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All kinds of clever

Putting our finger on the pulse. Improving mungbean productivity in the paddock

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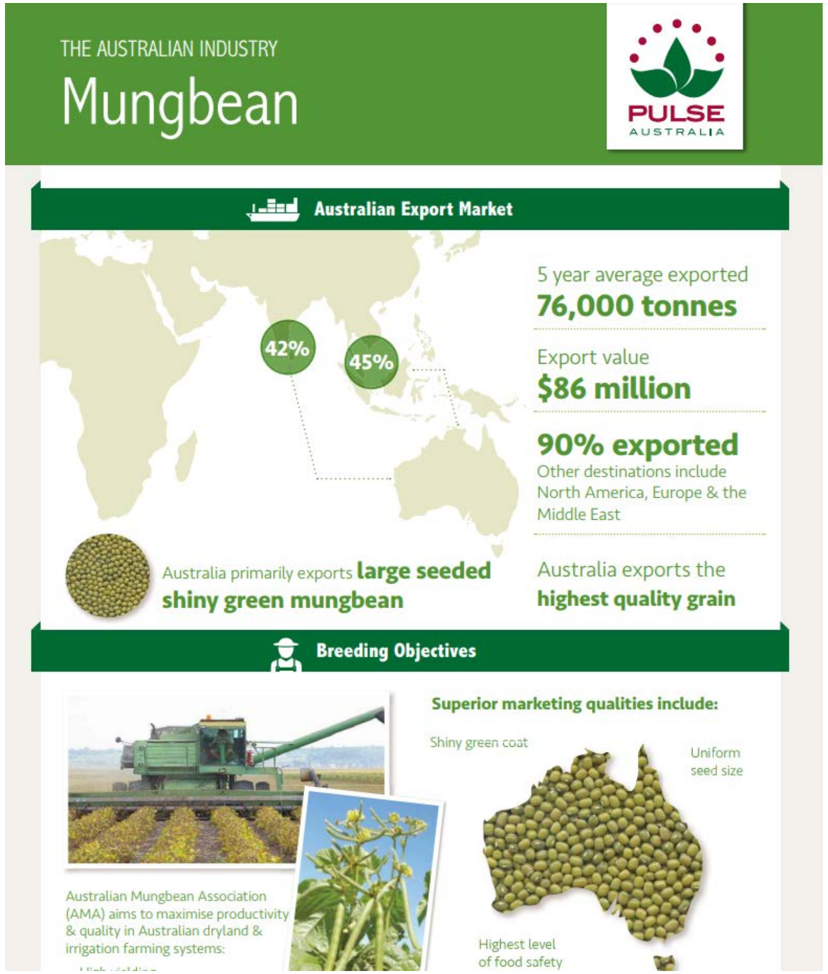
CSIRO

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

High value market and growing

- Pulses will play a vital role globally in meeting future food demands, particularly as a valuable protein source
- Global market for pulses is increasing, yet only represent < 5% crop
- The potential for the pulse crop in Australia, assuming all constraints are overcome , is to increase its current size of roughly 2.2 M t to 4.2 M t with a commodity value of A$1.5B and a farm system benefit of A$538M – a total of over A$2B



THE AUSTRALIAN INDUSTRY

Mungbean

PULSE AUSTRALIA

Australian Export Market

42%

45%

5 year average exported
76,000 tonnes

Export value
$86 million

90% exported
Other destinations include North America, Europe & the Middle East

Australia primarily exports **large seeded shiny green mungbean**

Australia exports the **highest quality grain**

Breeding Objectives

Australian Mungbean Association (AMA) aims to maximise productivity & quality in Australian dryland & irrigation farming systems:

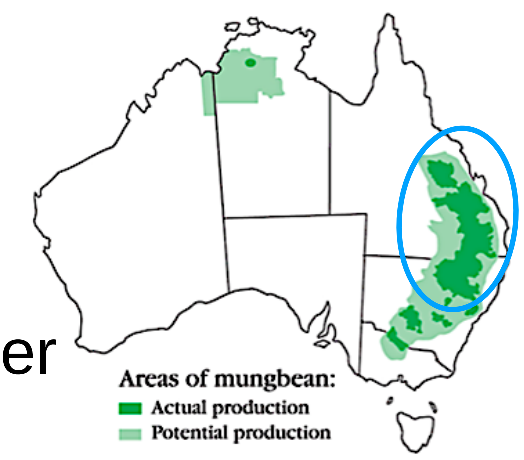
Superior marketing qualities include:

Shiny green coat

Uniform seed size

Highest level of food safety

Mungbeans in NGR



- Important spring-summer pulse crop of northern grain region (NGR), short duration 90 days, often double cropped after winter crops
- Industry yield average is 0.9 t/ha
- High yield variability → commonly known as MONGREL BEANS
- Yield potential yield > 2 T ha^{-1}
- High domestic market growth, export opportunity and relatively high commodity prices → potential to turn into ”MONEY BEANS”

Mungbeans in NGR

- High demand for improved yield and yield stability
- Currently don’t understand:
  1. Constraints to production
  2. Periods of vulnerability
  3. Yield determination (physiology)

→ Common knowledge gaps to pulses

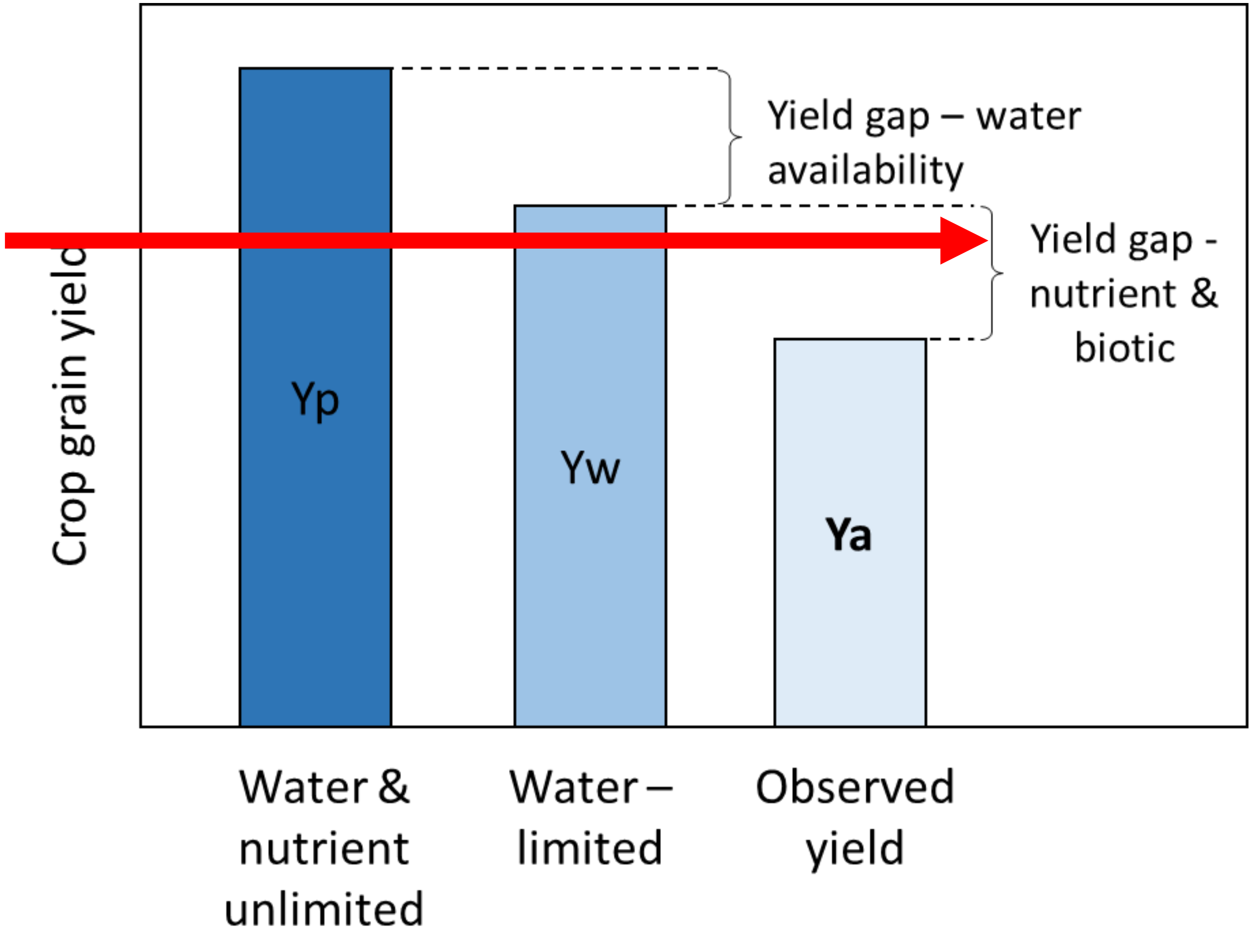
Project A: Mungbean paddock survey + APSIM modelling GRDC1099 01/18 to 09/18

Marisa Collins, Brook Anderson & Lindsay Bell CSIRO

- Objective: To identify key constraints to production across growing regions
- Approach: Paddock surveys combined with APSIM modelling to complete yield gap analysis

Estimating yield gap

Exploitable yield gap: difference between 80% Yw and Ya. Based on observations that farmers’ yields generally plateau at 80% of Yw, probably due to diminishing returns to investment and aversion to risk (Lobell et al., 2009; van Ittersum et al., 2013).



Calculations of yield gap are the difference between either water and nutrient unlimited yield potential (Yp) or water-limited yield potential (Yw) and observed yields (Ya).

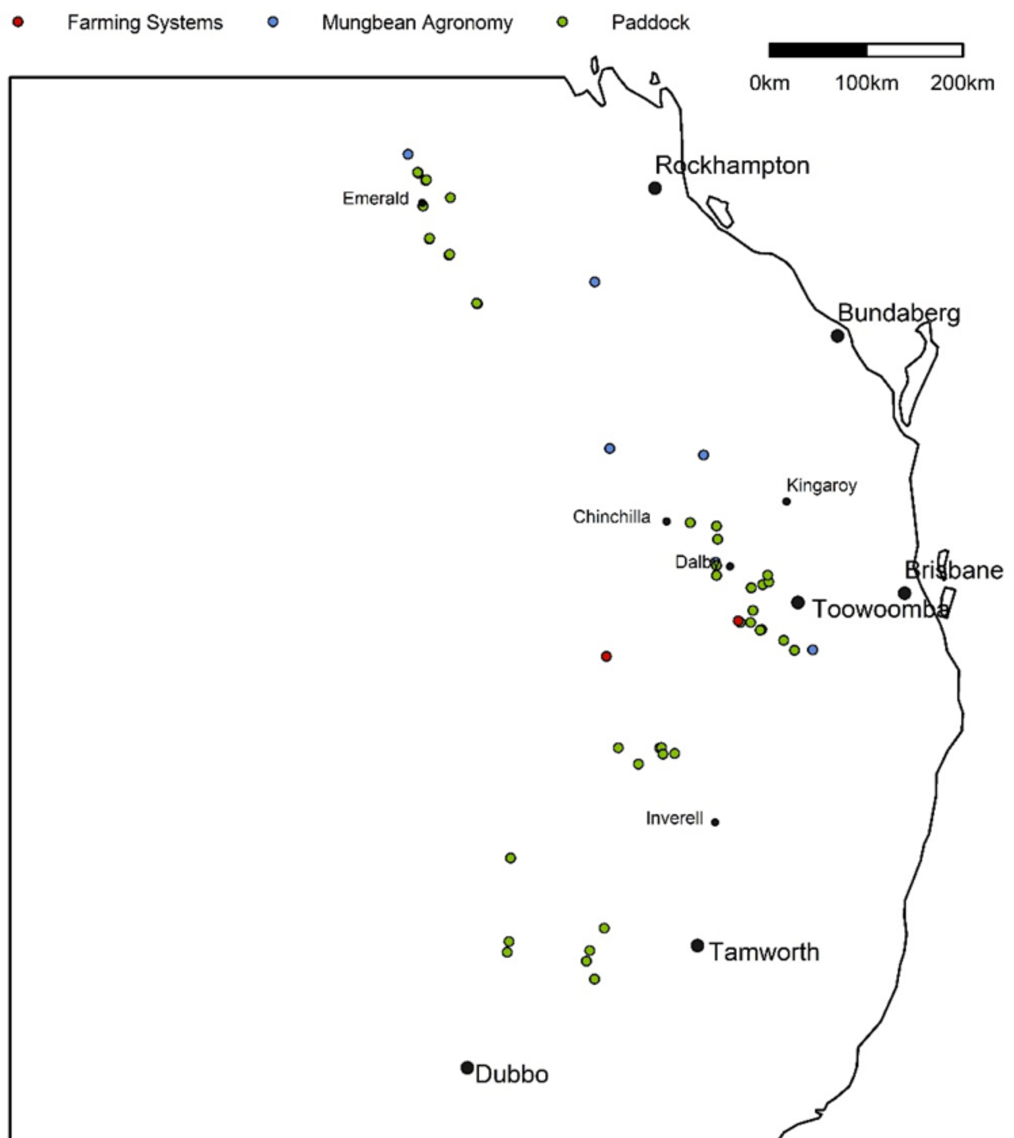
Overview of work completed

Paddock survey + simulation modelling approach

- 71 paddocks surveyed primarily in 17/18
- Paddock conditions, growth and yield data combined with simulation modelling approach to capture water supply and demand factors + abiotic stress
- Differences between observed and simulated water-limited yield to predict the yield gap.

Where did we collect data from?

- Central Queensland (12)
- Darling Downs (17)
- Moree and Liverpool Plains (13)
- Paddock survey data in season 2017-18
- Supplementary data collected in the GRDC farming systems and legume agronomy experimental projects (29)



Locations of 71 mungbean crops across subtropical grains region of eastern Australia sourced from paddock surveys (n = 42), farming systems experimental sites (n = 11) and mungbean agronomy research (n = 18).

Yield gaps

- Paddock data was representative of industry with average 0.9 T/ha across CQ, SQLD and NNSW. Yield ranged from 0.3 to 2.6 T/ha

Yield Gap (t/ha)	All (n = 71)	Experimental (n = 29)	Paddock survey (n = 42)
< 20%	35	31	38
20-40%	28	28	28
40-60%	21	28	17
>60%	15	14	17

Good news: One third (35%) of crops achieved > 80% water limited yields with these farmers nailing best practice in their paddocks

But … one third (36%) yielded < 60% of the water-limited yield potential and at $800-1200 t that's a lot of potential $$.

Yield gaps

- Nearly half (44%) of all monitored crops had yield gaps > 500 kg/ha
- Results for survey paddocks against experimental paddocks were similar suggesting factors other than weeds, pests and diseases were driving yield gaps

Yield Gap (t/ha)	% all (n = 71)	% Experimental (n = 29)	% Paddock survey (n = 42)
< 0.2	34	27	38
0.2-0.5	22	21	24
0.5-1.0	34	45	26
>1.0	10	7	12

Key findings

- Mungbean crops with low observed yield and high yield gaps were those with a low harvest index
- Low yields were often but not always associated with low crop biomass

Key findings: Yield, biomass and HI

- Mungbean crops with low observed yield and high yield gaps were often but not always associated with low crop biomass
- At higher crop biomass > 4.5 t/ha yield variability was high illustrating conditions at flowering also play an important role in yield determination

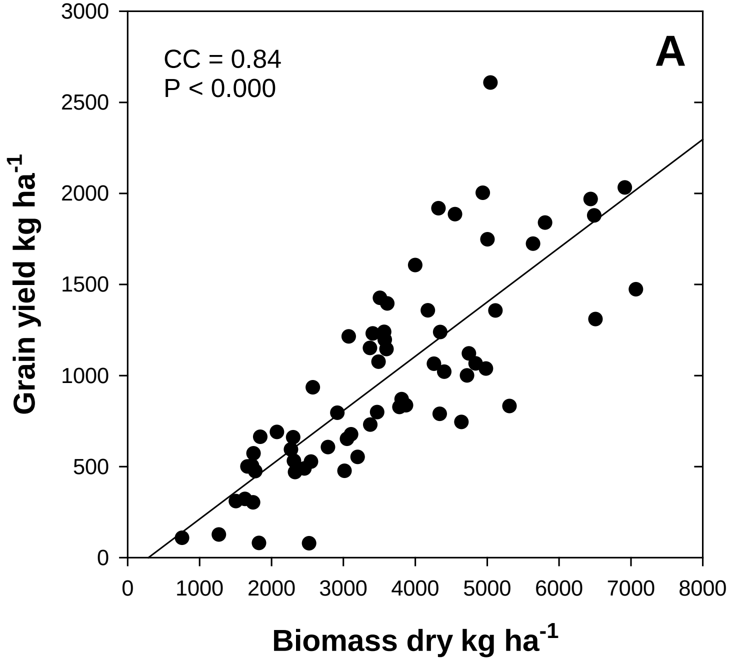


Figure 4. Relationship between grain yield kg ha^{-1} and (A) dry biomass kg ha^{-1} and harvest index (B). across mungbean paddocks in season 2017-18. Spearman correlation coefficient (CC) and significance indicated on the figures.

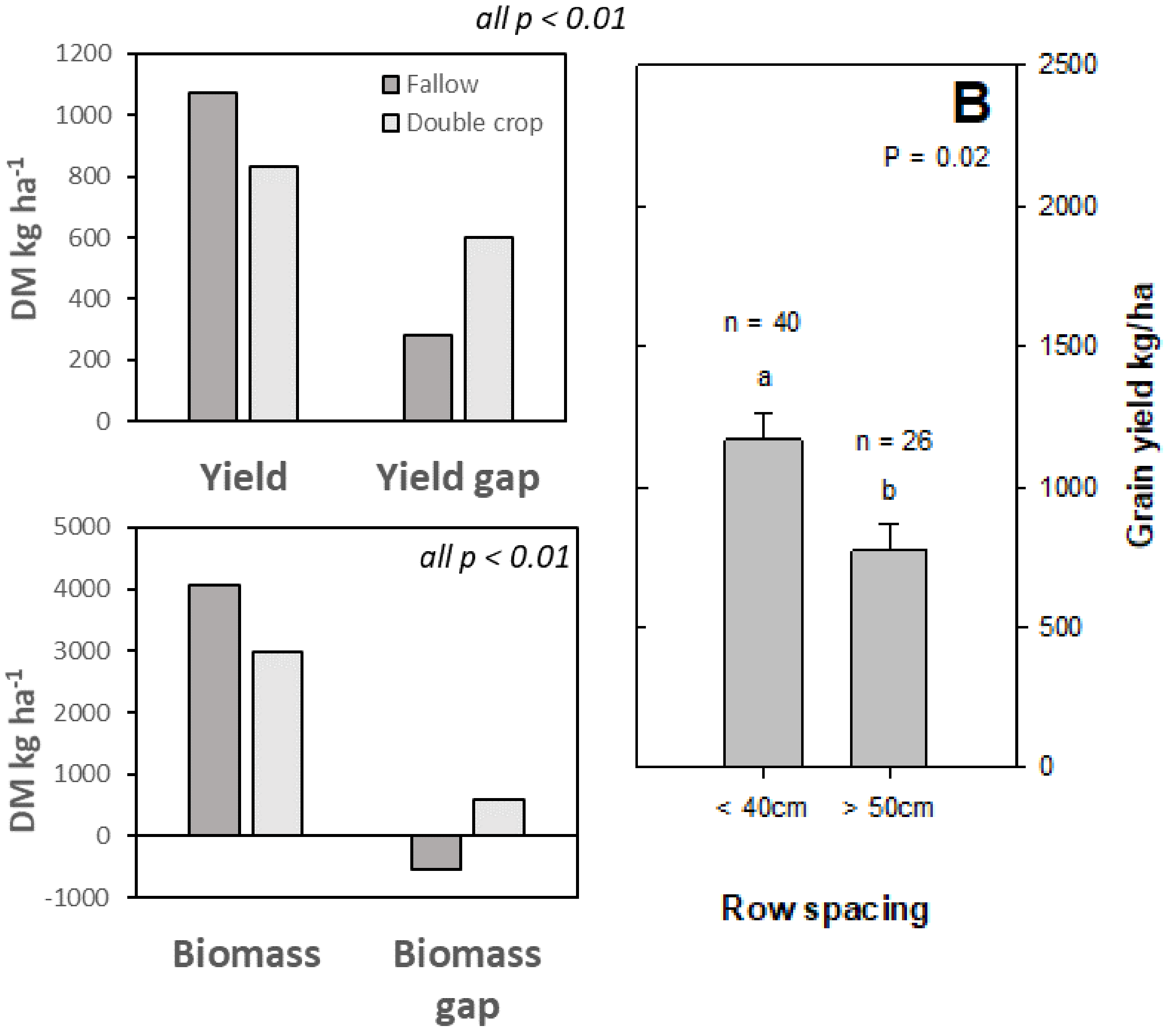
Differences in crop harvest index was the key difference between simulated and observed grain crop yields

Impact of management factors

- There were limited relationships between yield and essential nutrients across the surveyed paddocks (N, P, K, Zn, S, Mg and others)
- Two key management factors found to significantly increase yield:

(A) Crops sown on short or long fallow rather than double cropped (+240 kg/ha).

(B) Narrow row spacing (<50 cm) (+400 kg/ha).



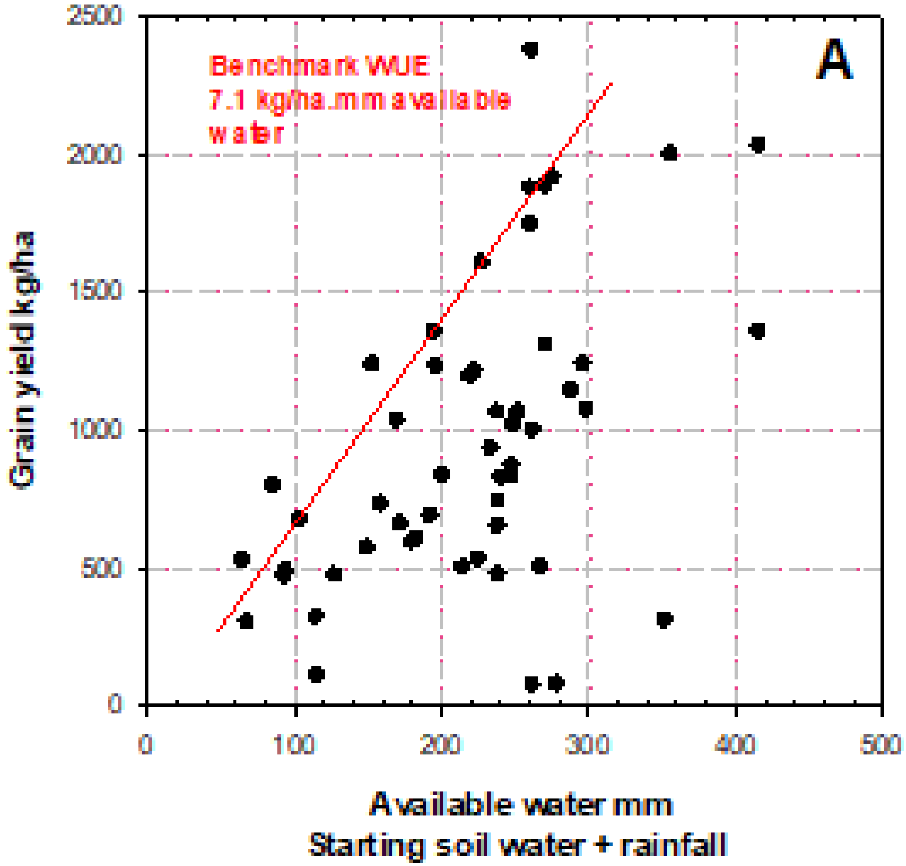
Paddock history

- Significant differences in both crop dry biomass and yield in response to planting conditions
- Fallow crops grew for longer and had higher starting soil water – with same available water and less in-season rainfall
- Fallow crops had higher Colwell P and Mg levels (location?)
- RLN pressure higher but NS

History		Fallow	Double-crop	P-value
Colwell P	mg kg-1 0-30cm	25 a	15 b	0.04
Magnesium	mg kg^{-1} 0-30cm	19 a	12 b	0.00
Biomass	dry kg ha^{-1}	4052 a	2981 b	0.00
Yield	dry kg ha^{-1}	1075 a	834 b	0.01
HI		0.26	0.25	0.13
Grow time	days	82 a	76 b	0.00
In-crop rainfall	mm	97	117	0.40
Available water	mm	230	222	0.78
Starting soil water	mm	133 a	106 b	0.01
P.thornei	nematodes g soil^{-1}	0.08	2.27	0.09

Relationships between yield and water

- Benchmark WUE approx. 7 kg.ha.mm available water (starting stored water + in-crop rainfall)
- Differences in starting water at this WUE explained observed yield differences between fallow and double crop mungbeans.
- Yields > 1.25 T/ha required > 200mm available water and had 85mm stored soil water at planting



Relationship between grain yield and (A) available water (starting soil water and in-season rainfall mm) across mungbean paddocks in season 2017-18.

Regional differences

Region	Units	CQ	DD	NNSW	P-value
n		17	16	13	
Fallow / double crop		5/12	8/8	9/4	
Nitrate N	kg ha^{-1} 0-90cm	104	132	100	0.42
Colwell P	mg kg^{-1} 0-30cm	14 a	18 ab	27 b	0.07
BSES P	mg kg^{-1} 0-30cm	116	96	91	0.93
Colwell K	mg kg^{-1} 0-30cm	246 ab	206 a	316 b	0.05
Sulfur	mg kg^{-1} 0-60cm	5.2 a	11.5 b	5.9 a	0.04
Mg	mg kg^{-1} 0-30cm	15	14	16	0.75
Zinc	mg kg^{-1} 0-30cm	0.5 a	1.2 b	1.5 b	0.00
Biomass	kg ha^{-1}	3866	3463	3537	0.73
Yield	kg ha^{-1}	941	982	1227	0.33
HI		0.24	0.26	0.30	0.30
Grow time	days	77	84	69	0.58
In-crop rainfall	mm	129	99	100	0.48
Available water	mm	267	244	213	0.06
Starting soil water	mm	135 a	101 b	113 ab	0.00
P.thornei	nematodes g soil^{-1}	1.3 a	3.2 b	0.8 a	0.05
P.neglectus	nematodes g soil^{-1}	0.0a	0.0	0.1b	0.05
AMF		36a	32a	75b	0.03
Charcoal rot	log(kDNA copies g soil^{-1})	3.0 a	1.8 b	1.0 c	0.00

- No significant differences in yield, biomass, harvest index and rainfall
- Paddocks across the three areas all had > 100 kg nitrate N kg, > 90 mg kg^{-1} BSES P, > 14 mg kg^{-1} Mg.
- Colwell-P levels in CQ and DD are likely to be causing yield limitations and deep P trials (Mike Bell UQ) are showing significant yield increases in other pulses

Additive factors and yield gap

- No single biotic or abiotic factor was found to be associated with low mungbean observed crop yields or high yield gaps
- However, 88% of crops with a high yield gap (< 65% water limited yield) had either *P.thornei* > 3/g and/or maximum temperatures > 39°C during flowering and/or soil nitrate levels below 65 kg N/ha

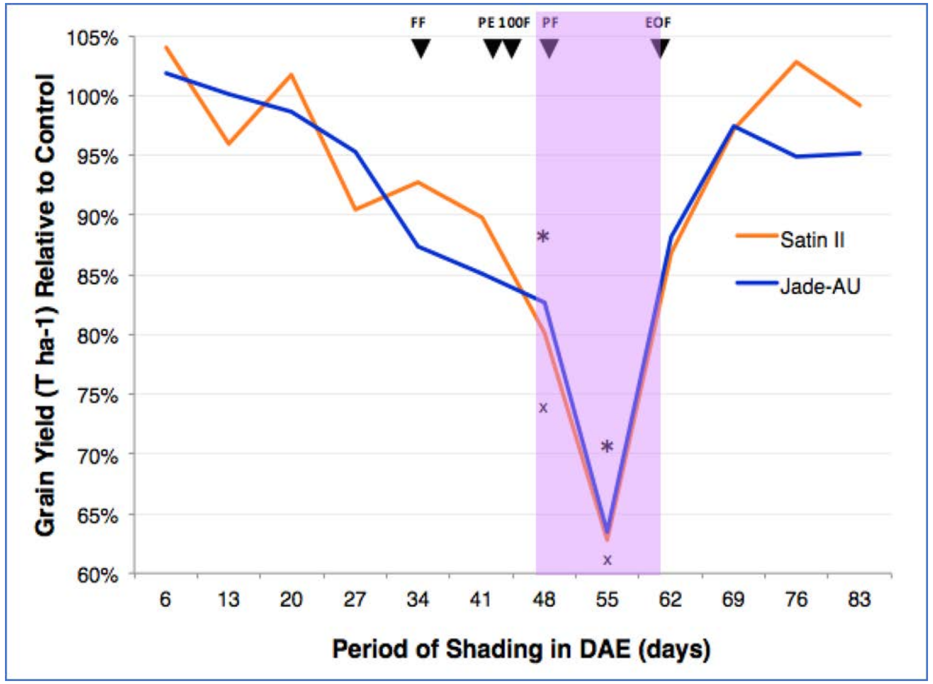
Stress criteria	**High YG (% group)**	**Low YG (% group)**	**p**
P. thornei > 3.0/g soil	14 (53%)	4 (23%)	0.064
+ Max. temp > 39°C during flowering	19 (73%)	7 (41%)	0.057
+ NO_3 (< 65 kg/ha)	23 (88%)	7 (41%)	0.002
N	26	17	

Farmer recommendations

- For higher yields narrow rows and planting onto fallow > maximises yield potential, mungbeans offer good double cropping opportunity too but likely won’t yield to full potential
- To minimise yield lost in the paddock:
  - Measure RLN levels before planting mungbeans
  - Starting soil N counts – early rapid root development essential for setting up a good season
  - Heat during flowering – stick to recommended planting windows
- Multiple factors leading to missed yield – key is identifying major constraints to maximise profits

Mungbeans in NGR

- Where we are now:
  1. Constraints to production
  2. Periods of vulnerability
  3. Yield determination (physiology) → current four year project



Average yield (t ha-1) relative to the control for mungbean varieties, Jade-AU and Satin II, subjected to shading for 1 week increments starting 6 days after emergence (DAE). Periods of shading after DAE were in 7 day increments starting from the day labeled, e.g. 13DAE was shaded from 13-19 days after emergence.

Consistent with other grain legumes critical period is late flowering / early pod fill.

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