Mungbeans: response to applied nitrogen

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Abstract
Mungbeans are becoming an increasingly important component of northern grains region farming systems. Currently, most growers inoculate crops with commercial rhizobia to promote nodulation and nitrogen (N) fixation, however, poor nodulation commonly results in N deficiency and significant yield reductions. To counteract these issues a proportion of the industry apply N to maximise yield. In response, a series of eight trials were implemented to quantify the response of mungbeans under different soil N concentrations and the impact this had on N fixation, from Emerald in Queensland to Narrabri in New South Wales. There was a strong indication that mungbeans will not respond to applied nitrogen fertiliser under a wide range of environmental conditions except for low starting mineral nitrogen and high yielding conditions under irrigation. This lack of response was due to rapid mineralisation and the plants ability to fix atmospheric N if well-nodulated. All treatments utilised mineral N (starting soil N + applied N), including the 0 kg N/ha treatments which utilised from ~50 to 75 kg N/ha except for one site. The percentage of N fixation decreased as the N rate increased at both the Emerald and Hopeland summer sites with the higher N rates not fixing any N at all, supporting the concept that mungbeans will not fix N if planted in a soil with high levels of available N.

Keywords
Mungbean, nitrogen, response, yield, fixation.

Introduction
Mungbeans are becoming an increasingly important component of northern grains region farming systems. Past trial work (unpublished) has been inconsistent, with mungbeans often not responding to nitrogen (N) applied. However, anecdotal evidence from industry is that mungbean yields increase in response to higher nitrate-N levels in the soil profile. Research shows for all legumes that the proportion of N in the plant derived from fixation decreases with increasing levels of soil mineral N. The challenge is that as growers improve their soil nutrition, and levels of soil N increase, nodulation will be reduced resulting in the mungbean crop subsequently relying on mineral N. This may result in a "danger zone" where soil N levels are too high to support nodulation but too low to optimise mungbean production.

In response, the Grains Research and Development Corporation in conjunction with the Department of Agriculture and Fisheries and New South Wales Department of Primary Industries supported the Mungbean Agronomy project team to implement a series of trials to quantify the response of mungbeans under different soil N concentrations and the impact this had on N fixation. These trials were designed to investigate the following questions:

- Can N fertiliser application be used to improve mungbean yields?
- Is there any benefit in applying N fertilisers to mungbeans in situations where inoculation is effective?
- Where do mungbeans get their N from – atmospheric fixed N or soil mineral N - and how does this change under different N concentrations?

Methods
The Mungbean Agronomy project conducted eight trials across three sites: Emerald in central Queensland, Hopeland in southern Queensland and Narrabri in New South Wales in summer 2020. Sites low in mineral N were identified via soil analysis. The following treatments were established:

1. 0 *applied* N *no* inoculation (0 kg N/ha (-inoc))
2. 0 applied N *with r*hizobium inoculation (0 kg N/ha*)*
3. 30 kg applied N/ha *with* rhizobium inoculation (30 kg N/ha)

4. 60 kg applied N/ha *with* rhizobium inoculation (60 kg N/ha)
5. 90 kg applied N/ha *with* rhizobium inoculation (90 kg N/ha)
6. 120 kg applied N/ha *with* rhizobium inoculation (120 kg N/ha)
7. 150 kg applied N/ha *with* rhizobium inoculation (150 kg N/ha)

All trials were planted with the mungbean variety Jade-AU$^{\Phi}$ on 50 cm row spacings. At each site, two experiments were located side by side, with one managed as rainfed (dryland) and the other receiving supplementary irrigation, creating two differing yield potentials. Nitrogen was applied as urea prior to planting. Plots were established using a randomised complete block design with four replications per treatment. Seed of a non-nodulating mutant of the soybean variety (cv Bragg) was planted into micro-plots within each N treatment plot. These were used as the non N-fixing reference plants for the natural abundance method (^{15}N isotope) to be able to then calculate the proportion of N in the plants that was fixed (derived from the atmosphere (%Ndfa)) by the mungbean plants under each N fertiliser treatment. The following formula was used:

$$\%\text{Ndfa of mungbean} = \frac{\delta^{15}\text{N of reference plant} - \delta^{15}\text{N of N}_2\text{−fixing legume}}{(\delta^{15}\text{N of reference plant} - \text{B})} \text{ x } \frac{100}{1}$$

where B is the δ^{15}N of shoots of mungbean that are fully dependent upon N_2 fixation and sampled at the same growth stage (given in Unkovich et al. 2008, Appendix 3). Soybeans were used as there are no non-nodulating mungbean varieties and nodulation cannot be controlled in field trial conditions.

Results

The seasons experienced at each of the sites were quite variable. The *Hopeland spring dryland* crop received no in-crop rain over 10 mm, with the *irrigated* crop receiving two irrigations (flowering and podding). Daytime air temperatures at Hopeland reached maximums above 35ºC during the time from first flower to just before desiccation. The *Emerald* trial received moderate conditions with early in-crop rain and reasonably mild temperatures. In comparison, the *Hopeland summer* and *Narrabri* trials received good in-crop rain and moderate temperatures. These weather conditions impacted yields.
Yields varied between sites, with *Hopeland spring dryland* recording the lowest yield of 0.27 t/ha through to the highest yield recorded at *Narrabri irrigated* of 2.44 t/ha (Table 1). Each trial was analysed separately using linear mixed models and significant differences (Fprob≤0.05) between treatments were detected at *Hopeland spring irrigated*, *Hopeland summer irrigated*, and at both Narrabri trials. The *Hopeland spring irrigated* site showed no yield difference between the 0 kg N/ha and 150 kg N/ha treatments, with the N rates in between achieving lower yields than these, and the 0 kg N/ha (-inoc) achieving the lowest yield overall. The *Narrabri irrigated* site showed an increase in yield with inoculation, and no difference between nitrogen treatments. Similarly, the *Narrabri dryland* site also showed no difference between nitrogen treatments. *Hopeland summer irrigated* was the only site that showed a significant increase in yield when nitrogen was applied, with significant differences between 150 kg N/ha and both 0 and 60 kg N/ha. Biomass at harvest followed similar trends (results not shown).

Table 1. Yields from all sites in 2020 in t/ha corrected to 12% moisture.

Treatment	Emerald		Hopeland spring		Hopeland summer		Narrabri	
	Irrigated	Dryland	Irrigated	Dryland	Irrigated	Dryland	Irrigated	Dryland
0 kg N/ha (-inoc)	1.15	0.66	0.76*d*	0.28	1.99*c*	1.13	2.20*bc*	1.63*bc*
0 kg N/ha	1.21	0.65	0.83*ab*	0.28	2.08*bc*	1.16	2.29*ab*	1.67*ab*
30 kg N/ha	1.28	0.77	0.81*abcd*	0.32	2.12*abc*	1.25	2.34*ab*	1.68*ab*
60 kg N/ha	1.19	0.69	0.77*bcd*	0.29	2.11*bc*	1.34	2.28*ab*	1.65*abc*
90 kg N/ha	1.16	0.81	0.78*bcd*	0.29	2.22*ab*	1.32	2.40*ab*	1.80*a*
120 kg N/ha	1.06	0.76	0.77*cd*	0.29	2.26*ab*	1.27	2.44*a*	1.60*bc*
150 kg N/ha	1.15	0.69	0.82*ab*	0.27	2.32*a*	1.30	2.40*ab*	1.74*ab*
lsd	0.42(NS)	0.17(NS)	0.55	0.05(NS)	0.20	0.14(NS)	0.23	0.15

NB: Within each experiment means with same letter are not significantly different at the P = 0.050 level. NS indicates no significant difference between treatments.

These yield results are not surprising given the starting soil nitrate-nitrogen at each of the sites (Table 2). Each site was chosen due to its low N status. However, the *Emerald, Narrabri* and *Hopeland spring* sites all had high rates of mineralisation in the weeks leading into the mungbean crop, resulting in high levels of available N at planting. As there was a cover crop planted during the spring on the *Hopeland summer* site, to minimize the nitrate-nitrogen, mineralisation rates are not applicable. Given that it is reported that mungbeans require 60 –70 kg N/t (GRDC Northern Region Grownotes – Mungbeans), the *Hopeland summer irrigated* site, with its very low starting soil N levels (52 kg N/ha), coupled with yields over 2t/ha, was the only site that showed a response to N. All other sites had sufficient N to maximize yields in the respective climatic conditions.

Table 2. Fallow and starting soil nitrate-nitrogen (kg NO_3-N/ha) and mineralisation rates.

	Emerald	Hopeland (spring)		Hopeland (summer)		Narrabri
		irrigated	dryland	irrigated	dryland	
Nitrate-N @ fallow (kg N/ha 0-90cm)	33	50	50	50	50	55
Nitrate-N @ planting (kg N/ha 0-90cm)	101	58	89	52	92	115
Mineralisation rate (kg N/ha/day 0-90cm)	0.54	0.09	0.44	NA	NA	0.45

**Values not applicable (NA) due to cover crop planted prior to sowing mungbean crop*

Soil nitrate-N was also tested at harvest (Figure 1) (only Emerald and Narrabri sites shown, all with significant differences between treatments, Fprob≤0.05). Both sites had similar starting N levels (Table 2), however the yields obtained at Narrabri were almost twice that of Emerald (Table 1). The trend in N used by the crops was similar, with the 150 kg N/ha treatment leaving significantly more N behind in the soil profile. The 0 kg N/ha treatments utilised ~ 50 to 75 kg N/ha with all N treatments utilising soil N (starting soil N + applied N) except for the Narrabri site at the 150 kg N/ha treatment. The higher yielding crop at Narrabri left far more N behind compared to the lower yielding crop at Emerald, despite its higher N requirements due to the much higher levels of available N at planting.

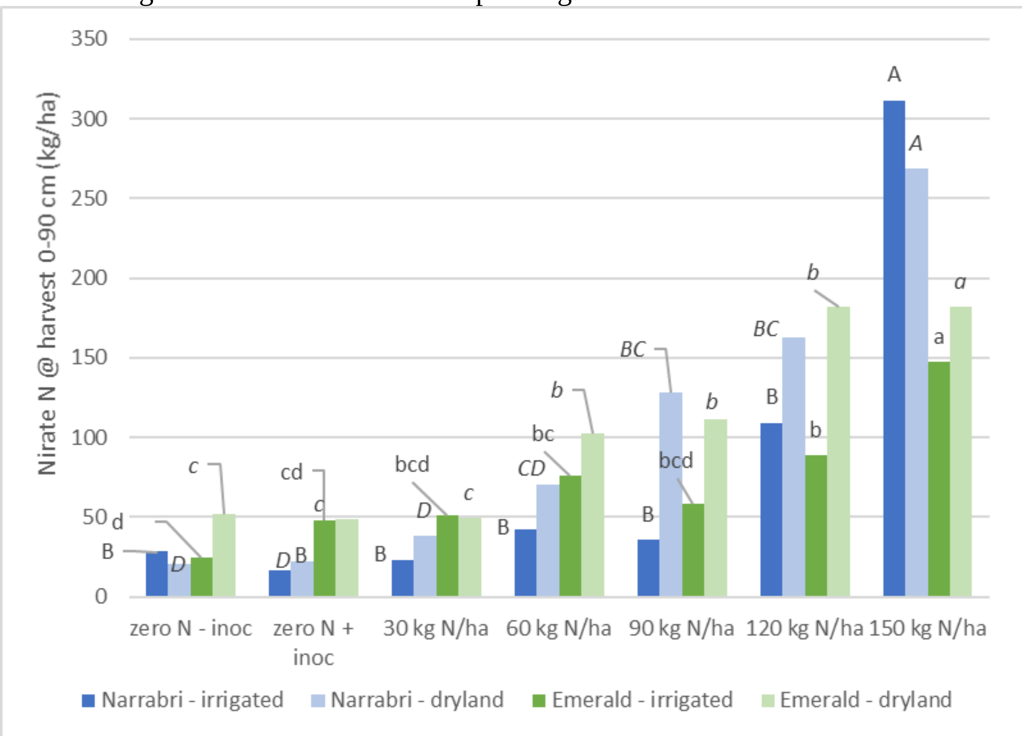

Figure 1. Nitrate-N @ harvest 0-90cm. ***Within each experiment, means with same letter are not significantly different at the P = 0.050 level using a protected LSD test.***

One of the main aims of this research was to determine the impact of varying amounts of mineral nitrogen on nitrogen fixation. These analyses were performed on the *Emerald, Hopeland summer* and *Narrabri* sites (Figure 2). There was no statistical difference between any of the treatments at Narrabri due to the high starting N levels (data not shown). However, the *Emerald* and *Hopeland summer* trials showed significant difference between treatments. Both the uninoculated and inoculated 0 kg N/ha treatments fixed similar amounts of N. This was not surprising as both treatments nodulated, indicating that there was either background rhizobia in the soil and/or contamination from inoculation. Across these sites the N fixation (%Ndfa) decreased as the N rate increased with the higher N rates not fixing any N at all. The highest N fixation was seen in the *Hopeland irrigated* site, which had the lowest starting N conditions (Table 2). This data strongly supports that as soil mineral N increases, N fixation of mungbean decreases. Given that there was very little difference detected in yield across these treatments this indicates that mungbean are able to switch from utilising fixed N to nitrate N with no yield penalty.

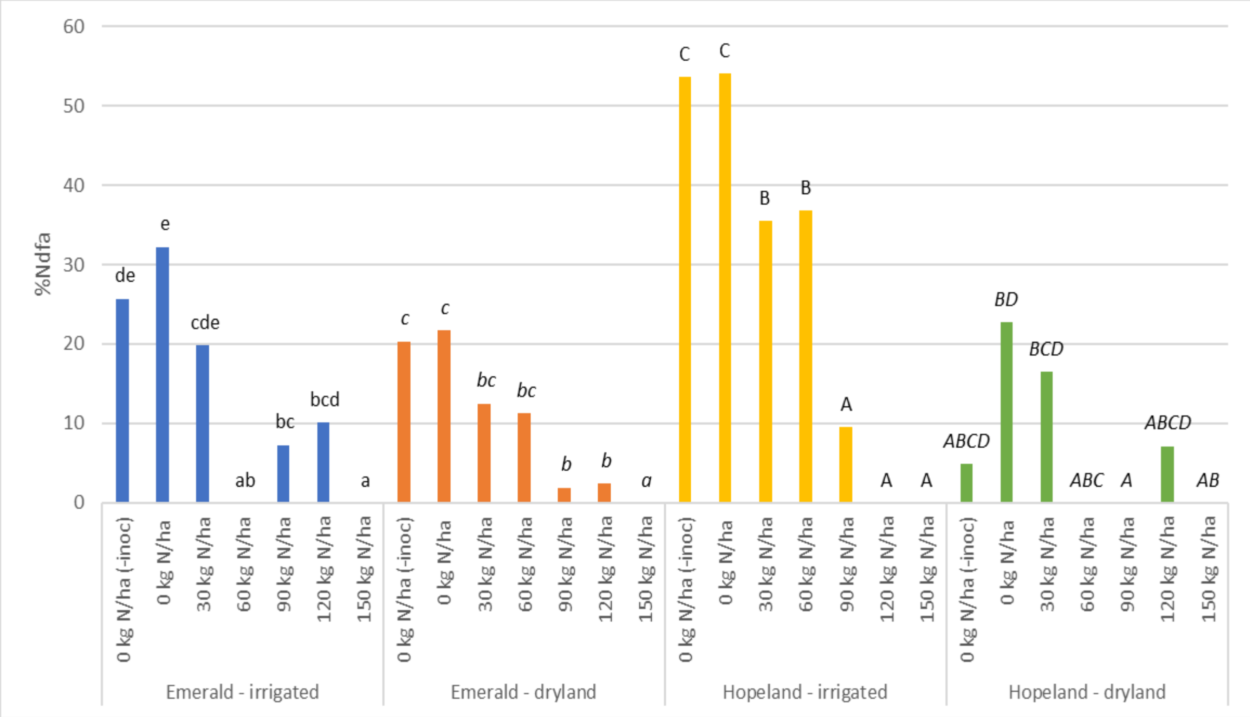

Figure 2. Nitrogen derived from the atmosphere percentage of mungbean cv Jade-AU. ***Within each experiment, means with same letters are not significantly different at the P = 0.050 level, using a protected LSD test.***

Conclusion

There was a strong indication that mungbeans will not respond to applied N fertiliser under a wide range of environmental conditions. These trials quantified the large contribution of mineralised N to the soil profile over the spring period. With this rapid mineralisation occurring in spring coupled with the plants ability to fix atmospheric N if well-nodulated, when required there was adequate available N to support mungbean yields up to 2.4 t/ha. The only trial that indicated a significant increase in mungbean yield with the application of N fertiliser (although there was no significant difference detected between rates) was the *Hopeland summer irrigated* site; the site with the lowest mineral N at planting and achieved yields over 2 t/ha. All treatments utilised mineral N (starting soil N + applied N), including the 0 kg N/ha treatments which utilised from ~50 to 75 kg N/ha except for the 150 kg N/ha treatment at the Narrabri site. The percentage of N fixation decreased as the N rate increased at both the *Emerald* and *Hopeland summer* sites with the higher N rates not fixing any N at all.

Growers are recommended to consider starting available N and yield potential of the mungbean crop to determine if to apply N fertiliser. Inoculation is still recommended to ensure adequate N is available under all N profiles. However, as N fixation decreases with increasing levels of soil N if planting mungbean on soils with moderate levels of available N mungbeans will not fix N but will instead utilise this available N which needs to be considered when N budgeting for future crops.

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