WARIALDA
NEW SOUTH WALES
WEDNESDAY 14TH
AUGUST 2019

# GRAINS RESEARCH UPDATE

## DRIVING PROFIT THROUGH RESEARCH

GRDC
GRAINS RESEARCH
& DEVELOPMENT
CORPORATION

grdc.com.au

# GRDC Welcome

## Welcome to the 2019 GRDC Grains Research Updates

Growers, advisers and industry stakeholders are constantly faced with challenges to farm profitability and productivity, which makes staying informed about the latest research and development outcomes a critical part of being in business.

Keeping growers and advisers informed is the key role of the annual Grains Research and Development Corporation (GRDC) Grains Research Updates, which are premiere events on the northern grains industry calendar and bring together some of Australia's leading grain research scientists and expert consultants.

For more than 25 years the GRDC has been driving grains research capability and capacity with the understanding that the continued viability of the industry hinges on rigorous, innovative research that delivers genuine profit gains. GRDC's purpose is to invest in research, development, and extension (RD&E) to create enduring profitability for Australian grain growers.

Despite the tough seasonal conditions currently being experienced across much of the Queensland and New South Wales grainbelts, the industry remains confident about the future and committed to learning more about innovation and technology and embracing practice change that has the potential to make a tangible difference to on-farm profits.

In response, this year's GRDC Grains Research Updates offer regionally relevant, credible and new science-based information covering priority issues like climate and environmental variability, new technology and market conditions to ensure growers and their advisers have up-to-date knowledge to make informed decisions on-farm.

So, I hope you enjoy the 2019 Updates and that the events provide an invaluable opportunity for learning, knowledge sharing and networking.

***Luke Gaynor,***

*GRDC Senior Manager Extension and Communication*

GRDC™
GRAINS RESEARCH
& DEVELOPMENT
CORPORATION

# GRDC Grains Research Update
# WARIALDA
## Wednesday 14 August 2019, Warialda Golf & Bowling Club

Registration: 8:30am for a 9am start, finish 3:10pm

| AGENDA<br>Time | Topic | Speaker(s) |
|---|---|---|
| 9:00AM | **GRDC welcome** | |
| 9:10AM | **Sowing grain sorghum early**: reducing risk of water and heat stress at flowering and increasing chances of double cropping to chickpeas or of ratooning irrigated sorghum into a second harvest. | Loretta Serafin<br>(NSW DPI) |
| 9:30AM | **Grower experiences with early sowing sorghum:** pros and pitfalls. | John McDonald<br>(Leverton Pastoral) |
| 9:40AM | **Early sowing sorghum discussion - grower and adviser experience** | |
| 9:55AM | **Cover crops for fallow efficiency:** research observations on soil water, health, nutrition and crop performance. | David Lawrence<br>(DAF Qld) |
| 10:20AM | **Multi species cover cropping and optimising soil health.** | Alex Nixon<br>(Nuffield Scholar, Drillham, Qld) |
| 10:45AM | **Morning tea** | |
| 11:15AM | **New frontiers in cereal breeding for a changing climate.** | Greg Rebetzke<br>(CSIRO) |
| 11:40AM | **The yield gap in mungbean:** how much yield is lost and what can we do? | Lindsay Bell<br>(CSIRO) |
| 12:05PM | **Mungbean and soybean agronomy:** time of sowing, row spacing and plant population. | Natalie Moore and Mathew Dunn<br>(NSW DPI) |
| 12:40PM | **Mungbean disease management:** tan spot, halo blight and powdery mildew. | Lisa Kelly<br>(DAF Qld) |
| 1:00PM | **Lunch** | |
| 1:50PM | **5 years of nitrogen research:** do we have the system right?<br>o N movement, use efficiency, application timing & impact on N uptake – do we fertilise the system or the crop<br>o N in pulse crops?<br>o N impacts on screenings | Richard Daniel<br>(Northern Grower Alliance) |
| 2:15PM | **Upgrading nutritional strategies to feed the farming system:** P & K timing, placement and implications for N timing and placement. | Mike Bell<br>(UQ) |
| 2:40PM | **Recovery after the drought:** getting back to productivity, discussion session led by Peter Birch (B & W Rural) and Andrew Morelli (McGregor Gourlay) | |
| 3:10PM | **Close** | |

## Contents

Compiled by Independent Consultants Australia Network (ICAN) Pty Ltd.
PO Box 718, Hornsby NSW 1630
Ph: (02) 9482 4930, Fx: (02) 9482 4931, E-mail: northernupdates@icanrural.com.au
Follow us on twitter @GRDCNorth or Facebook: http://www.facebook.com/icanrural

ⓓ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994.
® Registered trademark

# Sowing sorghum super early – after two years is it still a good idea?

*Loretta Serafin[1], Mark Hellyer[1], Andrew Bishop[1], Daniel Rodriguez[2], Joe Eyre[2]*
*and Darren Aisthorpe[3]*

[1] NSW DPI, Tamworth
[2] QAAFI, UQ Queensland, Toowoomba
[3] QDAF, Emerald

**Key words**

Grain sorghum, cold tolerance, heat stress, flowering

**GRDC code**

Optimising sorghum agronomy project (UOQ 1808-001RTX)

**Take home messages**

- Sowing time for sorghum can be moved earlier than the traditional 16 – 18 °C soil temperature without negatively impacting on crop establishment and grain yield
- Defining the minimum soil temperature required for establishment is still tenuous as temperatures are variable in the late winter/ early spring and the risk of mild and severe frosts are still present. However, a minimum of 12° C seems to be the current limit from these experiments to ensure even and timely establishment
- Sowing earlier at both Moree and Breeza moved the flowering window forward and, in both sites, resulted in improved grain yields through reduced exposure to heat and moisture stress during flowering and grain filling.

## Introduction

The traditional sowing window for grain sorghum in northern NSW has been challenged in recent years by increasing climate variability predisposing the crop to heat and moisture stress during the critical stages of flowering and grain fill. The impacts have been devastating, resulting in reduced yields and grain quality and even crop failure in some instances. This is ultimately costing grower's money in lost returns.

Similar to the changes we have seen in the adoption of early sowing time with wheat, growers are making incremental changes to the time of sowing with their sorghum crops. Traditionally, the recommendation was to delay sowing until the frost risk period had past and when soil temperatures at sowing depth reached 16-18 °C and were rising, with measurements taken at 8 am for three days. However, in recent years, particularly last season, many crops were sown when soil temperatures were closer to 14 °C, especially in the Moree region where a missed winter crop and continuing dry conditions were driving the need for cash flow.

Since 2017, the GRDC, University of Queensland and NSW DPI have partnered in a research program to test the boundaries of sowing sorghum earlier and measuring the impacts on plant establishment, crop development, grain yield and quality. Research trials have been conducted from Emerald (with QDAF joining the team this season), Southern Qld, Moree and the Liverpool Plains.

Experiments were designed to develop a data set to define how early growers can plant sorghum in each of these environments and what are the potential benefits and risks from adopting this strategy of "winter sown sorghum". In this study we considered effects on the sorghum crop as well as follow-on impacts on crop rotation intensity and the possibility of ratooned sorghum.

In 2017-18 three sites were conducted in northern NSW at Mallawa, Gurley and Breeza. During 2018-19 two sites were conducted at Moree and Breeza; with the Breeza site containing both a dryland and a supplementary irrigated trial. Only the results from the two dryland trials in 2018-19 are reported here.

## Trial details 2018-2019

**Table 1.** Site characteristics for two sorghum time of sowing trials sown during the 2018/19 season

| Time of sowing (TOS) | Sowing date | Soil temp. at 8 am[#] (°C) | Soil water[##] at sowing (mm) | In-crop rainfall (mm) | Irrigation (mm) |
|---|---|---|---|---|---|
| "Ponjola" Moree, NSW (dryland) | | | | | |
| 1 | 7 & 8 Aug | 12.3 | 97.5 | 199.7 | 33* |
| 2 | 11 & 12 Sept | 17.1 | 112.8 | 153.2 | - |
| 3 | 27 Sept | 18.9 | 115.7 | 153.2 | - |
| "LPFS" Breeza, NSW (dryland) | | | | | |
| 1 | 6 Sept | 11.2 | Pre-irrigated | 222.9 | - |
| 2 | 17 Sept | 10.3 | Pre-irrigated | 222.9 | - |
| 3 | 23 Oct | 18.8 | Pre-irrigated | 170 | - |

[#]Average soil temperature (°C) at sowing depth for seven days after sowing
[##]Soil water (mm, 0-1.2 m) at the time of sowing
*33 mm of water was applied post sowing on the 14th August using dripper lines to ensure even establishment due to dry seedbed conditions.

**Table 2.** Description of treatments (sowing dates, target populations and hybrids)

| Time of sowing (TOS) | Sowing date | Target plant population (pl/m$^2$) | Hybrids |
|---|---|---|---|
| "Ponjola" Moree, NSW (dryland) | | | |
| 1 | 7 Aug | 3, 6, 9, 12 | MR Buster, MR Apollo, MR Taurus, Agitator, Cracka, HGS114, A66, G33 |
| 2 | 11 & 12 Sept | | |
| 3 | 27 Sept | | |
| "LPFS" Breeza, NSW (dryland) | | | |
| 1 | 6 Sept | 3,6,9,12 | MR Buster, MR Apollo, Agitator,Cracka, HGS114, G33 |
| 2 | 17 Sept | | |
| 3 | 23 Oct | | |

## Results and discussion

### *"Ponjola" Moree*

Plant establishment

The first time of sowing (TOS) occurred under dry seedbed conditions, so to ensure even establishment at the desired soil temperature, a total of 33 mm of water was applied one-week post sowing using dripper lines. The first establishment counts which recorded plants emerging were taken on the 31st August, 3 weeks post sowing and 2 weeks post watering. Plants emerged slower under TOS1, than TOS 2 and TOS 3 which had more even and quicker establishment.

There was no impact of time of sowing on any of the final established plant populations except the 120,000 plants/ha treatment which established more plants as the TOS became later (Table 3).

**Table 3.** Impact of time of sowing on plant establishment at "Ponjola"

| Target plant population (plants/$m^2$) | TOS 1 (7 August) | TOS 2 (11 Sept) | TOS 3 (27 Sept) |
|---|---|---|---|
| 3 | 2.44 f | 2.63 f | 2.77 f |
| 6 | 5.22 e | 5.23 e | 5.34 e |
| 9 | 7.60 d | 8.32 cd | 8.35 cd |
| 12 | 8.94 c | 10.80 b | 11.83 a |
| L.s.d: 1.02, $P<0.05$ | | | |

There was an interaction between TOS and hybrid. Comparing across times of sowing, Agitator had the poorest establishment at nearly all TOS. TOS 2 and TOS 3 had improved establishment for nearly all hybrids when compared to TOS 1 but the differences were not always statistically significant (data not shown).

Impacts of time of sowing and plant population on crop development

Increasing plant population reduced the number of fertile tillers produced as did delaying the TOS. Averaged across populations and hybrids; TOS 1 resulted in more fertile tillers, 4.34/ $m^2$ compared to 2.88 / $m^2$ tillers for TOS 2 and 1.78 / $m^2$ for TOS 3. Hybrids also produced different numbers of tillers with Agitator, which had the lowest plant establishment, producing the highest number of fertile tillers. In contrast MR-Apollo had the lowest number of fertile tillers (data not shown).

Time of sowing, hybrid and plant population all impacted on the number of heads produced. More heads were produced from TOS 1 than TOS 3. The differences between TOS 1 and TOS 2 were not significant. As plant population increased so did the number of primary heads. Hybrids varied in their number of heads produced. The lowest numbers of primary heads were produced by MR-Apollo and Agitator (data not shown).

Did sowing earlier impact on flowering?

There was a significant impact of sowing time, population and hybrid on the number of days taken to reach 50% flowering.

Sowing timing had a significant impact on days to flowering; the earlier we sowed, the longer the time taken to reach flowering. TOS 1 took an average of 106 days to reach 50% flowering which reduced to 82 days for TOS 2 and 75 days for TOS 3.

Delaying sowing from TOS 1 to TOS 2; a period of 4 weeks; reduced the time to 50% flowering by 24 days. The days to flowering difference between TOS 2 and TOS 3 was much smaller, only 7 days, even though there as a 16-day difference in sowing time.

In TOS 1, the slowest hybrid to reach 50% flowering was MR-Apollo at 115 days, and the quickest was Agitator at 99 days, a spread of 16 days over the eight hybrids examined. In contrast by TOS 3, MR-Apollo flowered in 81 days, while Agitator was 70 days, a difference of 11 days. Agitator was consistently the quickest and MR-Apollo consistently the slowest of the hybrids tested to reach 50% flowering (Figure 1).

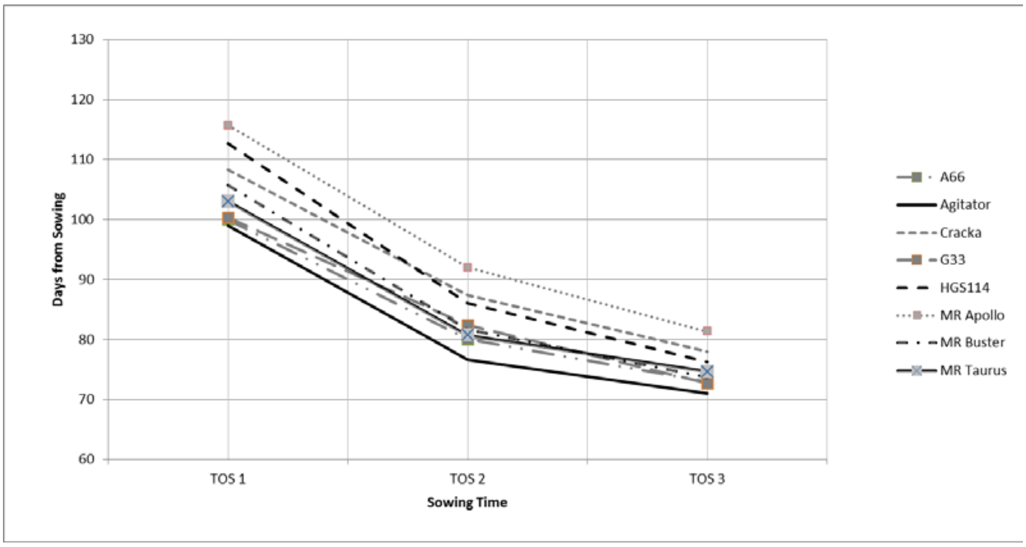


**Figure 1.** Days to 50% flowering at "Ponjola" for 6 plants/m$^2$ target population.

TOS 1 moved the flowering window for all hybrids forward by around three weeks compared to sowing at the recommended soil temperature (TOS 3). This meant flowering was completed prior to the onset of very high temperatures at the beginning of December (Figure 2).

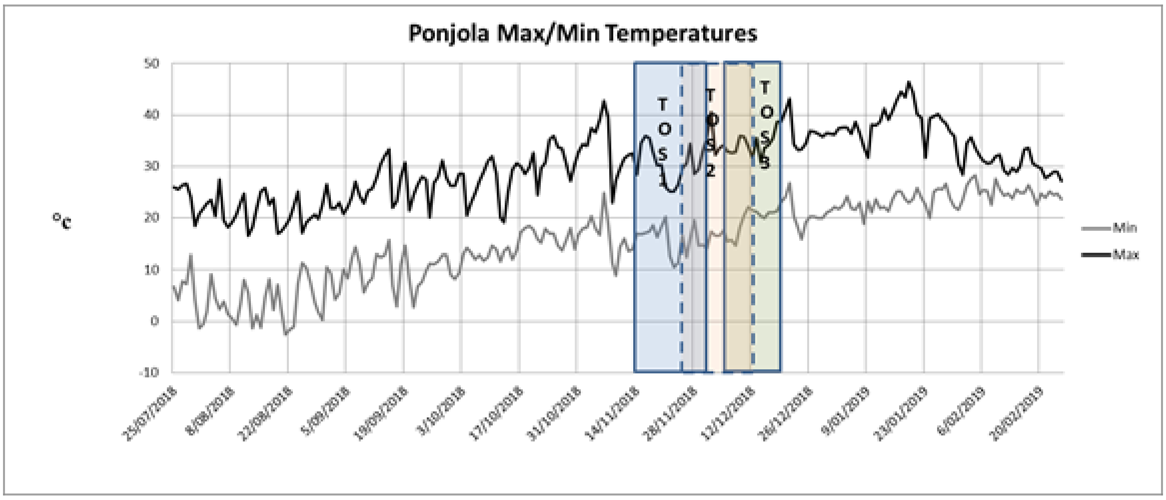


**Figure 2.** The flowering windows for TOS 1, TOS 2 and TOS 3 at "Ponjola" Moree in 2018-19

What was the impact on grain yield and quality?

The site mean yield was 1.78 t/ha at “Ponjola” in 2018-19. There was a significant interaction between time of sowing and hybrid yields (Figure 3). Plant population did not have a significant impact on grain yield. TOS 1 was the highest yielding at 2.14 t/ha. There was no significant difference in yields achieved between TOS 2 and TOS 3 being 1.51 and 1.68 t/ha respectively.

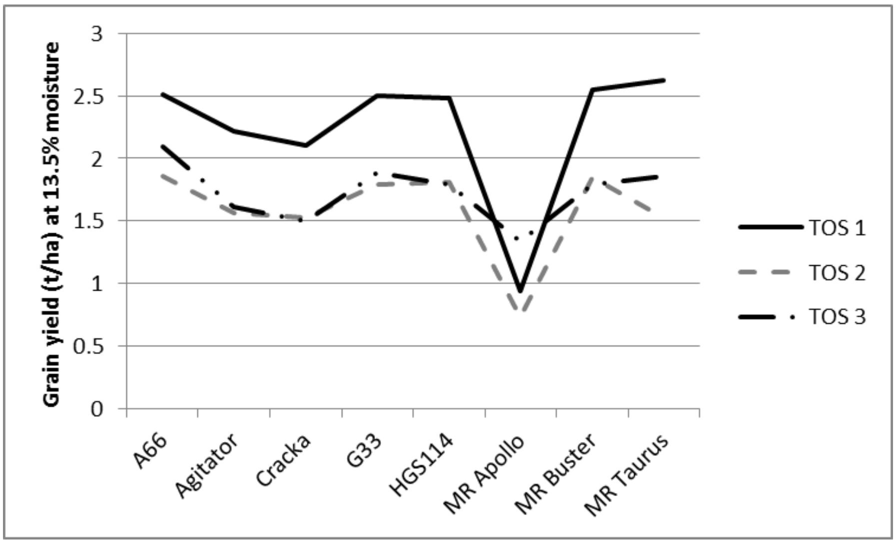


**Figure 3.** Grain yield at three times of sowing (TOS) at "Ponjola" Moree in 2018-19

Grain protein achieved was significantly less at TOS 1 (10.7%) compared to the TOS 2 and TOS 3 planting times at 11.1% and 11.2% respectively. However, all grain proteins were still at an acceptable level to show that nitrogen was not limiting.

Screenings were impacted by TOS, population and hybrid. TOS 1 had significantly lower screenings at 10% compared to TOS 2 at 16.6% and TOS 3 at 17.9%. The hybrid interaction was also significant with Agitator averaging the lowest screenings at 10.5% while G33 and MR-Buster had the highest between 18-19%. The 120,000 plants/ha target population was the only treatment to show significantly higher screenings at 15.9% while all other target plant populations were between 14-15%, when averaged across hybrids and sowing times. This means that only TOS 1 met the sorghum 1 standards for screenings.

Test weights were generally low. No hybrid averaged the required test weight to achieve grade 1 sorghum (>71 kg/hL). The only treatment to achieve sorghum 1 was Cracka at TOS 3 with 71.3kg/hL (data not shown).

### *Breeza dryland*

Plant establishment

At Breeza the soil temperatures with TOS 1 were cooler than the Moree site (11.2°C vs 12.3°C; (Table 1)), even though the first sowing date at Breeza was close to one month later than Moree on the 6th September. Soil temperatures rose at Breeza during mid-September but then plummeted again following TOS 2 resulting in a 7-day average of 10.3 °C. At these cooler soil temperatures, time of sowing had a significant impact on plant establishment. TOS 1 and TOS 2 had significantly reduced plant establishment compared to the standard (TOS 3) sowing date.

Most hybrids did not achieve the four target plant populations of 3, 6, 9 and 12 plants/m$^2$ for TOS 1 or TOS2. TOS 3 which established in soil temperatures closer to 18 °C was better.

There were a couple of small differences between hybrids. Agitator had a significantly lower establishment than all other hybrids and G33 established fewer plants than MR-Buster (Figure 4).

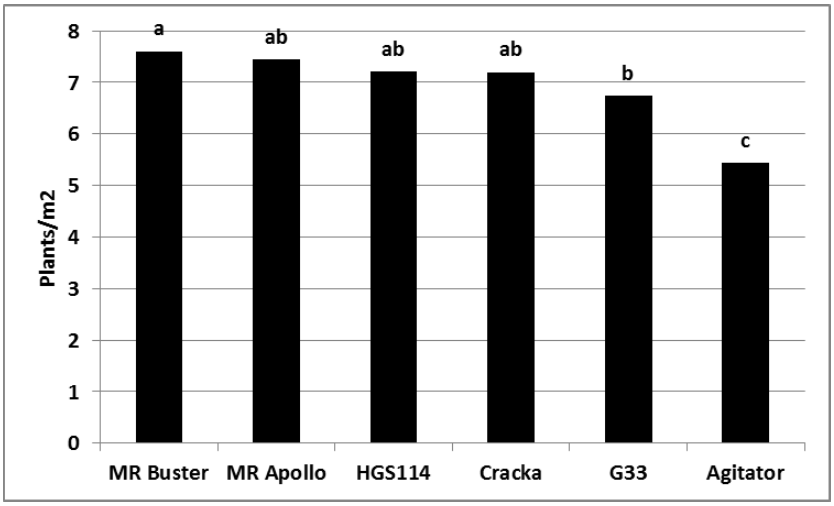


**Figure 4.** Hybrid establishment (plants/m$^2$) averaged across times of sowing and plant population

Impact of time of sowing and plant population on crop development

There was a significant interaction between time of sowing and population. The number of fertile tillers declined as the plant population increased at all sowing times. TOS 3 had much lower levels of tillering compared to TOS 1 and TOS 2 (Figure 5).

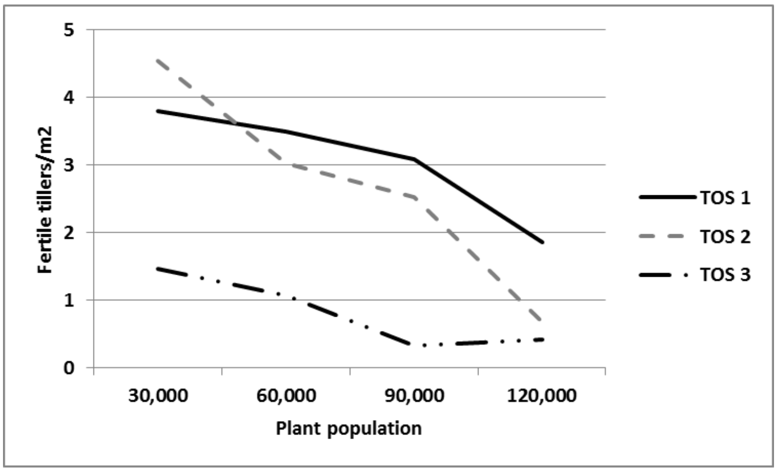


**Figure 5.** Interaction between time of sowing and target plant population on fertile tillers/m$^2$

Time of sowing did not have an impact on the number of primary heads at Breeza. There were more primary heads produced with higher plant populations. Agitator and MR Apollo produced the lowest number of heads (data not shown).

Did sowing earlier impact on flowering?

The number of days taken to reach 50 % flowering reduced as TOS was delayed. For TOS 1 it was 95 days, TOS 2 was 10 days faster at 85 days and for the standard sowing time at TOS 3, 69 days. Between TOS 1 and 2, delaying sowing by 15 days resulted in a 10-day difference in flowering. TOS 3 developed in much warmer conditions meaning even though there was a 30-day difference in sowing this only caused a 16-day difference in flowering compared to TOS 2.

There was a much smaller difference between the hybrids for time to flowering at Breeza compared with Moree in 2018-19. However, Agitator was still the quickest hybrid for all times of sowing, although by TOS 3 MR-Buster was as quick. MR-Apollo remained the slowest of the hybrids examined (Figure 6).

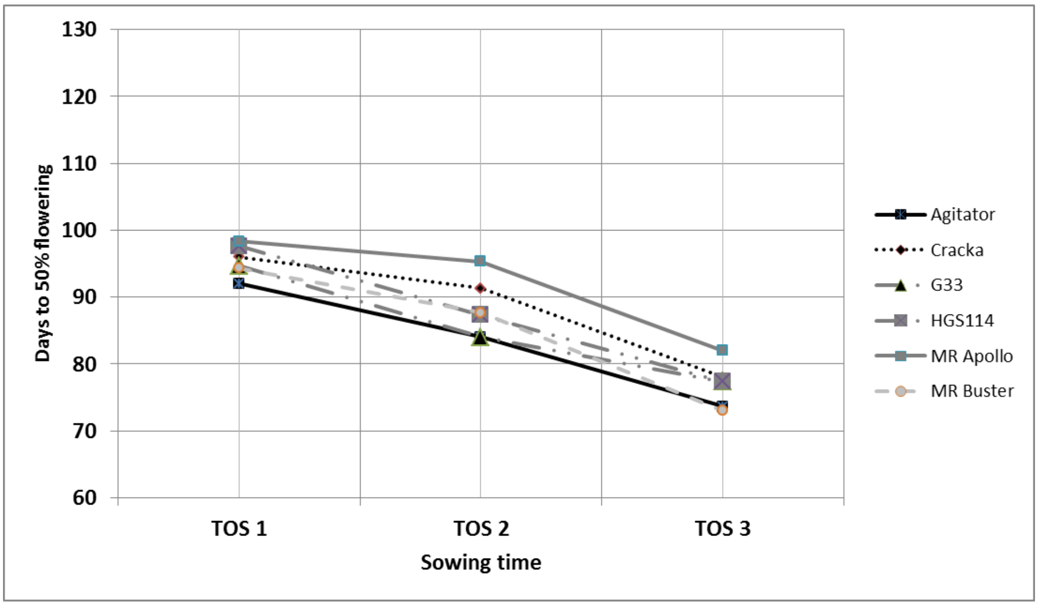


**Figure 6.** Days to 50% flowering at Breeza – Dryland at 6 plants/ha target plant population

What was the final impact on grain yield and quality?

The site mean yield was 1.73 t/ha at Breeza in 2018-19. There was a significant impact of TOS and hybrid on final grain yield (Table 4). TOS 1 (2.23 t/ha) and TOS 2 (2.12 t/ha) had significantly higher grain yield than TOS 3 (0.85 t/ha), averaged across hybrids and plant populations. There was no significant impact of plant population on grain yield.

**Table 4.** Impact of time of sowing (TOS) and hybrid on grain yield (t/ha) at 13.5% moisture Breeza – dryland in 2018-19

| Hybrid | TOS 1 | TOS 2 | TOS 3 |
|---|---|---|---|
| MR- Buster | 2.61 a | 2.41 ab | 1.26 def |
| G33 | 2.59 a | 2.43 ab | 0.83 eg |
| Agitator | 2.57 a | 2.31 ab | 0.88 eg |
| HGS114 | 2.22 bc | 2.32 ab | 0.87 eg |
| Cracka | 2.16 bc | 1.91 acd | 1.00 efg |
| MR-Apollo | 1.25 defg | 1.32 e | 0.26 h |
| L.s.d: 0.75, P<0.05 | | | |

Test weights were significantly lower at TOS 3 (54.8 kg/hl) compared to TOS 1(62.7 kg/hl) and TOS 2 (62.8 kg/hl), although neither made sorghum 1 classification.  Similarly, no hybrid averaged the required test weight to achieve grade 1 sorghum (>71 kg/hl).

Screenings were impacted by TOS, plant population and hybrid at Breeza with all screenings levels being relatively high. TOS 1 and TOS 2 had significantly lower screenings at 12.6% and 13.2 % compared with TOS 3 at 27.4%. The hybrid interaction was also significant with Agitator and Cracka producing the lowest screenings at 15.3% at 15.7%. G33 had the highest at 21.5%. Higher screenings also occurred as plant population increased (data not shown).

## Conclusions

At the Moree site, there was little impact on plant establishment from sowing in mid-august when soil temperatures were 12.3°C for the 7 days following sowing. In contrast sowing into slightly cooler temperatures (10-11°C) at Breeza had a significant impact on sorghum establishment.

At both Moree and Breeza, the flowering window was moved forward from sowing earlier in this season. This helped to ensure flowering occurred before the peak of heat and moisture stress set in. The earlier sowing time resulted in improved yields at both sites, even though average yields at Breeza and Moree were not high due to drought conditions. Varying plant population, from 3 to 12 plants/m$^2$ did not impact final grain yield. The plants modified their tiller and head production in response to the surrounding competition and seasonal conditions. For example, as plant population increased the number of primary heads increased and the number of fertile tillers decreased.

While the benefits of sowing sorghum earlier than traditionally recommended appear to be improved yields and grain quality, the risks have not been fully evaluated. The impact of frost in particular needs to be further assessed including determining the actual temperature where plant death occurs.

## Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

In particular the support of Geoff Manchee & JR McDonald “Ponjola” Moree, and Rob Holmes, HMAg is gratefully acknowledged. We would also like to acknowledge the technical support of Delphi Ramsden, Natalie Aquilina, Mitchell Clifton, Mathew Dunn, Scott Goodworth and Steve Jengos. Thanks to Steven Simpfendorfer for editorial comments.

## Contact details

Loretta Serafin
NSW Department of Primary Industries, Tamworth
Mb: 0427 311 819
Email: loretta.serafin@dpi.nsw.gov.au

Return to contents

# Grower experiences with early sowing sorghum: pros and pitfalls

*John McDonald, Leverton Pastoral*

## Notes

John (JR) McDonald
Mb: 0428 948 636
Email: jrmcdonald1@bigpond.com

## Notes

Return to contents

# Cover crops can boost soil water and protect the soil for higher crop yields

*David Lawrence[1], Andrew Erbacher[1], David Freebairn, Neil Huth[2], Brook Anderson[2], Graham Harris[1] and Nikki Seymour[1]*

[1] DAF Qld
[2] CSIRO

**Key words**

cover crops, millet, ground cover, soil water storage, fallow management, stubble, evaporation, infiltration, plant available water

**GRDC code**

DAQ00211

**Take home messages**

- Cover crops can increase fallow water storage, and improve crop performance and returns in northern farming systems
- In each experiment, a cover crop treatment provided the highest plant available soil water by the end of the fallow
- The best cover crop treatment depended on the length of the fallow. A later spray-out, with more resilient cover, was best in the longer fallow. However, delaying spray-out too long had a dramatic effect on water storage
- Cover crop saved 2-3 fallow herbicide sprays and dramatically improved establishment at one of the sites
- Yields and returns were increased by the best cover crop treatment at each trial, but yield effects appear to be in excess of those expected from the increased soil water storage
- Biology effects must be considered carefully; white French millet cover crops in the northern region have previously been shown to dramatically increase mycorrhizal colonisation of wheat (good), increase free-living nematodes (good), increase cellulase activity and bacterial abundance from additional fresh crop residues (good), but also increase root-lesion nematode populations (bad).

## Cover crops in the northern region

Cover crops are not new. They have been used (mostly) by organic and low-input growers to protect the soil from erosion in low stubble situations, return biomass that helps maintain soil organic matter and biological activity, and to provide additional nitrogen when legumes are used.

However, growing cover crops uses water, and storing Plant Available Water (PAW) is 'king' in northern farming systems; only 20-40% of the northern region's rainfall is typically transpired by dryland crops, up to 60% of rainfall is lost to evaporation, and a further 5-20% is lost in runoff and deep drainage. Every 10 mm of extra stored soil water available to crops could increase dryland grain yields by up to 150 kg/ha, with corresponding benefits to dryland cotton growers as well. So, growing crops that do not produce grain or fibre is understandably considered 'wasteful' of both rainfall and irrigation water.

Yet, research is now supporting growers' experience that cover crops can provide many of their benefits with little or no net loss of soil water at the end of the fallow period. GRDC's Eastern Farming Systems project and Northern Growers Alliance (NGA) trials have both shown that cover crops and increased stubble loads can reduce evaporation, increase infiltration and provide net gains in plant available water over traditional fallow periods. This suggests cover crops may be a key part of improved farming systems; providing increased productivity, profitability and sustainability.

## The science of stubble and evaporation

Retained stubble provides ground cover that protects the soil from rainfall impacts and so improves infiltration to store more water in the soil. Conventional wisdom is that increased stubble loads can slow down the initial rate of evaporation, but that these gains are short-lived and lost from accumulated evaporation after several weeks. However, further rain within this period and the manipulation of stubble to concentrate stubble loads in specific areas, provide an opportunity to reduce total evaporation and to accumulate more plant available water.

In southern Queensland and northern NSW, cover crops are used to overcome a lack of stubble and protect the soil following low residue crops (e.g. chickpea, cotton) or following skip-row sorghum with uneven stubble and exposed soil in the ‘skips’.

Growers typically plant white French millet or sorghum and spray them out within ~60 days to allow recharge in what are normally long fallows across the summer to the next winter crop. Allowing these ‘cover crops’ to grow through to maturity led to significant soil water deficits and yield losses in subsequent winter crops. However, the Eastern Farming Systems project showed only small deficits (and even water gains) accrued to the subsequent crops when millets were sprayed out after 6 weeks, with average grain yield increases of 0.36 t/ha. Furthermore, the Northern Growers Alliance showed that the addition of extra stubble (from 5-40 t/ha) after winter crop harvest appeared to reduce evaporation, with initial studies showing between 19 mm and 87 mm increases in plant available water. These gains will be valuable if validated in further research and captured in commercial practice.

Our current project is monitoring sites intensively to quantify the impact of different stubble loads on the accumulation of rainfall, the amount of water required to grow cover crops with sufficient stubble loads, the net water gains/losses for the following crops and the impacts on their growth and yield. This paper reports on the first two sites in southern Queensland, which will be used in simulation/modelling later in the project to assess the wider potential and economic impacts of cover crops in both grain and cotton production systems.

## Experiment 1 – Yelarbon (pivot-irrigated cotton, short fallowed to pivot irrigated cotton)

The Yelarbon experiment was on a pivot-irrigated paddock that grew cotton in 2016/17. The crop was picked and root cut in May, before offset discs were used on 12 June 2017 to pupae-bust and to level wheel tracks of the pivot irrigator. Nine cover treatments (Table 1) with five replicates were planted on the same day using barley (100 plants/m$^2$), barley and vetch mixtures (30 plants/m$^2$ each) and tillage radish (30 plants/m$^2$). Rain that night aided establishment, and the surrounding paddock was planted two weeks later to wheat for stubble cover.

Three planned termination times matched key growth stages of the main cereal treatments: Early-termination at first node (Z31) when the crop begins stem development; Mid-termination at flag leaf emergence (Z41) when the reproductive phase begins; and Late-termination at anthesis (Z65) for peak biomass production. Biomass of the cover crop treatments at their relevant termination times ranged from 1166 kg dry matter (DM)/ha (early) to 8175 kg DM/ha when the crop was grown through to grain harvest (Table 1).

The subsequent cotton crop was planted on 15 November 2017 and irrigated on a schedule determined by the surrounding wheat crop that was harvested for grain. We included a ‘grain harvest’ treatment in our experimental plots to align with the farmer’s practice. Above ground biomass was also monitored across the growth of the cover crops until termination and through the subsequent fallow. Establishment was counted in all plots and hand cuts used to estimate cotton yields.

**Table 1.** Cover treatments applied at the Yelarbon site prior to planting cotton

| Treatment | Cover crop | Termination time | Biomass (kg/ha) |
|---|---|---|---|
| **1.** | Control (Bare) | | |
| **2.** | Cereal | Early-sprayout | 1166 |
| **3.** | Cereal | Mid-sprayout | 4200 |
| **4.** | Cereal | Late-sprayout | 5104 |
| **5.** | Cereal | Mid-sprayout + Roll | 4200 |
| **6.** | Cereal | Grain harvest | 8175 |
| **7.** | Cereal + legume | Mid-sprayout | 4928 |
| **8.** | Cereal + legume | Late-sprayout | 4149 |
| **9.** | Tillage radish | Mid-sprayout | 4692 |

### *Soil water*

Soil water was estimated using soil cores to measure gravimetric soil water at key times across the fallow and the subsequent cotton, along with regular neutron moisture meters (NMM) and EM38 readings in each plot. These NMM and EM38 readings and the percentage ground cover were recorded every two-to-four weeks while the cover crops were growing, and every four weeks once all cover crops were terminated, and until canopy closure of the following cotton was achieved. Final EM38 and NMM readings were recorded at cotton defoliation.

The water cost of growing the barley cover crops, relative to the control treatment in the early stages of the fallow was ~40 mm for the early-termination, ~70 mm for the mid-termination and ~120 mm for the late-termination (Figure 1). However, by the end of the fallow, and a subsequent 170 mm of rainfall/irrigation in 8 events from mid-termination to cotton plant, the mid-termination treatment caught up to the control, and the early-termination had accumulated an additional 14 mm of water. Not surprisingly, this early-termination proved to be the best cover crop treatment on the short fallow. The crop that continued to harvest was ~145 mm behind by the end of the fallow. This treatment mirrored the wider paddock and so set the following pivot irrigation schedule.

### *Crop performance*

The irrigation schedule matched to the harvested crop provided more than adequate water across the cover crop treatments and yields for all cover crop treatments were similar. However, the Control with limited ground cover was the poorest performer, with ~3 bales/ha lower yield, lower infiltration in early growth stages and less extraction of water late in the crop.

The nominal costs to plant the cover crops ($50/ha) and to spray them out ($20/ha) were almost matched by the savings from three less fallow weed sprays ($60); so the measured cotton yield responses were very profitable. For grain growers, the extra 14 mm stored moisture from the early-termination cover crop would typically produce ~200 kg/ha grain in wheat at a water use efficiency of 15 kg grain/mm water, which is worth ~$50/ha (at $270/t) and would produce an overall return of $40/ha. Any further possible benefits from cover crops, which appear to have occurred in the cotton crop, have not been included.

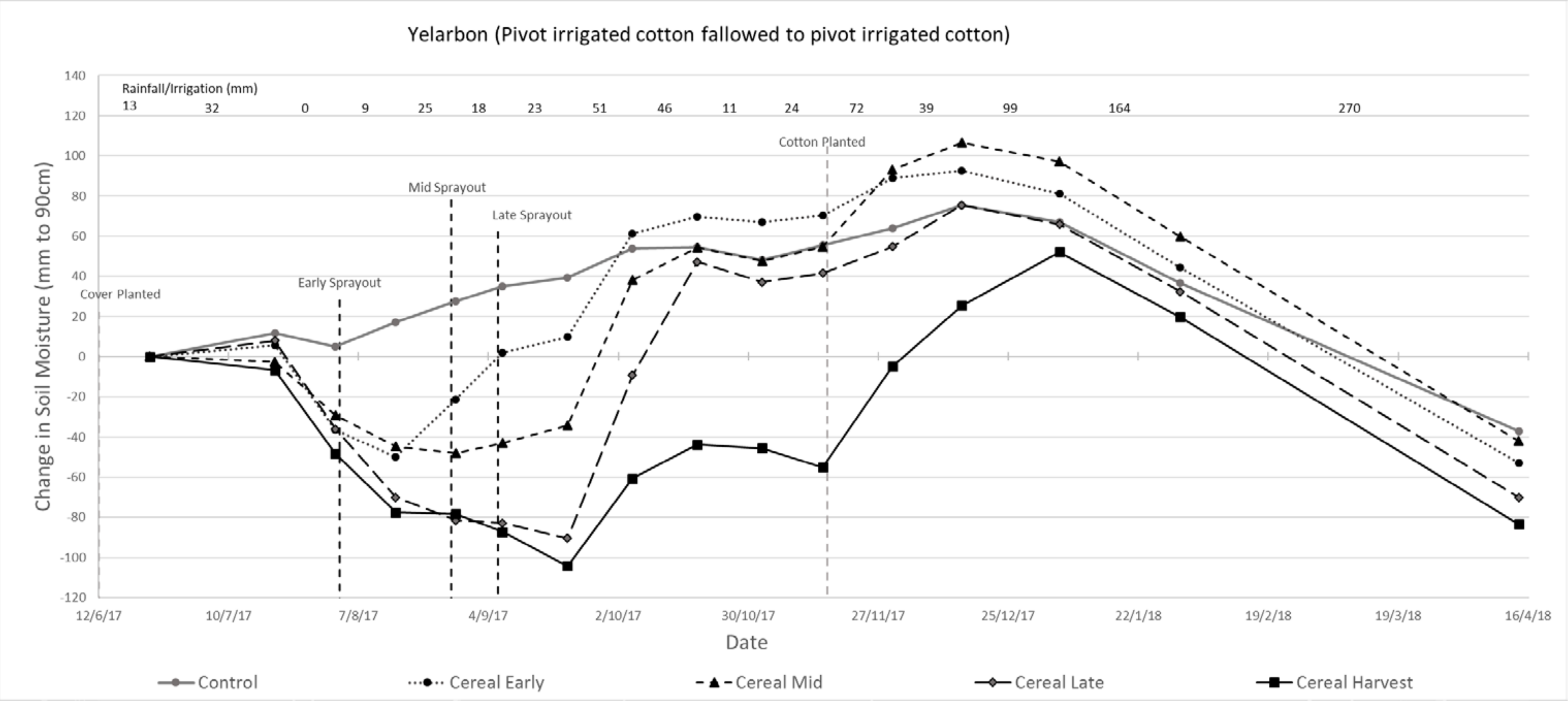


**Figure 1.** Changes in soil water (mm to 90 cm) from planting of key cover crop treatments until defoliation of the subsequent cotton crop at Yelarbon

**Table 2.** Net change in water storage over the life of the fallow (relative to the Control) and final cotton yield for each cover crop treatment at Yelarbon.

| Treatment | Cover crop | Terminated | Water gain (cf control) | Cotton yield (bales/ha) |
|---|---|---|---|---|
| **1.** | Control (bare)<br>Starting water ~100mm PAW | | 56 mm<br>(fallow gain) | 9.3 |
| **2.** | Cereal | Early | +14 mm | 12.9 |
| **3.** | Cereal | Mid | -1 mm | 12.7 |
| **4.** | Cereal | Late | -14 mm | 11.9 |
| **5.** | Cereal | Mid + Roll | -2 mm | 12.6 |
| **6.** | Cereal | Harvest | -111 mm | 14.1 |
| **7.** | Cereal + legume | Mid | -16 mm | 11.9 |
| **8.** | Cereal + legume | Late | -7 mm | 13.9 |
| **9.** | Tillage radish | Mid | -40 mm | 14.4 |

**Experiment 2 – Bungunya (Skip-row sorghum, long- fallowed to dryland wheat)**

The Bungunya experiment was in a long-fallow paddock following skip-row sorghum harvested in early February 2017. The paddock had deep phosphorus applied in August 2017 and was 'Kelly-chained' in September 2017 to level the paddock, which left it with little cover until the planned wheat crop. Cover crops were planted into ~120 mm of plant available soil water on 11 October. The subsequent wheat crop was planted on 1 May 2018, with hand cuts for yield done on 12 October and mechanical harvesting on 26 October. Soil water, cover crop and stubble biomass, ground cover, wheat establishment and yields were measured in the same way as the experiment at Yelarbon.

**Table 3.** Cover treatments applied at the Bungunya site prior to planting wheat

| Treatment | Cover crop | Termination time | Biomass (kg/ha) |
|---|---|---|---|
| **1.** | Control (Bare) | | |
| **2.** | Millet (White French) | Early-sprayout | 1533 |
| **3.** | Millet (White French) | Mid-sprayout | 2327 |
| **4.** | Millet (White French) | Late-sprayout | 4365 |
| **5.** | Millet (White French) | Mid-sprayout + Roll | 2476 |
| **6.** | Millet (White French) | Late-sprayout + Roll | 4737 |
| **7.** | Sorghum | Mid-sprayout | 2481 |
| **8.** | Lab Lab | Mid-sprayout | 1238 |
| **9.** | Multi-species<br>(millet, lab lab, radish) | Mid-sprayout | 1214 |

### *Soil water*

The water cost of growing the millet cover crops, relative to the Control treatment in the early stages of the fallow was ~50mm for the early-termination, ~40 mm for the mid-termination and ~60 mm for the late-termination (Figure 2). The lab lab mid-termination treatment also cost ~60 mm to grow, relative to the Control treatment. These figures reflect rainfall and different rates of infiltration between soil water measurements:

- Plant to mid-termination, 65 mm in 3 events (12/10/17 to 22/11/17)
- Mid-termination to plant, 205 mm in 11 events (22/11/17 to 1/5/18)

- Follow crop plant to maturity 41mm in 3 events (1/5/18 to 10/10/18)
- Follow crop maturity to soil sample 72mm in 7 events (10/10/18 to 5/11/18)

By early March, with a subsequent 175 mm of rain in ten falls after the mid-termination, the millet treatments had all recovered to have effectively the same soil water as the Control, except where the late-terminated millet was rolled; it had gained ~20 mm more water than the other treatments.

When the subsequent wheat crop was planted, the mid-terminated millet had ~14 mm more soil water than the Control treatment, the late millet ~19 mm more, and the late millet that was also rolled had ~36mm more soil water (Table 4). Interestingly, water extraction by the wheat crop was greater from all of the millet cover crop plots than the Control, which had lower yields; perhaps due to, or resulting in less root development.

### ***Crop performance***

All cover crop treatments increased the yield of the final wheat crop (Table 4) and saved two fallow weed sprays (~$40/ha). However, the biggest yield increases were from the cereal cover crops, especially the late-terminated millet and the sorghum.

The water differences at planting (end of the fallow) may explain some of the yield difference. However, the establishment of the wheat crop was dramatically better where cover crops were used, more so where cereals were used but also for lab lab. The expected yield increases from the higher fallow water storage alone would typically be ~200 kg grain in wheat (WUE 15 kg grain/mm water) for the mid-terminated millet (worth ~$50/ha), ~280 kg grain for the late millet (worth $75/ha) and ~540 kg grain for the late +rolled millet (worth $150/ha). These gains would represent net returns of $20/ha, $45/ha and $120/ha respectively. However, the measured yield gains for these treatments were 950 kg/ha, 1461 kg/ha and 1129 kg/ha respectively, representing increase returns of between $250 and $380 /ha.

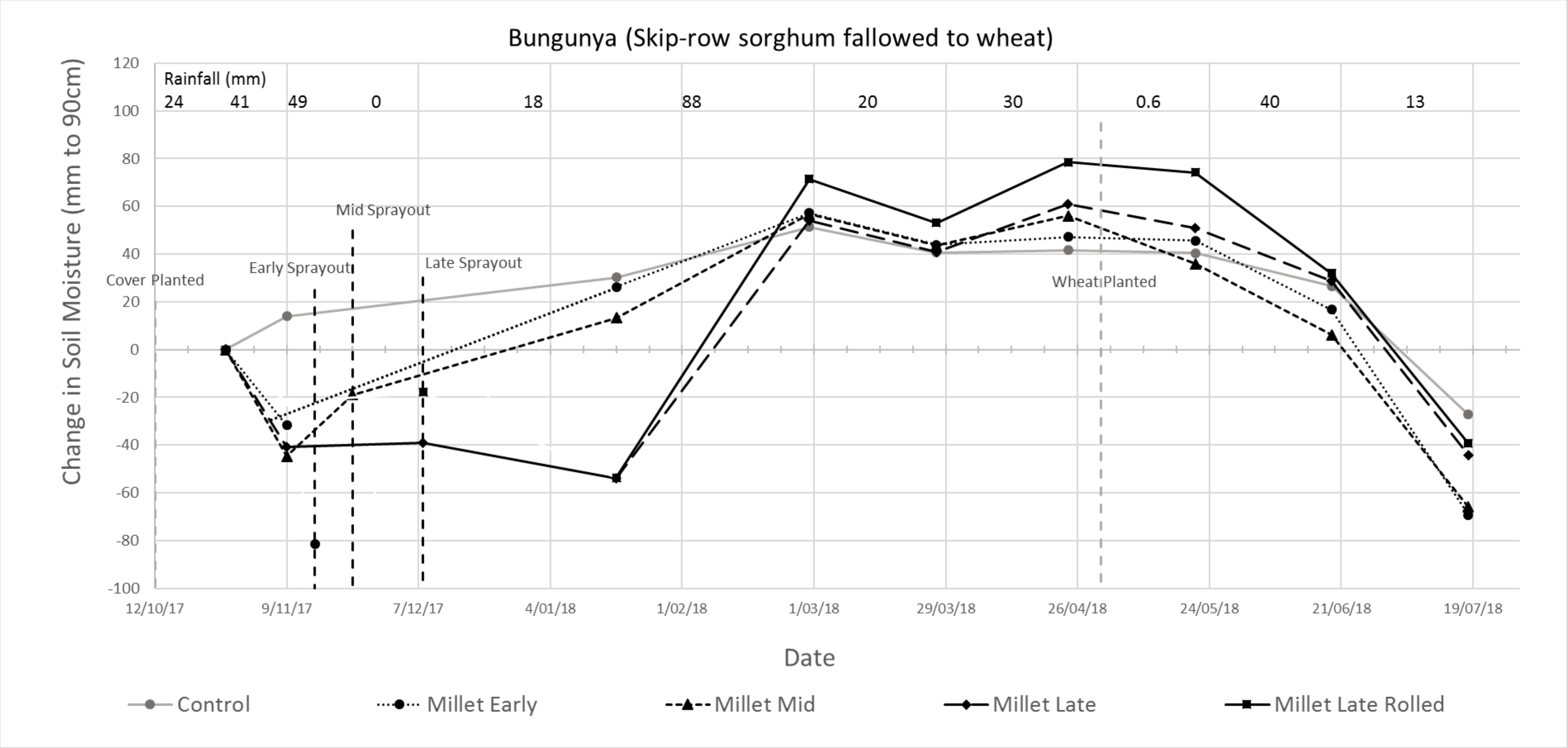


**Figure 2.** Changes in soil water (mm to 90 cm) from planting of the millet cover crop treatments sprayed out at different crop growth stages until harvest of the later wheat crop at Bungunya

**Table 4.** Net change in water storage over the life of the fallow (relative to the Control) and final wheat yield for each cover crop treatment at Bungunya.

| Treatment | **Cover crop** | **Terminated** | **Water gain (cf control)** | **Wheat yield (kg/ha)** |
|---|---|---|---|---|
| 1. | Control (bare)<br>Starting water ~120mm PAW | | 42mm<br>(fallow gain) | $1436^{f}$ |
| 2. | Millet (White French) | Early | +5 mm | $2223^{cd}$ |
| 3. | Millet (White French) | Mid | +14 mm | $2386^{bc}$ |
| 4. | Millet (White French) | Late | +19 mm | $2897^{a}$ |
| 5. | Millet (White French) | Mid + Roll | +17 mm | $2359^{bc}$ |
| 6. | Millet (White French) | Late + Roll | +36 mm | $2565^{b}$ |
| 7. | Sorghum | Mid | +17 mm | $2634^{ab}$ |
| 8. | Lab Lab | Mid | -4 mm | $1795^{e}$ |
| 9. | Multi-species<br>(millet, lab lab, radish) | Mid | +21 mm | $1954^{de}$ |

**Potential biological impacts**

These two experiments focused on soil water accumulation. Biological analysis was not undertaken, but some exploratory analyses will be included for selected treatments in future trials. However, past biological assessments on the Eastern Farming Systems project sites around Goondiwindi highlighted a range of biological effects following white French millet cover crops.

Mycorrhizal colonisation of roots in six-week-old wheat from 1.8% in the long-fallow following skip-row sorghum to 8.3% following an early terminated millet cover crop in the fallow (Seymour *et al.* 2006); crop growth was much stronger following the cover crop. Other positive biological effects included increases in free-living nematodes and cellulase activity that indicate a more active biological system with a greater food source from more residues; and increased Nematode Channel Ratios, which indicates greater bacterial activity from more disturbance and addition of higher quality residues (Table 5). Unfortunately, the white French millet cover crop also boosted root-lesion nematodes (*Pratylenchus* sp.), and so cover crop species must be selected carefully where root-lesion nematodes are a problem.

**Table 5.** Selected biological effects at wheat planting after a 15 month fallow from skip-row sorghum +/- a white French millet cover crop with different termination dates near Goondiwindi (Seymour *et al.* 2006)

| **District** | **Treatment** | ***Pratylenchus* sp/g soil** | **Free living nematodes/g soil** | **Nematode channel ration (0= fungal; 1= bacterial)** | **Cellulase assay** |
|---|---|---|---|---|---|
| Lundavra | Fallow | 0.64 | 0.58 | 0.39 | 0.21 |
| | Short-term millet | 1.31 | 2.76 | 0.39 | 0.59 |
| | Mature millet | 2.51 | 7.33 | 0.57 | 0.89 |
| North Star | Fallow | 0.92 | 0.65 | 0.52 | 0.03 |
| | Short-term millet | 0.92 | 7.41 | 0.79 | 0.23 |
| | Mature millet | 1.45 | 5.25 | 0.87 | 0.11 |
| LSD | ($P$=0.05) | 0.51 | 2.96 | 0.19 | 0.31 |

## Conclusions

The project results show that cover crops can indeed help increase net water storage across fallows that have limited ground cover. Importantly, these results were achieved in drier than normal seasons. For example, the Bungunya site with millet cover crops had a wet spring that allowed a well grown cover crop to develop, but was then followed by well below average rainfall through the fallow, with a few good storms in February/March. How often these soil water results will occur across different seasons will be explored across the rest of the project with further experiments and simulation modelling.

However, more dramatic are the early yield results for the subsequent cotton and wheat crops at each site. These yield responses are very large and represent big improvements in returns; far beyond what could be expected from the increases in net soil water storage across the fallows. Wheat establishment dramatically improved in the Bungunya experiment, and there was greater water extraction (especially at depth) in the Yelarbon experiment. How much of the responses can be attributed to these factors, how often such results might occur, and the contributions of other factors to these gains remains to be explored.

## Acknowledgements

The research undertaken in this project was possible through the significant contributions of growers through both trial cooperation and the support of the GRDC, the CRDC, DAF Queensland, CSIRO and DPINSW. The authors would like to thank them all for their continued support. Special thanks to Glen Smith at ‘Koarlo’, David Woods at ‘Coorangy’, and the DAF Biometry, Technical and Research Infrastructure staff that supported the heavy management and monitoring loads of these experiments.

## References

Seymour NP, Bell MJ, Price LJ, Stirling GR and Stirling AM (2006) Improving soil biology through using millet (*Panicum mileaceum*) as a short-term fallow cover crop. 4th Australasian Soilborne Diseases Symposium. Queenstown New Zealand. 3-6 September 2006

## Contact details

David Lawrence
DAF Queensland, Tor Street, Toowoomba
Mb: 0429 001 759
Email: david.lawrence@daf.qld.gov.au

Andrew Erbacher
DAF Queensland, Lagoon Street, Goondiwindi
Mb: 0475 814 432
Email: andrew.erbacher@daf.qld.gov.au

Return to contents

# Farming for the future: optimising soil health for a sustainable future in Australian broadacre cropping

*Alexander Nixon, Nuffield Scholar, Drillham, Qld*

**Key words**

Nuffield, cover crop, multi-species, soil function, soil health

**Take home messages**

- Observations from overseas are that incorporating multi-species cover crops is an effective and efficient means to improve soil function and health
- Multi-species cover rotations are a financially viable option for Australian broadacre cropping operations seeking to improve their soil and reap the subsequent benefits through increased cash crop yields
- Careful planning and management of the rotation schedule and seed-mix selection is required to optimise benefits.

## Introduction

For many years conventional farming practices have been degrading the state of our soils. The zero-till farming revolution has instigated a push towards improved soil health. New research indicates that bio-diversity and groundcover are essential contributing factors to optimal soil health, and many farms in the USA and England have been implementing multi-species cover crop rotations in conjunction with zero-till practices with amazing results in soil rejuvenation and increased cash crop yields. The sustainability of Australian broadacre dryland cash cropping operations, and the agricultural industry in general, hinges heavily on a soil health focus. Incorporating multi-species cover crops into cash crop rotations is the most effective way to improve soil health.

## Cover crops for ground cover

Maintaining ground cover is essential to soil health on multiple levels. As the name implies, cover crops aim to achieve exactly that. They are intended to be sown after the completion of a cash crop, in place of long-fallowing. Cover crops are typically left to grow until the milky stage of seed production, or until sufficient biomass has been obtained, after which point, they are terminated – usually either lightly tilled in, mowed or rolled/crimped or sprayed – with the residue remaining as ground cover. Weed suppression, prevention of erosion, increased soil organic matter (SOM) levels and improved water infiltration/moisture retention, can potentially be achieved by cover cropping.

## Soil function and bio-diversity through multi-species cover crops

The soil ecosystem is complex with many aspects of soil chemistry and physics are inter-related. Plant bio-diversity has proven to be a key factor when considering soil health, as different plants serve a variety of purposes both above and below the soil surface. Maintaining a diverse range of plant roots aids in preserving an array of different microbe communities and helps sustain the balance between fungi and bacteria, and also moderates the Carbon:Nitrogen (C:N) ratio. Concurrently, different plant types achieve varying degrees of cover on the soil surface and each species contributes in different ways to both the carbon and nutrient cycles. Species diversity is valuable to soil health due to its reliance on a range of functions which are often heavily inter-connected and overlapping.

## Financial viability of cover crop rotations in broadacre dryland farming

Optimal soil health is important to future sustainable and financially viable broadacre cropping. Multi-species cover crops are a method for rejuvenating and maintaining soil conditions. However, broadacre dryland farming businesses face several issues when moving towards such conservation management practices. Firstly, upfront costs of cover crop seed currently remain high. Machinery investments, such as rollers, mowers or crimpers are costly and are not yet readily available in Australia. The logistical implications associated with the scale of Australian farms could incur increased expenses. And finally, business cashflow can become compromised if input costs to establish the cover crop exceed the expected returns for the season.

### *Logistics and considerations*

Most research, trials and recommendations for implementing cover crops currently stems from the USA. When considering applying this knowledge to Australian broadacre cropping systems the information must be adapted, though many of the basic theories remain the same. Factors for consideration include, but are not limited to:

- Climate
- Soil type
- Current management practices
- Existing cropping schedules.

### *Species selection*

Species selection is perhaps the most important element to successful cover cropping. Several factors must be considered when choosing a cover crop mix, being:

- Current soil conditions – soil testing prior to seed mix selection is advisable to establish what functions are required and thus which species can best fulfil the requirements
- Subsequent cash crop – it is important to keep this in mind to avoid any potentially negative impacts from undesirable soil changes or pathogenic species to the following crop. Varieties selected must be compatible together, and with the subsequent cash crop
- Seasonal and climatic conditions – rainfall, temperatures and time of year should all be considered when choosing each variety for a multi-species cover
- Plant functional group – a selection of cereals, grasses, legumes, brassicas and chenopods is recommended for optimal soil health benefits.

### *Financial viability*

The effectiveness of incorporating cover crop rotations for rejuvenating and maintaining soil has been substantiated in many farming situations around the globe. Research for this report was conducted on several properties in the USA and England, with notable success in restoring soil health recorded at each. However, one common concern was the financial viability while transitioning to this management practice. A business, or business decision, is considered financially viable when generated income exceeds costs.

Another important point to note is the relative size and scale of the business. Some of the farms visited were as small as 600 acres (approximately 243 hectares), while the average farm size in Australia is 4,331 hectares (Australian Bureau of Statistics, 2017). Appropriating business funds for cover-cropping to such a scale as to fit the average Australian farm, could initially pose the following issues and risks:

- Increased upfront costs for seed and planting
- Compromised business cashflow
- Time allotted for planting/termination could result in the necessity for multiple machines to be operating to achieve the task within ideal timeframes, resulting in more business funds being absorbed by capital investments
- Soil types can vary dramatically from one end of a largescale paddock to another, impacting cover-mix selection and effectiveness.

Some suggestions to alleviate and manage these problems are to:

- Start small – one paddock at a time
- Consider frequency and size of cover rotations based on benefits produced, and increase accordingly over time
- Consider value-adding - Controlled grazing of cover crops can provide extra income/soil benefits over the cover-crop season. Investing in livestock or offering short-term agistment are two potential options.

While some financial difficulties may arise when farming operations initiate cover-crop rotations, the long-term monetary benefits are purportedly profitable. Some of the economic benefits of multi-species cover cropping are:

- Decreased fertiliser costs
- Reduced requirement for herbicides and pesticides
- Higher yields – due to improved soil health.

## Conclusion

The sustainability of Australian broadacre dryland cash cropping operations, and the agricultural industry in general, hinges heavily on a soil health focus. Incorporating multispecies cover crops into cash crop rotations is a way to improve soil health.

The evidence presented in this report demonstrates that multi-species covers can alleviate several environmental factors affecting soil health by:

- reducing or preventing erosion
- increasing water infiltration
- inhibiting weed growth
- stabilising losses of or increasing soil organic matter.

Further, this report emphasises the importance of bio-diversity within a cover crop, showing how a species-rich environment creates synergy between multiple soil components. Bio-diversity encourages:

- effective carbon and nutrient cycling
- a balance of C:N ratios
- microbial growth and activity
- healthy bacteria to fungi ratios.

Though implementing diverse cover-crops can pose initial economic issues, the long-term environmental and economic benefits prove to outweigh the financial deficit associated with the transition phase. Through careful management and mix-selection, multi-species cover cropping can certainly be a viable option for Australian broadacre farmers seeking to improve soil health.

### *Recommendations*

1. Employ zero-till farming practices wherever possible to lessen soil degradation.
2. Create a cover crop rotation schedule – based on soil test results and current cash crop rotations. It is imperative to have a plan, goal and strategy in place in order to be effective and efficient in any business venture.
3. Implement a business plan for the transition phase – expect that multi-species cover cropping is a long-term investment, interim alternative income sources may be required to support the associated expenditure.
4. Conduct regular soil testing – knowing your soil and monitoring soil changes will ensure that appropriate actions can be taken e.g. which paddocks require attention, what soil health issues are arising, and which plant species are most suited for rectification.
5. Research plant varieties suitable for the region – understanding species for both their benefits and their required growing conditions is advisable. Consider contacting a local agronomist if necessary and remember, the more species the better!
6. Construct a "seed budget". Seed will be the primary input cost. Pricing different varieties and options available and adhering to a budget will minimise any negative financial impacts in the initial season.
7. Decide which methods will be employed for planting and termination – performing an opportunity cost analysis may assist when considering alternatives.
8. Consider value-adding (such as livestock grazing). It is important to closely monitor and control any grazing to ensure the best results from plant growth benefits.
9. Encourage neighbours to get involved – a local cooperative initiative could be an option for capital investment of plant and machinery, bulk seed purchases to obtain discounts and disseminating local knowledge, information and findings from trials.
10. Consider applying for government grants and subsidies associated with agricultural conservation practices.

## Further information

This Update paper contains excerpts from the author's Nuffield Scholar Report. The unabridged report is available here: https://nuffieldinternational.org/live/Report/AU/2017/alex-nixon

## Acknowledgements

I would like to thank the GRDC for sponsoring my scholarship, and Nuffield Australia for the opportunity.

## Contact details

Alexander Nixon
Bexa Pty Ltd T/A Devon Court Stud
769 Wallan Creek Road
Drillham Qld 4424
Mb: 0429 432 467
Email: aanixon@live.com.au

Return to contents

# New genetics to improve wheat establishment and weed competitiveness

*Greg Rebetzke[1], C. Ingvordsen[1], W. Spielmeyer[1], B. French[2], C. Zaicou-Kunesch[3]*
*and N. Fettell[4]*

[1] CSIRO Agriculture and Food
[2] DPIRD, Merredin
[3] DPIRD, Geraldton
[4] Central West Farming Systems, Condobolin

**Key words**

wheat, breeding, genetics, dwarfing genes, coleoptile length, establishment

**GRDC code**

CSP00182, CSP00199, CSP00200

**Take home messages**

- Current Australian wheat cultivars contain dwarfing genes that reduce coleoptile length by 40%. New dwarfing genes are available that reduce plant height but don't reduce coleoptile length
- A gene increasing coleoptile length was identified and tagged with DNA markers. Breeding lines and DNA markers for new dwarfing and coleoptile length genes have been delivered to Australian breeders for efficient selection of improved crop establishment
- Deep-sowing studies in WA and NSW Managed Environment Facilities show benefit with new dwarfing and coleoptile length promoting genes in increasing emergence at sowing depths of up to 120mm but without changing plant height
- Moisture-seeking points coupled with new genetics should reliably allow seed placement and emergence from sowing depths of 100mm or greater, and/or with warmer soils
- Genetic variability exists with potential to suppress weeds through greater shoot and/or root competitiveness.

## Background

In rainfed environments typical of the eastern and southern wheatbelts, crops are typically sown on the first breaking rains but sometimes moisture accumulated through summer is too deep for sowing with conventional variety × drilling systems. Key to good leaf area development for tillering, growth and weed competitiveness is good crop establishment. An ability to establish wheat crops from seed placed 80mm or deeper in the soil would be useful in situations where the subsoil is moist but the surface dry. Seeding onto moisture at depth can assist to extend the opportunities for a greater portion of the cropping program to be sown in the traditional sowing months of May and June or earlier in April following summer rain. A separate but concerning issue is the influence of increasingly warmer soil temperatures on reductions in coleoptile (the shoot that grows from the seed and allows seedling emergence through the soil) length. Earlier sowing into warmer soils will reduce coleoptile length by as much as 60% so that a variety such as Mace with a 75mm coleoptile at 15°C will likely have a 40mm coleoptile at 25°C soil temperature. Some seed dressings and pre-emergent herbicides can further reduce this coleoptile length and affect establishment.

The green revolution *Rht-B1b (syn. Rht1)* and *Rht-D1b (syn. Rht2)* dwarfing genes reduced plant heights to reduce lodging and increase grain yields and so are present in most wheat varieties worldwide. Their presence also reduces the length of the coleoptile by as much as 40%. This reduces crop emergence when sown at depths greater than 50mm, tiller number and leaf size to reduce water-use efficiency and weed competitiveness.

## New dwarfing genes

A range of alternative dwarfing genes have been identified in overseas wheats with potential to reduce plant height and increase yields, while maintaining longer coleoptiles and greater early vigour. Some of these genes (e.g. *Rht8* and *Rht18*) have been used commercially overseas but have not been assessed for use here in Australia. We reduced the larger global set of alternative dwarfing genes to *Rht4, Rht5, Rht8, Rht12, Rht13* and *Rht18*, and then developed linked DNA-markers to assist with breeding of these genes in a commercial breeding program. Separately, we then bred these genes using conventional and DNA-based methods into the old, tall wheat variety Halberd for testing and disseminating to Australian wheat breeders.

## Genes that promote coleoptile growth

While switching to new dwarfing genes will remove the growth inhibition on early growth, there is a need to promote coleoptile growth, particularly in the presence of conventional dwarfing genes. A gene with major effect on coleoptile length was identified in current wheat cultivars. Through a GRDC funded project, we demonstrated that the gene not only increased coleoptile length but also emergence with deep sowing in field trials conducted over three years at Yanco NSW (Figure 1). The gene was tagged with molecular markers and tested in a wide range of Australian wheat germplasm. We estimated that only 10% of recently released cultivars carry the coleoptile growth promoting gene. The markers were distributed to Australian breeding companies to assist with the selection and the expected increase of gene frequency in future cultivars. Additional genetic variation for coleoptile length and early growth exists in elite germplasm. For breeders to take full advantage of this variation, additional genes controlling this trait need to be identified and tagged with markers for efficient selection and combining growth promoting genes for even better performance.

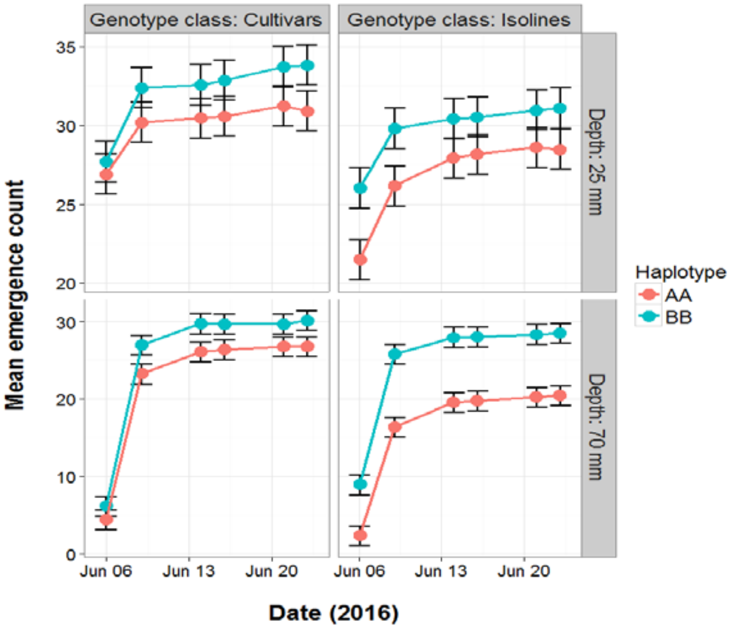


**Figure 1.** Emergence of wheat commercial cultivars carrying conventional dwarfing genes and tall isolines in Young background in the NSW MEF at Yanco in 2016. Sowing depth treatments were 25 mm and 70 mm depth. 12 cultivars and 12 isolines were grouped according to the presence of the coleoptile length promoting gene (BB, long coleoptiles) and the lack of the gene (AA short coleoptiles).

### Preliminary sowing depth field studies

Field studies have commenced on the Halberd-based dwarfing gene lines and show that lines containing these new dwarfing genes produced coleoptiles of equivalent length to Halberd (up to 135mm in length; Figure 2) and established well when sown at 100mm depth in deep sowing experiments conducted at Mullewa and Merredin in 2016 (Figure. 3). Grain yields of lines containing the new dwarfing genes were equivalent to the yields of lines containing the commonly used *Rht-B1b* and *Rht-D1b* dwarfing genes while previous studies have shown the new dwarfing genes were linked to greater grain yields when sown deep, owing to greater plant number with improved establishment.

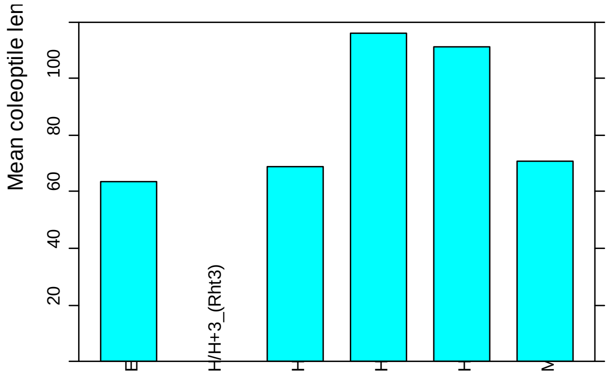


**Figure 2.** Coleoptile lengths of a tall wheat genotype (Halberd) and genotypes with dwarfing genes *Rht-B1b (syn. Rht1)* and *Rht8* emerging in the field in a Halberd background. Emu RockΦ and MaceΦ are current commercial cultivars with *Rht-B1b* and *Rht-D1b*, respectively.

The most likely useful new dwarfing genes, *Rht13* and *Rht18*, have been bred into a range of current commercial wheats (Figures 4 and 5). Long coleoptile wheat breeding lines in MaceΦ, ScoutΦ, EspadaΦ, EGA GregoryΦ and MagentaΦ have been delivered to Australian breeders for testing and use in breeding. If there are no problems with these new dwarfing genes, we may see the first of the long coleoptile wheat varieties in 3-4 years in NVT testing!

### Agronomic opportunities

Although there is real promise in the new genetics, there is significant opportunity in coupling new genetics with new existing seeding technologies. Deep sowing is an issue overseas and in the eastern Australian states. The availability of moisture-seeking points commonly used elsewhere should allow the reliable placement of seed at depths of 100mm or greater. These points produce a slot deep into the soil at the base of which a seed is sown at 10-50mm depth. That said, further research is required aimed at tools and methods assessing across different moisture-seeking points to optimise seed placement at depth across a wide range of soil types.

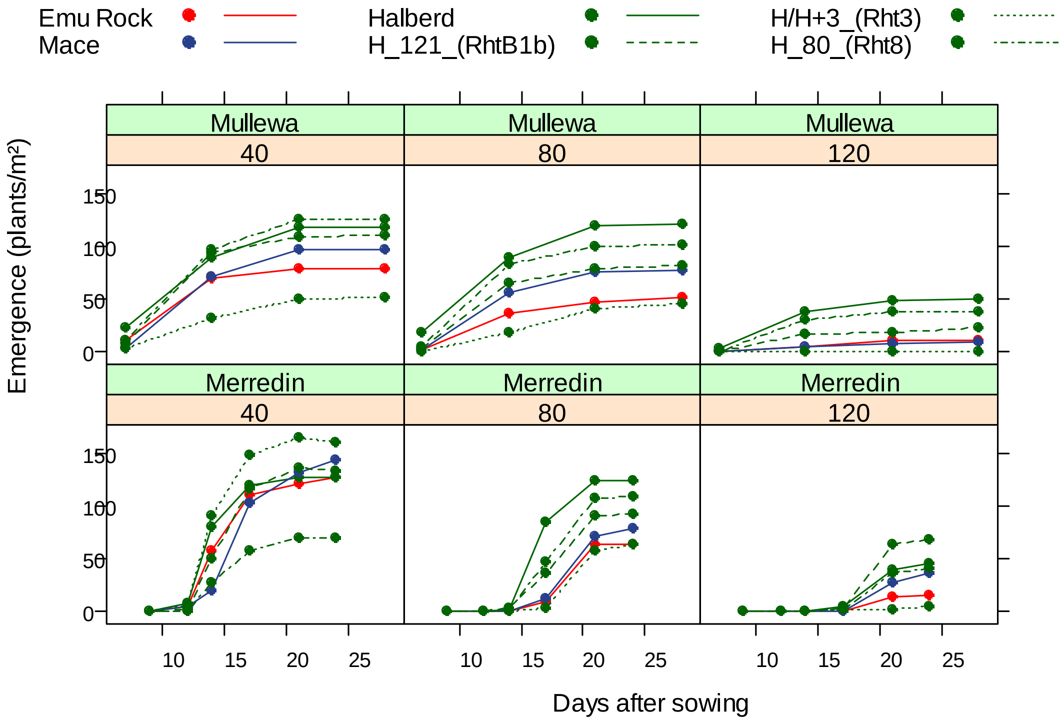


**Figure 3.** Patterns of emergence of wheat genotypes with different dwarfing genes sown at target depths of 40, 80, or 120 mm at Mullewa and Merredin in 2016 (after French *et al.* 2017).

## Weed competitiveness

Weeds cost Australian grain growers an estimated $4B annually through lost production, reductions in crop quality, and herbicide use. These costs are unlikely to reduce with pressure on new actives in the widespread development of herbicide resistance in multiple weed species. Observed differences across cereal species and wheat varietal differences in crop competitiveness with weeds, provides impetus to use breeding and genetic improvement to aid in-crop weed control. In wheat, comparisons across a historic 100-year set of varieties highlighted that older varieties were more competitive with weeds. Presumably, this reflects selection for improved performance in the absence of in-crop herbicides. Overseas studies have demonstrated a reduction in herbicide use of up to 50% when using weed-competitive wheats, while a broader benefit is in integrating competitive varieties with cultural management (e.g. weed seed harvest and tillage) to slow herbicide resistance and reduce herbicide use.

Competitiveness can be thought of as the partial to complete suppression of competing weeds to increase crop yield, or the ability of a variety to tolerate a competitor to maintain higher yields. Selection for greater tolerance is a breeding strategy for many crop insects and diseases but is of less value in weed management as low numbers of weed survivors replenish the seed bank for the next season. In turn, breeding of competitive crops has focussed on selection of genotypes that can better access light, water and nutrients to suppress the growth of weeds. Greater early vigour, as rapid leaf area development and biomass at stem elongation and altered root architecture are mechanisms that contribute to the ability to out compete weeds. Root exudates used in plant defence (allelopathy) may also slow the growth of neighbouring competitors.

In cereals, greater leaf size and rapid early leaf area development are associated with larger seed embryos, higher leaf area, and new dwarfing genes for reducing stem height. Unfortunately, commercial wheat varieties selected for increased yield potential often exhibit poor early growth. A global survey identified 30 wide-leafed, wheat donors which were subsequently used in a CSIRO long-term breeding activity to accumulate favourable genes to increase early vigour. High vigour lines derived from this program have been used to develop wheats with capacity to suppress the growth of ryegrass by up to 50% (Zerner et al. 2016). Field comparisons between current semi-dwarf wheat varieties and weed-competitive wheat breeding lines indicate wheat yield loss and weed suppression is greater in the weed-competitive lines (Figure 4).

Breeding companies are limited in their ability to develop and deliver new traits. The identification of new opportunities that will deliver greater grower profitability together with development of a clear value proposition will allow for pre-breeders to identify those traits and their underlying genetics and methods in selection for uptake by commercial breeders. In the case of weed competitiveness, the genes for weed suppression have come from outside existing breeding programs and include old Australian varieties and overseas landraces. Parental germplasm has been developed over many years and intercrossed into modern Australian varieties. Together with high-throughput selection methods, these populations have been delivered to Australian breeders for use in their commercial breeding efforts toward new weed competitive wheat varieties.

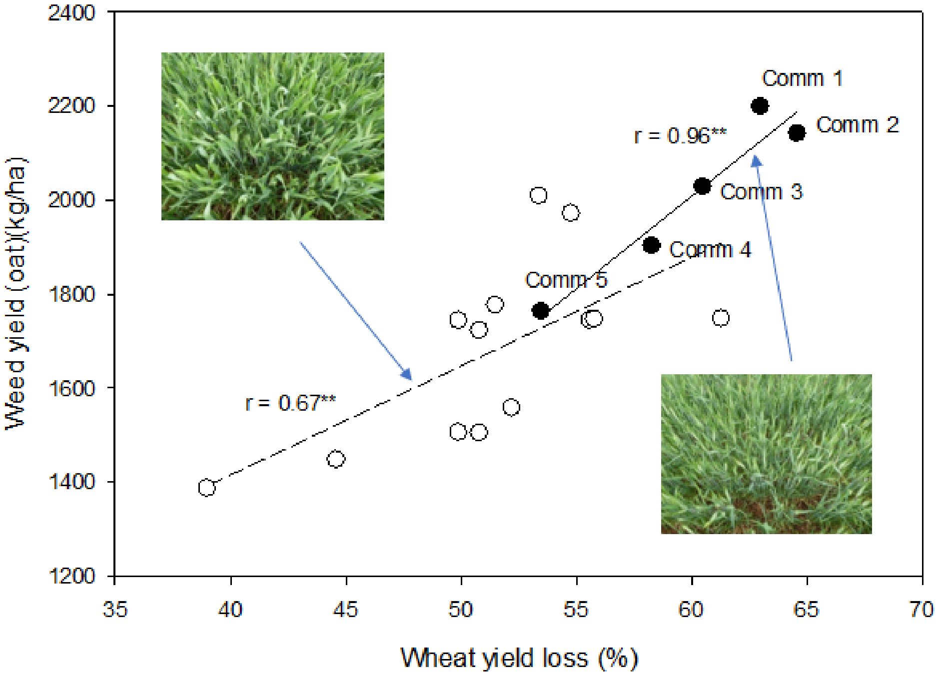


**Figure 4.** Relationship for yield loss in wheat and growth (as yield) of a weed mimic (oats) for breeding lines (○) and commercial wheat varieties (●) in field plots.

### Summary

Wheat breeders now have the new dwarfing genes to breed longer coleoptile wheat varieties. Genes that increase coleoptile length have also been identified and tagged with markers. These genes are expected to play an important role in improving emergence from depth in the presence of conventional dwarfing genes. Matching new genetics with appropriate agronomy and technologies should ensure the emergence and establishment of deep-sown wheats, particularly when sown early to make use of summer rains sitting deep in the soil profile or to increase sowing opportunities in the traditional months of May and June.

### References

French B, Zaicou-Kunesch C, Rebetzke G (2017) Alternative dwarfing genes improve emergence from deep sowing. GRDC Updates Perth

Zerner RK, Gill GS, Rebetzke GJ (2016) Stability of wheat cultivars in weed competitive ability in differing environments in southern Australia. *Crop and Pasture Science* **67**, 695-702

## Acknowledgements

We would like to acknowledge the support of the GRDC in funding much of the research reported herein. We'd also like to acknowledge the support of the managers of the GRDC's Managed Environment Facilities for their assistance.

## Contact details

Greg Rebetzke
CSIRO
Mb:  0429 994 226
Email: G.Rebetzke@csiro.au

Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994

Return to contents

**Figure 4.** Wheat variety Mace⦶ (left) side-by-side with long coleoptile, Mace⦶ containing the *Rht18* dwarfing gene (right) at Condobolin in 2017.

**Figure 5.** Wheat variety EGA Gregory⦶ (left) side-by-side with long coleoptile, EGA Gregory⦶ containing the *Rht18* dwarfing gene (right) at Condobolin in 2017.

# Yield gaps in mungbean crops across the northern grains region

*Marisa Collins[1], Brook Anderson[2] and Lindsay Bell[2]*

[1] University of Queensland (now La Trobe University)
[2] CSIRO Agriculture and Food

**Key words**

Nematodes, nitrogen, flowering, heat stress, water-use-efficiency, nutrition

**GRDC code**

CSP1801-002RTX

**Take home messages**

- Mungbean crops with low observed yield and high yield gaps were those with a low harvest index, which was not always associated with low crop biomass
- Management factors found to significantly increase yield were narrow row spacing (<50 cm) and crops sown on a fallow rather than double cropped
- Maximum water use efficiency (WUE) of approximately 7.5 kg/ha/mm of available water (in-crop rain + starting soil water) were found across the data set. Differences in starting water at this WUE explained observed yield differences between fallow and double crop mungbeans
- 35% of crops achieved > 80% of their water-limited yields, while 36% yielded < 60% of the water-limited yield potential. Nearly half of all monitored crops had yield gaps > 500 kg/ha
- 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 (i.e. < 65% water-limited yield) had either *P. thornei* present at > 3/g soil, or maximum temperatures > 39°C during flowering, or soil nitrate levels below 65 kg N/ha
- Consider soil tests for nutrient status and root lesion nematodes before sowing mungbeans to avoid risks of poor crop performance.

## Introduction

Mungbean crop yields in sub-tropical Australian farming systems are highly variable and the risk of low yields leads to grower perception they are a high-risk crop. The factors causing yield variability are poorly understood. A range of abiotic and biotic yield-reducing factors are likely to be important.

In this study a paddock survey approach was used to assess paddock conditions and yields across three main mungbean growing areas in the northern region. This was combined with simulation modelling to determine the water-limited yield potential and estimate yield gaps of mungbean crops across a diverse range of environments and growing conditions. The objective was to identify factors likely related to poor mungbean crop performance.

## Methods

### *Field survey of mungbean crops*

Consultants in Central Queensland (CQ), Darling Downs in southern Queensland (SQLD), northern New South Wales (NNSW; Moree and Liverpool Plains) were contracted to collect mungbean paddock survey data in season 2017-18. Supplementary data was collected from the GRDC farming systems and legume agronomy projects. Data was collected from 12 paddocks in CQ, 17 paddocks in SQLD and 13 paddocks in NNSW in addition to the supplementary data collected in the GRDC farming systems and legume agronomy projects. Paddock data including GPS latitude / longitude, soil type (if known), cropping history for past summer and winter seasons, fertiliser and herbicide applications were recorded, and in-season measurements completed. In-season measurements included starting / finishing soil water and starting soil nutrient analysis in 0-10, 10-30, 30-60 and 60-90cm soil layers, row spacing, cultivar, paddock rainfall, time of flowering, biomass and harvest cuts. In each paddock Predicta®B sampling was also completed. Crop measurements occurred across the 2017/18 season at five monitoring points (in the same location as the soil sampling) including plant counts, flowering date, biomass cuts, maturity date and harvest samples. Weeds, diseases and insects were monitored throughout the season.

### *Prediction of yield potential and gaps in mungbean crops*

#### *Simulation description*

The APSIM-mungbean model was used to simulate the water-limited yield potential of mungbean crops corresponding to the 42 farm fields surveyed, along with 29 experimental sites obtained from either Mungbean Agronomy research (2013-2018) or Farming Systems research sites (2015-2018). Simulations for each crop, replicated crop management deployed in each field (e.g. same sowing date, configuration). Climate data was obtained from the nearest climate station available from the SILO database or from climate stations located at the experimental site. Soils used in simulations were sourced from the closest soil with the same classification in the APSoil database. Where possible, simulations were initiated with soil water and nutrient samples taken prior to or at sowing. In many cases, starting soil water was not measured or could not be reliably estimated at sowing because of uncertainties with crop lower limits on the specific soils at each site. In these cases, estimations were made by resetting plant available soil water to zero at the completion of the previous crop and allowing APSIM to model soil moisture accumulation during the fallow period leading up to mungbean sowing. The cultivar Emerald was chosen to most accurately represent Jade⦶ and Crystal⦶ in the APSIM model.

#### *Estimation of yield gaps*

In rain-fed crops, yield gaps were calculated as the difference between the water-limited yield potential (Yw) and the achieved grain yield (Ya). The water-limited yield potential is influenced by soil type, soil water status at sowing and climatic conditions over the crops growing season but is not limited by nutrients or biotic stresses. The yield gap was computed as the difference between APSIM simulated yield and the observed yield for each of the 71 mungbean crops. Hence, computed yield gaps are attributable to sub-optimal nutrient supply, biotic factors reducing grain yield or other stress events (e.g. high temperature) which are not captured in the APSIM simulation model. The model was also used to compute three separate stress indices from simulations of each crop to indicate the degree that crops are exposed to high temperature stress events, low soil moisture status and photosynthetic reductions due to moisture stress during flowering and grain filling periods.

## Results

### *Agronomic drivers of mungbean yield - nutrition*

There were limited relationships between yield and both key macro and micro-nutrients across the surveyed paddocks. Across the sites, nitrate N in 0-90cm ranged from 10-300 kg/ha with an average of 115 kg N/ha and average grain yield of 1.0 t /ha. Higher yields were associated with higher starting soil N, however, this relationship was highly variable. Vegetative biomass ranged from 0.75 – 7.0 t dry matter (DM)/ha and there was no significant correlation between grain yield / biomass and phosphorus (P), zinc (Zn), sulfur (S), magnesium (Mg) and potassium (K) in the soil. This is not to say these nutrients aren't critical for crop growth and yield, but more that they weren't singularly the key factor driving yield.

### *Agronomic drivers of mungbean yield – harvest Index*

Unsurprisingly, grain yield was highly correlated with biomass (0.84) and harvest index (HI) at 0.68 (Figure 1). High biomass didn't guarantee high yields, with biomass being poorly correlated with harvest index (0.22). Crops with poor harvest index were strongly associated with lower yields and breeding / management factors that improve harvest index should be a future focus.

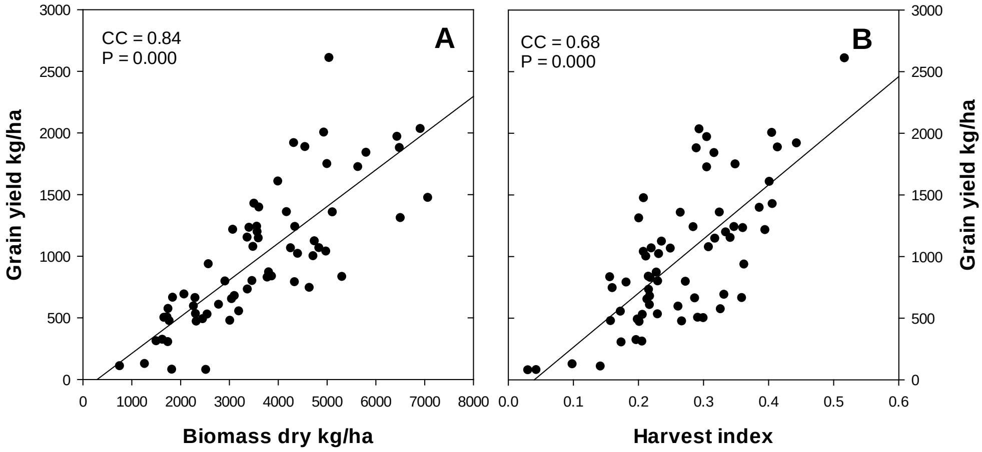


**Figure 1.** Relationship between grain yield (kg/ha) (A) and biomass kg DM/ha; (B) harvest index across mungbean paddocks in season 2017-18. Spearman correlation coefficient (CC) and significance indicated.

### *Agronomic drivers of mungbean yield – row spacing and WUE*

Management factors that improved yields included narrow row spacing and planting onto fallow. Row spacing < 40 cm yielded 33% higher than crops on row spacing > 50cm, at 1.2 and 0.8 t/ha, respectively (Figure 2).

Crops achieving yields higher than 1.25 t/ha, generally required a minimum of 200 mm of available water (starting soil water + in-season rainfall) (Figure 2). Benchmark water-use efficiency of 7.1 kg/ha/mm (n = 10) was observed in the best survey paddocks, with mungbean WUE across the survey paddocks ranging from 0.2 to 9.4 kg/ha/mm with an average of 4.4 kg/ha/mm. While overall available water was not different between double-crop and fallow, mungbeans planted onto fallow had an extra 27mm water in the soil at planting (starting water after fallow averaged 133 mm and when double cropped, 106mm).

This difference in starting soil water accounts for the observed yield increase of 241 kg/ha for crop preceded by fallow compared to double-cropped. Crops preceded by fallow also had significantly higher biomass than double cropped mungbeans (4.1 and 3.0 t/ha, respectively). Crops that achieved yields over 1 t/ha generally had a minimum of 85mm water in the starting profile. However, available water wasn't the only factor driving yield, as many paddocks with over 200 mm available water also yielded poorly (Figure 2).

.

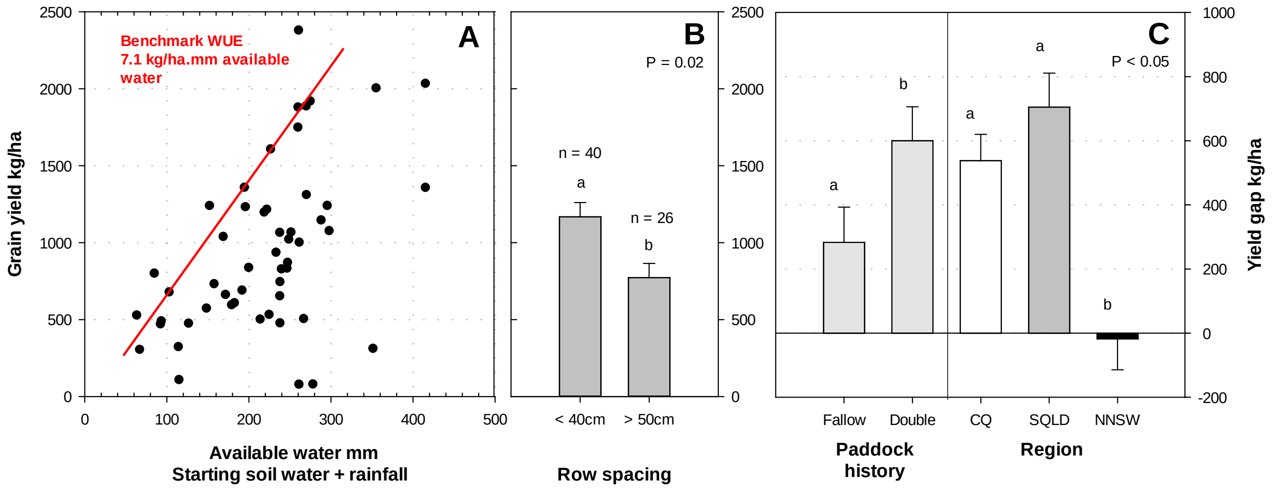


**Figure 2.** Relationship between grain yield and (A) available water (starting soil water and in-season rainfall mm) and (B) row spacing's across mungbean paddocks in season 2017-18. (C) Relationship between yield gap and paddock history (fallow versus double-crop) / region (CQ, SQLD and NNSW). Univariate ANOVA used to determine significance.

### *Regional differences in mungbean yields*

Comparison of paddocks between regions (CQ, SQLD, and NNSW) found no significant differences between regions for yield, biomass, harvest index and available water (starting soil water + in-season rainfall mm). On average, paddocks across the three areas all had > 100 kg nitrate N kg/ha, > 90 mg/kg Colwell P and > 14 mg/kg Mg. NNSW had higher P, K and Zn levels compared to SQLD and CQ. While nutrient thresholds for mungbeans are currently uncertain, it appears unlikely that most sites did not have nutrient status low enough to limit yields. However, low P levels in both CQ and DD may be contributing to yield limitations based on data in other legumes. In-crop rainfall was not significantly different across the regions, however much of the crop in NNSW suffered significantly from prolonged high temperatures in January 2018. Nematode pressure was significantly higher in SQLD with > 3 nematodes/g soil. The threshold for significant yield loss in intolerant crops including mungbeans is 2 nematodes/g soil. *P. thornei* levels in other regions were well below this level and there were no differences in *P. thornei* levels between fallow and double-crop paddocks

### *Mungbean yield gaps*

The model reasonably predicted the grain yields and harvest index of crops that achieved their potential. However, there were large differences between simulated and observed grain yields for a large number of crops analysed. These differences were used to estimate mungbean yield gaps. Across the whole dataset, simulated mungbean yields ranged from 0.5 – 2.6 t/ha across the spectrum of double-cropped following a winter crop the same year, following a short-fallow after a summer crop the previous year or where partial irrigation was provided. There were no clear differences due to location or data origin in terms of the simulated yield potentials or observed grain yields across this data set.

One third (24 of 71) of the crops analysed had no significant yield gap (< 200 kg/ha) or observed yields exceeded simulated yields (Table 1). Several observed crop yields from the both paddock surveys and mungbean agronomy datasets exceeded the simulated yield potential, but in most cases, this was within the boundaries of variation for those observed crop yields. Some uncertainties with information used to simulate these crops may also explain these differences. Forty-five % of crops had a yield gap > 500 kg/ha. Seven (10%) of the 71 crops were identified that had large yield gaps of greater than 1 t/ha (Table 1). The remaining 16 crops (22%) had yield gaps between 200 and 500 kg (Table 1). Interestingly, crops with yield gaps of different magnitudes and proportions were found across both data from experimental and paddock survey origins. As the crops grown under experimental conditions were managed using optimal weed, insect and disease control, this suggests that yield gaps are unlikely to be explained by these yield reducing factors alone.

### *Diagnosis of yield limiting factors*

In examining possible causes of yield gaps driven by paddock nutrient and pathogen status there were weak correlations between estimated yield gap and Colwell P ($R^2 = 0.11$), sulfur ($R^2 = 0.13$), or potassium ($R^2 = 0.18$). Yield and biomass gap differed across the regions and paddock history with higher yield gaps (500 – 700 kg/ha) in CQ and SQLD compared to NNSW. This suggests there are factors affecting crops reaching their predicted yield potential in those regions which are not well predicted by the mungbean APSIM model. Yield gaps in double-crop mungbeans were significantly higher than in fallow mungbeans (Figure 2). The yield gap observed in double-crop mungbeans strongly suggests there are other factors or combination of factors that are playing a role in crops not reaching their yield potential.

**Table 1.** Percentage of crops by yield gap (absolute t/ha or proportional %) (n in brackets) for mungbean crops analysed from different sources across the subtropical grain's region of eastern Australia.

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

### *Multiple yield reducing factors*

Only 43 or the 71 crops had a full complement of corresponding soil data; these were examined in more detail in an attempt to identify critical yield reducing factors. Of these a group of 26 had relative yields of < 65% of modelled water-limited yield potential (high yield gap group) and 17 were found to have relative yields > 65% of water-limited yield potential (low yield-gap group) (Table 2).

While discrepancies in the frequency of a range of factors between these two groups were examined, only a few factors were found to occur at different levels between the groups. These were also factors found to be more important in statistical analyses, giving us confidence that they are important potential factors to consider further. The population of *P. thornei* was the most prominent single factor discriminating amongst crops in the high and low yield gap groups. Of the high yield gap group, 53% of crops had *P. thornei* levels greater than 3/g soil, while in the low yield gap group this was 23%. This factor alone was not statistically significant (Table 2), but when additional factors were added, significant differences in the populations were evident. Thus, the model that distinguished best between high and low yield gaps was when crops had either high *P. thornei* populations (> 3/g soil).

Additional factor identified as reducing mungbeans crops yield were when more than 1 day of maximum daily temperatures of over 39°C during flowering, or the crops had soil nitrate levels of less than 65 kg N/ha in the top 60 cm at sowing.

A combination of at least one of these stresses occurred in 88% of crops with a high yield gap. This set of diagnostic criteria were found to provide a significantly higher probability of occurring in the crops that had a high yield gap compared to the group with the low yield gap. Hence, a combination of one of these 3 yield reducing factors are suggested to be possible foci for further work to understand their impact on mungbean yield accumulation and in particular low harvest index.

**Table 2.** Frequency of crops experiencing a combination of one or more stress criteria amongst groups with a high yield gap (i.e. relative yield < 65%) or low yield gap (> 65%). *P* was calculated using a Fischer exact test, n is the number of crops in each group for which a full complement of data was available.

| **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* | | |

## Conclusions

Overall, the project confirmed industry experience that there is a large proportion of mungbean crops that fail to achieve their water-limited yield potential. Crops with low observed yield and high yield gaps were those with a low harvest index, which was not always associated with low crop biomass. One third of crops achieved < 60% of the water-limited yield potential and nearly half had yield gaps > 500 kg/ha. Low mungbean yields or high yield gaps were not due to a single biotic or abiotic factor. Rather there was a multitude of factors that appear to be associated with high yield gaps (root lesion nematodes, high temperatures at flowering and soil nitrogen status). Being a single season study these findings should be interpreted with this in consideration.

## Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support. We would like to thank the consultants, Leigh Norton, Mike Balzer, Hugh Reardon-Smith, Rob Evans, Josh Bell and Jim Hunt, who collaborated by collecting soil and crop samples on the mungbean fields monitored here. We also thank the many farmers who allowed for this sampling to occur. Finally, we would recognise the contributions of previous research projects (Farming Systems CSA00050 and DAQ00192, and Mungbean Agronomy UQ00067) for provision of their experimental data.

## Contact details

Lindsay Bell
CSIRO Agriculture and Food
203 Tor St, Toowoomba Qld, 4350
Mb: 0409 881 988
Email: Lindsay.Bell@csiro.au

Marisa Collins
La Trobe University
Mb: 0409 160 355
Email: M.Collins@latrobe.edu.au

ᶲ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994

® Registered trademark

Return to contents

# Mungbean and soybean agronomy - time of sowing, row spacing and plant population: findings from combined trial analysis 2013-2018

*Natalie Moore and Mathew Dunn, NSW DPI*

**Key words**

Mungbean, soybean, combined trial analysis, Moonbiᶲ, Richmondᶲ, Jade-AUᶲ

**GRDC code**

DAN00171

## Take home messages

Mungbean and soybean experimental data from NSW and Queensland (2013-2018) was pooled to allow the application of the ‘combined trial analysis’ technique. This approach is different to the analysis that is usually applied to data from regional crop trials. Combined trial analysis can be used to identify critical crop management and environmental drivers of yield across seasons and regions. This was the first time that this technique was applied to Australian mungbean and soybean data.

*Key findings for mungbean variety Jade-AUᶲ from combined analysis of 18 trials*

- Adopting narrow row spacing (25 – 40 cm) over wide row spacing (100 cm) was found to provide a significant grain yield advantage ranging from 150 to >600 kg/ha
- The size of the yield advantage at narrow row spacing decreased as the mean maximum temperature increased. The predicted drop in yield was 30 kg/ha for each degree Celsius over 35.6$^{o}$C
- Late time of sowing was shown to contribute to yield decline. A clear trend is that later sowing date decreased potential yield of mungbean variety Jade-AUᶲ in the environments tested with an estimated yield decline of 2.5 kg/ha/day for every day that sowing was delayed after the recommended early sowing window

*Key findings for soybean varieties Moonbiᶲ and Richmondᶲ from combined analysis of 36 trials*

- For soybean variety Moonbiᶲ the current general recommended plant population of 300,000 plants established per hectare is too low to achieve yield potential and should be adjusted upwards to 450,000 in most situations
- Regression tree analysis of yield data with environmental descriptors indicated increased predicted yield potential of approximately 95 kg/ha for variety Moonbiᶲ at its optimal plant population when the mean maximum temperature for the duration of the crop was below 30$^{o}$C
- Time of sowing was shown to be a critical driver of yield of variety Moonbiᶲ, which must be sown in the early window to achieve yield potential. Variety choice must be matched to production region to achieve yield potential. For soybean varieties one size does not fit all
- Soybean variety Richmondᶲ showed remarkable capacity to compensate for low plant population, concluding that the general recommendation for established plant population of 300,000 plants/ha is adequate for variety Richmondᶲ in most situations
- Row spacing was found not to be a critical driver of yield for variety Moonbiᶲ in most situations. For variety Richmondᶲ adoption of narrow row spacing (25 – 40 cm) showed a yield benefit of 292 – 592 kg/ha over medium row spacing (50 – 60 cm), and a yield benefit of 301 – 474 kg/ha over wide row spacing (100 cm) in some but not all situations.

## Introduction

NSW DPI trial data from project DAN00171 2013-2018 was pooled with the Queensland summer pulse agronomy project (QDAF and QAFFI, UQ00067 2014-2018) to enable combined trial analysis by Kerry Bell, a specialist biometrician at the Statistics for the Australian Grains Industry (SAGI) group in Toowoomba. This kind of analysis has not previously been attempted for summer pulses in Australia. This paper summarises some of the key findings from the SAGI analysis and presents a new way to view and interrogate long term trial data for grain crops.

It should be noted that combined trial analysis is different to multi-environment trial (MET) analysis, which is used mainly by plant breeding programs to assess genotype x environment interactions. Combined trial analysis is appropriate for partitioning and contrasting data from long term and multi-locational studies with multiple fixed effects such as trials investigating agronomy and crop management. The broad objectives of the experiments conducted in the NSW DPI project were to:

1) Apply a statistical analysis technique to pooled experimental data in an attempt to identify management strategies for grain growers to optimise the yield of new varieties of soybean Moonbiᶲ and Richmondᶲ and mungbean variety (Jade-AUᶲ); and
2) Provide agronomic recommendations to improve the reliability of summer pulse crops in the Northern Grains Region.

Row spacing was categorised into narrow (25, 33, 35 or 40 cm), medium (50, 60 or 66 cm) and wide (100 cm) for consistency as the row spacing of planters and farming systems varied across sites. All yield data is expressed for the farming system used (i.e. yield for trials on a raised bed system are expressed for the whole hectare including unplanted furrows, and not for the bed top only). This allows more equitable comparison of yield across different farming systems and accounts for the benefits that are afforded by raised beds (e.g. improved drainage in irrigated systems). Actual established plant populations, not target, were used in all analyses. Findings from combined trial analysis for mungbean variety Jade-AUᶲ

In total, there were 93 statistical 'environments' formed for this study from the 18 mungbean trials harvested in central and northern New South Wales and southern and central Queensland between 2015-16 and 2017-18. The field experiment sites were located from Emerald in central Queensland to Trangie in central west New South Wales. In some analyses not all the environments could be used as they did not meet the criteria for the particular analysis or there was missing data.

### *Narrow versus wide row spacing*

Eleven field experiments generated 61 statistical 'environments' for combined data analyses of yield advantage of narrow row spacing (25 – 40 cm) verses wide row spacing (100 cm) for mungbean variety Jade-AUᶲ The analyses focussed on assessing each environment individually for the difference in grain yield between narrow and wide row spacings at an established plant population of 300,000 plants/ha.

Analysis indicated that in changing from wide to narrow row spacing the predicted yield increase ranged from 150 to >600 kg/ha, or the equivalent of \$105 to >\$420 per hectare based on a grain price of \$700/t.

The size of the predicted yield advantage of narrow row spacing decreased as the mean maximum temperature experienced by the crop for its duration increased above 35.6°C, with a predicted drop of 30 kg/ha for each increase in degree Celsius above 35.6°C.

### *Narrow versus medium row spacing*

When changing from wide to narrow row spacing there was a consistent increase in mean yield. The yield advantage of narrower row spacing (25 – 40 cm) compared to medium row spacing (50 – 66 cm) was not as clear.

### *Time of sowing and total in-crop water*

The regression tree analysis of clustered trial data, shown in Figure 1, allowed further investigation of the effects that time of sowing, total in-crop water (total rainfall+ irrigation) and mean maximum temperature for the crop duration have on mungbean grain yield. This is a new way to look at long term multi-site trial data and to identify drivers of yield.

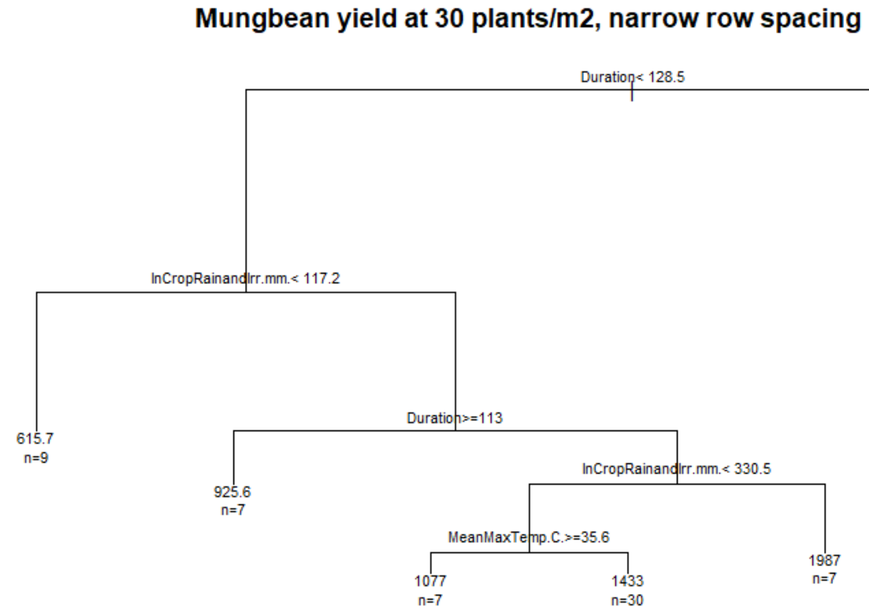


**Figure 1:** Results of a regression tree analysis of y=predicted yield of mungbean variety Jade-AUⒹ at 30 plants/m$^2$ for narrow (25 – 40 cm) row spacing and x=environmental descriptors. The figure at the terminal node of each branch of the regression tree is the average predicted yield in kg/ha and the number of environments in this category. The critical environmental descriptor is shown at each branching of the regression tree. The first terminal node to be separated by the analysis (node number 6 on the far right when counting node 1 from the left) is crop duration (over 128.5 days) and shows the highest average yield (2312 kg/ha) for a group of 7 environments. The next most significant environmental factor is total in-crop rainfall and irrigation below 117.2 mm, which differentiates a group of nine environments with average yield of only 615.7 kg and so forth until the final, and notably largest, group of 30 environments is differentiated with mean maximum temperatures for the crop duration of over 35.6$^{o}$C with an average predicted yield of 1433 kg/ha. Source: Kerry Bell (SAGI) report to NSW DPI and QDAF, October 2018.

Regression tree analysis of clustered trial data focused on the grain yield response of different crop management techniques for the mungbean variety Jade-AUⒹ at a narrow row spacing (25 – 40 cm) and plant population of 30 plants established/m$^2$.

Particular focus was placed on time of sowing and irrigation regimes as commonly altered management decisions. However, the regression analysis identified other environmental descriptors such as total in-crop water (total rainfall + irrigation) and mean minimum temperature for the crop duration in addition to sowing date as contributing the most to describing predicted grain yield.

An estimated yield decline of 2.5 kg/ha/day was found for every day sowing was delayed after 1st October (the statistical date marker used for analysis). This should be interpreted by growers and agronomists as planting in the early part of the early sowing window recommended for their region to achieve yield potential.

After crop duration (the number of days from sowing to harvest), the total amount of in-crop water (rainfall events >5mm + irrigation) was found to be the next most significant environmental factor influencing yield, with total in-crop water of less than 117 mm resulting in significantly lower grain yields with an average of only 617 kg/ha.

Mean maximum temperature for the crop duration was the next environmental factor to differentiate yield groups, with mean maximum temperatures over 35.6°C resulting in an average grain yield of 1077 kg/ha (1.08 t/ha) compared with 1433 kg/ha (1.43 t/ha) for the mean maximum temperature group of below 35.6°C.

**Findings from combined trial analysis for soybean**

Commercial soybean varieties are not broadly adapted across a wide range of production zones of northern Australia. Thus, each variety was analysed individually to avoid misinterpretations being made from the pooled data for multiple soybean varieties.

Thirty six soybean trials were conducted from 2012-13 to 2017-18 in nine locations including Trangie, Breeza, Narrabri, and Grafton in NSW and the Darling Downs in Queensland. This generated 58 statistically acceptable ‘environments’ for combined trial analysis. In some analyses not all environments were used as they did not meet the criteria for the particular analysis or there was missing data (e.g. yield data from inland NSW trials were lost due to flooding in 2016-17). Key findings and practical applications from the SAGI analyses are summarised as follows for the soybean varieties Moonbiⓓ and Richmondⓓ.

***Moonbi*ⓓ**

Based on findings in this study it is recommended that the plant population of variety Moonbiⓓ should be increased from 300,000 to 450,000 plants/ha in most situations. When outlier data clusters were removed, analysis of the plant population responses for Moonbiⓓ showed yield increases ranging between 59 and 570 kg/ha or $41 to $399 per hectare based on a grain price of $700/t for raising the plant population from 300,000 plants/ha to the optimum.

In some cases, the optimum yield for variety Moonbiⓓ was achieved at populations over 450,000 plants/ha, however, this is not recommended due to increasing known risk factors such as lodging and fungal diseases like Sclerotinia and soybean leaf rust. Growers and agronomists must, as always, balance these research findings with their understanding of the known risk factors in their individual paddocks and seasons.

For the variety Moonbiⓓ, there was an increased predicted yield potential of approximately 95 kg/ha or $66/ha based on a grain price of $700/t at optimal plant populations when the mean maximum temperature was below 30°C. This finding does not translate into a changed recommendation for soybean variety Moonbiⓓ *per se,* but it gives more insight into the factors driving yield in this variety.

Row spacing effects on variety Moonbiⓓ in inland trials, (central and northern NSW), showed that row spacing was not as critical a factor as plant population in driving the yield of this variety.

Time of sowing was consistently identified to be a critical driver of yield of variety Moonbiⓓ, which must be sown in the early window to achieve yield potential.

***Richmond*ᶲ**

Soybean variety Richmondᶲ contrasted to variety Moonbiᶲ in many ways in this study including in its relationship to row spacing, which was found to have a significant effect on the yield of variety Richmondᶲ. Ten trials across inland NSW (Trangie, Breeza and Narrabri) and southern QLD included narrow (25 – 40 cm), medium (50 – 66 cm) and wide (100 cm) row spacing treatments and the variety Richmondᶲ. Analysis of these combined trial data at 300,000 plants/ha showed predicted yield increases of 292 – 592 kg/ha (or $204 to $414/ha based on a grain price of $700/t) in changing from medium to narrow row spacing. In changing from wide to narrow row spacing, yield increases of 301 – 474 kg/ha (or $210/ha to $332/ha) were indicated.

Plant population was found to not be as critical a factor in determining yield response in variety Richmondᶲ. Variety Richmondᶲ demonstrated that it was able to compensate for low plant populations through developing additional branching and extra nodes on branches, which resulted in a ‘flat’ response across plant population treatments. Plants at low populations were shorter than those at higher plant populations, which would result in harvesting difficulties. Low plant populations are not recommended, but this result indicates that variety Richmondᶲ may be a better choice than variety Moonbiᶲ to maintain yield in situations where establishment issues may arise.

Optimum yield for variety Richmondᶲ decreased with later time of sowing across the six seasons of this study, but less markedly than for variety Moonbiᶲ. The recommended sowing windows for both varieties in NSW will not change as a result of this study. For inland central and northern NSW it is recommended to sow soybean in the early part of the sowing window to achieve yield potential.

The findings of this study strongly suggest that agronomic recommendations for soybean must be adapted to the variety and the farming system because the varieties in this study did not respond similarly to the experimental treatments imposed. Current ‘blanket’ recommendations for soybean in NSW (e.g. plant population) do not differentiate between varieties and must be adjusted to enable growers to achieve optimum performance and yield from newly released soybean varieties.

## Key findings from the application of combined trial analysis

The combined trial analysis technique of regression trees cannot be applied to data from trials conducted in a single season, irrespective of the number of replicates included in the trials. The technique becomes more powerful with long-term (minimum of 5 seasons), multi-environment trials that provide a range of responses, preferably with overlapping ranges. Trial designs must contain the same core treatment parameters within each trial to allow statistical comparison of crop performance across seasons and production environments. Biometricians need to be involved in trial design before trials are planted especially where combined trial analysis is intended.

The necessity for large and long-term repeated data sets with no missing data is an important learning for future studies that intend to use combined trial analysis. In some cases a missing value, such as starting soil moisture, can prevent an entire data set from one environment being able to be included in the analysis.

Agreement between crop researchers is needed on a standard set of environmental measures to collect for all crop research trials (e.g. growing degree days, daily rainfall and temperature and irrigation). This will enable better interrogation of combined data sets, particularly for the identification and management of environmental factors on the yield of grain crops in Australia.

## Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC; the authors would like to thank them for their continued support.

Grateful acknowledgement is made to Kerry Bell, Senior Biometrician at the Statistics for the Grains Industry (SAGI) group in Toowoomba for her expertise in achieving the first at combined trial data analysis for mungbean and soybean in Australia.

Technical support teams at all the NSW DPI and QDAF trial sites are gratefully acknowledged for their efforts in managing field trials to produce meaningful yield data from 2013-2018.

### Contact details

For soybean contact
Dr Natalie Moore, NSW DPI
Grafton Primary Industries Institute, Grafton, NSW 2460
Ph: 02 6640 1637
Mb: 0477 356 190
Email: Natalie.Moore@dpi.nsw.gov.au

For mungbean contact
Mat Dunn, NSW DPI
Australian Cotton Research Institute, Narrabri, NSW 2390
Ph: 02 6799 1511
Mb: 0447 164 776
Email: Mathew.Dunn@dpi.nsw.gov.au

For combined trial analysis contact
Dr Kerry Bell, SAGI
Leslie Research Centre, Toowoomba, QLD 4350
Ph: 07 4529 1205
Email: Kerry.Bell@daf.qld.gov.au

Ⓓ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994.

Return to contents

# Integrated disease management strategies in mungbean

*Lisa Kelly, Department of Agriculture and Fisheries, Toowoomba Qld*

**Key words**

Halo blight, tan spot, powdery mildew, disease, pathogen

**GRDC code**

DAQ00186 - Improving grower surveillance, management, epidemiology, knowledge and tools to manage crop disease

**Take home messages**

- Effective disease management relies on adopting several strategies
- To minimise the risk of halo blight and tan spot plant seed with the lowest possible levels of infection, use varieties with higher levels of resistance, ensure good farm hygiene, control weeds and volunteers, and adhere to recommended crop rotations
- The impact of powdery mildew is minimised by planting varieties with higher levels of resistance, and by applying fungicides at the first sign of disease.

## Introduction

Mungbean has become a valuable summer crop grown across Queensland and northern New South Wales (NSW). Diseases continue to be a constraint to many mungbean growers across the northern region in all seasons. The major diseases affecting mungbean in NSW and Queensland are the seed-borne bacterial diseases tan spot and halo blight, and the fungal disease powdery mildew. Emergent and less-well understood diseases are Fusarium wilt and root rot, charcoal rot, root knot and root lesion nematodes, phytoplasma, and other disorders such as gummy pod and puffy pod. Not all diseases are found in crops each year. The incidence and severity of diseases will depend on the interaction between the pathogen, the host, the environment, and vectors in the case of viruses and phytoplasmas. Halo blight, tan spot and powdery mildew are the most common diseases of mungbean and are typically present each season.

## Tan spot

Tan spot (also known as bacterial scorch or bacterial wilt) is caused by the bacterium, *Curtobacterium flaccumfaciens* pv. *flaccumfaciens* (*Cff*). Plants can be affected at all stages of growth. Seed borne infection will result in seedlings with symptoms seen on the 1st or 2nd trifoliate leaf where large chlorotic areas develop. Affected seedlings often wilt and die, or those that survive will be stunted and remain a source of inoculum for later infection in the crop. Leaves on older plants develop a scorched appearance, with interveinal necrotic lesions surrounded by a distinct chlorotic margin (see Figure 1). Lesions become tan in colour and become papery in nature, these may disintegrate during windy weather. The bacteria can cause death of florets, and small pods may abort or remain stunted. The bacterium is thought to be systemic within plants and will infect seeds. Bacterial cells enter plants through the vascular system from infected seeds, or through wounds on aboveground plant parts, for example as a result of wind, rain and hailstorms. The bacteria that causes tan spot can survive on plants without producing symptoms. Disease development is favoured by high temperatures (>30°C) and plant stress.

**Figure 1.** Symptoms of tan spot on mungbean with large tan-coloured interveinal necrotic lesions on leaves. Note that younger lesions are surrounded by a distinct yellow margin whereas the margin is less noticeable in older lesions.

### Halo blight

Halo blight is caused by the bacterium *Pseudomonas savastanoi* pv. *phaseolicola* (*Psp*). Similar to tan spot, the pathogen that causes halo blight can infect mungbean plants at any stage of growth. Infected seedlings are often a result of seed borne infection. Symptoms are often visible at the 1st or 2nd trifoliate leaf stage, characterised by small, water-soaked lesions that are surrounded by a yellow-green halo. Infected seedlings typically survive and act as a source of inoculum for later infection in the crop. Older lesions have less pronounced haloes and merge to produce larger necrotic regions (see Figure 2). Lesions are visible on both sides of leaves. Circular water-soaked lesions may develop on pods, with bacteria oozing from the lesions and often forming a red or brown crusty drop. Seed directly below pod lesions are often infected internally. Seed can become infected externally as it touches bacteria from infected crop debris or other infected seed.

The bacteria that causes halo blight is spread to healthy plants by water droplets from rainfall or overhead irrigation and contact between adjacent wet leaves. The bacterium enters plants through wounds and natural plant openings during periods of high humidity. Similar to tan spot, the halo blight bacterium can survive on the surface of both resistant and susceptible plants, without producing any obvious symptoms of disease. Disease development is favoured by cooler temperatures (18-23°C) and wet weather.

**Figure 2.** Plants infected with the halo blight pathogen have small, water-soaked lesions on both sides of leaves.

**Powdery mildew**

Powdery mildew of mungbean is caused by the fungus *Podosphaera xanthii*. The fungus has had multiple name changes in recent years and its taxonomy remains unclear. To complicate matters further, a different powdery mildew species was found on mungbean in 2018 and again in 2019, suggesting that at least two species of powdery mildew are infecting mungbeans across the northern region. Research is underway to identify this second powdery mildew and gain a greater understanding of the disease it causes.

Recent trials have demonstrated that *P. xanthii* can reduce yields by more than 40% in conducive seasons, when established well before flowering. Plants can be infected at any stage of growth, when air-borne spores land on the plant surface and germinate. The fungus then sends feeding structures (haustoria) into the cells of the leaf (epidermis), and then chains of spores develop from fungal strands, resulting in the white, powdery growth on infected tissues. Symptoms are first evident on the lower leaves as small, circular, white powdery colonies that can quickly move up plants and cover the surface of leaves under ideal conditions (see Figure 3). If severe enough, powdery mildew will also cover the stems and pods of plants. The fungus will only survive on living hosts and will not survive between seasons on seed or in crop debris. Plants are only infected via air-borne spores from nearby infected plants. It is not currently known what other weed and crops host *P. xanthii*, though it is thought to have a wide host range. Disease development by *P. xanthii* is favoured by cool (22-26ºC), dry weather and often is first seen in mungbean crops from autumn onwards across the northern region. Recent trials indicate that agronomic practices, such as row spacing, has minimal impact on disease severity.

**Figure 3.** White fungal growth on leaves caused by the mungbean powdery mildew pathogen.

**Integrated disease management strategies**

Utilising an integrated disease management strategy is the most effective way to minimise the risk of disease epidemics. Relying on one strategy alone will not be enough to prevent disease. The three aims of integrated disease management are to reduce pathogen inoculum carrying over from one season or paddock to the next, exclusion of the pathogen, and protection of the host.

***Reduction of inoculum***

- *Paddock selection and crop rotation*

  Selection of the most suitable paddock requires consideration of previous crops, the history of diseases in the paddock, the presence of other crops and weeds nearby, and the herbicide history. The presence of herbicide residues in the soil may also cause crop damage and favour the development of some diseases. Many pathogens have a wide host range and can infect neighbouring crops and survive in crop debris. Table 1 displays the range of hosts reported for either both or one of the halo blight and tan spot pathogens. Avoid planting two consecutive legumes in the same paddock, and rotate mungbeans with other crops for at least three years to help break the pathogen cycle. Soil borne pathogens, such as Fusarium wilt, will survive in the soil for several years. Paddocks with a history of soil borne diseases, such as Fusarium wilt, should be avoided.

- *Control volunteers and weed hosts*

  Many pathogens will survive between seasons on volunteer mungbeans and weed hosts (see Table 1 for the hosts of the bacterial diseases), and they should be managed through herbicides or other practices.

**Table 1.** Host range of the halo blight and/or tan spot pathogens

| Scientific name | Common name | Host of halo blight (HB) or tan spot (TS) |
|---|---|---|
| *Cajanus cajan* | Pigeon pea | HB |
| *Desmodium spp.* | Tick clover | HB |
| *Dolichos spp.* | Dolichos lablab | TS,HB |
| *Fumaria sp.* | Fumitory | HB |
| *Glycine max* | Soybean | TS |
| *Ipomoea diamantinensis* | Cowvine | TS |
| *Ipomoea plebeia* | Bellvine | TS |
| *Lablab purpureus* | Hyacinth bean | TS,HB |
| *Lupinus polyphyllus* | Garden lupin | TS |
| *Macroptilium atropurpureum* | Siratro | HB |
| *Macroptilium lathyroides* | Phasey bean | TS |
| *Mercuialis annua* | Annual mercury | HB |
| *Neonotonia wightii* | Perennial soybean | HB |
| *Phaseolus spp.* | various beans | TS,HB |
| *Pisum sativum* | Pea | TS,HB |
| *Pueraria sp.* | Kudzu vine | HB |
| *Sonchus oleraceus* | Sowthistle | HB |
| *Vigna spp.* | various beans | TS,HB |

- *Stubble management*

  Many pathogens will survive between cropping seasons in crops debris and in infected stubble. There may be a role for the removal of crop debris and stubble management when there is a high risk of inoculum carrying over to the next crop.

***Exclusion of the pathogen***

- *Low risk planting seed*

  Both halo blight and tan spot are highly seed-borne. Growers should avoid sowing seed from a crop that has shown symptoms of either halo blight or tan spot. Australian Mungbean Association approved seed is sourced from crops that were inspected for symptoms of halo blight and tan spot during the growing season. The development of a reliable test to screen seed for the presence of the bacteria is underway.

- *Practice good hygiene*

  Many pathogens of mungbean are spread through the movement of soil (e.g. the pathogens that cause Fusarium wilt, charcoal rot, and root lesion nematodes), or infected crop residues (e.g. the bacteria that cause halo blight and tan spot). Movement through the crop should be avoided to minimise wounding the foliage and spreading the pathogens further, particularly when the crop is wet. Any machinery, vehicles, other equipment, and boots should be thoroughly cleaned prior to entering a crop. Where possible, overland water flow should be managed to minimise the potential risk from contaminated soil and crop debris. Overhead irrigation should be avoided to minimise the risk of spreading disease further.

***Protection of the host***

- *Planting resistant varieties*

  Celera II-AUΦ has the best levels of resistance to the halo blight pathogen, although this variety is suited to a niche market. Jade-AUΦ and CrystalΦ offer the best resistance to the tan spot bacterium, although heavy infection and yield loss can still occur under high disease pressure.

Jade-AU offers the best resistance to the powdery mildew pathogen, although significant yield losses can still occur without the strategic use of fungicides.

- *Fungicides*

  Currently, there are no permitted or registered chemical treatments for the control of bacterial and fungal pathogens on mungbean seed. There are also no effective chemical treatments for the control of the bacterial diseases, tan spot and halo blight, once they have established within a crop. Tebuconazole, and Custodia® (120 g/L azoxystrobin and 200 g/L tebuconazole) are currently available for use under APVMA minor use permit for the control of powdery mildew in mungbean (PER13979 (expires 30-June-2020) and PER82104 (expires 30-Nov-2022), respectively). Fungicides should be applied at the first sign of powdery mildew and then again 14 days later, if needed.

### Crop monitoring and diagnostics

Crops should be closely monitored for the early detection of diseases. Early detection of diseases can help to avoid spreading the disease further throughout a crop. This is particularly important for powdery mildew where fungicides should be applied at the first sign of disease.

*Samples can be sent to the Department of Agriculture and Fisheries for disease diagnosis. Plant samples should be wrapped in paper towel and placed in labelled zip-locked bags and sent via courier or express post to Lisa Kelly, DAF, 203 Tor St, Toowoomba Qld 4350.*

### References

CABI/EPPO (2010) *Curtobacterium flaccumfaciens* pv. *Flaccumfaciens.* Distribution Maps of Plant Diseases, No. 370, CABI Head Office, Wallingford, UK.

EPPO (2011). *Curtobacterium flaccumfaciens* pv. *flaccumfaciens.* Bulletin OEPP?/EPPO, 41, 320-328.

Matingoni AC, de Cassia Camara R (2006). *Curtobacterium flaccumfaciens* pv. *Flaccumfaciens* detection in bean seeds using semi-selective culture medium. Brazilian Journal of Microbiology. 37, 451-455.

Noble T, Young A, Douglas C, Williams B, Mundree S (2019). Diagnosis and management of halo blight in Australian mungbeans: a review. Crop and Pasture Science, 70, 195-203.

Young JM (2010). Taxonomy of *Pseudomonas syringae.* Journal of Plant Pathology, 92, S1.5-S1.14

### Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support. Thanks to Col Douglas for his comments and reviewing this paper.

### Contact details

Lisa Kelly
Plant Pathologist
Department of Agriculture and Fisheries
203 Tor St, Toowoomba Qld 4350
Mb: 0477 747 040
Email: lisa.kelly@daf.qld.gov.au

® Registered Trademark

Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994

Return to contents

# 5 years of Nitrogen research – Have we got the system right?

*Richard Daniel, Rachel Norton, Anthony Mitchell, Linda Bailey, Denielle Kilby, Branko Duric and Lawrie Price, Northern Grower Alliance*

**Key words**

Nitrogen, efficiency, soil movement, timing

**GRDC code**

NGA00004

**Take home messages**

- Over the 14 trials from 2014 to 2017, the efficiency of nitrogen (N) grain recovery from soil N was ~4 times that of fertiliser N that was applied in the year of cropping
- Maintaining high soil N levels is critical for cereal production efficiency due to the poor fertiliser N grain recovery
- Testing of grain, stubble and soil at harvest was able to account for a mean level of ~79% of the applied fertiliser N over 23 comparisons, however in 4 of the 23 comparisons, testing only accounted for 30-50% applied fertiliser N
- The majority of the additional N at harvest was recovered in the soil and averaged ~65% of the applied quantity
- The slow and shallow fertiliser N movement in soil is likely to be impacting on grain recovery efficiency
- Strategies to get fertiliser N deeper, more quickly, may provide useful efficiencies in uptake and reduce potential losses
- Strategies that can improve N contribution from the legume phase will be highly productive
- Fallow N fertiliser applications are likely to provide a benefit over at planting application in years with low in-crop rainfall.

## Background

Northern Grower Alliance (NGA) have been heavily involved in nitrogen (N) management trials in wheat since 2012. The focus has always been on methods to improve the efficiency and economics of N nutrition in wheat but the specific focus shifted over time:

1) 2012-2014: Economics and fit of late application
2) 2014-2018: Impact of application method and timing.

In addition to generating answers on the two main themes, a large body of data had been created on N uptake efficiency together with measurements of soil movement and fate of N.

Rather than focusing on individual trial results, this paper focuses on N management 'system implications' and challenges whether we really have got the system right.

## Grain nitrogen recovery

Grain N recovery in wheat has been calculated in trials from 14 individual locations conducted during the 2014-2017 seasons. A wide range of production conditions have been experienced with yields ranging from ~1 to 5t/ha. Three steps were taken in calculating the grain N recovery from fertiliser:

1. Grain N recovery for each treatment was calculated as yield (kg/ha) x % protein/100 x 0.175
2. 'Net' grain N recovery was then calculated by deducting the grain N recovery in the untreated (unfertilised treatment)

3. % grain N recovery was calculated by dividing the net recovery by the amount of N applied

**Table 1.** % grain N recovery from urea applications in 15 trials, 2014-2017

| **Season** | 2014 | | 2015 | | 2016 | | 2017 | |
|---|---|---|---|---|---|---|---|---|
| **Method/ timing** | All IBS | | Drilled in fallow/IBS/ PSPE | | Incorporated in fallow/IBS/ PSPE | | Spread in fallow x 2/PSPE | |
| **Variety(s)** | EGA Gregoryⓓ | | EGA Gregoryⓓ | | Suntopⓓ | | Lancerⓓ, Suntopⓓ & 5 other varieties | |
| **# of trials** | 4 | | 5 | | 3 | | 3 | |
| | **Mean** | **Range** | **Mean** | **Range** | **Mean** | **Range** | **Mean** | **Range** |
| Urea 50 kg N/ha | 21% | 13-34% | 30% | <0-45% | 23% | 16-27% | 15% | 10-19% |
| Urea 100 kg N/ha | 16% | 12-26% | 19% | <0-31% | 18% | 12-23% | 9% | 7-12% |
| Urea 200 kg N/ha | 9% | 5-17% | 11% | <0-17% | 10% | 8-12% | 5% | 3-6% |

NB Data from two trials at Billa Billa 2017 site included. IBS = Incorporated By Sowing, PSPE = Spread Post Sowing Pre Emergent. Recovery data for each urea rate was generated from one application timing in 2014 but 3 timings in all 2015-2017 trials.

***Key points***

1. As expected, the % grain N recovery reduces as the N application rate increases.
2. Trials were conducted over a range of varieties with no indication of a consistent difference in response to fertiliser N rate between varieties.
3. Most applications were incorporated but some were surface spread and not incorporated.
4. No indication of difference between incorporated versus spread but not incorporated.
5. Recoveries appeared lower in 2017 – low in-crop rain, low yields with reduced N responses.

Grain N recovery from available soil N was also calculated for all trials in 2016 and 2017. Soil N was measured to 120cm at both planting and harvest. (Data from 2014 and 2015 was not included as soil N was only assessed during the fallow for site selection and often to 60cm depth). Two steps were taken in calculating the grain N recovery from soil N:

1. The quantity of soil N 'used' was calculated by the amount in the soil at planting minus the amount at harvest.
2. % grain N recovery was calculated by dividing the untreated grain N recovery by the amount of soil N used.

NB: an estimate of the quantity of N mineralised during the cropping season was not included for any calculation but was assumed to be consistent for all treatments. Inclusion of an estimate of mineralised N would lower the % grain recovery for both soil and fertiliser but is unlikely to change the relative differences.

**Table 2.** % grain N recovery from soil only, fertiliser only or combined soil and fertiliser application in 6 trials 2016-2017

| **Season** | 2016 | | 2017 | |
|---|---|---|---|---|
| **Number of trials** | 3 | | 3 | |
| **N 'source'** | Mean | Range | Mean | Range |
| Soil only | 98% | 73-112% | 62% | 55-70% |
| Fertiliser only | 23% | 16-27% | 15% | 10-19% |
| Soil & fertiliser | 62% | 54-74% | 40% | 33-46% |

NB: The mean and range used for 'fertiliser only' is for the most efficient rate (50 kg N/ha) from Table 1.

*Key points*

1. The % grain N recovery when calculated on combined soil and fertiliser quantities is in line with industry convention (~40-60% N efficiency depending on year).
2. However, **each kg of soil N was ~4 times more efficient** (range 3-6 times) in producing yield and protein than each kg of fertiliser N – even when fertiliser was applied at the most efficient rate.

### Situations of concern

N fertiliser recommendations are generally based on setting a target for yield and protein and then ensuring a quantity of soil and fertiliser N that is generally double that target (i.e. working on a 40-60% grain N recovery efficiency). This approach is generally effective, but on the basis of these results, will struggle when soil N levels become low. Common examples would be:

- Soil N levels are heavily depleted following an unexpectedly very high yielding crop (e.g. in 2012); and
- Following a very dry fallow where mineralisation is greatly reduced.

In these situations, N fertiliser application rates may need to be increased to commercially impractical and uneconomic levels to achieve the expected outcome. In some situations with very low starting N quantities, a change from cereal to a legume may be a much better option.

### Why is the fertiliser efficiency so low in the year of cropping?

#### *Movement of N*

One possible reason for the low observed efficiency of grain N recovery from fertiliser applied in the year of cropping may be the amount and speed of N movement in soil. During 2015-2017 a primary objective has been to evaluate the impact of N application into a dry soil profile during the fallow. The hypothesis was that the applied N would move further with fallow rain events so that N would be deeper and more uniformly distributed by planting.

Figures 1 and 2 are indicative of the results achieved following N application during the fallow in 2015/16 and 2016/17.

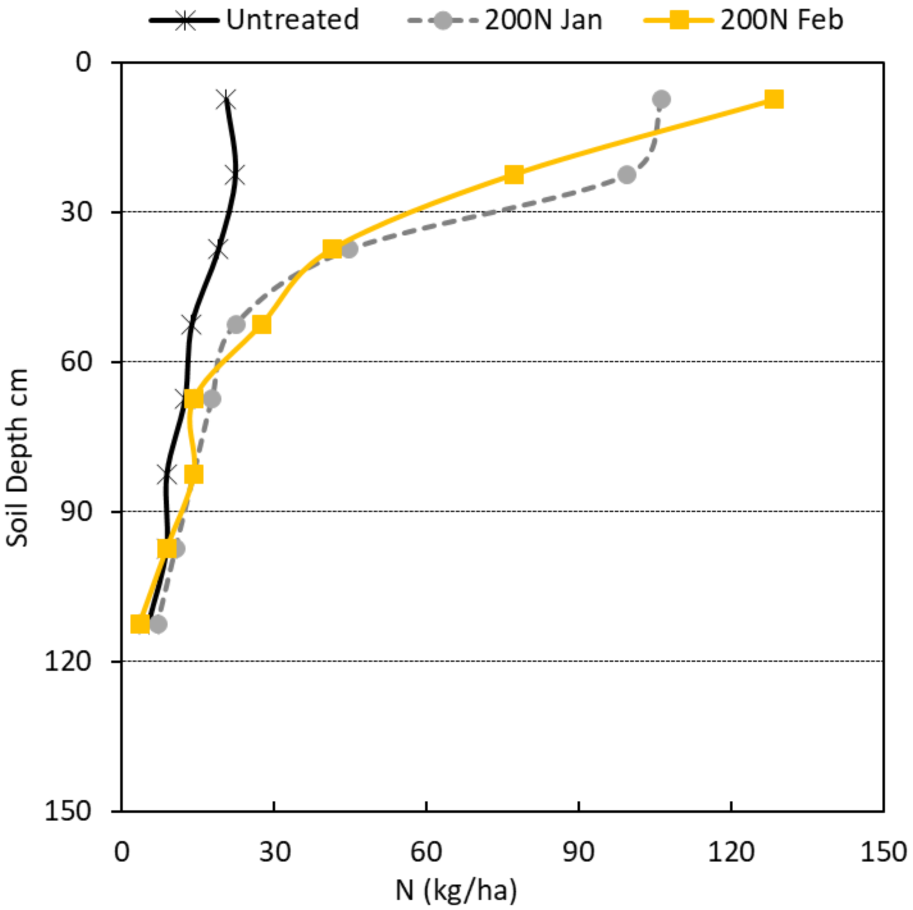


**Figure 1.** Soil distribution of N at Mullaley at planting (May 2017) following application of urea in January or February 2017. 175mm of rain was recorded between the January application and planting. 140mm of rain was recorded between the February application and planting.

(NB: Both N applications were spread and not incorporated. Sampling method - 6 individual 0-120cm depth cores taken per plot. Samples from each depth were bulked with a single sub sample taken for analysis. Not replicated. )

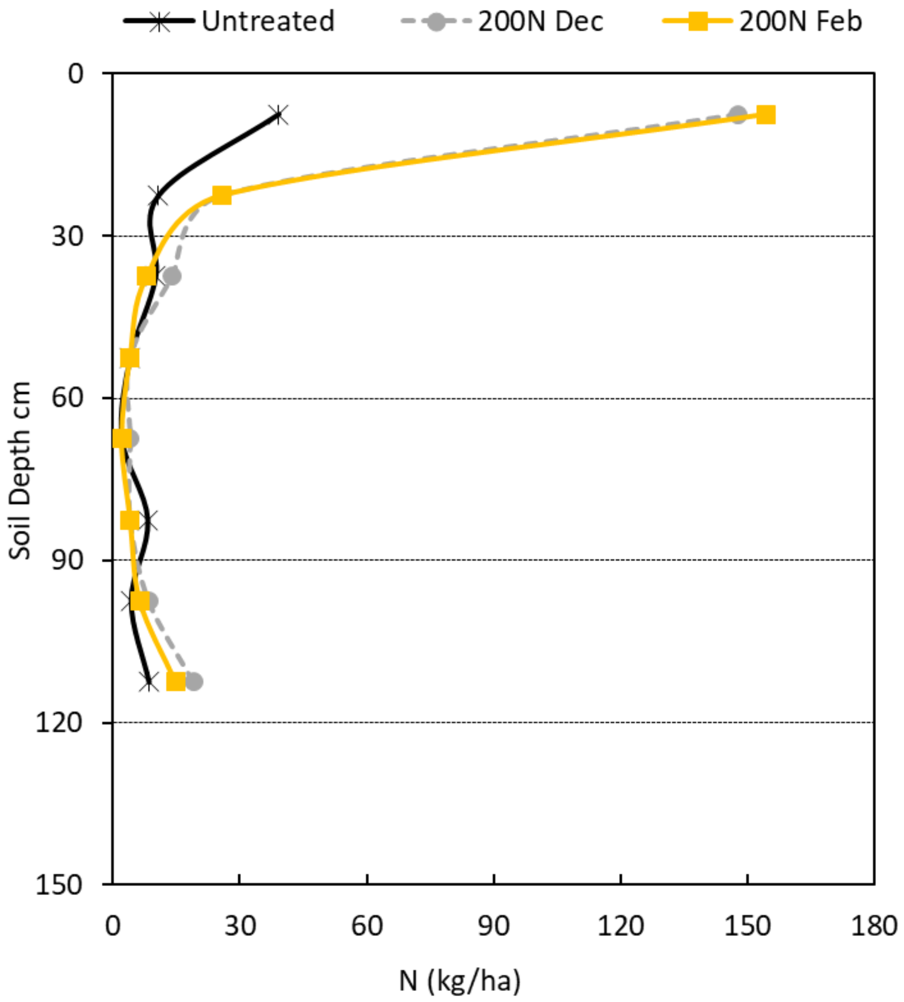


**Figure 2.** Soil distribution of N at Tulloona at planting (June 2016) following application of urea in December 2015 or February 2016. 225mm of rain was recorded between the December application (spread and incorporated) and planting. 65mm of rain was recorded between the February application (spread and not incorporated) and planting.
(NB: Sampling method - 6 individual 0-120cm depth cores taken per plot. Samples from each depth were bulked with a single sub sample taken for analysis. Not replicated. )

***Key points***

1. Even in a dry soil profile, the movement of N in these trials (predominantly vertosol soil types) was slower and shallower than expected.
2. The majority of N applied in fallow (either surface spread or incorporated to depths of ~3-5cm) was still in the 0-15cm soil segment at planting.
3. Sampling in smaller increments e.g. 5cm may reveal clearer differences in movement between application timings.

### Implications of reduced N movement

The slower observed movement of N in soil may explain why in 10 of the 11 application timing trials there has not been a significant advantage from fallow N application compared to N applied at planting - as long as there were reasonable levels of in-crop rain. The 2017 season was however characterised by useful fallow rains (particularly in March) but with very low levels of in-crop rain (particularly June-September).

***Billa Billa 2017***

The site at Billa Billa in 2017 was the first to show a significant benefit from both fallow N applications compared to the same quantity applied at planting (or in-crop).

Figure 3 shows the distribution of soil N at planting from fallow application with the majority of N in the 0-15cm depth for both December and March 2017 applications, but with apparent increased movement from the December application. This site had the deepest movement of N recorded in any of the trials in 2016 or 2017.

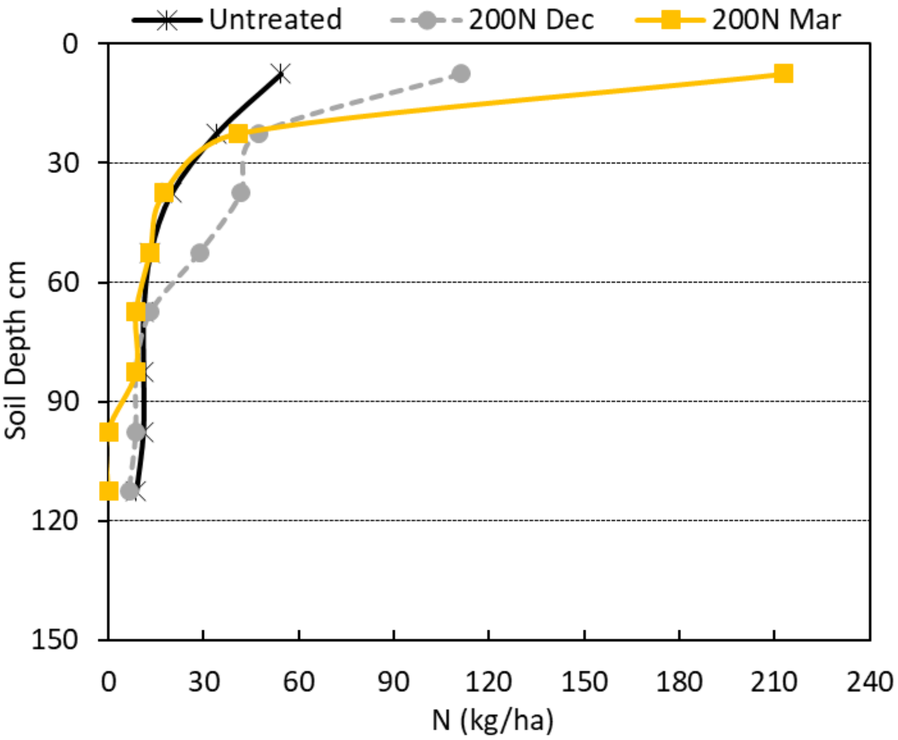


**Figure 3.** Soil distribution of N at Billa Billa at planting (May 2017) following application of urea in December 2016 or March 2017. 279mm of rain was recorded between the December application and planting. 154mm of rain was recorded between the March application and planting.

(NB: Both applications spread and not incorporated. Sampling method - 6 individual 0-120cm depth cores taken per plot. Samples from each depth were bulked with a single sub sample taken for analysis. Not replicated.)

Figure 4 shows the yield results (variety Lancer⦶) at this site. There was no significant N response from fertiliser applied at planting (or in-crop) at this site, with only 71mm of in-crop rain received between planting and the end of September. However applications in December or March provided a significant increase in both yield and protein (not presented).

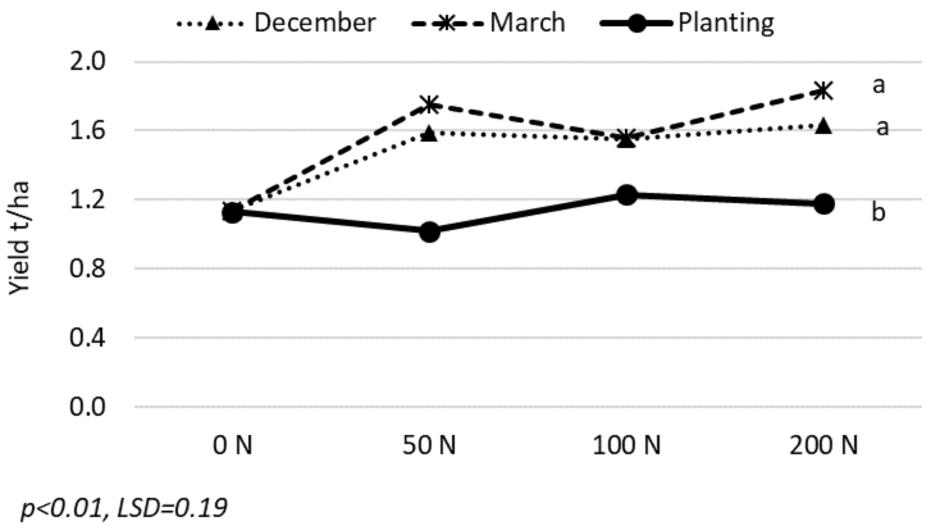


**Figure 4.** Effect of application timing and N rate on yield, Billa Billa 2017
(Treatments that share the same letter are not significantly different at P=0.05. All N rates were spread only)

Table 3 shows the distribution of N (in excess of untreated levels) by soil depth at harvest and the quantities of rainfall recorded between application and planting or harvest.

**Table 3.** Depth distribution of soil N at harvest (in excess of untreated levels) from 200 kg N/ha applications, Billa Billa November 2017

| | **December spread** | **March spread** | **Planting PSPE** | **In-crop Spread** |
|---|---|---|---|---|
| **Rainfall - application to planting** | 279mm | 154mm | - | - |
| **Rainfall - application to harvest** | 465mm | 340mm | 186mm | 160mm |
| **Soil depth** | **Additional soil N kg/ha v untreated at harvest** | | | |
| 0-15cm | 32 | 70 | 36 | 82 |
| 15-30cm | 48 | 48 | 4 | 2 |
| 30-45cm | 35 | 11 | 4 | 4 |
| 45-60cm | 20 | 7 | 4 | 4 |

NB There was no indication of any movement of fertiliser applied N deeper than 60cm. Soil recovery from PSPE application was very low with only 1mm of rain recorded 4 days after application, followed by 9mm at 37-38 days after application.

***Key points***

1. Although the majority of N from December or March application was still in the 0-15cm zone at planting (Figure 3), the yield and protein results indicate it had moved deep enough to be available to the crop in a season with very low in-crop rainfall.
2. Increased benefit from fallow N application compared to application at planting are likely in situations with good levels of fallow rainfall but followed by low levels of in-crop rainfall.
3. The majority of excess N applied in December was recovered in the top 45cm at harvest after a total of 465mm of rainfall.
4. The majority of N applied in March was recovered in the top 30cm at harvest after a total of 340mm of rainfall.

NB Soil recovery from the PSPE application was very low in this trial with the first useful rainfall (9mm) 37 days after application. Unfortunately soil sampling was not planned/conducted in plots where N was incorporated by sowing for comparison.

## How much nitrogen was actually recovered at harvest?

Assessment of the fertiliser N fate (in grain, soil and stubble) was conducted in 2015, 2016 and 2017 but with no attempt to estimate the residual N in the root system. Table 4 shows the mean quantities of N, in excess of the level where no fertiliser N was added. In 2015, results were only assessed for 200 kg N/ha applied and incorporated by sowing. Results in 2016 and 2017 are a mean of 4 application timings. In 2016, 3 of the 4 applications were spread and not incorporated with all applications spread and not incorporated in 2017.

**Table 4.** Mean levels of N (kg N/ha) in grain, stubble and soil samples at harvest following application of 200 kg N/ha, in excess of untreated levels, 8 trials 2015-2017

| **Season** | 2015 | | 2016 | | 2017 | |
|---|---|---|---|---|---|---|
| **Number of trials** | 3 | | 3 | | 2 | |
| | Mean | Range | Mean | Range | Mean | Range |
| Grain | 0 | -16-21 | 20 | 5-39 | 8 | 3-13 |
| Stubble | 17 | 6-48 | 17 | 3-43 | 8 | 1-26 |
| Soil | 79 | 58-102 | 136 | 50-221 | 128 | 54-234 |
| **Total** | **96** | **85-134** | **174** | **66-263** | **143** | **60-258** |

### *Key points*

1. Over 23 individual application timing comparisons, ~79% of the applied rate was recovered between grain, stubble and soil.
2. On average ~21% of the applied N was not able to be accounted for in grain, stubble or soil.
3. The majority of additional N was recovered in the soil and on average accounted for 65% of the applied N.
4. In 18 of 23 comparisons, testing accounted for more than 60% of the applied N.
5. The lowest recoveries were from 2 sites in 2015 where N was incorporated by sowing – both 40-50%, one site in 2016 from spreading on wet soil at GS30 – 30-40% and one in 2017 from application PSPE – 30-40%.
6. Grain recovery is likely to be the most accurate measure with stubble and soil more variable due to issues such as sampling and uniformity of spreading.

## Was nitrogen still available for the following crop?

Two of the trial sites from 2016 (Tulloona and Macalister) were planted to winter crop in 2017 and were monitored for response and benefits in the ‘year 2’ crop. Table 5 shows the soil test results taken at planting and harvest in year 2.

**Table 5.** Soil N levels (kg N/ha) at Tulloona and Macalister following application of N at different rates applied at wheat planting in 2016

| | Tulloona | | Macalister | |
|---|---|---|---|---|
| N rate at sowing in 2016 | April 2017 | Oct 2017 | Aug 2017 | Dec 2017 |
| Untreated | 53 b | 29 b | 78 c | 44 b |
| 50 kg N/ha IBS | 76 b | 32 b | 99 bc | 46 b |
| 100 kg N/ha IBS | 71 b | 21 b | 131 b | 80 b |
| 200 kg N/ha IBS | 162 a | 122 a | 237 a | 178 a |
| *P value* | *<.01* | *.04* | *<.01* | *<.01* |
| *LSD* | *33* | *75* | *39* | *62* |

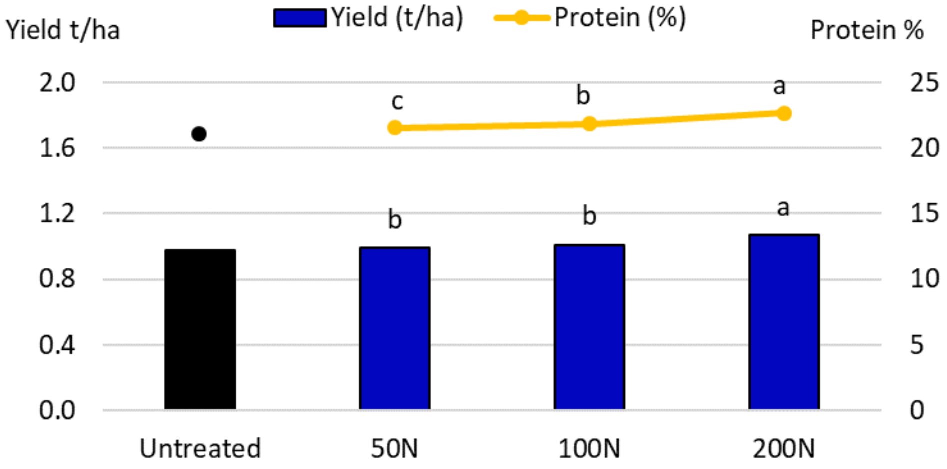
NB Sampling method - 4 individual 0-120cm depth cores taken per plot. Samples were separated into 0-30 and 30-90cm intervals with each depth bulked and a single sub sample taken for analysis. 4 replicates sampled in each treatment

***Key points***

1. The large LSD figures (least significant differences) highlight the variability that can occur with soil testing and that the number of soil samples collected should have been larger to account for this.
2. While acknowledging the above, soil testing ~12 months after N application (April and August 2017) showed significantly increased soil N levels in the 200 kg N/ha treatments (109-159 kg N/ha additional compared to untreated).
3. Differences were less clear from the 50-100 kg N/ha rates applied in 2016.
4. The lowest soil N levels at planting in 2017 were from the untreated samples.
5. At harvest of the year 2 crops, there was still an additional ~90-130 kg N/ha of soil N in plots that had received 200 kg N/ha in 2016.

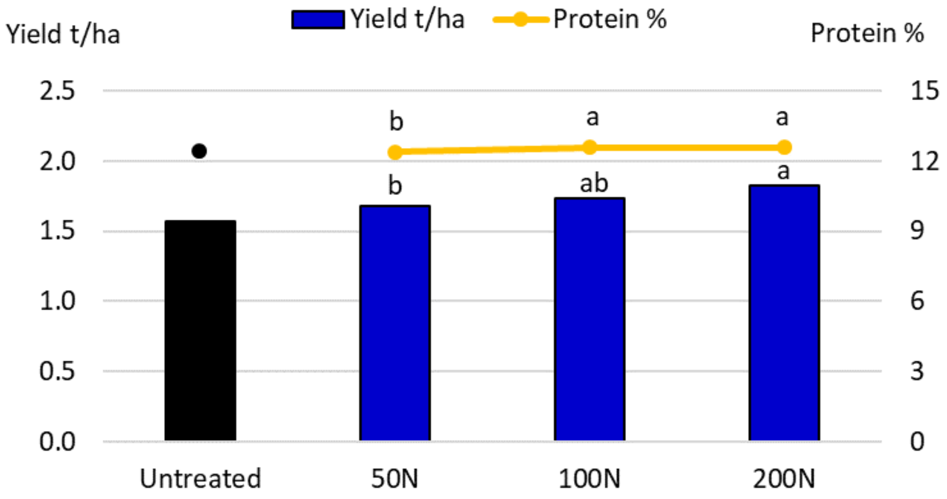
NB At the Tulloona site, ~60 % of the additional soil N was still found in the top 45cm with 45% found between 15 and 45cm. At the Macalister site, ~49 % of the additional soil N was still found in the top 45cm with 31% found between 15 and 45cm.

The Tulloona site was commercially planted to chickpeas and the Macalister site was planted to wheat. At Tulloona, at the end of September it was visually apparent that all plots that had received the 200 kg N/ha rate in year 1 were ‘greener’ than the remaining plots and the trial warranted harvest. Previous wheat results had indicated the most consistent N response was in grain protein, so yield and grain quality were assessed at both sites. Figures 5 and 6 show the yield and protein responses in year 2.



*Yield: p=0.02, LSD=0.06* *Protein: p<0.01, LSD=0.29*

**Figure 5.** 2nd year impact of N rate - chickpeas, Tulloona 2017
(Treatments that share the same letter, within an assessment, are not significantly different at P=0.05. Results for each N rate are from a factorial of 3 timings x 2 varieties. Untreated not analysed and included for comparison only)



*Yield: p=0.02, LSD=0.10* *Protein: p<0.01, LSD=0.1*

**Figure 6.** 2nd year impact of N rate - wheat, Macalister 2017
(Treatments that share the same letter, within an assessment, are not significantly different at P=0.05. Results for each N rate are from a factorial of 3 timings x 2 varieties. Untreated not analysed and included for comparison only)

***Key points***

1. Significant increases in both yield and grain protein were recorded in year 2 from the 200 kg N/ha rates applied in 2016 compared to the 50 kg N/ha rate at both sites.
2. Although soil testing did not show a significant difference in soil N between the 50 and 100 kg N/ha rates, there was a significant increase in grain protein recorded in both crops from the 100 kg N/ha treatments compared to the 50 kg N/ha rate.

## Economic impact

### *Tulloona*

- Wheat 2016: all nitrogen rates achieved at least break even in 2016 due to yield benefits (0.7-1.2t/ha) combined with increased grain quality in a ~4t/ha yielding situation
- Chickpeas 2017: although grain protein was increased by all rates of N applied in 2016, only the 200 kg N/ha rate resulted in a significant yield increase. This equated to an extra $60/ha net benefit
- Soil testing indicates an extra 90 kg N/ha is still available to benefit year 3 cropping from the 200kg N/ha applications.

### *Macalister*

- Wheat 2016: there was no yield impact from applied N but increases in protein of ~2-3%. There was no net benefit with mean yields ~2.0-2.5t/ha
- Wheat 2017: significant yield increases were recorded from all 2016 rates compared to the untreated (0.1-0.25t/ha). Despite significantly increased protein from the 100 and 200 kg N/ha rates, all grain was H2 quality. Net benefits of $32-$73/ha were achieved in year 2
- The 50 kg N/ha rate was the only one to achieve a net benefit over the 2 years of ~$20/ha
- Soil testing indicates an extra 130 kg N/ha is still available to benefit year 3 cropping from the 200 kg N/ha applications.

## Conclusions

This series of trials over 4 cropping seasons and 14 trial locations has provided results that question some of our current management practices.

- It has supported the general N grain recovery ‘rule’ applied in N budgeting of 40-60% of available soil and fertiliser N but highlighted a large difference in efficiency between the two sources
- It has highlighted the poor efficiency of fertiliser N grain recovery in the year of application with mean levels of ~15-20% applied N recovered in grain at common commercial rates (50 -100 kg N/ha)
- The relatively shallow and slow movement of the applied N is likely to be a major cause for this inefficiency
- Consider non-cereal options in paddocks with very low soil N levels
- Testing at harvest of grain, stubble and soil indicated nearly 80% of the applied N could be accounted for, although in a small number of situations this level dropped to as low as 30-50%
- There was no clear pattern of difference between urea surface spread or spread and shallow incorporated in terms of N recovery. They were both equally good (or bad)
- Initial assessment of response in 2nd year crops was encouraging with ~50% of the initial 200 kg N/ha rate still available for crop response in year 3
- At one of the two sites monitored in year 2, all of the net benefit from fertiliser occurred in year 2
- The errors associated with soil testing (e.g. core number, uniformity of sample mixing and sub sampling) make ‘precise’ recommendations on fertiliser N levels difficult.

### *Key industry challenges*

- Ensure soil N levels do not continue to decline as the required levels of fertiliser N in the year of cropping would rapidly become uneconomic and impractical and cereal production less efficient
- We need to identify methods to get fertiliser N deeper in the profile, more quickly, to improve availability and efficiency
- Identify and if possible, manage the unaccounted losses from fertiliser N application.

## Where to next?

The results from this work indicate we still have much to learn, or at least to refine, with the management of our most important and best understood nutrient for cereal production. Any practices that can improve the efficiency of N accumulation from the legume phase are going to be exceedingly valuable, together with methods to increase the efficiency of fertiliser N use in the year of cropping.

## Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

NGA would particularly like to acknowledge the assistance from our trial co-operators during this series of trials: Scott Ferguson, Jason Schelberg, Lee Maxwell, The Frater Family, Drew Penberthy, Michael Leddingham, Hugh Ball, Simon Doolin, George Picton, Peter Butler and Anthony Martin, together with Kalyx staff for trial planting, maintenance and harvest. In addition we would like to thank AGT and Pacific Seeds for seed supply.

## Contact details

Richard Daniel
Northern Grower Alliance
Ph: 07 4639 5344
Email: richard.daniel@nga.org.au

ᶲ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994

Return to contents

# Nutritional strategies to support productive farming systems

*Michael Bell[1], David Lester[2] and Doug Sands[3]*

[1] University of Queensland Gatton Campus
[2] Department of Agriculture and Forestry, Toowoomba
[3] Department of Agriculture and Forestry, Emerald

**Key words**

fertilisers, placement, blends, recovery efficiency, application strategies

**GRDC code**

UQ00063, UQ000666, UQ00078, UQ00082

**Take home messages**

- A critical success factor for cropping systems that rely heavily on stored soil water is co-location of plant nutrients with moist soil and active roots
- Our current fertiliser management practices need refinement, with low efficiency of fertiliser recovery often associated with nutrients and water being in different parts of the soil profile
- There needs to be greater consideration of placement and timing of fertiliser applications to improve fertiliser nutrient recovery
- Declining native fertility reserves means more complex fertiliser combinations will be needed to meet crop.

## Introduction

This will not be a traditional paper that reports results of a specific research trial or set of trials from specific research projects. Rather, it is a set of observations made from the projects listed above, as well as those made by Richard Daniel (NGA) in their work on fertiliser N application strategies for winter crops. Collectively, the findings from this research, backed by the underlying regional trends in soil fertility and the drivers for successful rainfed cropping in our region, provide some useful insights into what are likely to be the critical success factors for future fertility management programs.

## Do we have successful fertility management systems?

An effective fertiliser management strategy needs to consider all of the 4R's (right product, in the right place, at the right time and at the right rate – Johnson and Bruulsema 2014) to maximize the chance of achieving effective use of available moisture. While everyone pays lip service to these 4R's, our real thinking is often driven by considerations about only one – rate. We spend a lot of time agonizing over rate, because rate is clearly an important part of the economics of growing the crop. Rate is also an important consideration in terms of soil fertility maintenance (i.e. replacing what we remove in grain). In many cases the rate we can afford is not always the rate we need to apply to optimize productivity, much less balance nutrient removal, but we still spend a lot of time thinking about it.

Because of that, we find that the thinking about the other 3R's tends to be much more superficial. Occasionally we might have a try at something a bit different, but in many cases we tend to keep doing what we have always done, and put the same products in the same place at the same time each year. At the same time, our background soil fertility reserves have fallen and our crops are becoming increasingly reliant on inputs of fertility (fertilisers, manures etc) to sustain productivity. It is this increasing reliance on fertilisers, especially N and P and (increasingly) K, that allows us to really see the inefficiency in use practices. The impact of these inefficiencies in terms of lost productivity can often dwarf any of the considerations of rate, and highlights challenges for productivity and profitability in the long term.

We will now cover some examples of inefficiencies that are apparent in what has been considered as best practice for both N and P, and how the emergence of K infertility is adding further complexity to fertiliser best practice.

### *Management of fertiliser N*

In the case of N in winter cereals, the recent comprehensive analysis of a series of N experiments from 2014-2017 by Daniel *et al.* (2018) highlighted the poor winter crop recovery of fertiliser N applied in the traditional application window (the months leading up to sowing, or at sowing itself). Fertiliser N recovered in grain averaged only 15% for applications of 50 kg N/ha and 9% for 100 kg N/ha. On average, 65% of the applied N was still in the soil as mineral N at the end of the crop season, while only 15% was in the crop (grain and stubble). The fate of the other 20% of applied N could not be determined. Some of that N will carry over until the next season, but it means that you need **last** year's fertiliser to get you through **this** year, but if you had a big year last year, leaving little residual N, or a lot of N was lost due to a wet season, the current crop may see little of the N applied in the previous year and will suffer as a result.

The poor winter crop recovery of applied N in the year of application mirrored that reported for summer sorghum in the NANORP research program reported by Bell, Schwenke and Lester (2016), with the use of $^{15}$N tracers enabling a more precise quantification of the fate of N applied prior to planting. Data from the Qld sites in commercial fields are shown in Figure 1 for the 40 and 80 kg N rates across three growing seasons. Fertiliser N in grain averaged 27% and 23% of the applied N for the 40 and 80N rates, respectively, while total crop uptake averaged only 37 and 32% for the same N rates. What is noticeable in this figure is the variable N losses (presumably via denitrification) and the residual N in the soil, which may or may not be available for a subsequent crop in the rotation, depending on the fallow conditions.

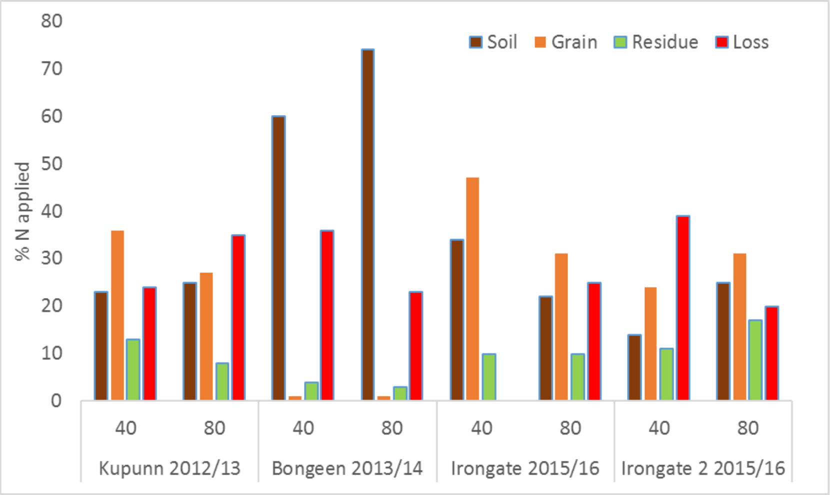


**Figure 1.** Partitioning of fertiliser N between soil, plant and environmental loss pools for summer sorghum crops grown on the Darling Downs in UQ00066 from 2012 – 2016.

Both extensive studies have shown there can be significant amounts of residual N in the soil at the end of the growing season. Large amounts of that N are often found in quite shallow parts of the soil profile (i.e. the 0-10cm and possibly 10-20cm layers) and still strongly centred on the fertiliser bands, despite what were often significant falls of rain in-crop (i.e. 200-300mm). Even after a subsequent fallow, the Daniels *et al.* (2018) paper found that 50-60% of the mineral N residual from fertiliser applied in the previous season was still only in the top 45cm, with as much as half still in the 0-15cm layer. This largely surface-stratified residual N would have contributed to the quite muted (although still significant) grain yield response to the residual N in those studies.

Interestingly, findings from both the summer sorghum and winter cereal research suggest that crops recover mineral N that is distributed through the soil profile with much greater efficiency than fertiliser applied at or near sowing. In both seasons, 70-80% of the mineral N in the soil profile was recovered in the crop biomass, compared to recoveries of applied fertiliser that were commonly less than half that. The distribution of that N relative to soil water is likely to have played a major role in this greater recovery efficiency.

### ***Management of fertiliser P***

The substantial responses to deep P bands across the northern region where subsoil P is low have been detailed in a number of recent publications (Lester *et al.* 2019b, Sands *et al.* 2018), with these responses typically additive to any responses to starter P fertiliser (the traditional P fertiliser application method – e.g. Figure 2a, b). There has unfortunately been no direct measurement of P unequivocally taken from either deep or starter P bands due to the lack of suitable tracer technology, especially when we consider residual benefits over 4-5 years. However, simple differences in biomass P uptake in a single season suggest that the quantum of P accumulated from deep bands (3-5 kg P/ha) is substantially greater than that from starter P alone (1-1.5 kg P/ha) in all bar exceptionally dry seasons.

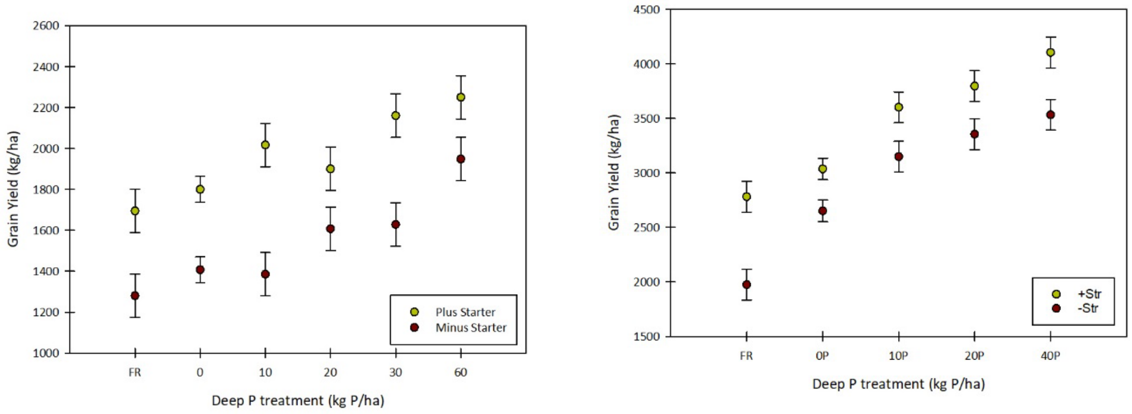


**Figure 2.** Response to different rates of deep P with and without applications of starter P fertiliser in (a) a wheat crop at Condamine in 2018, and (b) a sorghum crop at Dysart in 2018/19. Grain yield for deep-placed P treatments (kg P/ha) with or without starter application. The vertical bars represent the standard error for each mean. (Lester *et al.* 2019a).

Perhaps one of the most significant findings from the deep P research has been the relative consistency of P acquisition from deep bands, despite significant variability in seasonal conditions. Research results from sites in Central Queensland often provide the best examples of this, due to the extremely low subsoil P reserves in some of those situations – if the crop cannot access the deep P bands, there is not much else to find elsewhere in the subsoil! Interestingly, this type of profile P distribution is consistent with the lack of grain yield responses to starter P that were recorded over a number of years of trials in CQ and that contributed to reluctance to use starter P in some situations. Early growth responses that were consistent with the crop obtaining an extra 1-1.5 kg P/ha from the starter application were observed, but a lack of available profile P to grow biomass and fill grains limited any resulting yield responses.

The inability to acquire P from a depleted subsoil places a greater importance on access to P in the topsoil, which means that seasonal rainfall distribution has a huge impact on crop P status. This is illustrated for a site near Clermont in Figure 3 (a, b), in which the growing season conditions and crop P acquisition by successive crops of sorghum and chickpea are compared. From a yield perspective, deep P increased crop yield by 1100 kg and 960 kg for the sorghum and chickpea, relative to the untreated farmer reference treatment, and by 720 kg and 970 kg/ha for the same crops relative to the nil applied P treatment (0P) that received ripping and background nutrients. The similar quantum of yield responses in the two crops represented quite different relative yield increases (40-60% in the sorghum, versus about 300% in the chickpeas), and obviously had hugely different responses economically, given the price differential between sorghum and chickpea grain. However, from a nutrient use efficiency perspective it is interesting to note that the apparent P acquisition from the deep P was similar (3.3 kg P/ha in the sorghum and 2.7 kg P/ha in the chickpeas – Figure 3b)) despite the vastly different in-season rainfall (Figure 3a).

What is dramatically different, and what is driving the much larger relative yield response in the chickpea crop, was the inability to access P without deep P bands in that growing season. Crop P contents in the farmer reference and 0P treatments averaged 2.9 kg P/ha in the sorghum crop but only 0.6 kg P/ha in the chickpeas.  This difference was driven by the combination of deep sowing and extremely dry topsoils encountered in the 2018 winter season. The crop was planted below the 0-10cm layer, and there was never enough in-season rainfall to encourage later root growth and P recovery from that layer. Despite available moisture in the subsoil, there was not much P available to support growth and yield. In contrast, the sorghum crop was planted into the relatively P-rich top 10cm layer, which was then re-wet regularly over a significant proportion of the vegetative phase. This allowed better P acquisition from the background soil, but the deep P bands were still able to supplement this and provide an additional yield benefit.

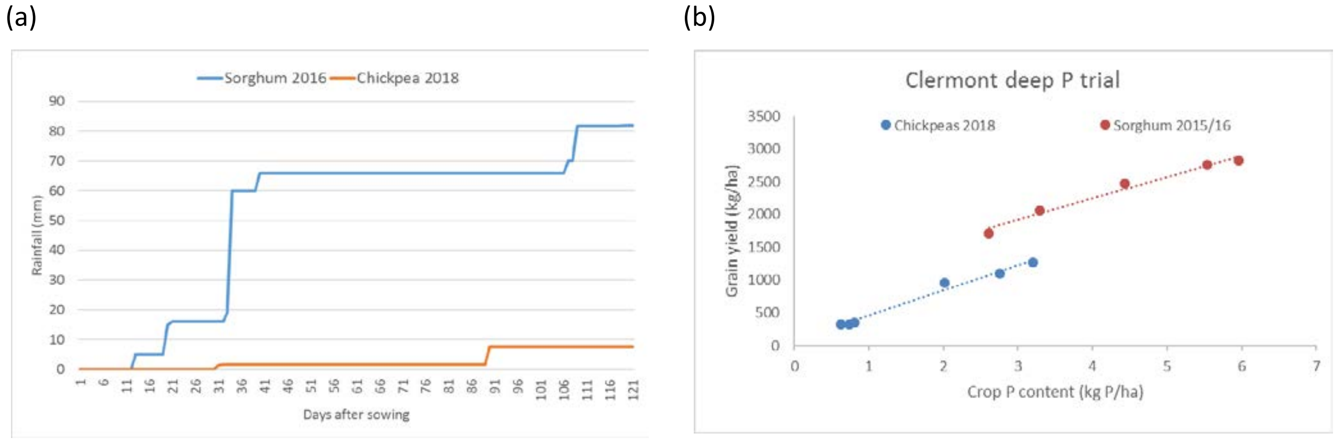


**Figure 3**. (a) Cumulative in-crop rainfall and (b) the relationship between crop P content and grain yield for consecutive crops of sorghum (2015/16) and chickpea (2018) grown at a site near Clermont, in Central Queensland (Sands et al., 2019).

### *Choice of product to address multiple nutrient limitations*

As native fertility has been eroded by negative nutrient budgets and/or inappropriate placement, there are an increasing number of instances of complex nutrient limitations that require compound fertilisers to address multiple constraints.  This is further complicated as the relative severity of each constraint can change from season to season. Perhaps the best example has been the emergence of widespread examples of K deficiency in recent (drier) seasons, but which can ‘disappear’ in more favourable ones. This is an example of the impact of increasingly depleted and more stratified K reserves and is an issue that adds complexity to fertility management programs. Soil testing benchmarks for subsoil nutrients are improving as a result of current programs, but at best they are only likely to ring alarm bells for the different constraints, rather than predict the relative importance of each in future (uncertain) seasonal conditions. Examples provided in Figure 4, again from sites in Central Queensland, show fields where subsoil P and K would both be considered limiting to productivity, but the responses to deep placed P and K have varied with crop and seasonal conditions. Assuming enough N is applied, the site at Dysart shows a dominant P constraint which is evident in most seasons, and a smaller K limitation that is only visible once the P constraint has been overcome. The Gindie site, on the other hand, has limitations of both P and K, but the relative importance of each constraint seems to depend on the crop choice and/or seasonal conditions. In both cases, the appropriate agronomic response would be to apply both nutrients, but the relative economic returns of adding K to the fertiliser program (as opposed to higher/more frequent P additions) would be different.

The emergence of multiple constraints such as those shown in Figure 4 require a greater understanding of the implications of co-location of different products, especially in concentrated bands applied at high(er) rates, less frequently. There is evidence that effective use of banded K, at least in Vertosols, is dependent on co-location with a nutrient like P to encourage root proliferation around the K source (Figure. 5 – Bell et al., 2017). However, there is also evidence that there can be interactions between P and K applied together in concentrated bands that can reduce the availability of both nutrients. The current GRDC project ‘UQ00086’ is exploring the reactions that occur in bands containing N, P and K, and the implications of changing the products and the in-band concentrations on nutrient availability.

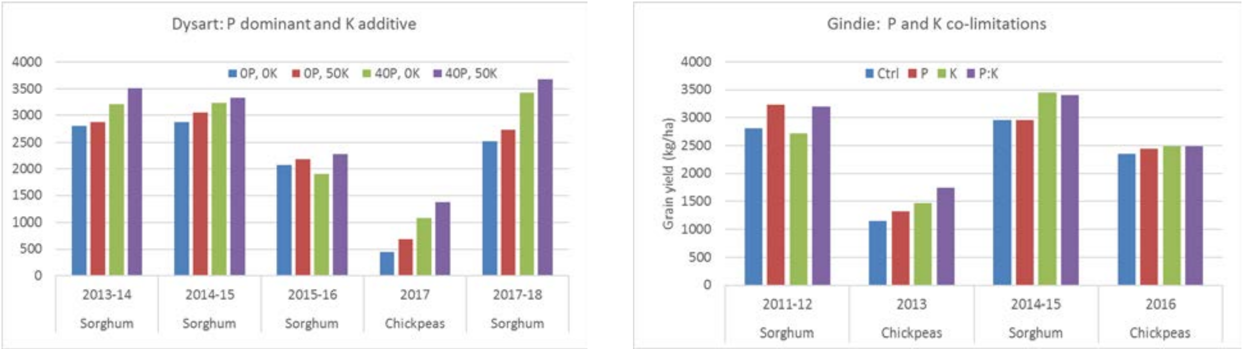

(a)
(b)

**Figure 4**. Examples of combinations of P and K limitations to crop performance at (a) Dysart and (b) Gindie, and the response to deep banded applications of those nutrients alone, or in combination.

### What are the key farming systems characteristics complicating nutrient management?

The changing nutrient demands in dryland grains systems, especially on Vertosols, are driven by the combination of nutrient removal that has not been balanced by nutrient addition (especially in subsoil layers), and the reliance of our cropping systems on stored soil water for much of the growing season. Crops need access to adequate supplies of water and nutrients to perform, and while crop roots can acquire water from a soil layer with little to no nutrient, they certainly can’t acquire nutrients from soil layers that are dry. The co-location of water, nutrients and active crop roots enables successful crop production. Historically our cropping systems have been successful because (i) soils originally had moderate or higher reserves of organic and inorganic nutrients; (ii) there were sufficient reserves of those nutrients at depth that the crop could perform when the topsoil was dry; and (iii) our modern farming systems are now much better at capturing water in the soil profile for later season crop use.

Our soils are now increasingly characterised by low organic matter, with reserves of P and K that are concentrated in shallow topsoil layers and depleted at depth. Our typical fertiliser management program applies all nutrients into those topsoil layers, with the immobile ones like P and K staying there, and the mobile nutrients like N applied late in the fallow or at planting, when there is no wetting front to move the N deeper into the subsoil layers. Without that wetting front, even mobile nutrients like N are unable to move far enough into the soil profile to match the distribution of water – at least in the current crop season. We also grow a very low frequency of legumes in our crop rotation, which increases overall fertiliser demand and produces residues that are slow to decompose and release nutrients during the fallow and for the following crop. This means that nutrients like N are mineralized later in the fallow, again with less chance to move deeper into the soil profile for co-location with stored water.

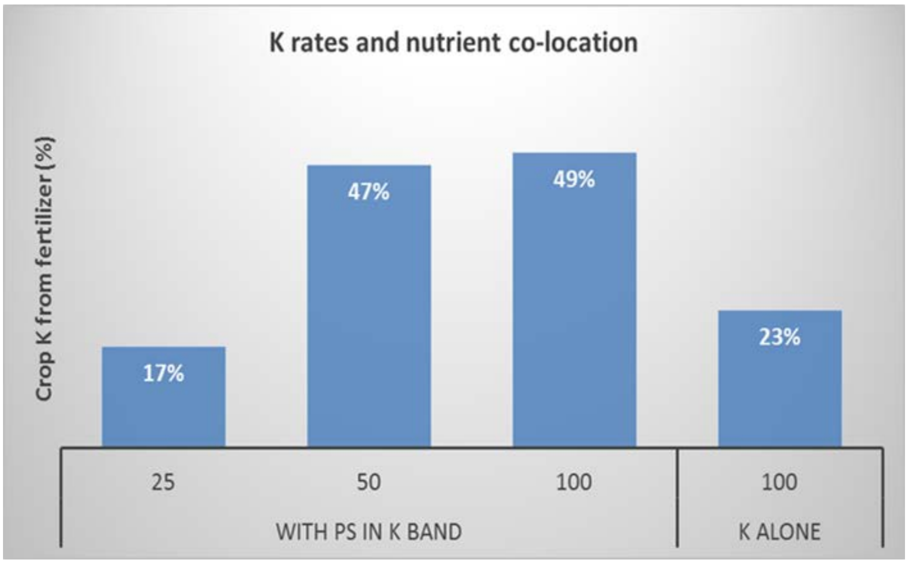


**Figure 5**. The impact of rate of applied K and co-location of K with other nutrients in a band (in this case P and S) on the proportion of crop K that was derived from applied fertiliser. The net result is an increasing frequency of dislocated reserves of stored soil water and nutrients, with in-crop rainfall at critical stages being a major determinant of whether the crop will be able to acquire the nutrients to achieve the water-limited yield potential. Unless our management systems change to address these issues, there will inevitably be a decline in overall water use efficiency across the cropping system, with an increasing frequency of poor or unprofitable crops. The changes that we think are needed require a stronger focus be placed on the 'forgotten' 3R's – placement, timing and product choice/combination.

In the concluding section of this paper, we provide a brief outline of what we feel are going to be key strategies that nutrient management programs of the future will need to consider. We note that a number of these have not yet been extensively validated or are simply hypotheses that are worth testing. However, they do show what we think are opportunities to address some of the main nutrient supply issues outlined in this paper.

## Future nutrient management opportunities

### *In general*

- Focus more on feeding the soil to support the farming system, in addition to targeting the next crop in the rotation sequence. This will involve applying nutrients at a time and in a part of the soil profile that maximizes the chance of having nutrients co-located with water when future crops need it. Leaving these decisions to when the profile water has largely accumulated and the planting decision is more certain, is frequently leading to spatial dislocation between nutrient and water supply

- Where possible, legume crops should be grown with greater frequency, as they reduce the fertiliser N demand. This will allow diversion of money from the fertiliser budget spent on N into other nutrients that can be exploited across the rotation
- Be adaptive in fertiliser management, respond to the opportunities that are offered to put the right nutrient in the right place at the right time, and chose the right combination of products to match the soil nutrient status for multiple nutrients. This will involve a good understanding of the variation in profile nutrient status from field to field, and also understanding how seasonal conditions may impact on those application decisions.

***For specific nutrients***

*N*

- Consider changing the timing of at least some of the fertiliser N input, so it is applied into dry soils at the beginning of a fallow. The Daniel et al. (2018) paper showed nice examples of how early fallow N applications can increase the proportion of fertiliser N that is accumulated in deeper profile layers, increasing the likelihood of N availability to support growth when the crop is experiencing dry periods. The greater efficiency of recovery of distributed 'soil' N compared to freshly applied fertiliser may allow possible rate reductions that could help to offset any interest paid on early fertiliser investment
- Be aware when conditions have changed from the 'normal' upon which strategies have been developed. For example, what would differences in (especially shallow) profile moisture status at the beginning of a fallow mean for the denitrification risk to early N applications? How should you respond to an unusually large crop that has depleted the soil N profile? How would you respond to an unseasonal rainfall event after N applications had been made?
- Legume residues should help to better synchronize the release of N with the recharge of profile moisture during a fallow. This should result in soil N that is readily accessible during a following crop, as well as lowering the fertiliser N requirement.

*P and K*

- Don't ignore starter fertilisers, but also be aware that they are not an effective solution to meeting crop P demand in most seasons. Starter P has an important role to play in early season growth and establishing yield potential, but the amount of P acquired from the starter P band is quite small. There may be opportunities to reduce the rates of P applied at planting if uniform distribution along the seeding trench can be maintained. Fluid forms of P may possibly have a role. The 'saved' P should be diverted into increase rates or frequencies of deep P application
- Starter P is especially important in very dry seasonal conditions, and can make an unusually large impact on crop P uptake due to restricted access to the rest of the P-rich topsoil. Under these conditions, starter P can also have a large impact on secondary root growth and improved soil P access
- Deep applied P and K work – use them. Question marks still exist about the length of the residual effect, and some of the risks from co-locating products in a band. Minimize the risk by applying products in more closely spaced bands (i.e. at lower in-band concentrations) more often (i.e. lower application rates more frequently)
- Remember that the main subsoil constraint has generally been P, so get the P rate right and complement that with additional K as funds allow
- Don't let subsoil P and K fall too far! Whilst we have achieved some great responses to deep P (and K) bands, and they are certainly economic, we have not seen evidence that a deep banded application (of P at least) is sufficient to completely overcome a severe deficiency. The band is a

very small proportion of the soil volume, and when roots proliferate around a band, they dry it out. Unless the band area re-wets during the season, allowing roots a second opportunity to access the banded nutrient, the amount of nutrient recovered will be limited. In short, bands provide a useful but not luxury supply. Crop nutrient concentrations in foliage and grains still show signs of being P deficient in many situations, and it is obvious that the more of the subsoil volume that can be fertilized (more bands, more often) the greater the chance we have of meeting demand.

### Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

### References

Bell M, Schwenke G and Lester D (2016). Understanding and managing N loss pathways. GRDC Updates in Coonabarabran and Goondiwindi, March 2016.

Bell MJ, Mallarino AP, Moody PW, Thompson ML, Murrell AS (2017). Soil characteristics and cultural practices that influence potassium recovery efficiency and placement decisions. Proc., Frontiers of Potassium Workshop, Rome 25-27 January 2017.

Johnston AM and Bruulsema T.W. (2014). 4R Nutrient Stewardship for Improved Nutrient Use Efficiency. Procedia Engineering 83:  365 – 370.

Daniel R, Norton R, Mitchell A, Bailey L, Kilby D, Duric B (2018). Nitrogen use (in)efficiency in wheat – key messages from 2014-2017. GRDC Update Goondiwindi, March 2018.

Lester D and Bell M (2019a). Responses to phosphorus and potassium by grain crops in southern Queensland. Pp. 26-29. In: Weir D and Grundy T (Eds). Queensland Grains Research 2018-19. Regional Research Agronomy Report, QDAF.

Lester D, Bell M and Hagan J (2019b). Deep P update 2019 – Multi-year grain yield impacts and economic returns for southern Queensland cropping. GRDC Update Warra, March 2019.

Sands D, Bell M and Lester D (2018). Getting nutrition right in Central Queensland. GRDC Updates at Emerald and Biloela, December 2018.

Sands D, Lester D, Bell M and Hagan J (2019). Responses to deep placement of phosphorus and potassium in chickpea – Clermont. Pp 45-52. In: Weir D and Grundy T (Eds). Queensland Grains Research 2018-19. Regional Research Agronomy Report, QDAF.

### Contact details

Mike Bell
University of Queensland
Gatton Campus
Mb: 0429 600730
Email: m.bell4@uq.edu.au

Return to contents

# Discussion session on recovery after the drought - getting back to productivity

**Notes**

Return to contents

# KEY CONTACTS

GRDC
GRAINS RESEARCH
& DEVELOPMENT
CORPORATION

## NORTHERN REGION

**TOOWOOMBA**
214 Herries Street
TOOWOOMBA, QLD 4350
northern@grdc.com.au
P:+61 7 4571 4800

### APPLIED RESEARCH AND DEVELOPMENT GROUP

**SENIOR MANAGER CROP PROTECTION (NATIONAL)**
**Emma Colson**
Emma.Colson@grdc.com.au
M: +61 4 5595 8283

**MANAGER AGRONOMY, SOILS AND FARMING SYSTEMS**
**Kaara Klepper**
Kaara.Klepper@grdc.com.au
M: +61 4 7774 2926

**MANAGER AGRONOMY, SOILS AND FARMING SYSTEMS**
**John Rochecouste**
John.Rochecouste@grdc.com.au
M: +61 4 7774 2924

**MANAGER CHEMICAL REGULATION (NATIONAL)**
**Gordon Cumming**
Gordon.Cumming@grdc.com.au
M: +61 4 2863 7642

**BUSINESS SUPPORT TEAM LEADER**
**Gillian Meppem**
Gillian.Meppem@grdc.com.au
M: +61 4 0927 9328

**CROP PROTECTION MANAGER**
**Vicki Green**
Vicki.Green@grdc.com.au
M: +61 4 2904 6007

**CONTRACT ADMINISTRATOR, CROP PROTECTION**
**Linda McDougall**
Linda.McDougall@grdc.com.au
M: +61 4 7283 2502

**CONTRACT ADMINISTRATOR**
**Tegan Slade**
Tegan.Slade@grdc.com.au
M: +61 4 2728 9783

**CONTRACT & TEAM ADMINISTRATOR**
**Brianna Robins**
P: +61 7 4571 4800

### GENETICS AND ENABLING TECHNOLOGIES GROUP

**NATIONAL VARIETY TRIALS OFFICER**
**Laurie Fitzgerald**
Laurie.Fitzgerald@grdc.com.au
M: +61 4 5595 7712

### GROWER EXTENSION AND COMMUNICATIONS GROUP

**SENIOR MANAGER EXTENSION AND COMMUNICATION (NATIONAL)**
**Luke Gaynor**
Luke.Gaynor@grdc.com.au
M: +61 4 3666 5367

**GROWER RELATIONS MANAGER**
**Richard Holzknecht**
Richard.Holzknecht@grdc.com.au
M: +61 4 0877 3865

**GROWER RELATIONS MANAGER**
**Susan McDonnell**
Susan.McDonnell@grdc.com.au
M: +61 4 3662 2649

**COMMUNICATIONS MANAGER**
**Toni Somes**
Toni.Somes@grdc.com.au
M: +61 4 3662 2645

### BUSINESS AND COMMERCIAL GROUP

**MANAGER COMMERCIALISATION**
**Chris Murphy**
Chris.Murphy@grdc.com.au
M: +61 4 2277 2070