Responses to deep placement of phosphorus and potassium in mungbeans—Dululu

Doug Sands[1], Dr David Lester[1], James Hagan[1] and Prof Michael Bell[2]
[1]Department of Agriculture and Fisheries
[2]University of Queensland

Research Question: *Do mungbeans respond to residual bands of deep-placed phosphorus and potassium in the same way as chickpeas?*

Key findings

1. Mungbeans did not respond to deep phosphorus treatments.
2. Mungbeans had a 15% yield response to deep potassium treatments.
3. After 3 years of cropping the return on investment to 20 kg deep banded phosphorus is 1.6 and 100 kg deep banded potassium is 1.7.

Background

Over the last four 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 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 an application of P or K placed as a band in the subsurface profile can provide a grain yield benefit and whether that benefit (response) can be maintained over several years. These results are being used to define the economic benefit of adding these non-mobile nutrients over successive cropping cycles.

What was done?

The Dululu trial site was first treated with deep banded fertiliser treatments in November of 2015 and has had three crops planted and harvested since then (wheat 2016 and chickpea 2017). The third crop, mungbeans, was planted on 27 November 2017 and harvested on 23 February 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).

Phosphorus (P)

There were seven unique treatments (Table 2; 0P was doubled up to make 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 last treatment was a farmer reference (FR), to act as a benchmark control treatment. The FR

Table 1. Original soil analysis for the Dululu site.

Depth (cm)	Nitrate nitrogen (mg/kg)	Phosphorus Colwell (mg/kg)	Sulfur (KCl-40) (mg/kg)	Exc. potassium (meq/100g)	Phosphorus BSES (mg/kg)	PBI	ECEC (meq/100g)
0-10	7	17	4	0.23	21	99	22
10-30	22	3	7	0.12	5	109	28
30-60	18	1	18	0.09	4	81	29

treatments had nothing applied except what the farmer applied in line with normal commercial practice from season to season (Table 2).

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 28 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 four replicates of each making a total of 64 plots for the trial.

In the 2018 mungbean crop, Granulock® Z was applied as the starter P treatment at 40 kg/ha and the variety Crystal⁽ᵖ⁾ was planted at 20 kg/ha. The crop received 139 mm of in-crop rainfall.

Potassium (K)

There were seven unique treatments (Table 2; 0K was doubled up to make eight plots per replicate), which included four K rates; 0, 25, 50, 100 kg K/ha. All of 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 a 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; every plot received starter P (Granulock® Z @ 40 kg/ha).

Data collection for both trials included emergence plant counts, with starting soil water and N measurements taken shortly after emergence. Total dry matter cuts were taken at physiological maturity and yield measurements were taken with a plot harvester when commercial harvesting started in the same paddock. A grain sample was kept from each plot for nutrient analysis. Both the dry matter samples and the grain samples were ground and subsampled for a wet chemistry analysis.

Table 2. Summary of nutrient application rates (kg/ha) for both 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

Results

Phosphorus

Despite this crop receiving 139 mm of in-crop rainfall its general yield performance was not high with yields between 0.7 to 0.8 t/ha. It is quite often difficult to extract clear significant differences from low-yielding crops. The yield data (Table 3) would suggest there was no response to the deep placement of P despite there being a close to a 15% response in the previous chickpea crop (Figure 1).

Table 3. Mean grain yields for 2018 deep-P trial in mungbeans.

Treatment	Mean grain yield (kg/ha)		Relative yield difference to '0P' plots (kg/ha)	(%)
FR	717	a	-151	-17
0P-KS	793	ab	-75	-9
0P	868	c	0	0
10P	839	bc	-29	-3
20P	843	bc	-26	-3
40P	858	bc	-10	-1
40P-KS	821	bc	-47	-5

Letters indicate least significant difference P(0.05). Means with the same letters are not significantly different (lsd = 69) .

The only significant difference in the P trial was the relative poor performance of the FR treatment in comparison with all other treatments (Table 3). There will be a background K influence on this performance as proven

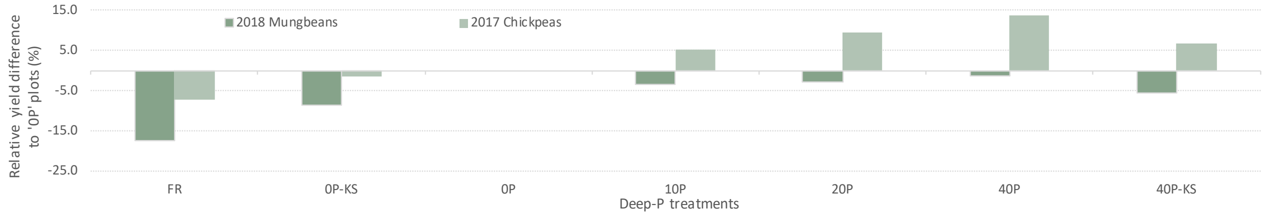

Figure 1. Comparison of relative yield response to deep-P between 2017 chickpea and 2018 mungbean crops.

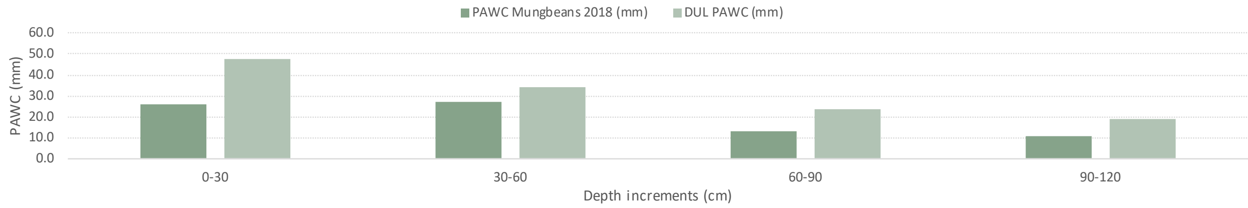

Figure 2. Mean starting plant available water content (PAWC) in comparison to estimated drained upper limit for this site soil type (full moisture profile).

by the results in the K section of this report however there was a significant difference between the FR plots and the 40P -KS treatments (Table 3), which may indicate another factor (not easily defined) is having a small impact on the mungbean yields.

The poor crop result from such good in-crop rainfall (Figure 4) seems contradictory; however part of the reason could be attributable to the modest starting soil moisture levels at planting (Figure 2). The profile was not full at planting which means through redistribution of moisture over time the plants may have been running dry before rainfall was received in early January (Figure 4). Stressing plants through the vegetative growth phase has the potential to limit yield, as has been proven by other project data (Queensland Pulse Agronomy Initiative, 2013-2018).

Plant analysis would indicate that the mungbean crop did not access the P nutrition bands in the same way that the chickpea crop did in the previous year (Figure 3). It is also worth noting that the P concentration in the dry matter (%) for the mungbeans is consistently higher, however mean plant uptake (kg/ha) matches the levels attained in the chickpea where deep-P was supplied (Figure 3).

This would indicate that the mungbeans in 2018 had enough access to P to not limit yield without having to utilise the deep-placed bands. Recent soil analysis from the P trial (Table 4) would suggest that the surface soil (0-10 cm) has more than adequate soluble P supplies. This may also explain why there was no response to starter P at planting in this trial (data not shown). However the subsurface layers (10-30, 30-60 cm) are the opposite with soluble P levels almost non-existent. This would mean that the mungbean crop extracted enough P to meet demand from the surface soil however this could only occur while the surface soil is wet enough for nutrient extraction to occur.

Rainfall figures would suggest that the surface soil was wet from 30 DAS through to 50 DAS. Later rainfall at 68 DAS would have been largely irrelevant as the crop was defoliated by 75 DAS. This means a large proportion of the P required

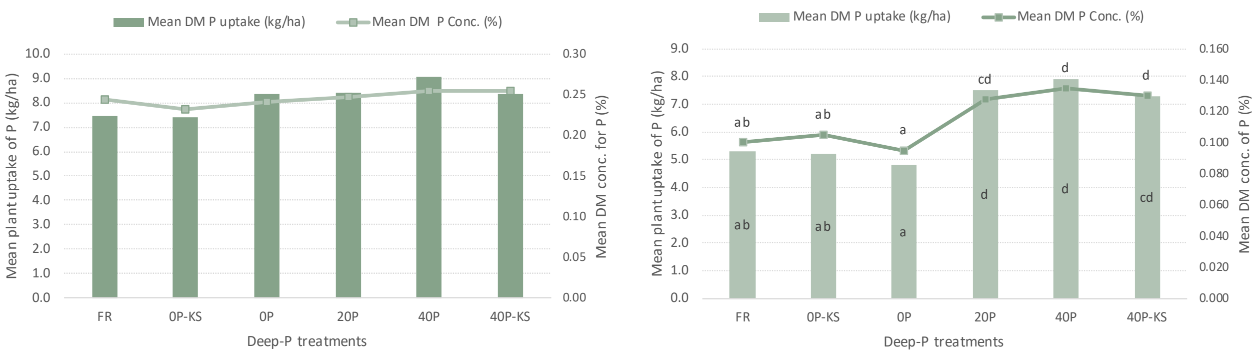

Figure 3. Phosphorus concentration in total dry matter and overall plant uptake in kg/ha for 2018 mungbean (left) and 2017 chickpea (right).

Table 4. Soil analysis taken from FR plots in each replicate of the P trial at the planting of the 2018 mungbean trial.

Depth (cm)	Replicate	Values (mg/kg)*	
		Colwell P	BSES P
0-10	1	20	18
	2	19	22
	3	30	32
	4	29	30
10-30	1	2	1
	2	1	1
	3	1	2
	4	1	2
30-60	1	1	1
	2	1	1
	3	1	2
	4	1	2

* Laboratory analysis cannot measure less than 2 mg/kg. This result is represented in the table as a 1.

by the plant was taken during the 20 day period starting just before flowering (first flower 40 DAS). Moisture at planting would have provided some opportunity to access P in the surface layers however the plant would have had a limited root system during the first two weeks after planting and uptake of P would have been limited by this.

Days above 35 °C were rare for this crop (Figure 4) and humidity levels were generally above 45%, so surface soil layers may have retained moisture for longer giving better access to surface nutrients. Mungbeans may also be able to redistribute P around the plant better than other crops. This is an unknown aspect as this is the only mungbean crop that has been grown on a deep-P site so there is no other data to compare.

Canopy closure had not occurred close to flowering. This indicates some stress in the vegetative growth phase slowing down biomass accumulation.

Potassium

In contrast to the P trial, there has been a significant response to the deep-applied K treatments. All treatments that had K supplied (25K, 50K, 100K and 100K-PS) were significantly different to the 0K treatments (Table 5). Also worth noting is that treatments where the background P and S was not supplied (100K-PS and 0K-PS) were not significantly different to yields where P and S ere included, further confirming the results in the P trial where there was no significant response to P.

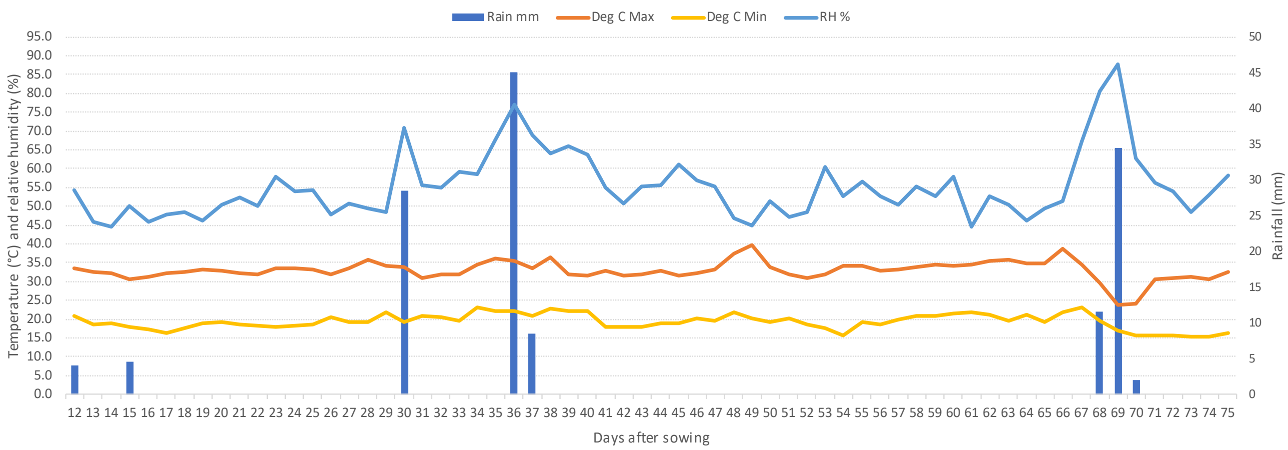

Figure 4. Rainfall, temperature and relative humidity data recorded for the duration of the 2018 mungbean crop.

Table 5. Mean grain yields for 2018-19 deep-K trial in mungbeans.

Treatment	Mean grain yield (kg/ha)		Relative yield difference to '0K' plots (kg/ha)	(%)
FR	665	a	26	4.0
0K-PS	619	a	-20	-3.1
0K	639	a	0	0.0
25K	725	b	86	13.4
50K	741	b	102	15.9
100K	735	b	96	15.0
100K-PS	759	b	120	18.7

Letters indicate least significant difference P(0.05). Means with the same letters are not significantly different (lsd = 47).

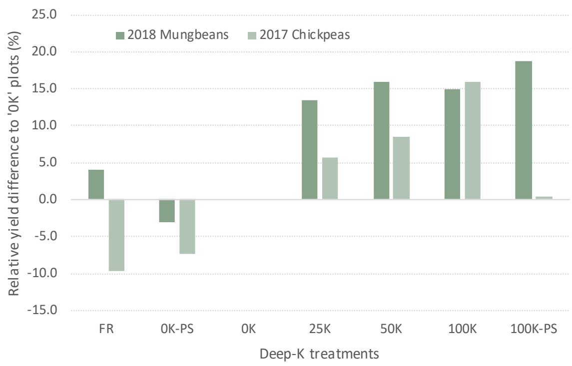

Figure 5. Comparison of relative yield response to deep-K between 2017 chickpea and 2018 mungbean crops.

While mean yields are generally considered low, the relative yield differences (%) are similar to the previous chickpea crop grown on the site in 2017 (Figure 5).

The 2018 mungbean crop has shown a more consistent response to the deep-applied K than chickpea, however the chickpeas were also clearly responsive to P bands at the same time as demonstrated by the change in yield response when the background P was removed from the treatment (100K -PS and 0K –PS) (Figure 5). Plant analysis can confirm that the mungbean crop was accessing the deep-applied K bands (Figure 6).

The plant analysis data shows that both the chickpeas (2017) and the mungbeans (2018) had similar patterns of uptake when comparing the 0K treatment and all other treatments that contained K. An interesting point in this comparison is the concentration of K in dry matter (DM) is higher in the mungbeans than in chickpeas and subsequently total K uptake (kg/ha) is also higher in mungbeans. This is surprising given that the chickpeas in 2018 produced, on average, 5.2 t/ha of DM versus the mungbeans that produced, on average 3.5 t/ha.

This means that in general terms mungbeans have either a higher requirement for K than chickpeas or the mungbeans have taken up luxury levels of K, given the response values at this site.

There is some conflict in the data between the K trial and the P trial in respect to the 2018 mungbean crop. It is clear that the mungbean plants had access to the deep bands of fertiliser in regards to K uptake but seemingly did not take up P even though both elements were placed in the same band. Logic would suggest that if the circumstances were good enough (moisture, soil conditions) for K uptake out of the deep fertiliser bands than P should have also been taken up.

Soil analysis taken at the planting of the 2018 mungbean crop (Table 6) shows a similar pattern of stratification to the P soil tests (Table 4) although not quite as dramatic. Surface levels could be termed as adequate to marginal (>0.2) with the subsurface levels then dropping down to deficient levels (<0.15) (Table 6). While both nutrients in each trial have deficient levels in the subsurface layer, for reasons unknown at this stage, the mungbean crop has only responded to the K nutrient in these deep-placement bands.

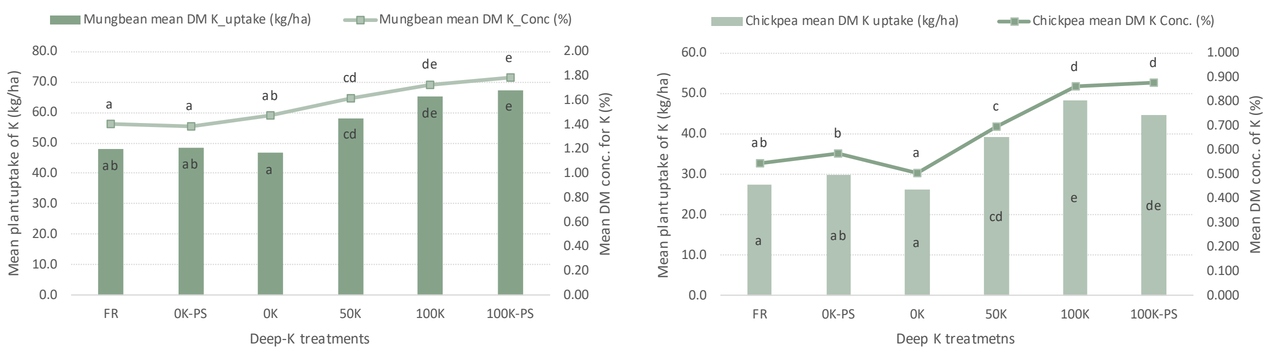

Figure 6. Potassium concentration in total dry matter and overall plant uptake in kg/ha for 2018 mungbean (left) and 2017 chickpea (right). Means with the same letters are not significantly different.

Table 6. Soil analysis taken from FR plots in each replicate of the potassium trial at the planting of the 2018 mungbean crop.

Depth (cm)	Rep	K values (meq/100g)	Mean K values (meq/100g)
0-10	1	0.237	0.212
	2	0.208	
	3	0.193	
	4	0.194	
	5	0.239	
	6	0.204	
10-30	1	0.093	0.1
	2	0.083	
	3	0.122	
	4	0.109	
	5	0.109	
	6	0.085	
30-60	1	0.084	0.104
	2	0.075	
	3	0.072	
	4	0.076	
	5	0.038	
	6	0.080	

Relative concentrations of P and K in the surface (0-10 cm) may go some way to explaining the differences in responses. The P concentration in the surface soil could be termed as luxury levels (20-30 mg/kg) whereas the K level in the surface soil could be considered marginal (0.19–0.23).

This relative difference in concentration may mean that the concentration gradient across the root membrane for P in the surface soil was a lot higher than for K and this could assist in the efficiency and quantity of uptake into the plant for P. If the concentration gradient is lower for K in the surface soil and therefore it could not take up enough K in the period when moisture in the surface soil was available; then the plant would have to meet some of its deficiency from the banded deep-K where the concentration gradient may have been more favourable for uptake. In relative terms the plant has to take up far more K (70 kg/ha) than P (8 kg/ha) to satisfy its metabolic demand which then means K may need a much wider window for uptake.

Economic analysis

Economic assessment of the P experiment treatments (Table 7) shows positive payback in the second crop (chickpea in 2017). Currently 20P and 40P with KS applied are providing the highest cumulative benefits, but the higher cost of setting up 40P over 20P is reducing the return on investment ratio (ROI) slightly. Within this three year scenario it is the chickpea response in 2017 that is driving most of the economic benefit, and paid back the original investment in the second year of production. Any further productivity gains will continue to add directly to profit and improve the ROI.

Table 7. Cumulative benefit ($/ha) analysis of three crops grown on the deep-placed phosphorus trial using the FR treatment as the baseline.

P rate (kg/ha)	Wheat 2016	Chickpea 2017	Mungbean 2018	ROI
0	-$106	$87	$267	1.4
10	-$127	$202	$348	1.5
20	-$147	$278	$428	1.6
40	-$231	$291	$459	1.4
0P -KS	-$78	$91	$181	1.8
40P -KS	-$189	$165	$289	1.3

As with P at the site, the K trial has shown the inclusion of high value pulse crops at the site has boosted economic returns (Table 8), increasing profit by the second year of production. The highest ROI has been achieved where K application rate has been greatest (100 kg K/ha) supplemented with basal P and S applications. Even though both pulse crops at this site have responded to deep-K nutrition the ROI for the K trial is similar to the P trial (Tables 7 and 8). It is worth noting that the highest rate (100K) has shown the highest ROI despite the costs for this treatment also being the highest.

Table 8. Cumulative benefit ($/ha) analysis of three crops grown on the deep-placed potassium trial using the FR treatment as the baseline.

K rate (kg/ha)	Wheat 2016	Chickpea 2017	Mungbean 2018	ROI
0	-$88	$130	$100	0.50
25	-$93	$255	$328	1.47
50	-$156	$253	$345	1.39
100	-$158	$422	$514	1.72
0K -PS	-$11	$40	-$14	-0.14
100K -PS	-$73	$156	$271	1.35

Implications for growers

The results from this trial site once again reinforce that responses to deep placed nutrients can vary in relation to crop species, seasonal weather patterns and the level of nutrient stratification. There are a number of data sets that demonstrate chickpeas can respond to deep placement of both P and K in CQ soils, however the amount of data recorded on mungbeans is limited. This Dululu site is the first deep placement trial in CQ that has had a mungbean crop harvested off it, and so no conclusion can be made in regards to the fact that the crop responded well to the K treatments but not to P despite the fact that the previous chickpea crop responded well to both P and K treatments.

Whether this pattern of response is particular to the mungbean species or more relatable to the level of stratification for each nutrient and the in-crop rainfall for the season is still difficult to determine. However, this trial's plant analyses have highlighted that a mungbean crop does have a high requirement for K in view of the plant analysis data. Further trial data will be required to ascertain the true characteristics of mungbean interaction with deep-placed P and K.

Despite the moderate yields produced in the mungbean crop in 2018 the ROI for both nutrients are positive and approaching up to two times the cost of deep placement. Future crops will boost this ROI further and will dictate which rate of nutrition will be the most economical.

Acknowledgements

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Trial details

Location:	Dululu
Crop:	Mungbeans
Soil type:	Grey, Brown Vertosols (Brigalow scrub) on minor slopes
In-crop rainfall:	138 mm
Pre-plant fertiliser:	Nil