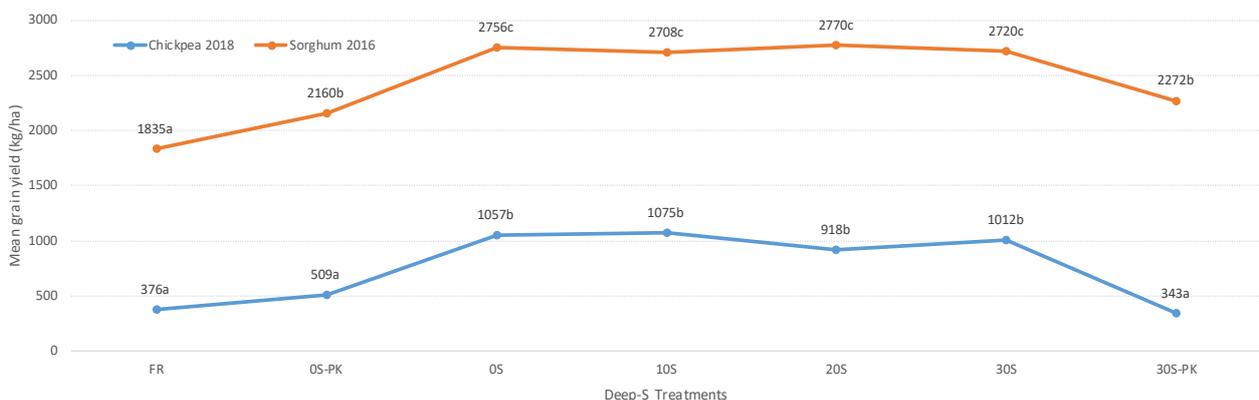
Accumulated grain yields over the two crops (Figure 6) for the K trial show a large advantage (1693 kg/ha) over the FR plots (baseline) but only a small (317 kg/ha) advantage over the OK treatments. It is interesting to note that on average the background P applied in the K trial (includes OK, 25K, 50K, 100K treatments) resulted in an average of 1100 kg/ha increase in yield over the FR treatment. Without background P (the OK-PS and 100K-PS treatments), that advantage was an average of only 374 kg/ha over the FR treatment. This means the background P was having a 2.9 times bigger effect on yield than the K treatments.

## Sulfur

There was consistently no response to the banding of sulfur across both crops (Figure 7). There was a consistent significant difference between the treatments without background P and K (0S-PK, 30S-PK) and those that received it (0S, 10S, 20S and 30S) of between 500–700 kg/ha. There was a small significant difference between the FR and 0S-PK treatments in the sorghum crop (325 kg/ha), but this difference was not evident in the following chickpea crop.

## Economic analysis

Economic assessment of the P experiment treatments (Table 4) show all treatments except 0P achieving positive returns in the second crop (chickpea in 2018). Currently there is minimal difference in total benefit between 40P and 40P-KS; with 40P –KS having a higher ROI due to ~\$100/ha lower upfront cost. Both sorghum and chickpea have been responsive to deep-P, however there was minimal K response for deep-planted chickpea. The continuation of expected benefits in future years will no doubt add directly to the profit from deep-P applications. Whilst the ROI of treatments can change over time, it usually improves for higher rates of P as these have the longest expected duration.



**Figure 7. Mean grain yields from deep S trial for 2016 sorghum and 2018 chickpea.** Means with the same letters are not significantly different at the 5% level; sorghum lsd = 185, chickpea lsd = 213.

**Table 4. Cumulative benefit (\$/ha) analysis of two crops grown on the deep-placed P trial using the FR treatment as the baseline.**

P rate (kg/ha)	Sorghum 2016	Chickpea 2018	ROI
0	-\$106	-\$114	-0.6
10	-\$9	\$359	1.5
20	-\$58	\$458	1.7
40	-\$6	\$766	2.3
0P - KS	-\$1	\$19	0.2
40P - KS	\$88	\$725	3.4

**Table 5. Cumulative benefit (\$/ha) analysis of two crops grown on the deep-placed K trial using the FR treatment as the baseline.**

K rate (kg/ha)	2016 Sorghum	2018 Chickpea	ROI
0K	\$64	\$547	3.3
25k	\$43	\$428	2.2
50K	\$71	\$498	2.2
100K	\$25	\$531	1.8
0K-PS	\$4	-\$11	-0.1
100K-PS	-\$87	-\$141	-0.6

Reinforcing the primacy of P limitations at this site are the K trial results (Table 5). There were no significant differences between treatments receiving 0-100K, but where there was no background P, both 0K-PS and 100K-PS treatments were worse off than the benchmark farm reference treatment. This observation is further supported by the 0K treatment having both the highest ROI and highest net benefit.

### Implications for growers

Phosphorus and potassium are often thought of as having similar characteristics in terms of nutrient mobility and plant uptake. This often means the solution to observed deficits is the same by using the deep banding of these nutrients together; therefore there is a saving in mechanical cost, soil disturbance and application time. However, there are situations where applying just one nutrient has a more favourable result.

This particular site has shown very strong responses to P nutrition and inconsistent responses to K. Based on the soil analysis this not surprising, as the soil test would indicate the response to K should be negligible. In this scenario when evaluating how much fertiliser to put down in a deep application, the trial data indicates there is far more benefit in just applying P at the highest rate possible.

The trial data would suggest that as the highest rate of P (40 kg P/ha) gave the highest grain production, there may have been even greater yield responses if higher P rates had been tested. The addition of 50kg K/ha as background fertiliser in the P trial failed to make a significant response, although as the increase in P from 20 kg/ha to 40 kg/ha did make a significant response in both crops, the K trial may have still been slightly P-limited.

The economic analysis also confirms this point; the strongest return on investment after two crops was where the maximum amount of P was applied without any associated K application (40P-KS = 3.4, 0K = 3.3). Therefore when equipment capacity and cost of application is limited, there can be ultimately a greater benefit in increasing the rate of the primary limiting nutrient and dropping the other one out of the mix altogether. This is why the decisions based around the soil analysis are ultimately so important for long term yield improvement.

### Acknowledgements

It is greatly appreciated to have the continued support of trial co-operators, by hosting this trial site. This work is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under project UQ 00063 Regional soil testing guidelines for the northern grains region.

### Trial details

Location:	Clermont
Crop:	Chickpea
Soil type:	Dark Grey, Brown Vertosols (open downs) on minor slopes
In-crop rainfall:	8 mm
Pre-plant/plant fertiliser:	20 kg MAP/ha