Responses to deep placement of phosphorus and potassium in chickpea—Comet River

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Research Question: *Can deep-planted chickpea respond to residual deep bands of phosphorus and potassium, with low in-crop rainfall?*

Key findings

1. 20% yield response to deep-placed phosphorus at the highest rate in the third year of production.
2. No significant response to deep-placed potassium.

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) 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?

The Comet River trial site was first treated with deep-banded fertiliser treatments in November of 2015 and has had three crops planted and harvested since then (chickpea 2016 and wheat 2017). The third crop, chickpea, was planted on 25 May 2018 and harvested on 27 October 2018. The original soil test from the site (Table 1) would indicated adequate levels of P and K in the top 10 cm but a significant change in that analysis in the deeper layers (10-30 cm, 30-60 cm).

Table 1. Original soil analysis for the site.

Depth (cm)	Nitrates	Colwell P	Sulfur (KCl-40)	Exc. K	BSES P	ECEC
0-10	8	22	4.5	0.46	24	20
10-30	10	5	5.3	0.12	5	21
30-60	7	<2	4.3	0.1	3	27

Phosphorus

There were seven unique treatments (0P was doubled up to make eight plots per replicate) for the P trial (Table 2), 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 last treatment was a farmer reference (FR) plot, to act as a benchmark control treatment. The FR treatments had nothing extra applied compared to normal commercial practice from season to season (Table 2).

Table 2. Summary of original nutrient application rates (kg/ha) for phosphorus and potassium trials.

Treatment	N	P	K	S	Zn
Phosphorus					
0P	80	0	50	20	2
0P	80	0	50	20	2
10P	80	10	50	20	2
20P	80	20	50	20	2
40P	80	40	50	20	2
0P-KS	80	0	0	0	2
40P-KS	80	40	0	0	2
FR	0	0	0	0	0
Potassium					
0K	80	20	0	20	2
0K	80	20	0	20	2
25K	80	20	25	20	2
50K	80	20	50	20	2
100K	80	20	100	20	2
0K-PS	80	0	0	0	2
100K-PS	80	0	100	0	2
FR	0	0	0	0	0

These treatments were banded using a fixed tyne implement which delivered the P and K at 25 cm depth; the N and S at 15 cm depth. The bands of fertiliser were placed 50 cm apart in plots that were six metres (m) wide by 32 m long. The bands were placed in the same direction as the old stubble rows. A split starter P treatment was also added to this trial so that each deep-P treatment was doubled to make a 'with' and 'without' starter P treatment. This effectively doubled the treatments from 8 to 16 and there were six replicates of each making a total of 96 plots for the trial.

In the 2018 chickpea crop, Granulock® Z was chosen as the starter P treatment at 40 kg/ha and the variety Kyabra$^{\phi}$ was planted at a rate of 40 kg/ha. Unfortunately due to planting conditions being very dry, the crop was deep-planted with the co-operator's 18 m minimum till planter at depth of 18 cm. This meant that the 'with' and 'without' starter strips could not be incorporated into the trial, and the whole site received the blanket rate of Granulock® Z. The crop received 118 mm of in-crop rainfall, although 71 mm of this total (60%), fell after the crop had reached maturity.

Potassium

There were seven unique treatments (0K was doubled up to make eight plots per replicate) for the K trial (Table 2), 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 last treatment was farmer reference (FR) to act as a second control. The FR plots were not treated with anything except what the farmer applied in line with normal commercial practice (Table 2).

Applications were done in the same way as the phosphorous trial and the other trial details remain the same. There were no split starter P treatments in the K trial so every plot received starter P (Granulock® Z @ 40 kg/ha).

Difference between chickpea seasons; 2016 (right) and 2018 (left).

Table 3. List of commercial granular products used in nutrient treatments.

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

Data collection was done in the same way for both trials. 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. At harvest, a grain sample was taken from each plot and processed for nutrient analysis. Both the dry matter samples and the grain samples were ground and subsampled for wet chemistry analysis.

Results

Phosphorus

Despite the dry seasonal conditions which forced this trial to be a deep sown crop the response to deep-P is still evident (Table 4). Any treatment that had deep-P applied gave between a 240–320 kg response (15–20%) above the 0P treatment, and a 360-460 kg response relative to the standard grower practice (25-30%).

This has been a consistent response to deep-P over the three crops that have been grown at this site (Figure 1), however the wheat in 2017 experienced very dry conditions and did not have an opportunity to develop a secondary root system. Consequently yields were low (<1.2 t/ha) and the much smaller differences were not statistically significant, despite the pattern of response being similar to previous results (Figure 1).

Table 4. Mean grain yields across all treatments in P trial for chickpea in 2018.

Treatments	Mean grain yield (kg/ha)		Relative difference to '0P' plots (kg/ha)	Relative difference to '0P' plots (%)
FR	1413	b	-114	-7.5
0P-KS	1448	b	-79	-5.2
0P	1527	b	0	0.0
10P	1810	a	283	18.5
20P	1768	a	241	15.8
40P	1841	a	314	20.6
40P-KS	1796	a	269	17.6

Least significant difference P(0.05); means with the same letter are not significantly different (lsd = 210).

While there is always fluctuation between years and seasons, the cumulative effects of the highest rate of deep-P addition after three years of cropping have been an extra 1900 kg/ha of grain compared to the FR treatments and 900 kg/ha more grain than the 0P treatment (Figure 2). It is interesting to note that the size of the cumulative response to deep-P alone (i.e. with the same background nutrient addition and tillage, at 900 kg/ha) was effectively the same as the quantum of response to the tillage and background nutrients themselves (i.e. 1000 kg/ha, Figure 2). Some of this 'background' response (25-30%, or 250-300 kg/ha) was clearly due to the application of K and S, as the '0P-KS' and '40P-KS' treatments were consistently ~5% lower yielding than the corresponding treatments with K and S added (Figure 1). The remaining response was due to the combined effects of extra N and Zn, in addition to the tillage effect presumably allowing for greater exploitation of the soil volume.

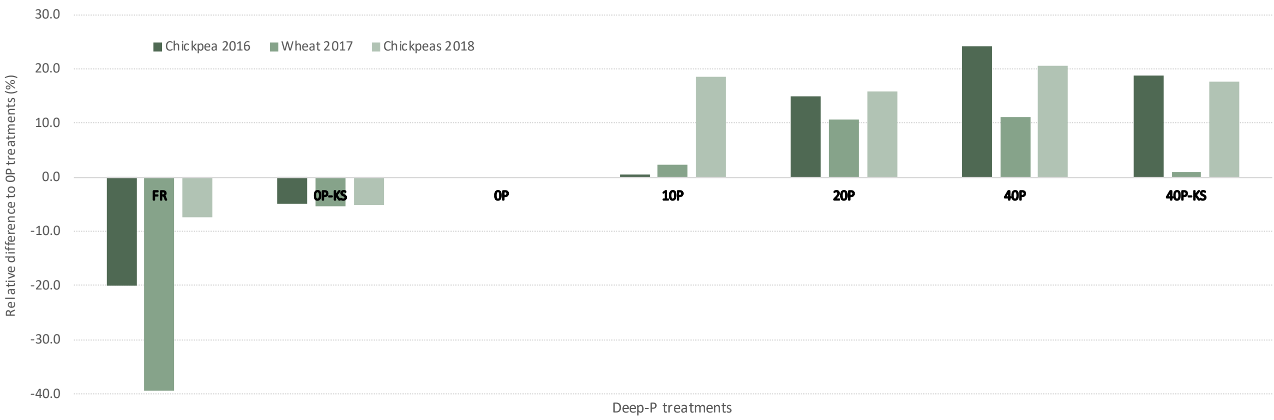

Figure 1. Comparison of relative differences in grain yield across deep-P treatments for three consecutive crops.

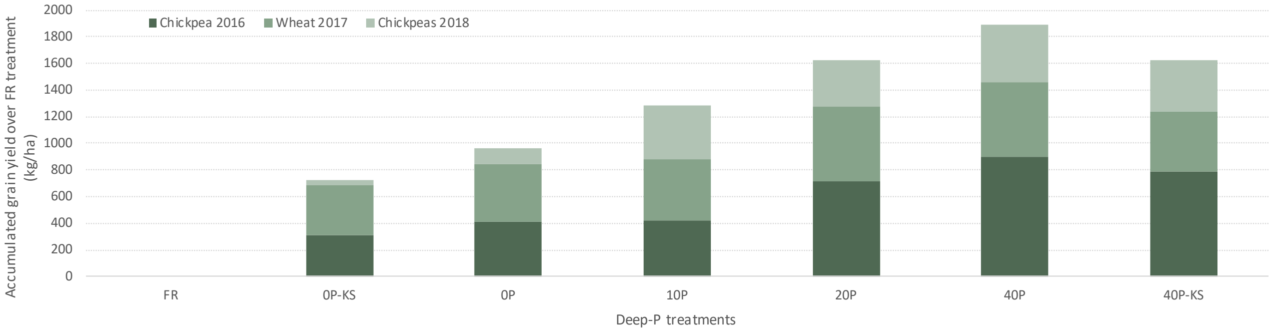

Figure 2. Mean accumulated grain production for each P treatment over and above the FR treatment.

Deep-P treatments at this site have been highly profitable, with both 20 and 40P increasing profit by ~$800/ha over 3 years (Table 5). Each of the treatments returned positive returns in the first year with subsequent years all adding directly to profit. The 20P treatment currently has the highest ROI, however 40P has generated the greatest extra profit; returns in future years will affect final ROI.

Table 5. Cumulative deep-P profit compared to FR over 3 years.

P rate	2016 - chickpea	2017 - wheat	2018 - chickpea	ROI
0P	$144	$276	$345	1.9
10P	$119	$259	$528	2.5
20P	$395	$563	$788	3.2
40P	$409	$578	$853	2.8

It is worth noting the variability in Colwell P analysis at this site. Recent soil tests show average Colwell P concentrations for each replicate showing a degree of inconsistency both in surface and subsurface levels (Figure 3). This makes it more difficult to establish clear treatment responses in grain yield, especially when yields are low. To illustrate the effects this has on crop yield in the 2018 season, the individual plot yields for the FR plots (6 replicates * 2 plots per replicate) are plotted against Colwell P in the 10-30 cm layer (Figure 4).

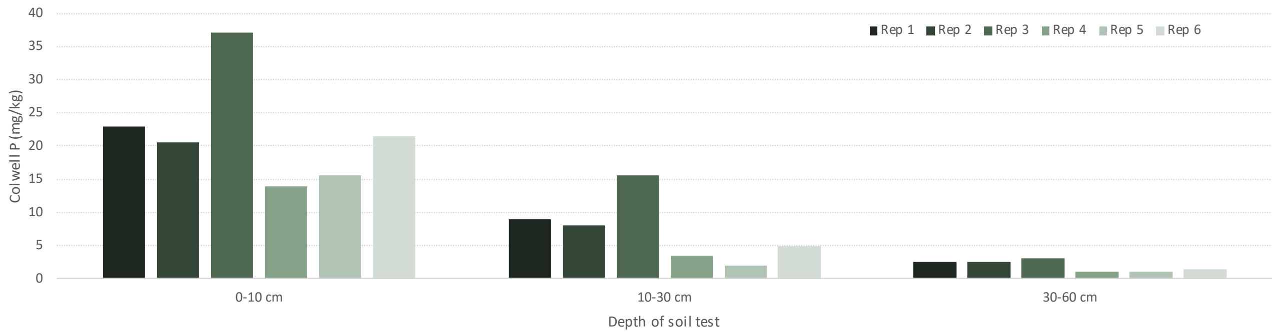

Figure 3. Results for Colwell P tests taken in each replicate across the P trial at three depths.

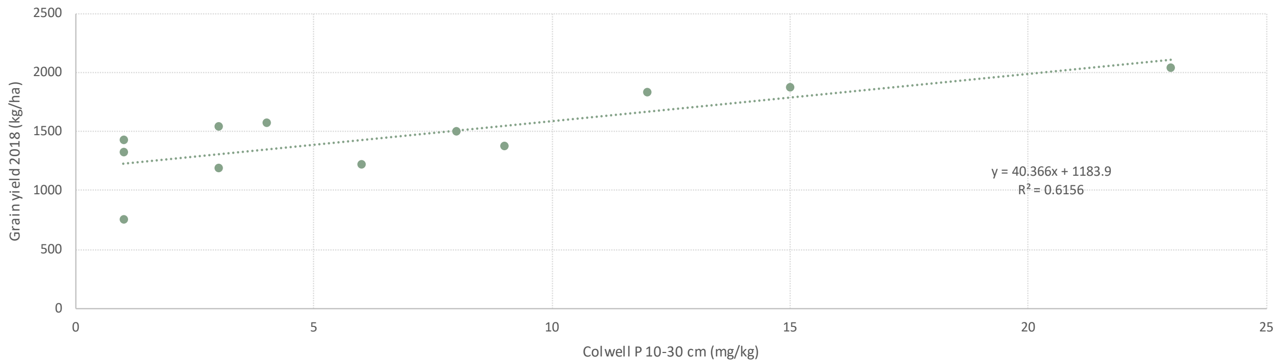

Figure 4. Relationship between Colwell P (10-30 cm layer) and grain yield for the FR plots across the P trial.

Potassium

In contrast with the P trial the grain yields from the K trial showed no statistically significant response to deep placed K, even though treatments that had additional K and background P were consistently higher-yielding than the treatment with background P but 0K (Table 6).

Table 6. Mean grain yields across all treatments in K trial for chickpea in 2018.

Treatments	Mean grain yield (kg/ha)		Relative difference to '0K' plots (kg/ha)	(%)
FR	1309	b	-199	-13.2
0K-PS	1425	ab	-83	-5.5
0K	1508	ab	0	0.0
25K	1634	a	126	8.4
50K	1579	ab	71	4.7
100K	1571	ab	63	4.2
100K-PS	1477	ab	-31	-2.1

Least significant difference P(0.05); means with the same letters are not significantly different (lsd = 260).

This trial site has shown inconsistent results in regards to responses to deep-placed K across the three crop seasons (Figure 5). The initial chickpea crop in 2016 showed no positive responses to increasing rates of applied K, which was perhaps not surprising given the relatively wet growing season (in-crop rainfall of 208 mm) and the more-than-adequate K supply in the top 10 cm layer (0.46 cmol/kg). What was surprising was that a number of the treatments that received P and K tended to yield less than with P alone, with the reasons for this not immediately obvious.

In 2017 the wheat crop showed an increasingly positive response to increasing rates of K addition, although the differences were not large enough to be statistically significant. This was largely because the crop was severely water limited (31 mm in-crop rainfall), growing on a primary root system and with a low plant population. The combination of natural variability across the trial and low yielding conditions was always going to make it difficult to find significant differences.

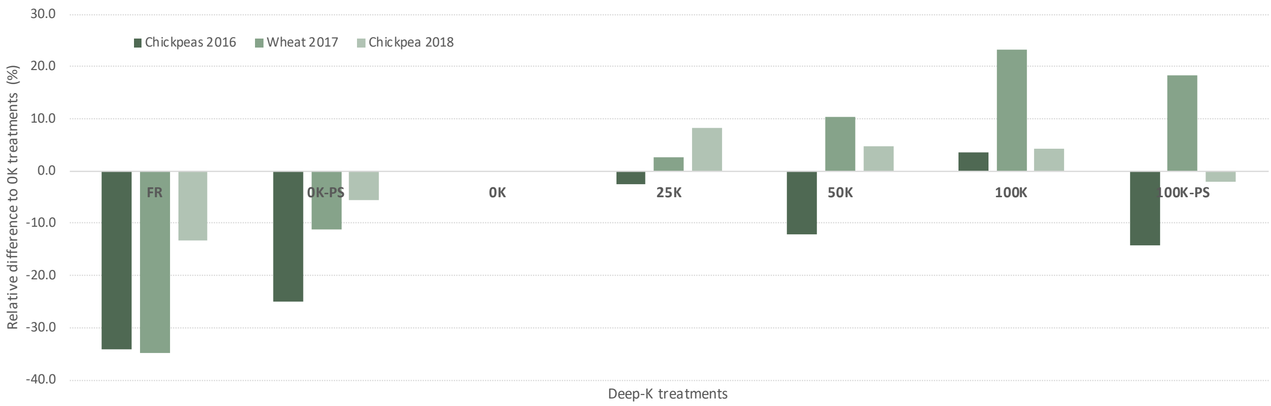

Figure 5. Comparison of relative differences in grain yield across deep-K treatments for three consecutive crops.

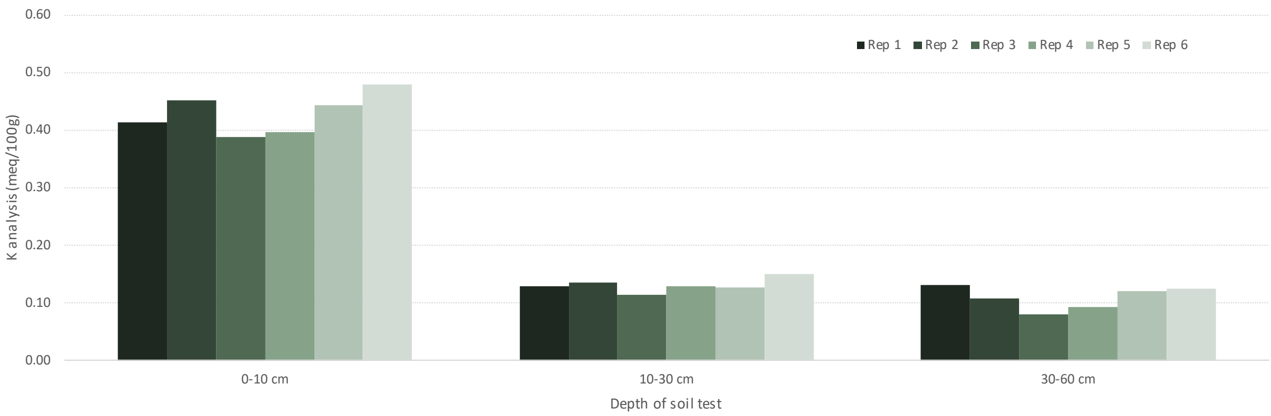

Figure 6. Results for exchangeable potassium in soil tests taken in each replicate across the potassium trial at three depths.

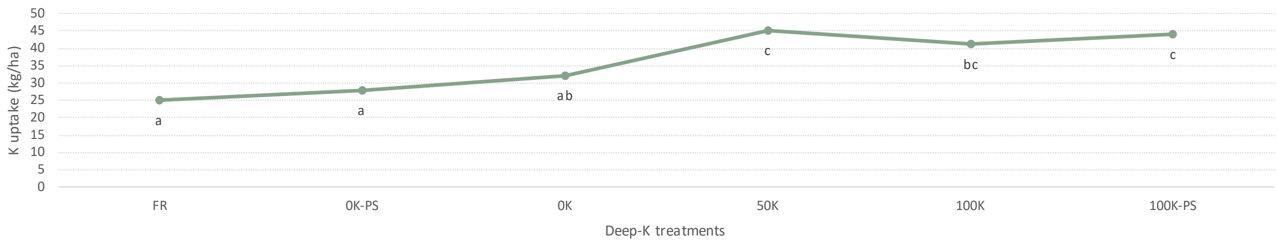

Figure 7. Results for potassium analysis in total dry matter across deep-K treatments in 2018 chickpea.

The 2018 chickpea crop was deep-planted on stored moisture with no in-crop rainfall for the first 35 days. This meant that the plant would have had no access to the surface profile (0-10 cm) and was solely reliant on the K that was available in the subsurface layers (10-30 cm, 30-60 cm). Soil analysis figures (Figure 6) across the trial showed a large decline in the amount of available K in these deeper layers, which should mean an ideal situation for a response to deep-K placement. Grain yields (Table 6) have proven to be unresponsive and in comparison to the previous crops have shown almost no change in relation to the 0K treatments.

It is interesting to note that the plant analysis (Figure 7) did indicate a significant response to deep-K placement in terms of plant K uptake. Although data variability precluded differences being statistically significant, the treatments with additional K have accumulated 8-10 kg/ha higher levels of K in total dry matter compared to treatments receiving P alone, and up to 20 kg/ha more than the FR treatment. This means that the combination of improved P nutrition and soil disturbance, combined with deep-K applications, was able to improve crop K acquisition substantially—even though there was no yield response.

The overall yields (1.3–1.6 t/ha) would suggest water was a major yield constraint in this growing season, limiting the potential K demand to meet a water-limited yield potential. Crop K acquisition in the plots without added K ranged from 25-32 kg K/ha, which was most likely adequate to grow the 3-4 tonnes of crop biomass and achieve crop yields of 0.7-1.1 t/ha. With yield potentials limited by availability of water, increased crop K uptake was therefore unable to deliver higher crop yields.

It is interesting to note that there was a difference in crop yield potential between the K trial and the P trial. While there was no significant difference between P treatments (10P, 20P, 40P, 40P-KS) the average yield across these treatments was 1800 kg/ha in contrast with the average of all the K treatments that received background P (100K, 50K, 25K, 0K), which was 1570 kg/ha. The lack of apparent P rate responses would suggest the 20 kg P/ha applied throughout the K trial (to overcome P limitations) should have been enough to allow a K response to manifest. However, the variability in P status across the site and the 15% difference in potential yields between the two trials suggest that there could have been another yield-limiting factor (perhaps low P) that was impacting the crop response to K.

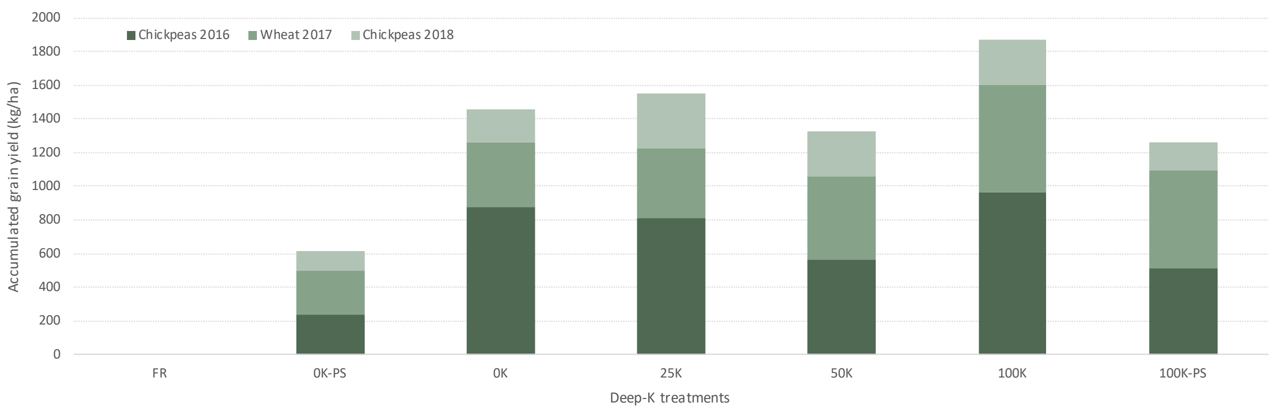

Figure 8. Mean accumulated grain production for each potassium treatment over and above the FR treatment.

The accumulated grain yields for this K trial (Figure 8) do not show as large a response to the deep-banded treatments as the P trial. While there is an 1800 kg/ha advantage over three crops for the 100K treatment over the FR treatment there is only a 400 kg/ha difference between the 0K treatment and the 100K treatment. This means the payback period on getting a return from the investment in deep-banding K will be longer. It also indicates that this site is far more responsive to P than K, and the investment in P is far more profitable over a shorter time frame.

Implications for growers

This site has been one in which the variable P status across the site has meant that clear deep banding responses can be difficult to demonstrate conclusively, especially for a secondary nutrient limitation like K in a season where water stress constrains potential yields. Not all soil types are necessarily this variable and the ones that are tend to be well known or obvious, particularly if using yield mapping data. Trials situated on these soil types can result in variability masking responses to deep P or K applications.

Well-validated critical nutrient concentrations become more important at these sites. On average, this site would seem to be mostly limited by P although the levels can change from 15 mg/kg to <2 mg/kg in the 10-30 cm layer across the site. This is reflected in the solid 15-25% yield increase with deep-P, despite some parts of the trial showing little response. Where this situation occurs the banding of deep-P can have a levelling effect across the whole management area so that yields and maturity across a field become more uniform. This has management implications for the timing of harvest and the use of pesticides.

The overall K response at this site is far more variable than P from season to season, even though soil analysis would suggest the subsurface layers are K-depleted. The data from this site would suggest that whilst low, this site may still be able to provide enough K to allow smaller crop yields to be obtained without K becoming limiting.

At these low yields, small differences in topsoil access or root morphology may make a big difference in the frequency of fertiliser responses. However, it would be expected that in seasons with higher potential yields and greater nutrient demands, this balance between supply and demand may not be sustained and fertiliser responses become more obvious. When a site is both P and K limited then it would seem that the P limitation will often dominate, and there is bigger yield gain from P than K in those circumstances. The interactions between the two nutrients when both are limiting yield is not well understood and there needs to be more crop data gathered from these particular sites.

In these variable soil types it is critical for growers and agronomists to know the chemical analysis of the profile both in depth and spatially across the paddock. Yield maps, grain quality data and EMS surveys can help with identifying the different areas that require separate soil test analysis. This information goes a long way towards making the best use of deep placement nutrition.

Acknowledgements

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Trial details

Location:	Comet River
Crop:	Chickpea
Soil type:	Grey, Brown Vertosols (Brigalow scrub) on minor slopes
In-crop rainfall:	118 mm
Fertiliser:	40 kg/ha Granulock® Z at planting