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# Northern NSW research results 2019

RESEARCH & DEVELOPMENT – INDEPENDENT RESEARCH FOR INDUSTRY

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RESEARCH & DEVELOPMENT – INDEPENDENT RESEARCH FOR INDUSTRY

## an initiative of Northern Cropping Systems

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ISSN 2208-8199 (Print)

ISSN 2208-8202 (Online)

jn 17009

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# Foreword

The Northern Cropping Systems Unit of NSW Department of Primary Industries (NSW DPI) is pleased to be able to offer you a snap shot of results from their research and development work undertaken in the Northern Grains Region of NSW. This book aims to compile and extend the findings and outcomes of these experiments which can then be implemented to shape and form practice change throughout the region. Our audience includes agribusiness, consultants, other research bodies and, of course the growers themselves.

The majority of this work is conducted in partnership with the Grains Research and Development Corporation (GRDC), using grower's funds to address key production constraints and opportunities facing growers, covering both summer and winter cropping.

The NSW DPI Northern Cropping Systems Unit is based across the Northern Grains Region of NSW with the key research hubs at Trangie, Tamworth, Narrabri and Grafton and satellite sites at Breeza and numerous on-farm locations. This geographical spread allows work to be replicated throughout differing rainfall and climatic scenarios creating greater rigor of the findings and recommendation. A number of sites have supplementary irrigation which allows trials to be run in low rainfall years, critical in 2019.

These short papers have been compiled to improve the awareness and accessibility of the results from the NSW DPI trials in the region. The papers are based on scientifically sound and independent research but need to take into account the situation, location and season in which the work has been conducted. It is hoped that this research will prompt more questions and we encourage you to contact the authors to discuss these queries. These experiments cover disciplines from agronomy to plant breeding, crop protection, along with phenology, soils and nutrition research. This is the 9th Edition and in many cases provides updates on research that has been conducted over several years and locations.

The research reported on in this book is only possible through the cooperation of the many growers, advisors and consultants who willingly work with our research teams throughout the year. These collaborators are individually acknowledged at the end of each paper. NSW DPI is fortunate to partner with other organisations such as universities, CSIRO, grower groups and other state-based agricultural departments providing greater breadth and width to our trial portfolio.

A special thanks to all the authors and editorial staff for their willingness to contribute to this publication and their efforts in reviewing the diverse range of papers in this year's book.

We hope you find the papers to have some value to your business and appreciate any feedback that will help improve future editions of the Northern NSW Research Results book

Guy McMullen
Director Northern Cropping Systems,
Tamworth Agricultural Research Institute
On behalf of the Northern Cropping Systems Unit
NSW Department of Primary Industries

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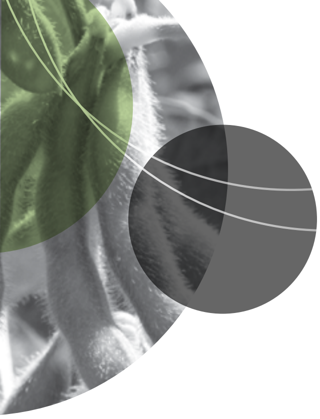

# Farming systems

## The influence different farming systems have on soil nitrogen, phosphorus and potassium – NSW northern region

Jon Baird[1] and Jayne Gentry[2]

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### Key findings

- Most farming systems extract more nutrients than are supplied by common fertilisation strategies.
- Increasing the frequency of legumes in the system does not necessarily reduce the nitrogen (N) inputs required, but it does increase the potassium (K) export across the crop sequence.
- Higher soil mineral N levels have been maintained by increasing fertiliser applications, but grain yields or total system N use have rarely been increased.

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### Introduction

Growers face challenges from declining soil fertility, increasing herbicide resistance, and soil-borne pathogens in their farming systems; change is needed to maintain farming system productivity and profitability. The Queensland Department of Agriculture and Fisheries (DAF), New South Wales Department of Primary Industries (NSW DPI) and CSIRO are collaborating to conduct extensive field-based farming systems research programs. These will be focused on developing farming systems that better use the available rainfall to increase productivity and profitability.

One of the aims of the experiment was to examine how farming systems compared in their requirements for nutrient inputs and the long-term impacts on soil nutrient status and cycling. Several modifications of farming systems were targeted to increase the nutrient efficiency and overall nutrient supply.

### Treatments

In 2014 research began in consultation with local growers and agronomists to identify the key farming system limitations, consequences and economic drivers in the NSW northern cropping region. The aim was to:

- assess the farming systems and crop sequences best suited to meet the emerging challenges
- develop systems with the most potential.

Experiments were established at seven locations: a large factorial experiment at Pampas, and six locally relevant systems at Emerald, Billa Billa, Mungindi, Spring Ridge, Narrabri and Trangie, where there were experiments on both the red and grey soils.

This report focuses on comparisons between the following systems:

- Baseline (the common farming system in each district) including: the dominant crops; sowing on a moderate soil water threshold, crop intensities of approximately 0.75–0.8 crops per year; and fertilising to 50% crop yield potential.

- Higher legume frequency: every second crop is a legume across the sequence, using high biomass legumes (e.g. faba bean) when possible.
- Higher nutrient supply: increasing the fertiliser budget for each crop based on a 90% of yield potential.

Table 1 Nutrient status of sites at the beginning of the project (February 2015).

| Site | Mineral N (kg/ha) | Colwell P (mg/kg) | | BSES P (mg/kg) | | Colwell K (mg/kg) | |
|---|---|---|---|---|---|---|---|
| | 0–90 cm | 0–10 cm | 10–30 cm | 0–10 cm | 10–30 cm | 0–10 cm | 10–30 cm |
| Billa Billa | 366 | 22 | 3 | 33 | 7 | 518 | 243 |
| Pampas | 200 | 64 | 35 | 728 | 711 | 480 | 291 |
| Spring Ridge | 199 | 66 | 19 | 71 | 40 | 670 | 286 |
| Trangie (grey) | 106 | 50 | 6 | 62 | 10 | 506 | 235 |
| Emerald | 99 | 45 | 12 | 70 | 21 | 438 | 225 |
| Narrabri | 58 | 44 | 10 | 433 | 407 | 588 | 209 |
| Mungindi | 61 | 19 | 5 | 111 | 86 | 752 | 428 |
| Trangie (red) | 19 | 30 | 9 | 53 | 15 | 427 | 268 |

## Results

### How does increasing legume frequency affect system nitrogen (N), phosphorus (P) and potassium (K) inputs and use?

The results from the Northern Farming System project suggest that increasing legumes frequency in a cropping sequence has little effect on reducing the requirement of applied N fertiliser. For instance, at some sites such as Emerald, the amount of N fertiliser required was reduced, (reduction of 83 kg N/ha). At other sites, such as the grey soil at Trangie and Pampas, the higher legume system increased N fertiliser required in subsequent crops by 25 kg N/ha compared with the baseline system. These findings can be explained by the higher legume system exporting more N (average. 30 kg N/ha) from the cropping system at harvest than the baseline system for eight of 11 sites (Table 2).

This was also reflected in total system N use (soil mineral N depletion plus fertiliser N inputs), with only six of the 11 higher legume systems reducing total N use compared with the baseline – the largest reduction was 88 kg N/ha at Emerald.

Phosphorous export was variable across the experiment (Table 3). The amount of K exported from all sites relative to the baseline for the higher legume system (average of 14 kg K/ha) increased. The moderate intensity site at Pampas exported 31 kg /ha K more from the higher legume system compared with the baseline system.

### What are the consequences of increasing fertiliser inputs on system nutrient balance and use?

Relative to the baseline system, the higher nutrient system increased the amount of N fertiliser applied (average 83 kg N/ha extra) at each site over the cropping sequence. Results show that applying N fertiliser to aim for a 90 percentile yield potential could reduce the mining of soil available N, especially in soils with high fertility (e.g. Billa Billa). In addition, significant amounts of the additional N applied remained in the mineral N pool during the fallow period, becoming available for the subsequent crop. Where additional N was applied in the higher nutrient system sites, the amount of exported N increased at seven of the 11 sites (Table 4).

Additional N applied in the higher nutrient system reduced the depletion of background soil mineral N at 10 of the 11 sites. On average, across all sites, the higher nutrient system had 43 kg N/ha more soil mineral N than the baseline with approximately 55% of additional N applied found in the mineral N pool, but this varied greatly across sites. This data is highly dependent on sample timing, the previous crop, residue loads and types, and soil moisture conditions.

Table 2 Cumulative N dynamics for the baseline and higher legume systems (2015–2018).

| Site | N export (kg/ha) | | Applied fertiliser N (kg N/ha) | | Mineral N change (kg N/ha) | | System total N use (kg N/ha) | |
|---|---|---|---|---|---|---|---|---|
| | Baseline | Higher legume | Baseline | Higher legume | Baseline | Higher legume | Baseline | Higher legume |
| Billa Billa | 220 | 259 | 12 | 17 | 249 | 194 | 261 | 211 |
| Emerald | 227 | 249 | 91 | 8 | 52 | 47 | 143 | 55 |
| Mungindi | 79 | 80 | 54 | 54 | −22 | −6 | 32 | 48 |
| Narrabri | 177 | 227 | 127 | 127 | 43 | 36 | 170 | 163 |
| Spring Ridge | 227 | 305 | 211 | 211 | 25 | 35 | 236 | 246 |
| Trangie (grey) | 113 | 106 | 54 | 80 | −213 | −221 | −167 | −141 |
| Trangie (red) | 108 | 117 | 84 | 78 | -31 | -38 | 53 | 40 |
| Pampas (moderate intensity) | 271 | 309 | 13 | 39 | 248 | 257 | 261 | 296 |
| Pampas (higher intensity) | 249 | 303 | 101 | 108 | 285 | 280 | 386 | 388 |
| Pampas (summer) | 237 | 233 | 78 | 109 | 288 | 231 | 366 | 340 |
| Pampas (winter) | 287 | 347 | 42 | 17 | 275 | 274 | 317 | 291 |

Table 3 Cumulative P and K removal for baseline and higher legume systems (2015–2018).

| Site | P export (kg/ha) | | Applied fertiliser P (kg N/ha) | | K export (kg K/ha) | |
|---|---|---|---|---|---|---|
| | Baseline | Higher legume | Baseline | Higher legume | Baseline | Higher legume |
| Billa Billa | 41 | 34 | 27 | 36 | 57 | 66 |
| Emerald | 29 | 32 | 22 | 21 | 56 | 63 |
| Mungindi | 12 | 14 | 7 | 7 | 24 | 25 |
| Narrabri | 26 | 34 | 24 | 24 | 42 | 54 |
| Spring Ridge | 32 | 35 | 33 | 33 | 53 | 64 |
| Trangie (grey) | 15 | 14 | 35 | 35 | 19 | 22 |
| Trangie (red) | 17 | 19 | 35 | 35 | 23 | 26 |
| Pampas (moderate intensity) | 37 | 42 | 23 | 20 | 53 | 84 |
| Pampas (high intensity) | 41 | 41 | 25 | 29 | 59 | 87 |
| Pampas (summer) | 40 | 33 | 21 | 21 | 45 | 70 |
| Pampas (winter) | 40 | 46 | 18 | 22 | 66 | 95 |

Table 4 Cumulative N dynamics for the baseline and higher nutrient systems (2015–2018).

| Site | N export (kg/ha) | | Applied fertiliser N (kg N/ha) | | Mineral N extraction (kg N/ha) | | System total N use (kg N/ha) | |
|---|---|---|---|---|---|---|---|---|
| | Baseline | Higher nutrient | Baseline | Higher nutrient | Baseline | Higher nutrient | Baseline | Higher nutrient |
| Billa Billa | 220 | 253 | 12 | 62 | 249 | 190 | 261 | 252 |
| Emerald | 227 | 246 | 91 | 147 | 52 | 33 | 143 | 180 |
| Mungindi | 79 | 86 | 54 | 125 | -22 | -26 | 32 | 99 |
| Narrabri | 177 | 158 | 127 | 201 | 43 | 15 | 170 | 215 |
| Spring Ridge | 227 | 235 | 211 | 316 | 25 | -2 | 236 | 314 |
| Trangie (grey) | 113 | 96 | 54 | 160 | -213 | -174 | -157 | -14 |
| Trangie (red) | 108 | 157 | 84 | 261 | -31 | -225 | 53 | 36 |
| Pampas (moderate intensity) | 271 | 257 | 13 | 89 | 248 | 229 | 261 | 318 |
| Pampas (high intensity) | 249 | 278 | 101 | 209 | 285 | 193 | 386 | 402 |
| Pampas (summer) | 237 | 243 | 78 | 116 | 288 | 235 | 366 | 351 |
| Pampas (winter) | 287 | 277 | 42 | 100 | 275 | 267 | 317 | 367 |

Note: Total N use is calculated from applied fertiliser plus the mineral N balance (ammonia and nitrate N) before sowing 2015 minus the mineral N post the 2018 harvest

The additional P applied to the higher nutrient systems did not influence grain P export. There was no difference for K exports between any of the treatments at any of the sites. This was not unexpected as we did not see significant yield responses to the higher nutrient application strategies.

### How do different crops impact N cycling and fallow mineralisation?

Given the diversity of crops grown across the sites in this project, comparisons can be made between the mineral N dynamics in-crop and in the fallow period after harvest for wheat and chickpea, across multiple seasons and locations. In three of four comparisons (Emerald 2015 and 2016, Pampas 2016), there was no additional N accumulation after chickpea compared with wheat, measured during the fallow postharvest. Where higher mineral N was recorded after a chickpea crop, it was associated with higher N at sowing (Table 5).

## Conclusions

Overall, these results indicate that across our farming system sites adding legume crops in the crop sequence has not reduced N fertiliser input needs or reduced soil N use. The legumes are using soil mineral N to the same extent as cereal crops and have a higher N export which offsets their N fixation inputs. This result is consistent across a wide range of starting soil N conditions, from very high to low mineral N, where legumes would require to fix N to meet their needs. These results significantly challenge the commonly held assumption that grain legumes will reduce N fertiliser needs in the crop sequence. As our capacity to grow high yielding grain legumes has increased, so too has our harvest index and the ratio of N removed in grain to that left in biomass, diminishing the contributions of residual N after the crop.

Phosphorous export was variable across the sites, however, the higher legume system did increase the amount of K exported relative to the baseline system. This is not unexpected as legume seed has more than double the K content than cereal grain. In situations where K deficiency might be an emerging issue or levels are marginal, growers need to be aware of the effects legumes might have on soil available K and that nutrients will need to be replaced sooner or else a higher level of replacement may be required in the future.

Table 5 Comparisons of wheat and chickpea influences on soil N use and subsequent fallow N accumulation.

| Site/season | Crop | Sowing mineral N (kg N/ha) | Harvest mineral N (kg N/ha) | End of fallow mineral N (kg N/ha) | Subsequent fallow mineral N accumulation (kg N/ha) |
|---|---|---|---|---|---|
| Emerald 2015 | Wheat | 105 | 59 | 153 | 94 |
| Emerald 2015 | Chickpea | 78 | 32 | 126 | 94 |
| Emerald 2016 | Wheat | 126 | 12 | 114 | 102 |
| Emerald 2016 | Chickpea | 153 | 23 | 141 | 118 |
| Narrabri 2016 | Chickpea | 69 | 38 | 43 | 5 |
| Narrabri 2016 | Field pea | 86 | 41 | 49 | 8 |
| Narrabri 2016 | Faba bean | 77 | 41 | 38 | -3 |
| Spring Ridge 2016 | Chickpea | 157 | 173 | 277 | 105 |
| Spring Ridge 2016 | Field pea | 169 | 156 | 248 | 92 |
| Spring Ridge 2016 | Faba bean | 160 | 154 | 237 | 84 |
| Pampas (long fallow) 2015 | Wheat | 184 | 117 | 179 | 62 |
| Pampas (long fallow) 2015 | Faba bean | 186 | 58 | 153 | 97 |
| Pampas (long fallow) 2015 | Chickpea | 203 | 68 | 168 | 100 |
| Pampas (long fallow) 2015 | Field pea | 190 | 94 | 217 | 123 |
| Pampas (long fallow) 2015 | Canola | 186 | 93 | 183 | 90 |
| Pampas (short fallow) 2016 | Wheat | 83 | 17 | 61 | 44 |
| Pampas (short fallow) 2016 | Chickpea | 93 | 34 | 76 | 42 |

Nutritional benefits were limited in the first four years of the experiment between the various farming systems treatments. Legumes, in particular chickpea, were planted commonly in the baseline system (20–33% of crops planted). Growing chickpea in this system followed current local grower practice, however, it resulted in smaller differences between the higher legume, higher nutrients and baseline systems.

The first four years of the farming system project showed that modifying the cropping system through higher nutrients balanced the net export of nutrients (N, P) relative to the input in several cases. However, in some of the sites there was a positive yield advantage from providing these additional nutrients. This could change as soils age and their inherent fertility declines.

Future comprehensive soil analysis across all sites will be interesting to detect changes in parameters such as total N and organic carbon levels. Longer-term examination of cropping systems could lead to greater differentiation between systems and locations, providing greater insights into the effect different farming systems have on nutrient balances and long-term soil fertility.

## Acknowledgements

The team would like to thank the trial co-operators, local growers and consultants for their ongoing support and contribution to the project. Thanks also to the Grains Research and Development Corporation (GRDC), DAQ00190 and CSA00050, the Queensland Department of Agriculture and Fisheries (QDAF) and the New South Wales Department of Primary Industries (NSW DPI).

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# Differences between farming systems – Spring Ridge 2015–2017, northern NSW

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## Key findings

- For 2015–2017, differences between farming systems for total grain production were small, with yields ranging from 11,084 kg/ha for the high legume system down to 8573 kg/ha for the high crop intensity system.
- Differing commodity prices, not yield, drove the gross margins (GM) between systems. The low crop intensity system (wheat/fallow/cotton) had a GM of $2739/ha, outperforming the high nutrition systems (wheat/chickpea/wheat + 200 kgN/ha) GM of $2011/ha.
- Water use efficiency (WUE) measures the $GM/mm of water used (rain + change in soil water) to determine the farming system benefits and profitability of the various crop sequences. The low crop intensity system returned $1.66 $GM/mm compared with the high nutrition system at $1.30 GM/mm.

## Introduction

While advances in agronomy and individual crop performance have helped grain growers to maintain their profitability, current farming systems are underperforming with only 30% of the crop sequences in the northern grains region achieving 75% of their water limited yield potential.

Growers are facing challenges from declining soil fertility, increasing herbicide resistance, and increasing soil-borne pathogens in their farming systems. Changes will be needed to meet these challenges and to maintain the productivity and profitability of our farming systems.

The Queensland Department of Agriculture and Fisheries (QDAF), Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the New South Wales Department of Primary Industries (NSW DPI) are collaborating to conduct an extensive field-based farming systems research program. This program is focused on developing farming systems to better use the available rainfall to increase productivity and profitability.

The northern farming systems projects investigate how modifications to farming systems affect the system's performance as a whole over several crops in the sequence. This involves assessing various aspects including WUE, nutrient balance and nutrient use efficiency, changes in pathogen and weed populations, and changes in soil health.

The system modifications examine changes to:

1. **Crop intensity**: the length of time that crops are grown that affects the proportion of water transpired and unproductive water losses. Planting opportunities can be triggered by changing soil water thresholds.

- High crop intensity system: low soil water threshold >30% full profile.
- Moderate intensity system: threshold of 50% full profile.
- Low intensity systems: profile >80% full before a crop is sown and higher value crops used when possible.

2. **Increased legume frequency**: every second crop as a legume across the sequence, aiming to reduce nitrogen (N) fertiliser inputs.
3. **Increased crop diversity**: 50% of crops resistant to root lesion nematodes (RLN) (preferably two in succession). Crops with similar in-crop herbicide modes of action cannot follow one another. The aim is to test systems where the mix and sequence of crops are altered to manage soil-borne pathogens and weeds.
4. **Nutrient supply strategy**: increasing the fertiliser budget for 90% of yield potential compared with a 50% of yield potential. The aim is to boost background soil fertility, increasing N cycling and maximising yields in favourable years.

This range of farming system modifications were tested across seven locations, plus the core site at Pampus. These include Emerald, Billa Billa (both in Queensland) and Mungindi, Spring Ridge, Narrabri and Trangie (red and grey soils), all in NSW (Figure 1). The core experiment site at Pampas on the eastern Darling Downs, aimed to explore the interactions amongst the various modifications to the cropping systems across a range of crop sequences common to the northern grains region. The core site is comparing 34 different system treatments.

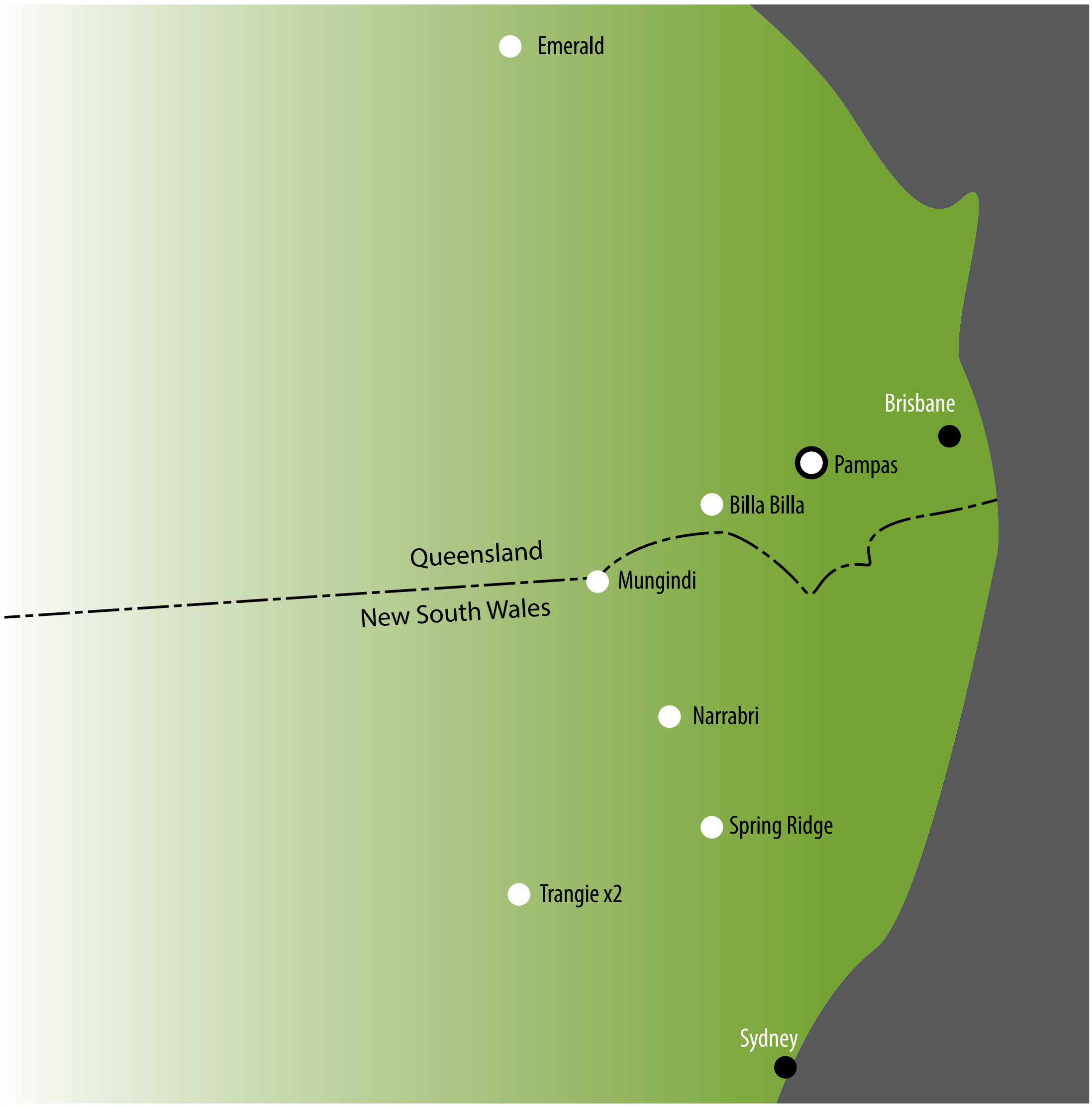

Figure 1 Location of experiments across northern New South Wales and southern and central Queensland.

## Site details

The Nowley farm is owned by the University of Sydney and is located 21 km north-west of Spring Ridge. The site has been cropped for over a hundred years. Spring Ridge lies in the northern end of the southern region of the Liverpool Plains. Rainfall distribution and variability is shown in Table 1. This southern region has the highest summer rainfall, along with relatively high winter rainfall, of any area in north-eastern NSW. The Liverpool Plains are considered one of the safest dryland cropping areas in northern NSW, with summer cropping a major component of the system, coupled with high water holding capacity and vertosol soils. .Zero tillage systems, based on control traffic, dominate the region.

Table 1 The 90, 50 and 10 percentile rainfall and variability indexes for summer and winter rainfall (mm) and the summer/winter ratio for rainfall for the northern and southern Liverpool Plains.

| Region | Summer rainfall | | | | Winter rainfall | | | | Summer/Winter ratio |
|---|---|---|---|---|---|---|---|---|---|
| | 90% | 50% | 10% | VI | 90% | 50% | 10% | VI | |
| Northern | 564 | 411 | 288 | 0.67 | 395 | 261 | 153 | 0.93 | 1.57 |
| Southern | 595 | 435 | 295 | 0.69 | 377 | 240 | 145 | 0.97 | 1.81 |

Table 2 Summer and winter rainfall for Nowley, 2015–2017.

| Period | Rainfall (mm) | | |
|---|---|---|---|
| | 2015 | 2016 | 2017 |
| Preceding summer | 265 | 200 | 408 |
| Winter | 190 | 349 | 80 |

### Site characteristics

Sloping, black vertosol, plant available water capacity (PAWC) >200 mm.

### Fertiliser

All treatments had 50 kg/ha of Granulock® Zn and 100 kg/ha of N as urea at sowing.

The high nutrient system had an additional 100 kg N/ha applied as urea at the late tillering stage.

### Cropping sequence

The site was fallowed out of a sorghum crop at the start of the experiment. Wheat was sown in the winter of 2015 across all systems to establish a base allowing various crops to be planted in the 2016 cropping year. The site is subject to major weed pressure, but has no other biotic stresses of note. Crop sequences for the various systems are shown in Table 3.

Table 3 Cropping sequence for the six farming systems at Spring Ridge, 2015–2017.

| System | 2015 | | 2016 | | 2017 | |
|---|---|---|---|---|---|---|
| | Winter | Summer | Winter | Summer | Winter | Summer |
| Baseline | Wheat | | Chickpea | | Wheat | |
| High nutrient supply | Wheat | | Chickpea | | Wheat | |
| High crop intensity | Wheat | | Fallow | Sorghum | Chickpea | |
| Crop diversity | Wheat | | Field peas | | Wheat | |
| High legume | Wheat | | Faba bean | | Wheat | |
| Low intensity | Wheat | | Fallow | | Fallow | Cotton |

In 2016, systems started to become more diverse with the inclusion of winter pulses (chickpea, faba bean and field pea). The high crop intensity system followed the Liverpool Plains commercial practices and was fallowed through to sorghum sown in the summer of 2016/17.

The 2017 season was one of the most demanding and difficult winter growing seasons on record with an unprecedented number of frosts. Luckily, the 2016 crops were mainly composed of pulse residue rather than large amounts of cereal straw, which would have further exacerbated the radiant frost incidence. Reasonable rainfall was received over the summer of 2016/17. This resulted in adequate stored soil moisture before a very dry 2017 winter (Table 2). In 2017 wheat was planted across most systems following a range of winter pulses in 2016, except the high intensity system, which was double cropped to chickpea after the 2016/17 sorghum crop.

## Cropping systems

Six systems were identified as priorities through consultation with farmers and advisers in northern NSW:

1. Baseline: representing a standard cropping system for northern NSW and to be kept consistent across all the farming systems locations. Planting trigger will be 50% full moisture profile. The baseline system consisted of wheat/fallow/sorghum/double cropped chickpea/wheat/chickpea.
2. Higher N supply: a duplicate of the baseline system, but designed to examine the economics and system performance of high N inputs. Fertilising to target a higher yield (90% of seasonal yield potential for N).
3. High crop intensity: planting trigger of a 30% full moisture profile. This mirrors current cropping sequencing on the Liverpool Plains and is based around the sequence of wheat/fallow/sorghum/double cropped chickpea.
4. Higher crop diversity: This system investigated alternative crop options to manage and reduce nematode populations, disease and herbicide resistance. The profitability of these alternative systems will be critical. A wider range of profitable crops could enable growers to maintain soil health and sustainability as their cropping lands age. Options considered for this system included: wheat, durum, barley, chickpea, field pea, faba bean, canola, mustard, sorghum, maize, sunflower, mungbean and cotton.
5. Higher legume: focused on soil fertility and reducing the amount of N fertiliser inputs. One in every two crops is a legume (chickpea, faba bean, field pea and mungbean). Planted at an average moisture trigger of 50% full profile.
6. Lower crop intensity: planted at a lower frequency when the profile is >80% full. High value crops are targeted (wheat, barley, chickpea, sorghum and cotton).

## Results

### Crop system yields at Spring Ridge

Wheat yields from the 2015 season suggested that the site was relatively uniform. The cumulative grain (or grain + lint) yields (Figure 2) are quite similar for the five main systems (not including the low crop intensity treatment) with only 2500 kg/ha separating the highest yield (high legume 11,084 kg/ha) from the lowest yield (high crop intensity 8573 kg/ha).

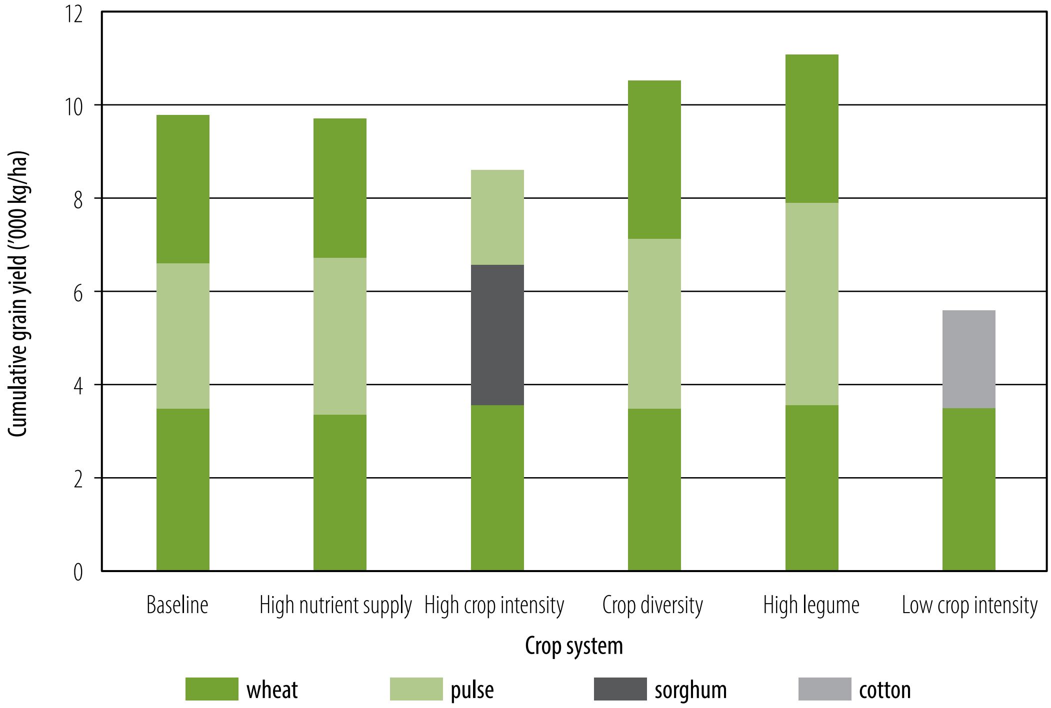

Figure 2 Cumulative grain (or grain + lint) yield of the Spring Ridge systems (kg/ha).

Crop choice had a major effect on grain yields in the 2016 winter season, with chickpea (baseline 3063 kg/ha and high nutrient at 3329 kg/ha) yielding lower than field pea (3631 kg/ha) and faba bean (4256 kg/ha) in the crop diversity and high legume systems respectively. The high intensity system was fallowed in 2016 into sorghum (2978 kg/ha) and then double cropped into a late chickpea crop (1981 kg/ha) in 2017. The low intensity system was cropped to cotton in the 2017/18 summer season and this yield value represents seed + lint (2078 kg/ha).

### Crop systems economics at Spring Ridge

Gross margins ($/ha) have been calculated for each crop within the six systems. Table 4 contains the grain pricing used in these calculations based on median prices over the past 10 years.

Table 4 Ten year median port prices, less $40/t cartage costs, for selected crops.

| Crop | Price ($/t) | Crop | Price ($/t) |
|---|---|---|---|
| Barley | 218 | Mungbean | 667 |
| Canola | 503 | Oat | 400 |
| Chickpea | 504 | Pasture grass | 150 |
| Cotton | 1090 | Pasture legume | 150 |
| Durum | 269 | Sorghum | 221 |
| Faba bean | 382 | Sunflower | 700 |
| Field pea | 350 | Vetch | 150 |
| Maize | 281 | Wheat | 269 |

After three growing seasons of the farming systems experiment at Nowley, the low crop intensity system (two crops in three years) had the greatest cumulative GM at $2739/ha (Figure 3). This is largely due to the high value cotton crop that produced ~4 bales/ha in the 2017/18 summer season. The other five systems are comparable with one another with the high legume system (wheat/faba bean/wheat) returning $2252/ha and the high intensity (wheat/sorghum/double crop chickpea) returning $2198/ha. The next best is the baseline system ($2184/ha), followed by crop diversity ($2022/ha) and high nutrition systems ($2011/ha), which are comparable with each other.

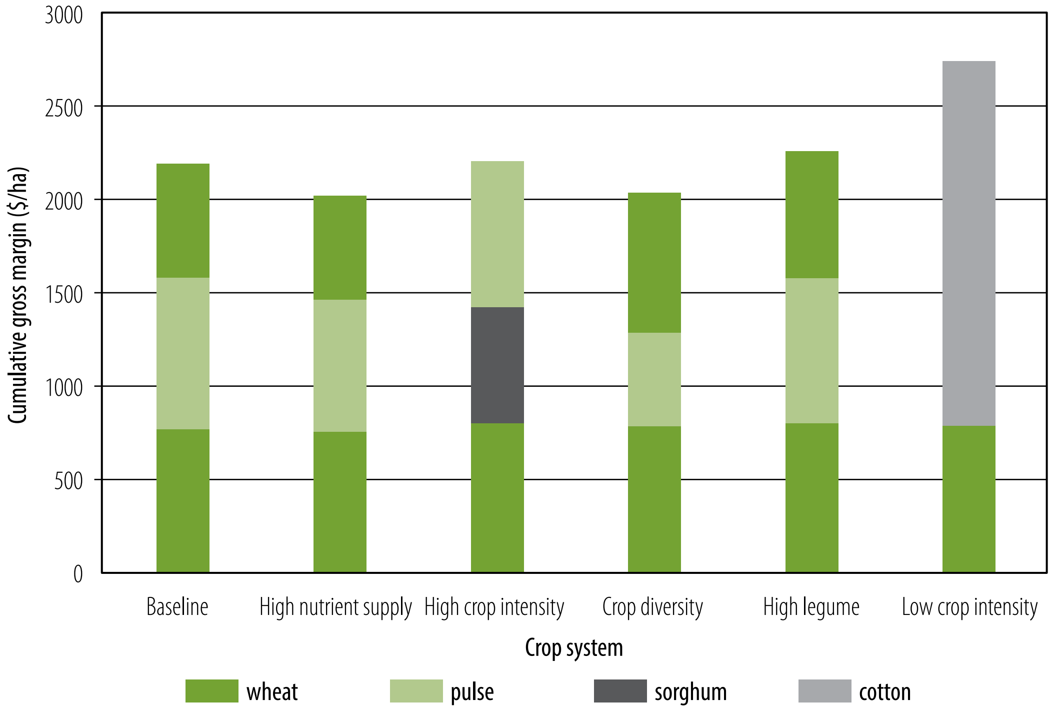

Figure 3 Cumulative grain gross margin ($/ha) of the Spring Ridge systems excluding fallow costs

In terms of wheat following pulses; wheat following chickpea had the lowest returns ($602/ha and $548/ha) compared with wheat following faba bean ($675/ha) and field pea ($724/ha).

### Crop system water-use-efficiency at Spring Ridge

While WUE is a useful tool to compare performances of individual crops, it fails to account for the efficiency of soil water accumulation from the previous fallow, or legacy effects after a particular crop either in the form of residual water at harvest, or the crop's effect on subsequent fallow efficiency. System water use efficiency is the $GM return per millimetre of water used (rainfall + change in soil water). Gross margins over the whole crop sequence were calculated from the sum of yield multiplied by the 10-year average price for each crop, minus variable costs (fertiliser, seed, herbicides, and operations) accumulated over the whole crop sequence (Figure 4).

Note the low intensity system has been calculated thru to March 2018 at the conclusion of the cotton crop while the other systems are through to the end of the 2017 winter season.

Only small differences have been observed between the systems, with WUE between $1.30/mm and $1.66/mm The high nutrient supply (wheat/chickpea/wheat), high crop intensity (wheat/fallow/sorghum/double crop chickpea) and crop diversity (wheat/field pea/wheat) systems showed lower WUE returns of around $1.30/mm. Adding extra N, as a split application, into the high nutrition system in a low rainfall season (2017) resulted in a –$0.20 decline in the return on water compared with the baseline system (wheat/chickpea/wheat).

Inserting faba bean into the system (high legume) has yielded equivalent WUE values to the baseline cropping system, while growing a high value dryland cotton crop (low crop intensity) on a full profile of soil moisture has resulted in the best WUE ($1.66/mm) return to date.

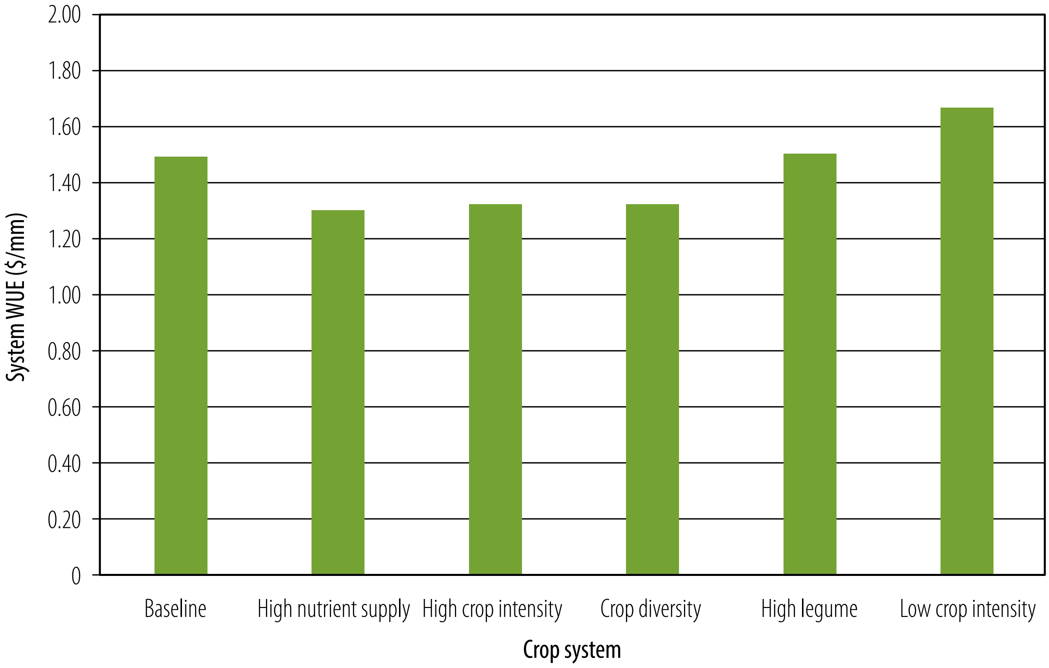

Figure 4 System WUE (March 2015 to Dec 2017/March 2018).

### Pathogens of the cropping systems at Spring Ridge

The whole site was sampled in early 2015 to examine the background pathogen status via soil DNA probing. When sampled, the site had been fallowed out of a sorghum crop.

Two DNA probes are taken each year; March and then in November–December. Table 5 compares the pre-sow DNA values in 2015 to the values at the end of the 2017 winter season for selected pathogens. The data presented in Table 5 is for soil samples taken in the crop row, so represent primary points of infection.

Table 5 DNA soil sample values for selected pathogens before first wheat crop (2015) and at harvest (2017).

| System | P.thornei (#/g) | | P.neglectus (#/g) | | Yellow leaf spot (copies/g) | | Bipolaris (pg/g) | | Fusarium (pg/g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-sow 2015 | Harvest 2017 | Pre-sow 2015 | Harvest 2017 | Pre-sow 2015 | Harvest 2017 | Pre-sow 2015 | Harvest 2017 | Pre-sow 2015 | Harvest 2017 |
| Baseline | 0.00 | 0.00 | 0.24 | 0.42 | 0.00 | 7.95 | 0.00 | 2.66 | 0.63 | 7.40 |
| High nutrient supply | 0.00 | 0.05 | 0.09 | 1.06 | 0.00 | 62.74 | 0.00 | 0.84 | 0.65 | 3.40 |
| High crop intensity | 0.00 | 0.01 | 0.06 | 0.22 | 0.00 | 0.13 | 0.00 | 0.39 | 1.32 | 0.97 |
| Crop diversity | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 2.97 | 0.00 | 2.37 | 0.25 | 14.02 |
| High legume frequency | 0.00 | 0.00 | 0.12 | 0.22 | 0.00 | 0.27 | 0.00 | 0.82 | 1.43 | 4.46 |
| Low crop intensity | 0.00 | 0.00 | 0.26 | 0.00 | 0.00 | 0.87 | 0.00 | 0.64 | 0.90 | 2.35 |

Note: #/g = number per gram of soil; pg/g = picograms per gram of soil

The range of values for individual pathogens across systems in 2015 represents site variability only, since there was no difference in cropping systems at the start of the trial. There were virtually no nematodes at this site except for low levels of *Pratylenchus neglectus* and levels below detectable levels for *P. thornei*. *P. neglectus* levels rose slightly where chickpea was grown, but remained at low levels. *P. neglectus* levels below 25 nematodes/g soil are considered a low density while *P. thornei* levels below 2.0 nematodes/g soil are regarded as a low disease risk.

Crop types responses to the different species of nematodes is as follows:

- chickpea: susceptible to both *P. thornei* and *P. neglectus*
- faba bean: susceptible to *P. thornei* and resistant to *P. neglectus*
- sorghum: susceptible to *P. neglectus* and resistant to *P. thornei*
- cotton: resistant to *P. thornei* and field pea is resistant to *P. neglectus*.

Large variations in nematode resistance and tolerance exist between chickpea and wheat varieties. PBA HatTrick⦹ is one of the least susceptible chickpea varieties for both *P. thornei* and *P. neglectus* (used at this site), while the wheat varieties Spitfire⦹ and EGA Gregory⦹ are both tolerant to *P. thornei* and *P. neglectus* yet also having some resistance susceptibility.

In 2017, yellow leaf spot (YLS) infected the zero tillage site and spiked sharply in the high nutrient system where 200 kg/N/ha was applied to EGA Gregory⦹ (as a split application). Both *Bipolaris* spp. and *Fusarium* spp. levels rose over the three seasons, but in quite low numbers with minor variation between systems. Spitfire⦹ and EGA Gregory⦹ were the only two varieties sown across the site; both are susceptible to YLS, *Bipolaris* and *Fusarium* infection.

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## Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both experiment cooperation and the support of the Grains Research and Development Corporation (GRDC); the author would like to thank them for their continued support.

We also thank, specifically, our co-operator and host at Nowley, The University of Sydney which has assisted us in implementing this experiment. We must also thank Michael Nowland for his management of the experiment site along with Mat Grinter and Peter Sanson for technical assistance in the field and laboratory.

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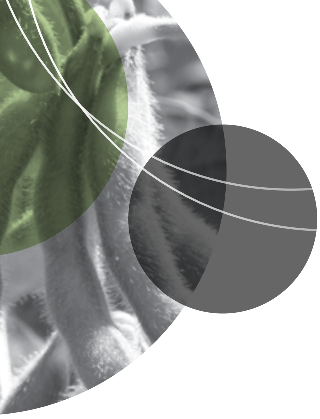

# Winter crops

## Durum wheat varieties grown in NSW since 1965: agronomy and quality

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### Key findings

- Australian durum varieties have had a yield increase of 90% since the first variety, Dural, was released in 1956.
- Dural is significantly later in maturity, much taller and more prone to lodging compared with Caparoi$^{\phi}$ (released in 2008).
- The varieties released after Dural include Mexican semi-dwarfing genes, have shorter stature and are earlier maturing than Dural.
- All the varieties released from the Tamworth node of Durum Breeding Australia (DBA) possess good grain and semolina quality as determined by the prevailing standards at the time of their release. This has increased grower's opportunities to produce grain of the higher valued Durum 1 (DR1) specification.
- The grain protein content of varieties has decreased over time. The newly released varieties, DBA Lillaroi$^{\phi}$, DBA Bindaroi$^{\phi}$ and DBA Vittaroi$^{\phi}$, readily achieve the minimum DR1 protein standard of 13% when soil nitrogen is adequate.
- Processing quality has steadily improved for the major parameters of semolina and dough properties. New varieties possess the highest semolina yellow pigment (Minolta b*) combined with reduced red hue (Minolta a), resulting in a bright pasta colour.

### Introduction

Durum wheat (*Triticum durum*) is a high yielding, specialty crop suited to the northern farming systems of Australia. It can be sown late into winter (e.g. July), which makes it suited for sowing after cotton.

Durum breeding in Australia began in the 1930s, at the NSW Department of Agriculture's Glen Innes Research Station .The first variety, Dural, was released in 1956. A total of 11 varieties suited to NSW have been released from this program since then, including some landmark varieties such as, EGA Bellaroi$^{\phi}$, Caparoi$^{\phi}$ and Jandaroi$^{\phi}$. These varieties have helped the NSW durum industry to gain a worldwide reputation for high quality grain that commands a premium price. Australian durum wheat is mainly used in blends by European millers and pasta makers to improve local grist quality. To obtain the highest grade – DR1 – grain needs to meet strict delivery specifications including protein >13%, screenings <5% and percentage of hard vitreous kernels >80%. The current DBA program targets yield, adaptation to drought and tolerance to crown rot, whilst maintaining or improving, where possible, quality for overseas markets.

In this experiment 14 historic durum varieties were evaluated over two seasons at Tamworth to quantify changes in agronomic and selected grain traits over the 62 years of releases in Australia. This experiment was restricted to varieties registered in NSW.

| | | |
|---|---|---|
| **Site details** | **Location** | Tamworth – Tamworth Agricultural Institute |
| | **Paddock history** | For both years, sorghum followed by a 12-month fallow, then durum. |
| | **Soil type and nutrition** | Vertosol<br>$pH_{Ca}$: 7.22 in 2016 and 7.54 in 2017<br>Granulock (N:P:S:Zn – 11:21.8:4:1) applied at 50 kg/ha.<br>Soil tests were carried out in both seasons and nitrogen nutrition managed for 13% grain protein at 4 t/ha yield. |
| | **Rainfall** | 744 mm in 2016<br>631 mm in 2017<br>Growing season rainfall was 647 mm in 2016 and 328 mm in 2017 (Figure 1). |
| | **Experiment design** | Row column experiment designs with three replicates.<br>Ten meter long plots with five rows on 35 cm spacings. |
| | **Sowing dates** | 17 June 2016 and 15 June 2017. |
| | **Sowing rate and established plant population** | The target plant density was 100 plants/$m^2$. |
| | **Weed management** | Pre-sowing and post emergent herbicides targeting broad leaf weeds. |
| | **Harvest date** | 10 December 2016 and 15 December 2017. |
| **Treatments** | **Varieties (14)** | Fourteen durum varieties grown in NSW since 1956 (Table 1). |

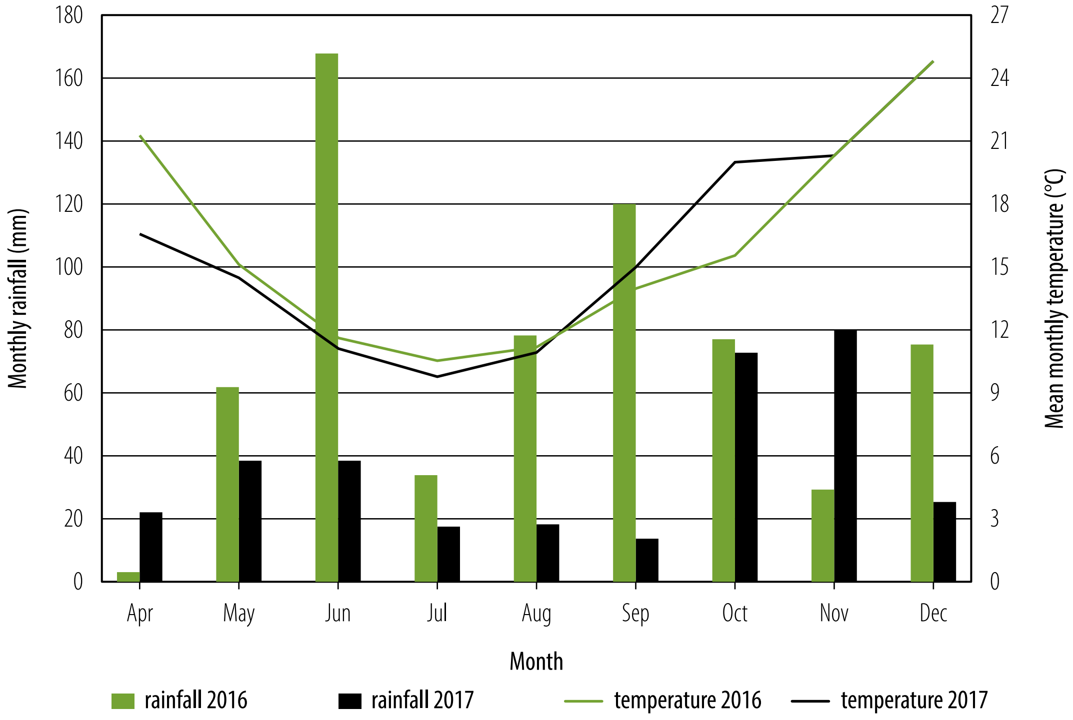

Figure 1 Monthly rainfall and average temperatures, 2016 and 2017 at Tamworth.

Table 1 Durum varieties grown in NSW since 1956.

| Name | Pedigree | Year released/first commercial production |
|---|---|---|
| Dural | Aleppo/Palestine | 1956 |
| Duramba | Mexican semi-dwarf/Dural | 1970 |
| Durati | Zenati Bouteille /Wells//Mexican semi-dwarf | 1977 |
| Kamilaroi | Durati 'S'/Leeds | 1982 |
| Yallaroi | Guillemot Seln3/ Kamilaroi 'S' | 1987 |
| Wollaroi | tam1b?17/kamilaroisib//rokel selection/kamilaroi sib | 1993 |
| EGA Bellaroi | (69778/870015)/(srn/sula's'23 idsn 91?92:245)/{[(yallaroi)//(tam1b?17 /Kamilaroi)]/[(Tam1b?17 /kamilaroi)/3/(Durati's' /leeds //guillemot's')]} | 2003 |
| Jandaroi | (Souri/Wollaroi)/Kronos | 2007 |
| Caparoi | LY2.6.3/ 930054 | 2008 |
| Hyperno | 'Lingzhi''Baimong''Baidamai'/2*'Yallaroi'//RH88009///'Wollaroi' | 2009 |
| DBA Aurora | Tamaroi*2/Kalka//RH920318/Kalka///Kalka*2/Tamaroi | 2014 |
| DBA Lillaroi | 960273/980596 | 2015 |
| DBA Vittaroi | 200856/980990 | 2017 |
| DBA Bindaroi | Caparoi/261102. | 2018 |

## Results

### Agronomy

The first variety released in Australia, Dural, was from a cross between two Middle Eastern landrace durums, Aleppo and Palestine (Table 1). It is the tallest of the 14 varieties and is susceptible to lodging. All subsequent varieties possess at least one semi-dwarf variety in the pedigree, donating the Rht1 gene, which results in a significant height reduction. Most varieties are of very short to medium stature including DBA Vittaroi$^{\phi}$, DBA Aurora$^{\phi}$, Yallaroi and Durati. Hyperno$^{\phi}$ and DBA Aurora$^{\phi}$ from the DBA University of Adelaide node, are taller than the varieties released from the Tamworth DBA node.

Dural and Duramba are the slowest varieties for ear emergence, with Jandaroi$^{\phi}$ (Figure 2) being the quickest. The latest releases tend to be early–medium in length in maturity. This reflects the prevalence of drier seasonal conditions in northern NSW where these varieties were selected. These seasonal conditions do not favour plant types that are later in maturity than Caparoi$^{\phi}$.

### Yield

Grain yield has improved by 90% since Dural's release in 1956 (Figure 3). Yields in these experiments were affected by excessively wet conditions in 2016. In 2017 there was a prolonged drought in early spring followed by good rains in late spring (Figure 1). These seasonal conditions favoured the later maturing varieties EGA Bellaroi$^{\phi}$ and Yallaroi$^{\phi}$, which achieved better yields in both seasons relative to Caparoi$^{\phi}$ (Figure 3).

Mean yields were similar in both seasons (5.33 t/ha in 2016 and 5.35 t/ha in 2017). Most varieties, excluding EGA Bellaroi$^{\phi}$, Hyperno$^{\phi}$ and DBA Aurora$^{\phi}$, had higher yields in 2017 than 2016. The results are consistent with how these varieties performed in previous wet seasons in other data sets e.g. NVT (www.nvtonline.com.au).

DBA Lillaroi$^{\phi}$, released in 2015, performed better than the benchmark, Caparoi$^{\phi}$, in both 2016 and 2017. The most recent release, DBA Bindaroi$^{\phi}$, also yielded higher than Caparoi$^{\phi}$ in 2017 (Figure 3). DBA Aurora$^{\phi}$ and Hyperno$^{\phi}$ are both high yielding varieties, but they are not grown substantially in NSW due to significant grain quality deficiencies. DBA Aurora$^{\phi}$ is prone to high screenings and low grain protein, whilst Hyperno$^{\phi}$ is also prone to high screenings and crop lodging.

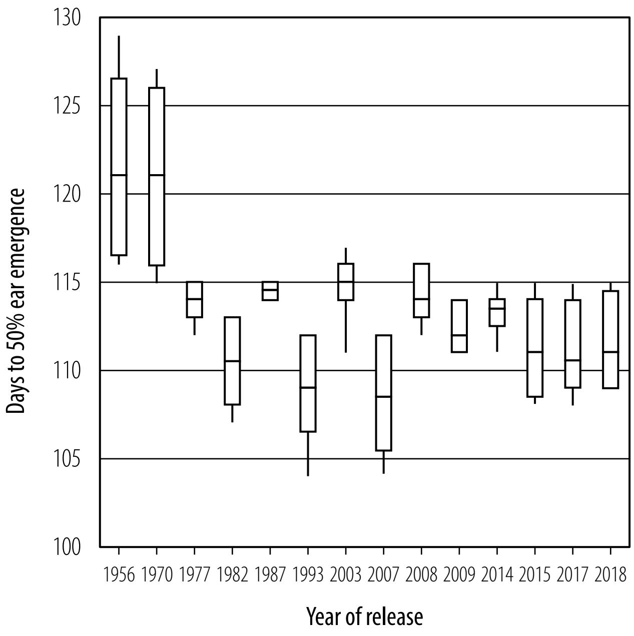

Figure 2 Days from sowing to 50% ear emergence for varieties grown at Tamworth in 2016 and 2017.

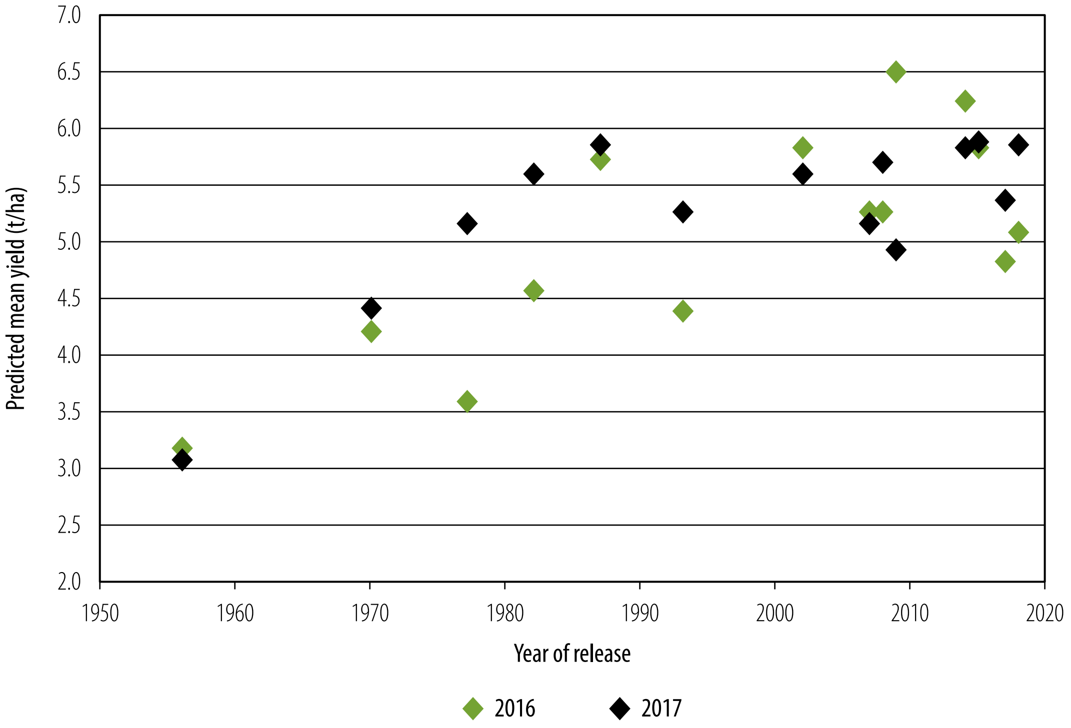

Figure 3 Predicted mean yield versus year of release for 2016 and 2017.

## Grain quality

When the first durum variety, Dural, was released it was excellent for thousand grain weight (TGW). There was a trend towards smaller grain size, coupled with increased yield potential, in the next few releases. Wollaroi had the lowest TGW in this experiment (Figure 4A). Since Wollaroi's release in 1993, greater emphasis has been placed on both increasing and improving TGW stability and minimising screenings (SCR), leading to the release of the very large grained DBA Lillaroi$^{\Phi}$ in 2015. These traits have been largely retained in two later releases, DBA Vittaroi$^{\Phi}$ and DBA Bindaroi$^{\Phi}$. There was variability in the screenings of all samples, but the levels were below the 5% limit, with the latest releases showing consistently low screenings levels (Figure 4B). While environmental conditions greatly affect the absolute screenings values, varieties still tend to maintain their ranking.

Grain quality is generally negatively correlated with yield, because high yielding varieties tend to have an increased number of grains per head (Dolferus, Xuemei and Richards, 2011), which in turn negatively affects TGW and SCR (Kadkol, unpublished data). It is likely that future yield increases for high quality durum could come from breeding for increased grain numbers per head while optimising TGW and maintaining low SCR.

## Semolina quality

There is a clear correlation between an increase in semolina b* (notation for yellowness in the Minolta scale) and a decrease in a* (notation for redness in the Minolta scale) and the year of release (Figure 5). This is because strong selection pressure has been applied on these traits from the early stages of breeding in the DBA/NSW DPI program. This selection is effective because the genes controlling colour in the grain are highly heritable allowing good genetic gain (Ficco et al. 2014). A bright yellow semolina with low redness is a desirable consumer trait and the increase in b* values from low 20s to low 30s has made Australian durum equal to Desert Durum® produced in south-western USA, which is considered to be the best in the world.

Grain protein and wet gluten content have declined with time (0.02% decline/year, protein) with some stability in varieties released between 1977 and 2007 (Figure 6). This most likely comes from the inverse relationship of increased yield and decreasing grain protein. Such decline has been noted in wheat breeding around the world and represents a challenge for future breeders (Simmonds, 1995). Despite this, the DBA northern durum varieties still readily achieve the necessary 13% protein with appropriate nitrogen management. Dough strength, which is important for making good pasta, has tended to improve with time despite the reduction in protein content. This was measured by a reduction in mixograph resistance breakdown (RBD) and an increase in gluten index (GI) (Figure 7), although the changes are not dramatic. GI values >80 represent very strong gluten levels; the measurement being independent of the protein content. Kamilaroi, released in 1982, had the weakest dough strength, while Jandaroi$^{\Phi}$, released in 2007, had the highest. Improvement in semolina b* and dough strength have led to brighter pasta (in appearance) and better cooking performance (data not shown).

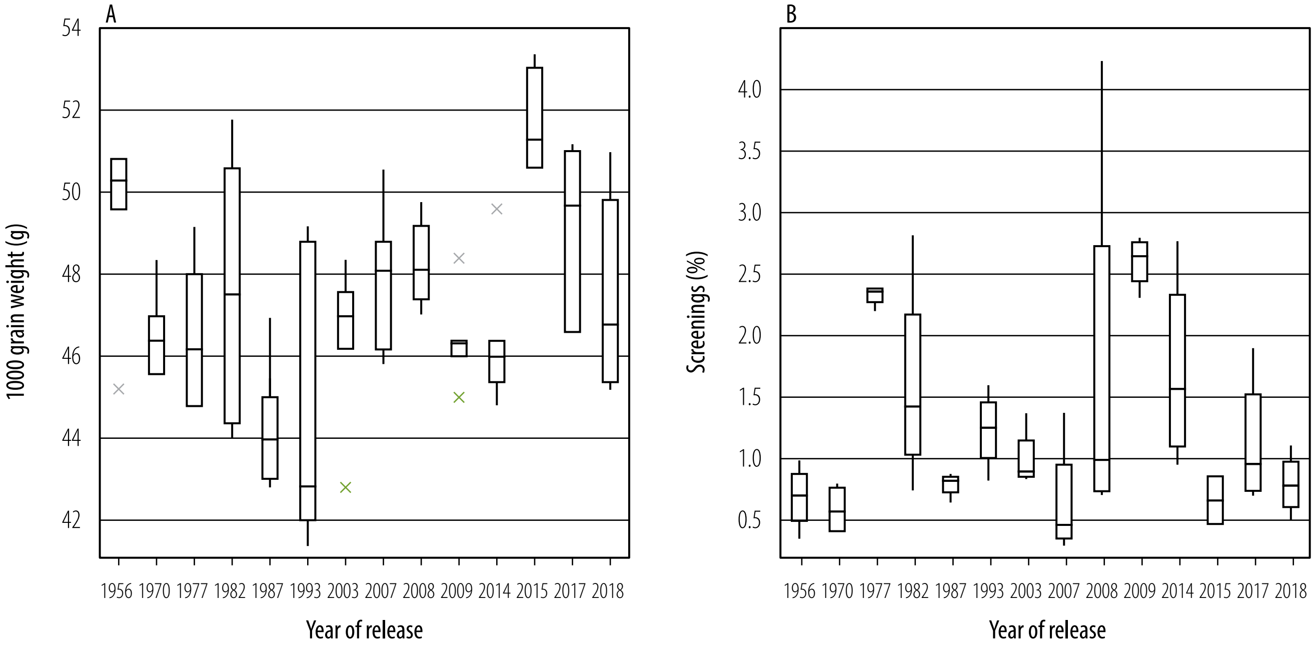

Figure 4 1000 grain weight (A) and screenings (B) vs. year of release for durum heritage varieties grown at Tamworth in NSW in 2016 and 2017.

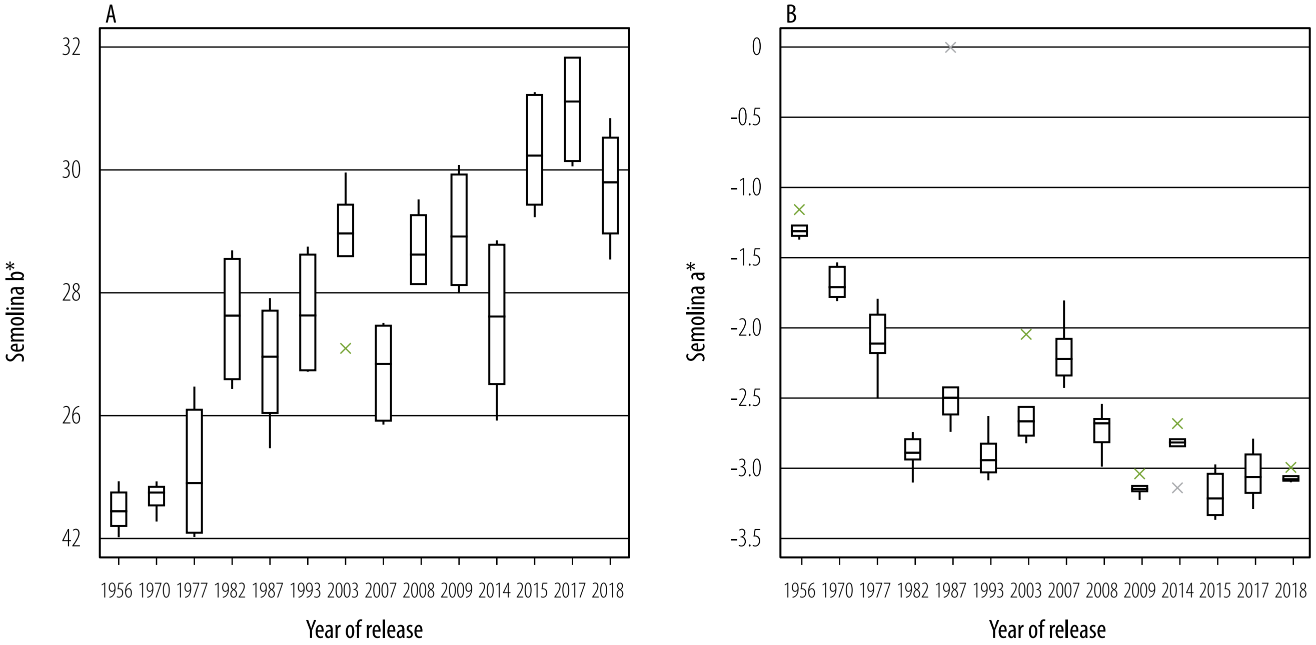

Figure 5 Semolina b* (A) and Semolina a* (B) vs. year of release over two years for the durum heritage varieties set.

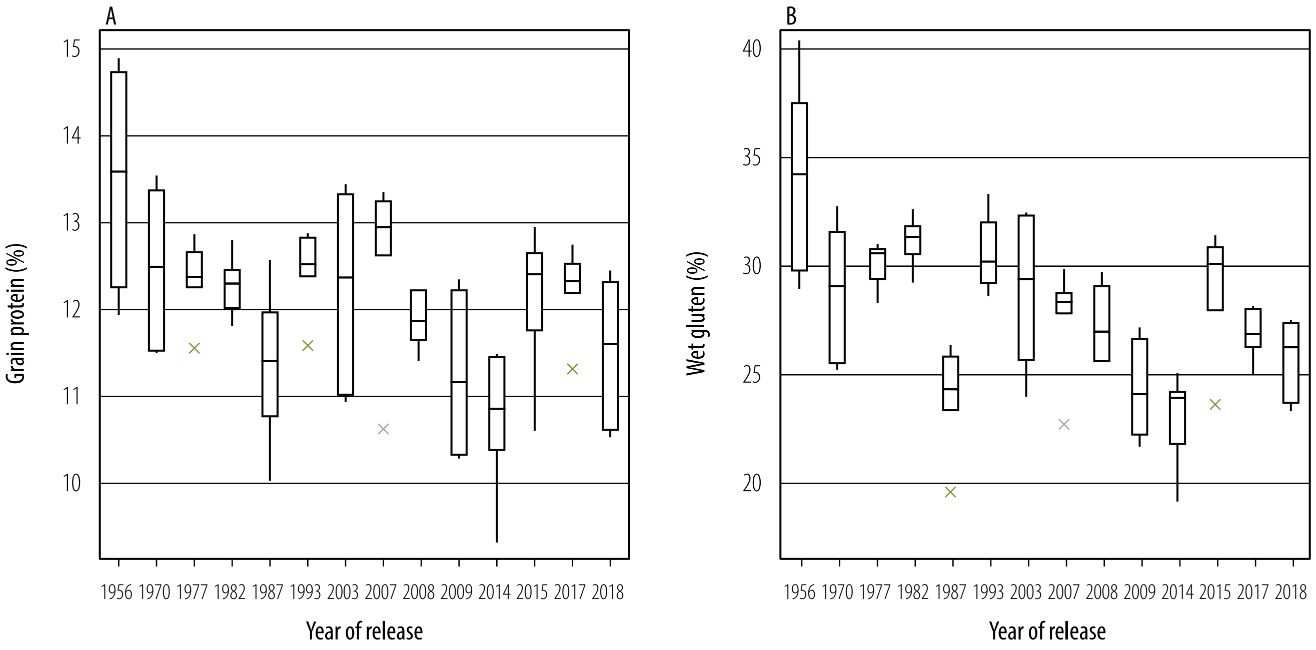

Figure 6 Grain protein (A) and wet gluten (B) vs. year of release over two years for the durum heritage varieties set.

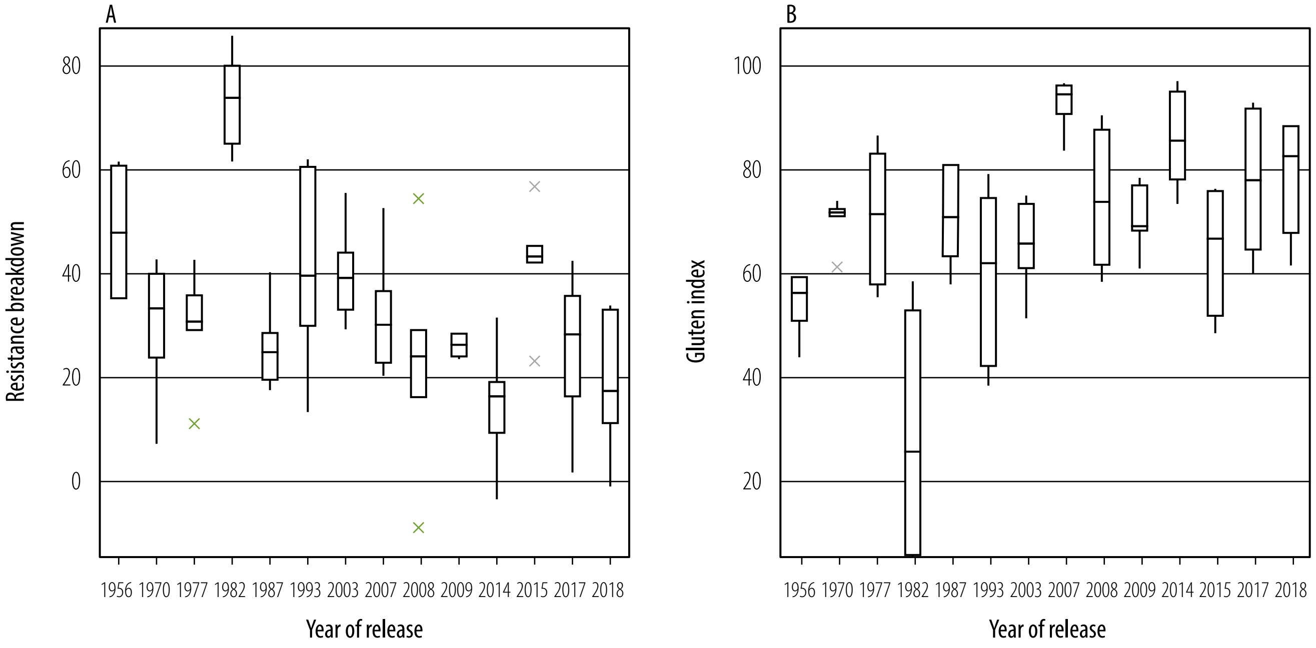

Figure 7 Resistance breakdown (A) and gluten index (B) vs. year of release over two years for the durum heritage varieties set.

## Conclusions

Quality improvements in varieties are expected to increase marketability of durum for NSW growers. This increase in quality could potentially provide access to new markets in Asia for local millers and pasta makers. The steady increase in durum yields will allow this crop to remain competitive, with other cropping options for growers in the northern cropping systems of NSW. The ongoing DBA breeding program is making significant progress in developing varieties with superior quality and high yield.

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## Acknowledgements

This work was supported in part by Grains Research and Development Corporation (GRDC) Project No. 9175799, Durum Breeding Australia (DBA). We are grateful for the technical support from the DBA breeding team (Sarah Kampe, David Wark, Rebecca Harley and Max Cloake) and the DBA quality team (David Gulliford, Blake Brangwin and Shaylene Sissons).

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# Chickpea pod set under cool temperatures – Tamworth 2018

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## Key findings

- Previous research shows cool temperatures (average day temperature <15 °C) during flowering and podding can result in flower and/or pod abortion in chickpea crops.
- Genotypes vary in their ability to set pods at sub-optimal temperatures.
- Days to flowering and pod set can vary for individual chickpea varieties depending on sowing date.
- While current varieties adapted to the northern growing region have generally poor chilling tolerance, there is an opportunity to incorporate this trait through breeding efforts.

## Introduction

Early sown chickpeas can be susceptible to poor flower fertilisation and pod set when the average daily air temperature is below 15 °C. This experiment aimed to identify chickpea genotypes capable of setting pods under cool spring conditions in northern NSW.

## Site details

**Location** Tamworth – Tamworth Agricultural Institute

**Paddock history** 2017 wheat

**Soil type and nutrition** Grey vertosol (see Table 1)

Table 1 Site soil chemical characteristics for 0–10 cm depth at TAI, 2018.

| Characteristic | Depth (0–10 cm) |
|---|---|
| $pH_{Ca}$ | 7.0 |
| Sulfur (mg/kg) | 13.6 |
| Phosphorus (Colwell) (mg/kg) | 24.0 |
| Organic carbon (OC) (%) | 1.1 |

**Soil water and rainfall** The experimental site was cored for soil water at the beginning of the growing season and found to have 85 mm of plant available water (PAW) to 1.2 m deep, with the majority of available water in the 10–60 cm zone (Table 1). A total of 68 mm of in-crop rainfall was recorded at the site (Table 2). The majority was recorded in August, September and October. Supplementary water was applied three times with dripper tape during the growing season – sowing, late vegetative and mid-podding – targeting 20 mm per application.

Table 2 Growing season rainfall for Tamworth Agricultural Institute in 2018.

| Month | May | June | July | August | September | October | November |
|---|---|---|---|---|---|---|---|
| Rainfall (mm) | 1.4 | 6.4 | 3.2 | 16.5 | 16.5 | 22.5 | 1.0 |

| | | |
|---|---|---|
| | **Experiment design** | Replicated split block design with sowing date as the main block and varieties as the subplot. |
| | **Fertiliser** | 57 kg/ha StarterZ |
| | **Plant population** | Target 35 plants/$m^2$ |
| | **Harvest date** | 19 November 2018 |
| **Treatments** | **Genotypes (24)** | The 24 genotypes included 11 PBA chickpea breeding lines, three pre-release lines, a wild chickpea hybrid line and nine released varieties: Howzat, Kyabra$^{\phi}$, Neelam$^{\phi}$, PBA Boundary$^{\phi}$, PBA HatTrick$^{\phi}$, PBA Seamer$^{\phi}$, PBA Slasher$^{\phi}$, PBA Striker$^{\phi}$, and Rupali. |
| | **Sowing date (SD)** | SD1: 7 May 2018<br>SD2: 12 June 2018 |

## Results

### Environment

Cool temperatures persisted throughout the winter months of 2018. It was not until early September (approximately 5 September) that the average daily temperatures rose above 15 °C. There were frosts at Tamworth in July and August, with the last frost on 30 August. Only the early-sown treatment (7 May 2018), had a significant cool temperature period during early flowering and pod set

### Flower and pod production

Results from the 2018 season indicated some variation in growth stage development and timing between genotypes. The beginning of flowering ranged from 191 days after sowing to 215 days after sowing for SD1 (Figure 1). However, there was an extended delay between flowering and podding in the earliest flowering genotypes (Figure 1). The range in pod-initiation dates was therefore smaller than the range in flowering dates, with the earliest genotype beginning pod initiation at 261 days after sowing, and the latest at 265 days after sowing. Of the 24 genotypes assessed at Tamworth, 13 began pod initiation before average daily temperatures exceeded 15 °C for SD1 (Figure 1). However, no variety reached the early pod fill stage before the average day temperatures exceeded 15 °C. Further research in 2019 will investigate if this delay is due to pod abortion early in their development or delayed development in cool conditions.

Pod mapping data shows that nine genotypes set pods containing seeds when flowering occurred when the average day temperature was below 15 °C (Table 3). The majority of these were breeding lines and southern adapted lines, with the exception of Kyabra$^{\phi}$. Since the breeding lines were not adapted to the northern region they were the poorest yielding at Tamworth. This highlights the potential for using these genotypes in further breeding efforts to incorporate this trait into more adapted backgrounds for the northern region.

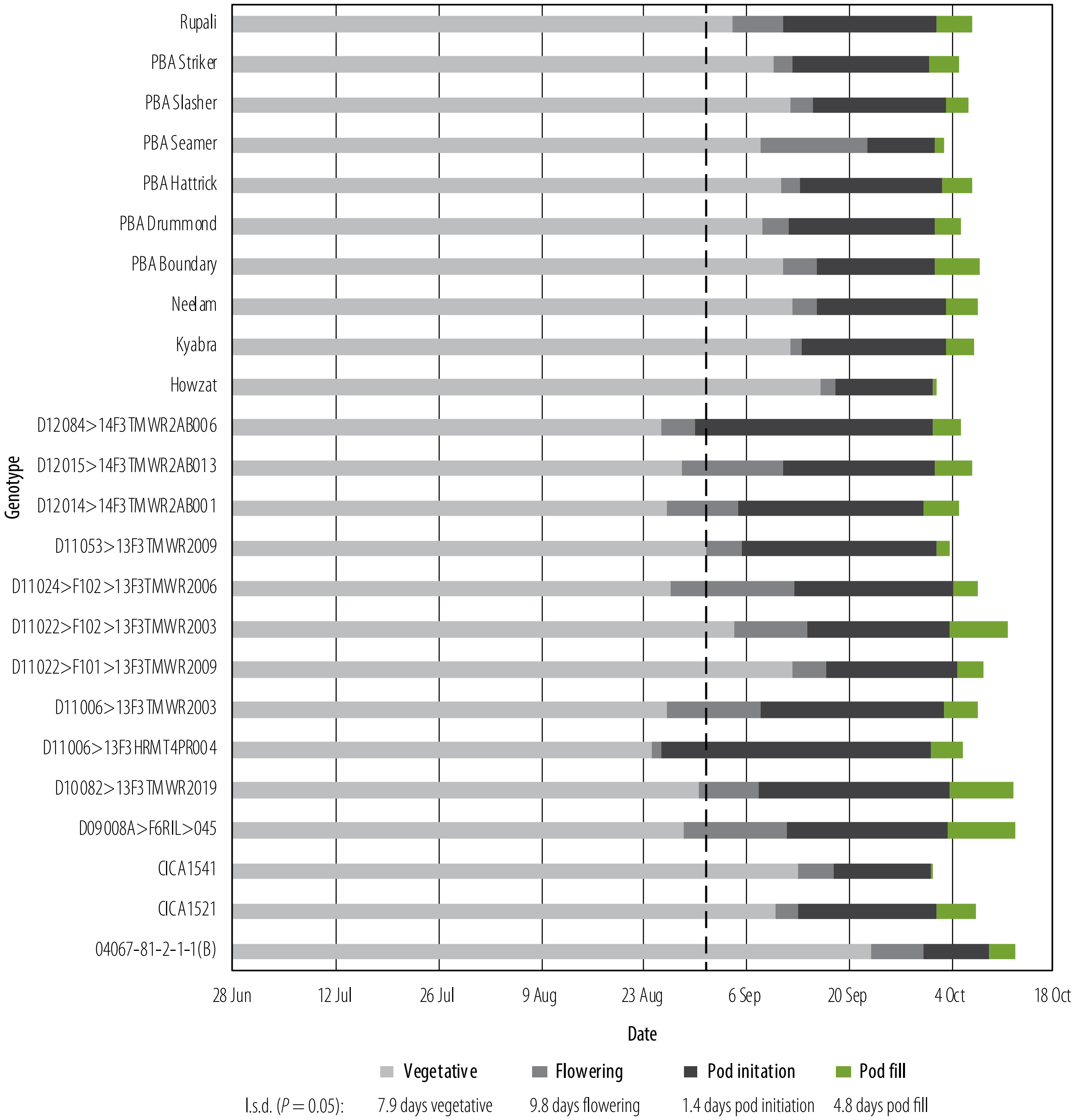

Figure 1 Average time to flowering and podding in 24 genotypes sown on 8 May in Tamworth.
*The dashed line indicates date when average daily temperature exceeded 15 °C*

Table 3 Genotypes that produced pods when average daily temperature was less than 15 °C at Tamworth in 2018.

| Name | No of pods | No of pods with seeds |
|---|---|---|
| Neelam | 1 | 1 |
| Kyabra | 1 | 1 |
| D11006>13F3TMWR2003 | 1 | 1 |
| CICA1541 | 3 | 2 |
| PBA Striker | 1 | 1 |
| PBA Slasher | 1 | 1 |
| D11053>13F3TMWR2009 | 1 | 1 |
| D12014>14F3TMWR2AB001 | 1 | 1 |
| D09008A>F6RIL>045 | 1 | 1 |

## Conclusions

Genetic variation in the ability to set pods under cool spring conditions was identified amongst current chickpea breeding material. While current varieties adapted to the northern region lack significant chilling tolerance, there is some promising material in the breeding program for further variety development.

## Acknowledgements

This experiment was part of the project 'Does improving chilling tolerance of chickpea increase and stabilise yield and improve farming system 'fit'?', BLG111, a project that involves researchers from both northern and southern NSW jointly funded by NSW DPI and the Grains Research and Development Corporation (GRDC). Technical assistance from Laney Davidson, and chickpea breeding and agronomy staff Judy Duncan, Andrew George, Tyson Peterswald, Ben Frazer, Mike Nowland, Madonna Rowe, Belinda Rowe and Mandy Rowe, is gratefully acknowledged.

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# Early sowing options: influence of sowing date on phenology and yield of long-season wheat genotypes – Wongarbon 2018

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## Key findings

- Slower developing spring and winter wheat genotypes achieved the highest yields in 2018 from an extended grain filling period due to significant rainfall in October and November.
- The winter types achieved stable flowering dates across sowing dates, compared with the spring types, which are not suited to early sowing.
- New winter genotypes had different phenology responses compared with current commercial genotypes, suggesting that management can manipulate cultivar performance, and vary across growing environments.

## Introduction

Recent trends in earlier sowing have renewed grower interest in winter wheats and breeders' focus on selecting and releasing new genotypes suited to various farming systems in NSW.

Sowing slower developing varieties early can result in increased water use efficiency and yields, with no additional cost to growers. Selecting the correct genotype choice, by matching phenology and sowing time, is vital to ensure that flowering and grain-filling occur at an optimal times. Winter wheats can be sown early, and will remain vegetative until their vernalisation (cold temperature) requirement has been satisfied. This acts to delay reproductive development so that flowering coincides with favourable seasonal conditions. Should a spring variety be sown early, when temperatures are warmer and days longer, development will progress quickly and flowering will occur earlier than optimum, reducing yield potential.

In 2018, field experiments were conducted at Wongarbon, central NSW and Wallendbeen, southern NSW to evaluate current commercial genotypes in conjunction with new breeder lines suited to early sowing in contrasting environments. This paper presents results from the Wongarbon experiment site, and focuses on the influence of sowing date on the phenology, yield and quality of 16 wheat genotypes.

## Site details

| | |
|---|---|
| **Location** | Hillview Wongarbon, NSW. (Elevation 362 m) S 32°20'2.32" E 148°42'53.95" |
| **Paddock history** | Canola (2017), Barley (2016) |
| **Sowing** | Direct drilled with Janke tynes spaced at 250 mm using a GPS auto-steer system. |
| **Target plant density** | 120 plants/m$^2$ |
| **Soil type and nutrition** | Chocolate basalt (Table 1) |
| **Mineral nitrogen (N)** | 101 kg N/ha at sowing (1.2 m depth) |

| | |
|---|---|
| **Fertiliser** | 100 kg/ha Granulock Z Extra Flutriafol 2.8L (N:P:S; 11:21.8:4:1) placed with the seed at sowing<br>80 L/ha Easy N applied 27 June immediately before receiving 20 mm rainfall which incorporated the product |
| **Weed management** | Pre-sowing: 2.5 L/ha Boxer Gold®<br>In-crop: Axial® 300 ml/ha (plus Adigor®) and Velocity® 650 ml/ha<br>In-crop pre-harvest clean-up: 1 L/ha Amicide Advance 700 |
| **Insect management** | Not needed |
| **Disease management** | Flutriafol® treated fertiliser @ 2.8 L/1000kg |
| **Rainfall** | A total of 343 mm of rainfall was recorded at the site during 2018. During the growing season (April–October) 259 mm was recorded along with above average rainfall for October and November (Table 2), which had a significant effect on the 2018 results. |
| **Harvest date** | 10 December 2018 |

Table 1 Site soil chemical characteristics for 0–10 cm depth at Wongarbon in 2018.

| Characteristic | $pH_{Ca}$ (1:5) | Aluminium Exc. (meq/100 g) | Zinc (mg/kg) | Sulfur (mg/kg) | Phosphorus (Colwell P) (mg/kg) | Organic carbon (OC) (%) | Nitrogen ($NO_3$) |
|---|---|---|---|---|---|---|---|
| Depth (0–10 cm) | 6.87 | 1.8 | 0.39 | 17 | 13 | 1.6 | 26 |

Table 2 Annual rainfall (mm) for Hillview, Wongarbon in 2018, and the long-term average (LTA) recorded at Dubbo airport.

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2018 | 31 | 0 | 6 | 12 | 8 | 16 | 3 | 37 | 8 | 102 | 73 | 48 | 343 |
| LTA | 57 | 41 | 61 | 33 | 40 | 51 | 41 | 35 | 43 | 48 | 61 | 61 | 570 |

## Treatments

### Trial design

A split-plot design; sowing date as the main plot and genotype as the sub-plots; three replications.

Sixteen wheat genotypes with varying responses to vernalisation and photoperiod (Table 3) were sown on three sowing dates: 3 April (SD1); 16 April (SD2); 2 May (SD3). Due to dry seedbed conditions, all plots were watered with dripper tape immediately after sowing to apply the equivalent of 10 mm to effect seed germination.

There was significant grazing pressure from kangaroos due to severe drought conditions in 2018, therefore results are only reported for SD2 and SD3.

Table 3 Expected phenology types of experimental genotypes at Wongarbon, 2018.

| Phenology type | Genotypes | |
|---|---|---|
| Winter | RGT Accroc$^{\Phi}$ (slow)<br>Manning$^{\Phi}$ (slow)<br>ADV08.0008 (mid–slow)<br>DS Bennett$^{\Phi}$ mid–slow)<br>EGA Wedgetail$^{\Phi}$ (mid) | LongReach Kittyhawk$^{\Phi}$ (mid)<br>ADV13-1292 (mid)<br>Illabo$^{\Phi}$ (mid-fast)<br>Longsword$^{\Phi}$ (fast) |
| Spring | LongReach Nighthawk$^{\Phi}$ (LPB14-0392) (very slow)<br>RGT Zanzibar (very slow)<br>Sunlamb$^{\Phi}$ (very slow)<br>Sunmax$^{\Phi}$ (very slow) | Cutlass$^{\Phi}$ (slow)<br>LongReach Lancer$^{\Phi}$ (mid–slow)<br>Trojan$^{\Phi}$ (mid–slow) |

## Results

### Establishment

The average seedling establishment was 70 plants/m$^2$, lower than the targeted 120 plants/m$^2$. The average plant densities were 76 plants/m$^2$ (SD2), and 55 plants/m$^2$ (SD3).

### Phasic development

Generally, the genotype and sowing date combinations, which flowered in early to mid October at Wongarbon, achieved the highest grain yields. The winter wheats all had a prolonged vegetative phase and relatively stable flowering dates across the SDs compared with the faster developing spring types (Figure 1). Despite this, there was significant variation in phasic duration among the winter types, which influenced yield responses (Table 4).

Illabo$^{\Phi}$, EGA Wedgetail$^{\Phi}$ and LongReach Kittyhawk$^{\Phi}$ recorded similar flowering dates for each SD. Differences were observed between SDs for growth stage 30 (GS30) – the start of stem elongation. For SD2 and SD3, Illabo$^{\Phi}$ was 2–3 days slower than LongReach Kittyhawk$^{\Phi}$, and both reached GS30 15–18 days faster than EGA Wedgetail$^{\Phi}$.

The fast winter type, Longsword$^{\Phi}$, had a similar vegetative period to LongReach Kittyhawk$^{\Phi}$ for both SDs, but was 3–4 days faster to flowering. Longsword$^{\Phi}$ was the quickest variety to flower for SD2.

The slow winter types Manning$^{\Phi}$ and RGT Accroc$^{\Phi}$ were significantly slower to GS30 and flowering than the other winter types, with RGT Accroc$^{\Phi}$ flowering 11 days later than LongReach Kittyhawk$^{\Phi}$ in SD2 and five days later for SD3. Despite this, there was also variation in phasic duration among the slower winter types, with RGT Accroc$^{\Phi}$ reaching GS30 five days earlier than Manning$^{\Phi}$.

Faster developing spring types, with minimal response to vernalisation, sown early when temperatures are warmer and days longer, progressed quickly. These types, when sown later in the appropriate sowing window for its given phenology type, were able to flower within the optimal period (OFP) (Figure 1). It was observed that some slower developing spring types, such as Sunmax$^{\Phi}$, had relatively stable flowering dates (SD2: 6 October; SD3: 9 October), offering some flexibility in sowing dates for growers in central NSW. Despite Sunlamb$^{\Phi}$ flowering later than the OFP, there was no significant grain yield penalty in 2018, most likely due to rainfall and mild conditions in mid–late October (Figure 1; Table 4).

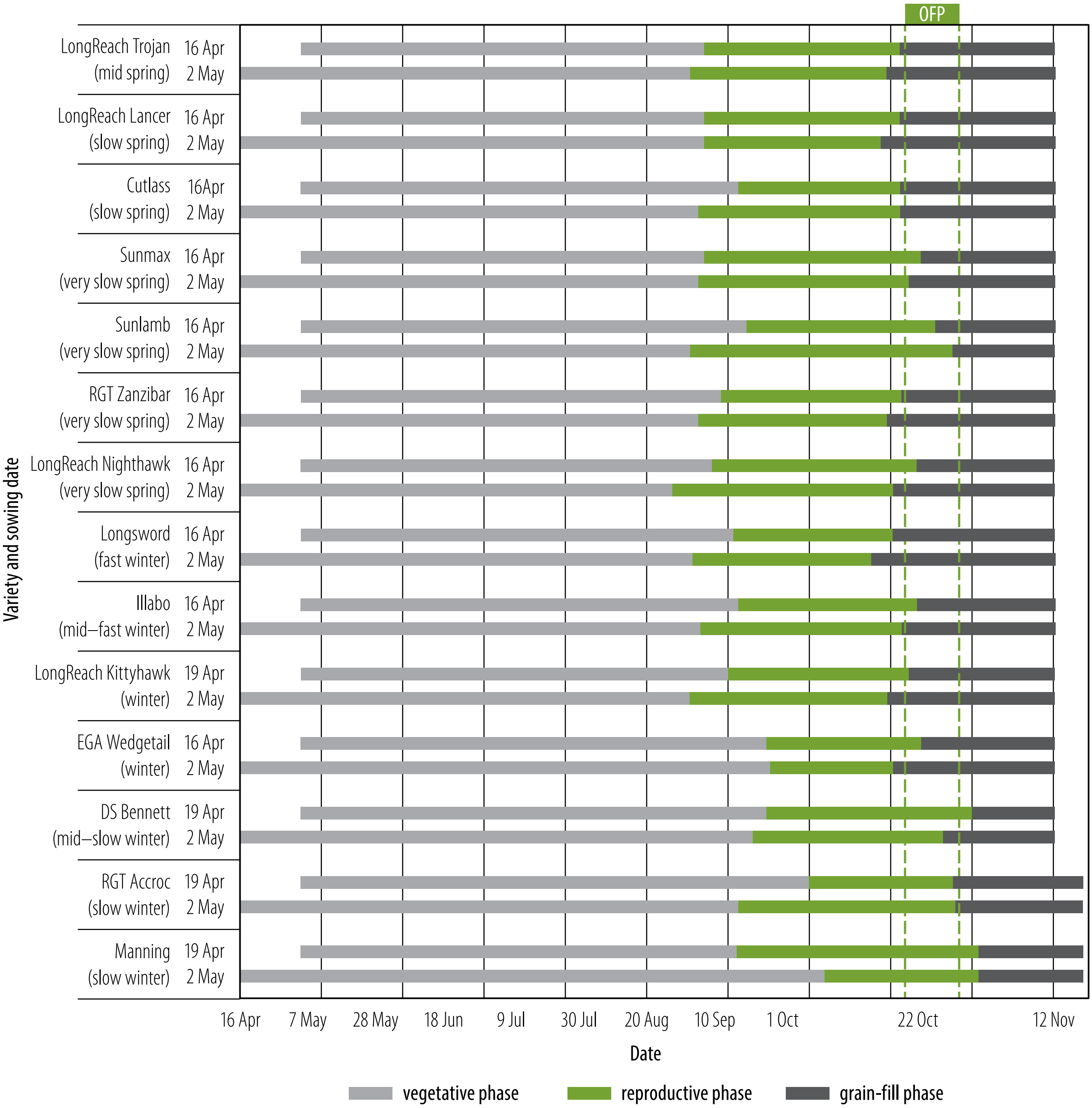

Figure 1 Sowing date influence on development of 16 genotypes of wheat. Vegetative phase (sowing to GS30), reproductive phase (GS 30 to GS 65 – flowering), grain-fill phase (flowering to maturity).

### Grain yield

Late rainfall in 2018 favoured the slower developing spring and winter genotypes, which achieved consistently higher yields across the two SDs due to the extended grain filling period. New genotypes indicated a possible yield advantage compared with the benchmark variety EGA Wedgetail$^{\phi}$, which ranked 8th for SD2 and 9th for SD3 (Table 4). The faster developing spring types, such as Lancer$^{\phi}$ and Trojan$^{\phi}$ were among the lowest yielding for both SD2 and SD3. There was no significant genotype × SD interaction, indicating that genotype performance was similar across both SDs.

Table 4 Grain yield and rank of genotypes across two sowing dates at Wongarbon in 2018.

| **Genotype** | **SD2: 16 April** | | **SD2: 2 May** | |
|---|---|---|---|---|
| | **Grain yield (t/ha)** | **Yield rank** | **Grain yield (t/ha)** | **Yield rank** |
| ADV08-0008 | 2.57 | 3 | 2.46 | 7 |
| ADV13-1292 | 2.07 | 11 | 2.59 | 5 |
| Cutlass | 2.10 | 9 | 2.17 | 13 |
| DS Bennett | 2.53 | 4 | 2.84 | 2 |
| EGA Wedgetail | 2.11 | 8 | 2.34 | 9 |
| Illabo | 2.25 | 7 | 2.24 | 11 |
| LongReach Kittyhawk | 1.88 | 13 | 1.89 | 15 |
| LongReach Lancer | 1.74 | 16 | 1.84 | 16 |
| Longsword | 1.83 | 14 | 2.26 | 10 |
| LongReach Nighthawk | 2.10 | 10 | 2.48 | 6 |
| Manning | 1.98 | 12 | 2.21 | 12 |
| RGT Accroc | 2.93 | 1 | 3.10 | 1 |
| RGT Zanzibar | 2.30 | 6 | 2.40 | 8 |
| Sunlamb | 2.32 | 5 | 2.68 | 3 |
| Sunmax | 2.62 | 2 | 2.61 | 4 |
| Trojan | 1.81 | 15 | 1.94 | 14 |
| Mean | 2.20 | | 2.38 | |
| l.s.d (genotype) | 0.35 | | | |
| l.s.d. (SD) | 0.12 | | | |
| l.s.d. (genotype × SD) | ns | | | |

### Grain quality

Sowing date had no significant effect on screenings percentage.

Protein levels were mostly high ranging from 11.7% (RGT Accroc$^{\phi}$ SD 2) to 17.6% (LongReach Lancer$^{\phi}$ SD1) (Table 5).

Table 5 Protein, screenings and test weight of genotypes across two sowing dates.

| Genotype | Protein (%) | | Test weight (kg/hL) | | Screenings (%) | |
|---|---|---|---|---|---|---|
| | 16 April | 2 May | 16 April | 2 May | 16 April | 2 May |
| ADV08-0008 | 14.9 | 14.9 | 81.2 | 80.6 | 7.2 | 6.0 |
| ADV13-1292 | 15.6 | 14.5 | 81.3 | 81.7 | 2.1 | 2.7 |
| Cutlass | 14.5 | 14.0 | 81.8 | 81.2 | 3.4 | 3.5 |
| DS Bennett | 11.5 | 12.2 | 81.8 | 81.0 | 6.1 | 7.2 |
| EGA Wedgetail | 15.2 | 14.8 | 78.3 | 78.6 | 2.2 | 2.6 |
| Illabo | 14.9 | 14.1 | 79.0 | 78.8 | 2.4 | 2.7 |
| LongReach Kittyhawk | 13.8 | 14.4 | 83.5 | 83.5 | 4.5 | 3.9 |
| LongReach Lancer | 15.6 | 16.2 | 81.3 | 81.3 | 2.7 | 2.5 |
| Longsword | 14.5 | 14.6 | 81.7 | 82.1 | 1.6 | 1.6 |
| LongReach Nighthawk | 15.1 | 14.0 | 80.9 | 81.5 | 3.4 | 3.8 |
| Manning | 11.9 | 13.0 | 73.1 | 73.0 | 9.6 | 8.2 |
| RGT Accroc | 11.8 | 12.1 | 77.7 | 78.4 | 5.0 | 5.1 |
| RGT Zanzibar | 12.5 | 13.8 | 81.2 | 80.3 | 6.8 | 5.0 |
| Sunlamb | 14.9 | 15.0 | 81.3 | 81.8 | 4.0 | 5.9 |
| Sunmax | 14.7 | 14.7 | 81.9 | 81.7 | 5.7 | 4.2 |
| Trojan | 15.1 | 14.2 | 83.1 | 83.8 | 1.5 | 1.9 |
| Mean | 14.1 | 14.2 | 80.6 | 80.6 | 4.2 | 4.2 |
| l.s.d. (genotype) | 1.1 | | 0.8 | | 0.9 | |
| l.s.d. (SD) | ns | | ns | | ns | |
| l.s.d. (genotype × SD) | ns | | ns | | 1.3 | |

## Conclusions

The highest grain yields in 2018 were achieved by slower developing winter and spring types, due to significant rainfall in October and November. Winter types had relatively stable flowering dates across the SDs, however, there were significant differences in their early phasic development, suggesting cultivar performance of new winter types can be manipulated with management (SD) and can vary across environments. In contrast, the faster developing spring types were not suited to early sowing, flowering earlier than optimum. Faster spring types, sown later, were not able to achieve comparable yields in this season. These results highlight the importance of matching genotype and SD to achieve OFP as an effective management strategy to optimise yields, as well as highlighting the opportunity for early sown wheat in grain-only systems in central NSW.

## Acknowledgements

This experiment was part of the project 'Optimising grain yield potential of winter cereals in the northern grains region', BLG104, 2017-2020, a joint investment by Grains Research and Development Corporation (GRDC) and NSW DPI under the Grains Agronomy and Pathology Partnership (GAPP).

We sincerely thank the Kelly family at Hillview, Wongarbon for hosting the experiment and assistance with site management. We gratefully acknowledge Steve Harden (NSW DPI, Tamworth) for biometric support, Bruce Haig (NSW DPI Tamworth) and Jayne Jenkins and Paddy Steele (NSW DPI, Trangie) for their technical support.

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# The impact of waterlogging on phytophthora root rot resistance in chickpea

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## Key findings

- The level of waterlogging tolerance in Pulse Breeding Australia (PBA) chickpea material is minimal.
- A source of phytophthora root rot (PRR) resistance in the wild *Cicer* backcross 04067-81-2-1-1(B) has positive waterlogging tolerance and outperformed the moderately resistant variety Yorker$^{\Phi}$ and the susceptible Rupali$^{\Phi}$ following two days of waterlogging and *Phytophthora* in combination.
- In the presence of PRR (*Phytophthora medicaginis*), inoculum dry root weight decreased in the wild *Cicer* backcross by 26% (93.7 mg) after incurring an additional two days waterlogging, and 51% (62.3 mg) after six days waterlogging when compared to and inoculated control under normal soil moisture conditions (126.2 mg)

## Introduction

This controlled environment seedling experiment investigated the effect of waterlogging on PRR resistance, ranking material from the PBA chickpea breeding program. Material included the wild *Cicer* backcross PRR resistant 04067-81-2-1-1(B) and the moderately resistant *Cicer arietinium* Yorker$^{\Phi}$; along with D09024B>F6RIL>040 and D09024D>F6RIL>028, the elite progeny of this parental cross. The information gained from this experiment will be used to understand the waterlogging tolerance mechanisms involved and whether pyramiding this tolerance will improve chickpea PRR resistance. Figure 1 demonstrates the scale of crop loss in a high rainfall season due to both waterlogging and PRR.

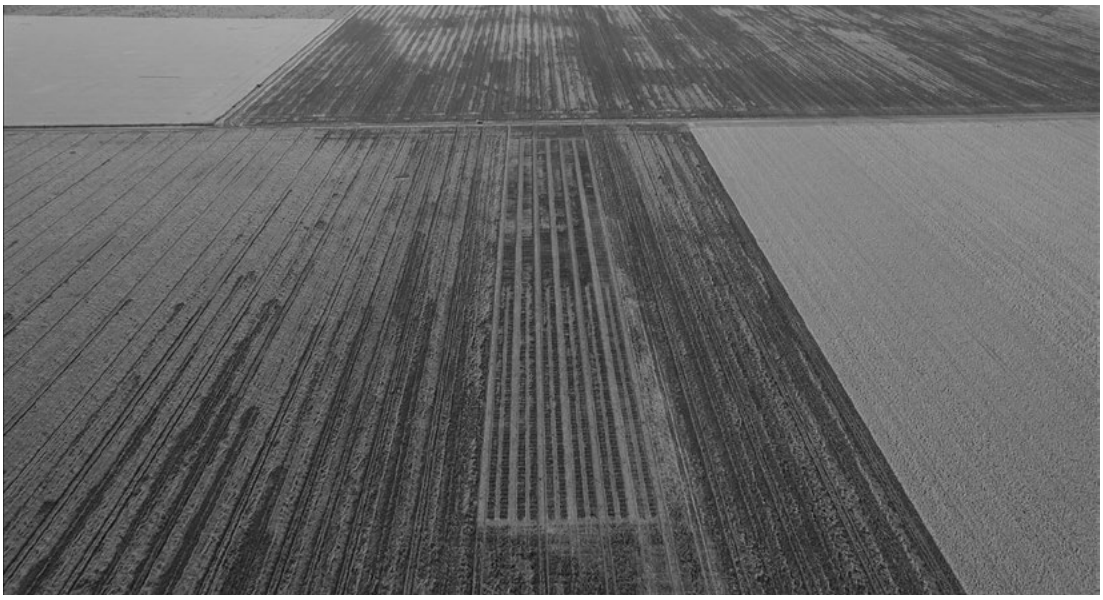

Figure 1 Damage across a chickpea trial paddock after 370 mm in-crop rainfall, Moree 2016. Photo credit: Michael Nowland

## Site details

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|---|---|
| **Location** | Glasshouse – Tamworth Agriculture Institute, Tamworth |
| **Trial design** | Randomised complete block design with waterlogging and PRR treatments as the main blocks and varieties as sub-blocks; three full replicates with two pseudo-replicates at the variety level. |

## Treatments

**Varieties and breeding lines (8)**

04067-81-2-1-1(B), Yorker$^{\Phi}$, Rupali$^{\Phi}$, Kyabra$^{\Phi}$, D09024B>F6RIL>040, D09024D>F6RIL>028, D10075>12F3TMWR2AB016, and D11042>13F3HRMT4PR024

**PRR Treatments (4)**

PRR inoculated
PRR inoculated, plus two days waterlogging
PRR inoculated, plus four days waterlogging
PRR inoculated, plus six days waterlogging

## Results

### Dry root weight

Waterlogging had a major effect on the reduction of dry root weights due to extensive root rot. After four days of waterlogging with PRR present, all material except 04067-82-2-1-1(B) and 04067-82-2-1-1(B)/Yorker$^{\Phi}$ progeny D09024B>F6RIL>040 had significantly lighter dry root weights when compared with the inoculated PRR controls (Table 1). D09024B>F6RIL>040 had no significant difference in dry root weight after six days of waterlogging.

Kyabra$^{\Phi}$, a PRR-susceptible variety, unusually after six days waterlogging had a significantly higher dry root weight when compared with four days waterlogging. The experiment will need to be repeated as most varieties had a reduced dry root weight as flooding period extended. Preliminary evidence from this experiment (data not shown) indicated that inoculum levels across three tested varieties reduced significantly under waterlogging conditions and this will be further investigated.

Table 1 Dry root weights (mg) of varieties and PBA breeding lines under different treatments. l.s.d. (*P*<0.05) = 36.6 mg/plant

| | PRR only | PRR plus 2 days waterlogging | PRR plus 4 days waterlogging | PRR plus 6 days waterlogging |
|---|---|---|---|---|
| 04067-81-2-1-1(B) | 126.2 | 93.7 | 99.5 | 62.3* |
| Yorker | 134.6 | 90.4* | 57.1* | 66.1* |
| Rupali | 109.0 | 74.1* | 36.7* | 43.8* |
| Kyabra | 122.4 | 93.0 | 50.4* | 92.5 |
| D09024B>F6RIL>040 | 82.9 | 72.5 | 60.8 | 79.1 |
| D09024D>F6RIL>028 | 114.8 | 99.4 | 62.0* | 60.9* |
| D10075>12F3TMWR2AB016 | 162.4 | 86.1* | 83.4* | 69.7* |
| D11042>13F3HRMT4PR024 | 137.0 | 104.9 | 58.9* | 59.9* |

*Dry weights for these treatments differ significantly from the PRR-only treatment for that line.

### Root disease score

Table 2 indicates the material's root disease score. A score of one is free of disease and nine indicates the presence of severe disease symptoms (Figure 2). The number of days of waterlogging for the maximum level of root disease varied between lines indicating that there could be differing mechanisms and levels of tolerance and/or resistance to waterlogging and PRR. 04067-81-2-1-1(B) was the only line not to have a significant increase in root disease after six days of waterlogging.

Table 2 Root disease score (1–9 scale) of varieties and PBA breeding lines exposed to Phytophthora and Phytophthora with waterlogging for 2, 4, and 6 days.
l.s.d. ($P<0.05$) = 1.7/plant

| | PRR only | PRR plus 2 days waterlogging | PRR plus 4 days waterlogging | PRR plus 6 days waterlogging |
|---|---|---|---|---|
| 04067-81-2-1-1(B) | 2.3 | 3.2 | 2.7 | 3.3 |
| Yorker | 2.5 | 3.2 | 4.8* | 4.2* |
| Rupali | 4.0 | 4.8 | 7.9* | 7.2* |
| Kyabra | 2.2 | 2.6 | 5.7* | 4.2* |
| D09024B>F6RIL>040 | 1.1 | 3.9 | 5.2* | 3.3* |
| D09024D>F6RIL>028 | 1.7 | 3.5* | 3.8* | 4.0* |
| D10075>12F3TMWR2AB016 | 2.7 | 5.0* | 5.3* | 6.0* |
| D11042>13F3HRMT4PR024 | 2.3 | 3.7 | 5.2* | 4.8* |

* Root disease score for these treatments differ significantly from the PRR-only treatment for that line.

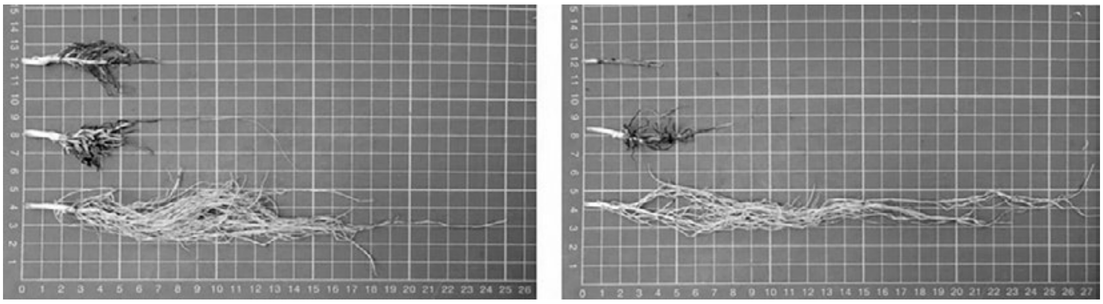

Figure 2 04067-82-2-1-1(B) on the left and Rupali$^{\phi}$ to the right. Top: roots after four days waterlogging; middle: two days waterlogging with PRR; bottom: a control with no waterlogging or PRR. Images were taken from a previous experiment.

## Conclusions

The experiments confirm that waterlogging increases the susceptibility of chickpea to PRR. The ability of 04067-82-2-1-1(B) and its progeny to maintain resistance and root mass consistently is an indication that waterlogging tolerance could contribute to PRR resistance. A population developed from the cross of 04067-82-2-1-1(B) and Yorker$^{\phi}$ will be further investigated to identify and measure traits that could confer waterlogging tolerance, and how these traits affect chickpea susceptibility or resistance to PRR. Traits include:

- root length
- presence of adventitious roots
- cell wall and root exudate composition.

Growers should avoid paddocks prone to waterlogging or flooding if a high rainfall season is predicted and there is an identified presence or history of PRR. The moderate resistance levels of released varieties (PBA HatTrick$^{\phi}$, and PBA Seamer$^{\phi}$), which rate similarly to Yorker$^{\phi}$ for PRR resistance, can suffer significant yield losses under the combination of the two stressors. PRR presence in a chickpea crop can be determined using the Primary Industries and Regions SA (PIRSA) PREDICTA® B DNA-based soil testing service. Details can be found at the PIRSA website (https://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b).

## Acknowledgements

This experiment was part of the 'Grains and Pathology and Pathology Partnership project Improving phytophthora root resistance through waterlogging tolerance in chickpea', BLG302 2017-23, DAN00212. Part of a GAPP scientific capacity building PhD scholar program, jointly funded by the NSW Department of Primary Industry Industries (NSW DPI) and Grains Research Development Corporation (GRDC).

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# Chickpea response to deep placement of phosphorus on a chromosol soil – Gilgandra 2017

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## Key findings

- Applying phosphorus (P) as a starter fertiliser (MAP) resulted in a 90% increase in chickpea yield compared with nil starter, across all treatments, including the residual P treatments.
- There was a significant starter P by residual P rate effect, with yield responses to increasing triple superphosphate (TSP; P 20.1%) rates in the absence of starter fertiliser, but no increase when starter MAP was applied.
- Yields with no TSP, but with starter fertiliser were amongst the highest yielding in the experiment. TSP as residual P and starter P (~17 kg P/ha) at planting, maximised crop responses.
- These results highlight the effectiveness of in-furrow application of starter P on crop growth and efficiency of P uptake under conditions of limited moisture availability.
- In the absence of P uptake data, these findings suggest that MAP is an efficient source of available P, and when applied in the furrow in a dry season can provide strong yield benefits.

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## Introduction

Research looking at the benefits from deep placement P has focused on the black/grey self-mulching vertosol soils of the Northern Grains Region (NGR) of northern NSW and central/southern Queensland. This has been due to the growing awareness of nutrient rundown on these inherently fertile soils, and the stratified distribution of P within the soil profile. The region of nutrient rundown has typically been in the 10–30 cm layer, beneath where starter P fertiliser is placed at sowing and where residual plant matter is returned. As a consequence, P distribution has been stratified within the soil profile, with P more readily available in surface layers (0–10 cm) and less available further down the profile. Importantly, crops growing on these vertosol soils rely on subsoil moisture and nutrients for extended periods in the growing season, with the topsoil often dry. Unless immobile nutrients such as P are present in the subsoil, crop roots are unable to access nutrients required to meet yield potential. In dry seasons, when crops rely on stored water for growth, P is almost entirely obtained from the sub-surface layers (10–30 cm) for most of the growing season.

In the central west of NSW, with the adoption of no-till farming and associated intensification of cropping systems, there has been growing interest in the potential benefits from deep P placement on chromosol/dermosol soils. These soils, in contrast to the northern vertosols, tend to be of moderate fertility, have lower soil water holding capacity and crop production is more reliant on in-crop rainfall.

The aim of this experiment was to test whether placing immobile nutrients such as P deeper in the profile of chromosol soils will increase yields above the traditional approach of starter P placement in or near the seedling row. These experiments will contribute towards the Making Better Fertiliser Decisions for Crops (https://www.bfdc.com.au/interrogator/frontpage.vm) database that identified significant gaps in our knowledge of plant responses to P, particularly subsoil P requirements. Results presented from this experiment are a summary of data collected from the 2017 winter growing season of a chickpea crop grown over an ongoing residual P-response experiment near Gilgandra in central/west NSW.

## Site details

| | |
|---|---|
| **Location** | Gilgandra – 'Chippendale' |
| **Co-operator** | Kevin Kilby |
| **Crop, variety** | Chickpea, PBA HatTrick$^{\phi}$ |
| **Previous crop, variety** | Barley, Commander$^{\phi}$ |
| **Soil type** | Red/brown Chromosol<br>$pH_{Ca}$ 5.2 (0–10 cm)<br>$pH_{Ca}$ 5.5 (10–30 cm) |
| **Starting P** | Colwell: 21 mg/kg (0–10 cm), 7 mg/kg (10–30 cm)<br>BSES: 61 mg/kg (0–10 cm), 16 mg/kg (10–30 cm) |
| **Sowing date** | 25 May 2017 |
| **In-crop rainfall** | 131 mm (May to October) |
| **Starter fertiliser** | 80 kg/ha Granulock Z |
| **Residual fertiliser** | Triple superphosphate to ~20 cm deep parallel to the sowing direction on 33 cm row spacings in April 2015. |
| **Harvest date** | 7 November 2017 |

## Treatments

Experiment treatments were as follows:

- Twelve tillage × P treatments (applied shallow or deep) with or without starter fertiliser in the furrow at sowing, by four replicates (Table 1).
- Two farmer reference (FR) or control treatments: plus or minus starter P fertiliser application with no deep ripping.
- Deep-placed residual P: TSP to a depth of ~20 cm, parallel to the sowing direction on 33 cm row spacings in April 2015.
- Shallow-placed residual P: TSP to ~5 cm deep into the seeding furrow in April 2015.
- Starter fertiliser P (MAP): applied at sowing into the furrow.
- Nil treatments balanced for nitrogen and sulfur using urea and gypsum.

Means were compared by conducting two separate analyses of variance (ANOVA) assessments, using either:

1. the 12 tillage/P treatments plus or minus deep/shallow P, or
2. responses to starter fertiliser P in soil that had been deep-ripped and with varying rates of deep/shallow P before the first crop season, in April 2015.

The initial analysis compared the FR treatments with the deep or shallow-ripped treatments to see if there was any interaction between tillage/P use and starter P response. The second explored the interaction between deep/shallow P rate and starter fertiliser P, specifically to see whether the starter fertiliser P use could overcome the need for deep/shallow P, or vice versa.

Table 1 Grain yield response to treatments

| Treatment | Triple P (kg P/ha) | Starter P (MAP)$^{\#}$ | Cultivation* | Grain yield (t/ha) |
|---|---|---|---|---|
| 1 | 0 | Nil | Nil – FR | 0.28 |
| 1 | 0 | Plus# | Nil – FR | 0.70 |
| 2 | 0 | Nil | Deep ripped* | 0.39 |
| 2 | 0 | Plus# | Deep ripped* | 0.93 |
| 3 | 10 | Nil | Deep ripped* | 0.47 |
| 3 | 10 | Plus# | Deep ripped* | 0.70 |
| 4 | 20 | Nil | Deep ripped* | 0.42 |
| 4 | 20 | Plus# | Deep ripped* | 0.81 |
| 5 | 40 | Nil | Deep ripped* | 0.62 |
| 5 | 40 | Plus# | Deep ripped* | 0.85 |
| 6 | 80 | Nil | Deep ripped* | 0.64 |
| 6 | 80 | Plus# | Deep ripped* | 0.84 |
| 7 | 0 | Nil | Nil – FR | 0.28 |
| 7 | 0 | Plus# | Nil – FR | 0.70 |
| 8 | 0 | Nil | Shallow^ | 0.21 |
| 8 | 0 | Plus# | Shallow^ | 0.71 |
| 9 | 10 | Nil | Shallow^ | 0.26 |
| 9 | 10 | Plus# | Shallow^ | 0.80 |
| 10 | 20 | Nil | Shallow^ | 0.31 |
| 10 | 20 | Plus# | Shallow^ | 0.82 |
| 11 | 40 | Nil | Shallow^ | 0.44 |
| 11 | 40 | Plus# | Shallow^ | 0.58 |
| 12 | 80 | Nil | Shallow^ | 0.53 |
| 12 | 80 | Plus# | Shallow^ | 0.85 |
| | | | l.s.d. (*P* = 0.05) | 0.18 |

* Deep ripped to ~20 cm deep
^ Shallow placement ~5 cm into seeding furrow
$^{\#}$ 80 kg/ha MAP.

## Results

- There was a strong and consistent response to applied starter P across all treatments, with chickpea yield increases averaging 90% compared with the nil starter P (0.405 t/ha).
- There was a small, but significant yield increase from the deep residual P bands compared with the shallow TSP P bands. This response was small compared with that of starter P, with deep applications yielding ~29% higher than shallow applications (Table 1). There was no interaction between the original placement depth of TSP bands (deep or shallow) and either P rate or starter P use.
- There was a strong starter P × residual P rate interaction (Figure 1), which showed that in the absence of starter P, yields increased with high (40 kg P/ha and 80 kg P/ha) residual P rates relative to low rates (10 kg P/ha and 20 kg P/ha) or treatments without TSP bands. While the responses were large in relative terms (100% yield increase from 80 kg P/ha relative to zero P), they were exceeded by the response to starter P, with added starter P completely overriding any response to residual P.
- Both shallow TSP bands and MAP applications were placed at the same depth. The lack of response to shallow TSP bands compared with MAP in the same area of the profile suggests that banded TSP is an inefficient source of P. The close proximity of the starter P application to developing root

systems in a rapidly drying surface soil in 2017 could also have been a contributing factor. Chickpea biomass data was not analysed to test the effects of differing application strategies on crop P acquisition. Regardless, the data suggests much higher efficiency of MAP for chickpea crop use when P is applied as a starter rather than than P from the TSP applications.

- The strong linear relationship between yield and grain P content (Figure 2) indicates that any additional available P that the plant was able to access/uptake was converted into extra yield.

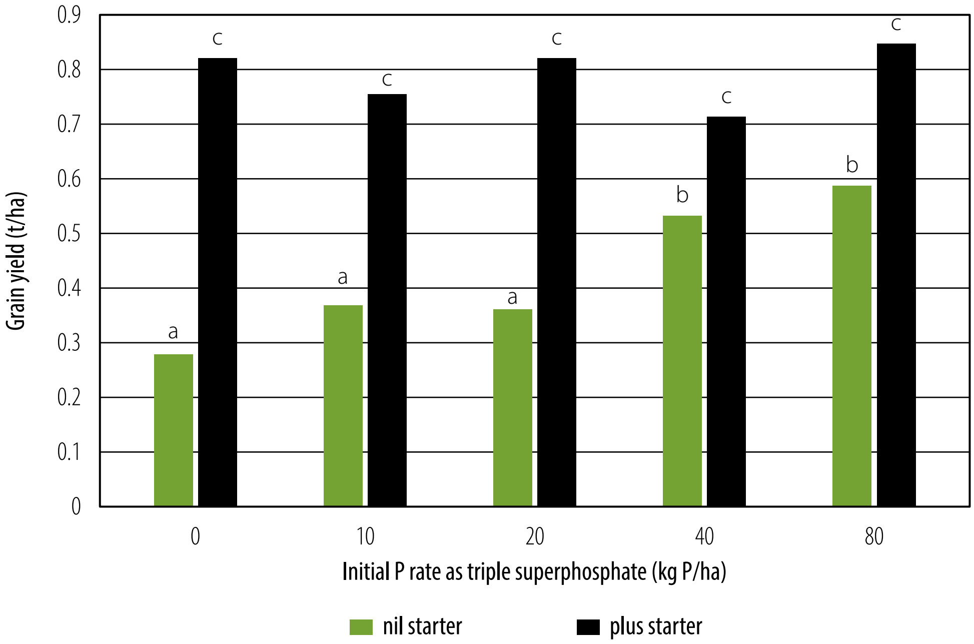

Figure 1 Yield response to residual P (TSP) and starter P fertilisers (minus vs plus). Bars with the same letter are not significantly different (*P* = 0.05). The residual P as TSP bands with data showing an average of shallow and deep applications. Starter applications were MAP applied in the seeding row at sowing.

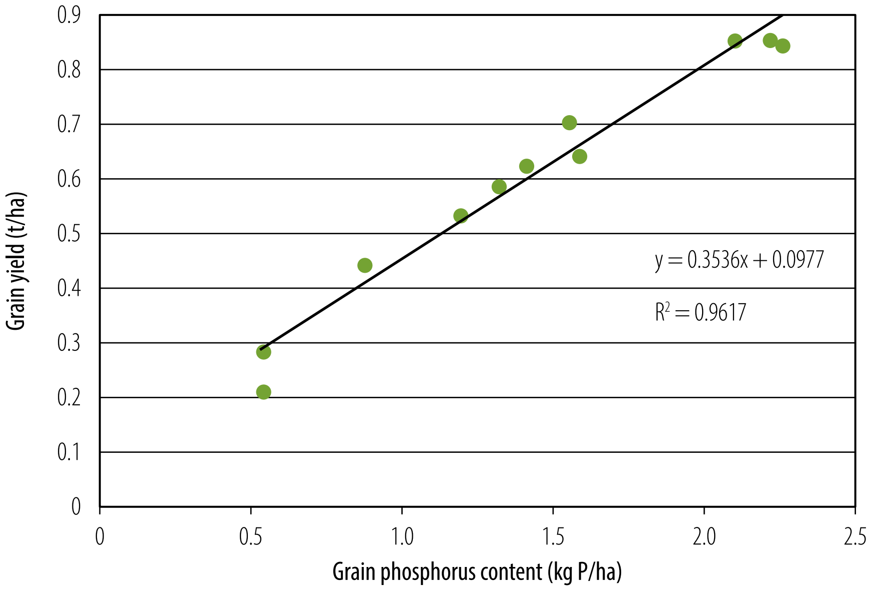

Figure 2 Chickpea grain P uptake (kg/ha) vs. yield (t/ha), Gilgandra 2017 (FR, 40 kg P/ha and 80 kg P/ha) plus and minus starter.

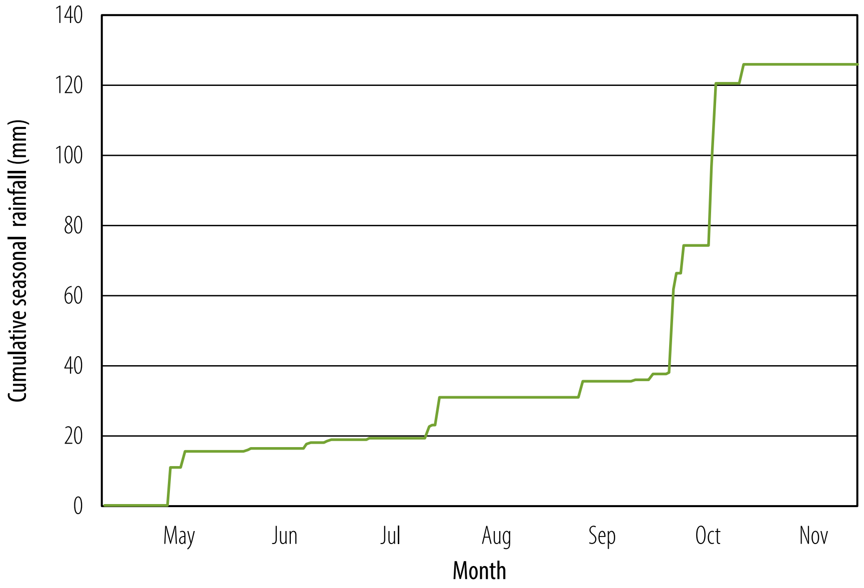

Figure 3 Cumulative in-crop rainfall, Gilgandra 2017.

## Conclusions

The positive yield response to starter P applied at sowing in this season shows that the chickpea relied heavily on MAP as a source of P. This would most likely have been due to restricted root access in the rapidly drying subsoil from the dry growing season conditions experienced in 2017 (Figure 3) and the moderate water-holding capacity of the soil. The crop probably only had access to the deep bands of TSP for a limited period following rain in late May/early June. In dry years, placing P in the seeding row ensures the best chance of P uptake versus the uptake of high rates of (residual) TSP applied deeper in the soil profile, which plant roots might not be able to access.

Results showed large yield responses of ~90% to starter P, averaged across all treatments, increasing from 0.405 t/ha to 0.774 t/ha. Although there was a positive yield response to residual deep bands of TSP in the absence of starter P, this was overshadowed by the response to starter P applied in the furrow (Figure 1). Yield responses to starter P applied at ~17 kg P/ha, were larger than for those from the deep bands of TSP applied at rates of 40 kg P/ha and 80 kg P/ha.

There was a small, but significant, response to deep P placement in 2017 (22% chickpea yield increase compared with the FR). This is consistent with other experiments in the 'Regional testing guidelines for the Northern Grains Region' project (UQ00063), which show distributing available P sources deeper into the soil profile will improve crop P recovery. The reasons for the relatively minor yield increase compared with starter P responses cannot be clearly determined. The crop had limited access to the deep P bands due to the soil's low plant available water capacity and the infrequency with which these bands were wet to allow root activity (Figure 3). The P source in the deep bands was TSP, which was potentially less available than the starter P. Either factor could have contributed to the small response to deep P bands in this year. Any additional P the crop acquired appeared to be used to grow more grain (Figure 2), as shown by the linear relationship between grain P content and yield, whilst maintaining a constant concentration of P in the grain.

Despite the confounding results of P uptake with moisture availability, it is apparent that this site shows a poor residual response to banded TSP for yield. This is consistent with the other 'Regional testing guidelines for the Northern Grains Region' (UQ00063) sites that show that TSP is an inefficient P source for producing bioavailable P for crop uptake. A solution would be to supplement the P uptake from starter fertiliser with bioavailable P, distributed throughout the soil profile where water is available and roots are present to ensure uptake.

Results from Queensland field sites in the UQ00063 project and glasshouse experiments in the 'Deep placement of nutrients' project (UQ00078, Bell et al., 2018), suggest that TSP is not as effective as MAP at supplying P to crops in general. To test this, it is intended to reapply deep P as MAP in some of the Gilgandra treatments, to provide a contrasting deep P treatment to high residual rates of TSP in 2019.

## References

Bell M, Lester D, Sands D, Graham R and Schwenke G (2018). The P story so far – an update on deep P research findings. GRDC Updates at Breeza and Allora, Feb–March 2018.

## Acknowledgements

This experiment was undertaken as part of the 'Regional testing guidelines for the Northern Grains Region' (UQ00063) project, which is a collaborative project between The University of Queensland, New South Wales Department of Primary Industries (NSW DPI) and the Grains Research and Development Corporation (GRDC). The authors would also like to thank Kevin Kilby for providing land on his property to undertake this research.

## Contact

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# Crop response to deep placement of phosphorus in a chromosol – Gilgandra 2018

Tendo Mukasa Mugerwa[1], Greg Brooke[2], Rick Graham[1] and Peter Formann[1]

[1] NSW DPI Tamworth
[2] NSW DPI Trangie

## Key findings

- There was a significant yield response to starter fertiliser at Gilgandra in 2018.
- No significant yield response to deep phosphorus was recorded when starter fertiliser was applied.
- Environmental conditions experienced at Gilgandra in 2018 limited crop yield and potentially limited crop access to deep phosphorus.

## Introduction

Research investigating the benefits from deep phosphorus (P) placement has previously focused on the black–grey self-mulching vertosol soils of the northern grains region (NGR) of NSW and central and southern Queensland (QLD) (Bell et al., 2018). This is due, in part, to the growing awareness of nutrient rundown within these inherently fertile soils and the stratified distribution of P that occurs within the profile.

This rundown has typically been in the 10–30 cm layer, beneath where starter P fertiliser is placed at sowing and where residual plant matter is returned to the soil. Phosphorus can be stratified within the soil profile, with P more available in surface layers (0–10 cm) and less available further down the profile. Crops growing on these vertosol soils rely on subsoil (10–30 cm) moisture and nutrients for extended periods in the growing season when the topsoil is often dry. Unless immobile nutrients such as P are present in this subsoil, crop roots are unable to access the nutrients required to meet the yield potential. In dry seasons, when crops rely on stored water for growth, P is almost entirely obtained from the sub-surface layers.

With no-till farming and intensified cropping systems being adopted in the central west, there has been growing interest in the potential benefits of deep P placement. In contrast to vertosols in the north, soils in the central west tend to have moderate fertility, lower soil water holding capacity and are more reliant on in-crop rainfall.

The aim of this experiment was to examine if placing immobile nutrients such as P deeper in a chromosol soil profile will increase yields above the traditional approach of starter P placed in or near the seeding row, close to the soil surface. Results presented in this report are a summary of data collected from the 2018 season from an ongoing residual deep-P experiment at Gilgandra, NSW.

## Site details

| | |
|---|---|
| **Location** | Chippendale, Gilgandra, NSW (31°59'18.18"S, 148°68"77.77'E). |
| **Soil type and nutrition** | Red–brown chromosol, $pH_{Ca}$ 5.2 (0–10 cm)<br>Starting P (Colwell), 21 mg/kg (0–10 cm), 7 mg/kg (10–30 cm)<br>Starting nitrogen (N) (nitrate), 66 mg/kg (0–10 cm), 9 mg/kg (10–30 cm)<br>Starting N (ammonium), 16 mg/kg (0–10 cm), 4 mg/kg (10–30 cm) |

| | |
|---|---|
| **Rain** | Yearly rainfall 2018: 408 mm<br>Yearly long-term average (LTA) rainfall: 560 mm (Bureau of Meteorology)<br>Starting soil moisture: ~130 mm (0–120 cm)<br>In-crop rainfall: 158 mm, a reduction from the LTA for in-crop rainfall of 215 mm |
| **Sowing** | At Gilgandra, Commander$^{\phi}$ barley and HatTrick$^{\phi}$ chickpeas crops were grown at the experiment site in 2016 and 2017, respectively.<br>Spitfire$^{\phi}$ wheat was sown for a target population of 120 plants/$m^2$ on 29 June 2018.<br>Plots were 9×2 metres 5 rows at 33 cm row spacings. |
| **Harvest date** | 27 November 2018 |

## Treatments

- Twelve treatments in a fully factorial experiment.
- Four replicates.
- A farmer reference (FR) treatment: an untreated control for baseline data where there was no additional nutrient input or soil disturbance.
- Deep P applied in April 2015 ~20 cm deep parallel to the sowing direction as triple superphosphate (TSP, monocalcium phosphate $[Ca(H_2PO_4)_2\ H_2O]$) on 33 cm spacings.
- Starter fertiliser (P): applied as monoammonium phosphate, MAP ($NH_4H_2PO_4$) at sowing with the seed.
- Treatments were balanced for N and sulfur (S) using urea and gypsum.
- Each treatment received an additional 30 kg N/ha side banded as urea (46% N) at sowing (Table 1).

Means were compared by analysis of variance (ANOVA) assessments using least significant difference.

Table 1 Deep P treatments at Gilgandra.

| Treatment | Phosphorus, triple superphosphate (kg P/ha) | Starter fertiliser[#] | Cultivation |
|---|---|---|---|
| 1 minus | 0 | Minus | Farmer reference (no deep P, no deep ripping) |
| 1 plus | 0 | Plus | Farmer reference (no deep P, no deep ripping) |
| 2 minus | 0 | Minus | Deep ripped* |
| 2 plus | 0 | Plus | Deep ripped* |
| 3 minus | 10 | Minus | Deep ripped* |
| 3 plus | 10 | Plus | Deep ripped* |
| 4 minus | 20 | Minus | Deep ripped* |
| 4 plus | 20 | Plus | Deep ripped* |
| 5 minus | 40 | Minus | Deep ripped* |
| 5 plus | 40 | Plus | Deep ripped* |
| 6 minus | 80 | Minus | Deep ripped* |
| 6 plus | 80 | Plus | Deep ripped* |

* Deep-ripped to 20 cm deep

[#] Starter fertiliser Plus = 60 kg/ha Granulock®Z

## Results

### Grain yield

The use of starter fertiliser resulted in a significant, 114% (0.47 to 1.01 t/ha), increase in yield across all treatments.

The highest yield was deep P applied at 80 kg P/ha (1.12 t/ha) together with starter fertiliser. Where deep P was applied without starter fertiliser, a significant increase in yield was not recorded compared with the FR treatment (Figure 1).

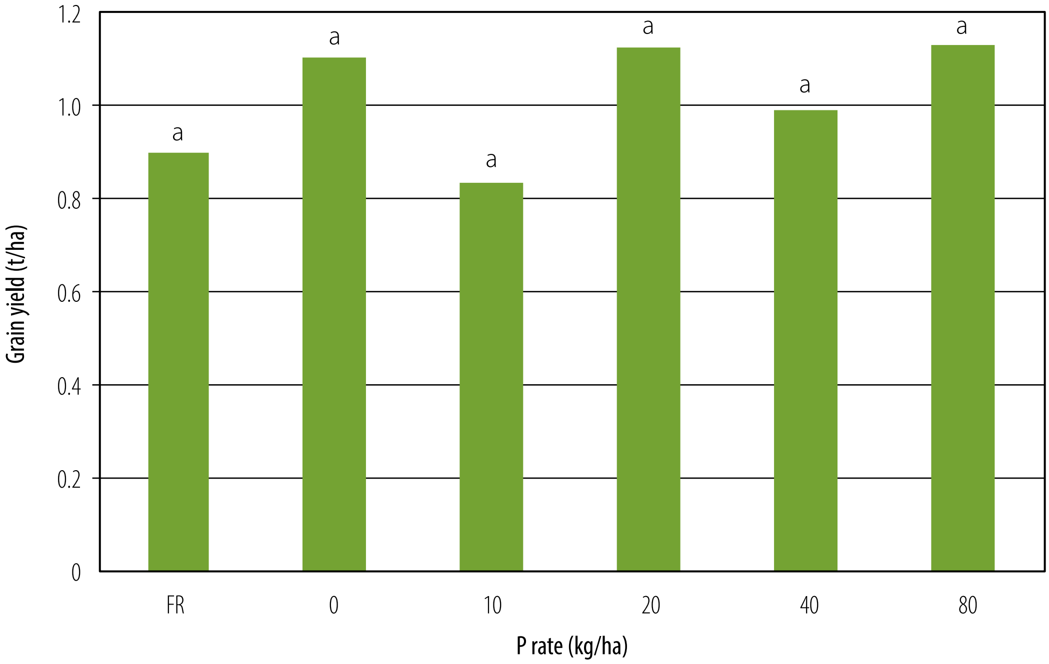

Figure 1 Yield response to deep P/tillage treatments plus starter fertiliser. Bars with the same letter are not significantly different ($P<0.05$).

Deep P applied at 80 kg P/ha (without starter fertiliser) gave the highest yield at 0.72 t/ha (Figure 2). Significant increases in yield were also recorded for the FR treatments where deep P was applied at 40 kg P/ha and 80 kg P/ha.

### Crop P content

Crop tissue and grain analysis (ICP test) was only conducted on plants from the FR and 80 kg P/ha deep-P treatments. Within the FR treatments, crop P content significantly increased when starter fertiliser was applied (Table 2). The highest crop P content (10.9 kg/ha) was measured from the treatment where deep P was applied at 80 kg P/ha with starter fertiliser. Crop P content from this treatment was not significantly higher than the crop P content from the FR treatment where starter fertiliser was applied.

Table 2 Crop P content of crops from the FR and 80 kg P/ha deep-P treatments.

| Treatment | Crop P content (kg/ha), minus starter fertiliser | Crop P content (kg/ha), plus starter fertiliser |
|---|---|---|
| Farmer reference | $4.0^{a}$ | $9.3^{cd}$ |
| 80 kg P/ha deep P | $7.5^{bc}$ | $10.9^{de}$ |

Numbers with the same letter are not significantly different ($P<0.05$)

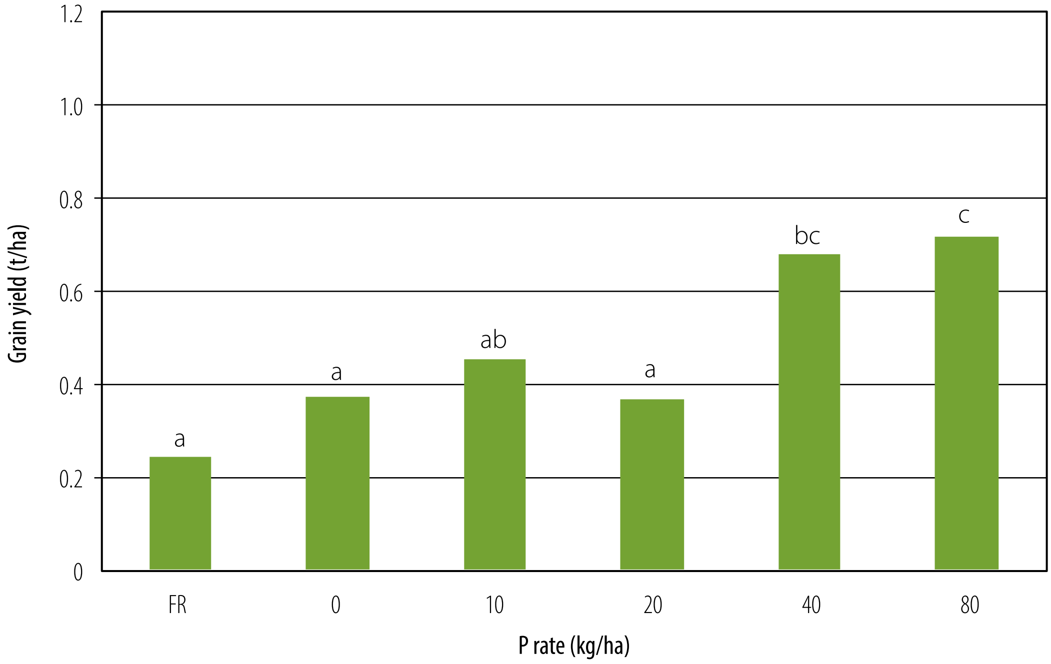

Figure 2 Yield response to deep P/tillage treatments without starter fertiliser. Bars with the same letter are not significantly different (*P*<0.05).

## Summary

In 2018 Gilgandra experienced drought conditions with only ~120 mm of in-crop rainfall. These harsh conditions meant limited plant growth and resulted in yields ranging from 0.2 t/ha to1.1 t/ha. In 2018 the state's wheat crop averaged 1.0 t/ha reflecting these drought conditions, with many crops failing, if sown at all.

Yields recorded at Gilgandra in 2018 were limited, however, some trends emerged. Across all treatments, a large yield response to starter fertiliser was recorded. This response indicated that the plants relied heavily on starter P applied with the seed. Root access to deep P might have been restricted due to low in-crop rainfall. Although there was a general trend of increasing yields with increasing deep P rates (plus starter fertiliser), significant responses were not recorded compared with the baseline FR treatment. The highest yield in 2018 was where deep P was applied at 80 kg P/ha (1.13 t/ha).

Significant yield increases occurred where deep P was applied at 40 kg P/ha and 80 kg P/ha without starter fertiliser. Yields increased where starter fertiliser was added, but where no deep P was applied, compared with the FR treatments. The treatments with starter fertiliser out-yielded the deep P only treatments compared with the control (Figure 2).

A significant response to deep ripping was not recorded at Gilgandra in 2018.

Grain yields did not appear to be limited by N as indicated by an average grain protein concentration across all treatments of ~16% (data not shown), which was above the industry minimum of 14% for APH1 wheat in 2017–2018. Nutrient analysis of grain and tissue was limited to the FR and 80 kg P/ha deep-P treatments. Within the FR treatment, crop P content significantly increased where starter fertiliser was applied (Table 1), again indicating that this source of P was used efficiently. Within the 80 kg P/ha deep-P treatments, a significant increase in P content was also recorded with added starter fertiliser. The highest crop P content was measured from this treatment.

## Conclusions

The yields obtained at Gilgandra in 2018 reflected the 2018 drought conditions. Where deep P was applied with starter fertiliser, no significant increases in yield were recorded. Limited in-crop rainfall and stored soil moisture restricted crop growth and could have restricted the plants' access to the deep-placed P. Results also indicated that deep-banded TSP might not be as efficient a source of P as other forms such as MAP. Deep-P experiments at alternative sites in northern NSW and southern QLD have resulted in regular responses to deep-banded MAP compared with deep-banded TSP in previous seasons (Bell et al., 2018). Similar observations have been recorded in glasshouse studies (UQ00078). In early 2019, a new deep-P treatment was established where MAP was applied at a rate of 40 kg P/ha. This new treatment will allow for yield comparisons where P is not limited and will provide a differing deep-P treatment to TSP.

## References

Bell M, Lester D, Sands D, Graham R and Schwenke G (2018). *The P story so far – an update on deep P research findings*. GRDC Updates at Breeza and Allora, Feb–March 2018.

## Acknowledgements

This experiment was part of the project 'Regional soil testing guidelines for the northern grains region' (UQ00063) and is a co-investment between NSW DPI and the Grains Research and Development Corporation (GRDC).

The project is led by Professor Mike Bell from The University of Queensland (UQ). Biometric assistance was provided by Mr Bruce Haigh, NSW DPI, Tamworth. Technical assistance provided by additional members of the NSW DPI Tamworth Agronomy and Soils teams is gratefully acknowledged. We would also like to acknowledge the Kilby family for providing their property to undertake this research.

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# Crop response to deep placement of phosphorus in a chromosol – Nyngan 2018

Tendo Mukasa Mugerwa[1], Greg Brooke[2], Rick Graham[1] and Peter Formann[1]

[1] NSW DPI Tamworth
[2] NSW DPI Trangie

## Key findings

- There was a significant yield response to starter fertiliser at Nyngan in 2018.
- No significant yield response to deep phosphorus was recorded when starter fertiliser was applied.
- Environmental conditions experienced at Nyngan in 2018 limited crop yield and potentially limited crop access to deep phosphorus.

## Introduction

Research investigating the benefits from deep phosphorus (P) placement has previously focused on the black–grey self-mulching vertosol soils of the northern grains region (NGR) of NSW and central and southern Queensland (QLD) (Bell et al., 2018). This is due, in part, to the growing awareness of nutrient rundown within these inherently fertile soils and the stratified distribution of P that occurs within the profile.

This rundown has typically been in the 10–30 cm layer, beneath where starter P fertiliser is placed at sowing and where residual plant matter is returned to the soil. Phosphorus can be stratified within the soil profile, with P more available in surface layers (0–10 cm) and less available further down the profile. Crops growing on these vertosol soils rely on subsoil (10–30 cm) moisture and nutrients for extended periods in the growing season when the topsoil is often dry. Unless immobile nutrients such as P are present in this subsoil, crop roots are unable to access the nutrients required to meet the yield potential. In dry seasons, when crops rely on stored water for growth, P is almost entirely obtained from the sub-surface layers.

With no-till farming and intensified cropping systems being adopted in the central west, there has been growing interest in the potential benefits of deep placement of P. In contrast to vertosols in the north, soils in the Central West tend to have moderate fertility, have lower soil water holding capacity and are more reliant on in-crop rainfall.

The aim of this experiment was to examine if placing immobile nutrients such as P deeper in a chromosol soil profile will increase yields above the traditional approach of starter P placed in or near the seeding row, close to the soil surface. Results presented in this report are a summary of data collected from the 2018 season from an ongoing residual deep-P experiment at Nyngan, NSW.

## Site details

| | |
|---|---|
| **Location** | Thorndale, Nyngan, NSW (31°54'68.43"S, 146°89'24.93"E). |
| **Soil type and nutrition** | Red–brown chromosol, pHCa 4.8 (0–10 cm)<br>Starting P (Colwell), 19 mg/kg (0–10 cm), 5 mg/kg (10–30 cm)<br>Starting nitrogen (N) (nitrate), 19 mg/kg (0–10 cm), 3 mg/kg (10–30 cm)<br>Starting N (ammonium), 8 mg/kg (0–10 cm), 2 mg/kg (10–30 cm). |

| | |
|---|---|
| **Rain** | Yearly rainfall in 2018: 266 mm<br>Long-term average (LTA) of 443 mm (Bureau of Meteorology).<br>Starting soil moisture: ~25 mm (0–30 cm)<br>In-crop rainfall: 119.6 mm. |
| **Sowing** | At Nyngan, Commander$^{\phi}$ barley and HatTrick$^{\phi}$ chickpeas crops were grown at the experiment site in 2016 and 2017, respectively.<br>Spitfire$^{\phi}$ wheat was sown for a target population of 120 plants/m$^2$ on 2 July 2018.<br>Plots were 9 × 2 metres 5 rows at 33 cm row spacings. |
| **Harvest date** | 26 November 2018. |

## Treatments

- Twelve treatments in a fully factorial experiment.
- Four replicates.
- A farmer reference (FR) treatment was included for baseline data where no there was additional nutrient input or soil disturbance.
- Deep P applied in April 2015 to around 20 cm deep parallel to the sowing direction as triple superphosphate (TSP, monocalcium phosphate [$Ca(H_2PO_4)_2 .H_2O$]) on 33 cm spacings.
- Starter fertiliser (P) was applied to treatments requiring starter fertiliser in 2018. Starter fertiliser was applied in the form of monoammonium phosphate [MAP, $NH_4H_2PO_4$] at sowing, with the seed.
- Treatments were balanced for N and sulfur (S) using urea and gypsum.
- Each treatment received an additional 30 kg N/ha side banded as urea (46% N) at sowing (Table 1).

Means were compared by analysis of variance (ANOVA) assessments using least significant difference.

Table 1 Deep P treatments at Nyngan.

| Treatment | Applied phosphorus, triple superphosphate (kg P/ha) | Starter fertiliser# | Cultivation |
|---|---|---|---|
| 1minus | 0 | Minus | Farmer reference (No deep P, no deep ripping) |
| 1plus | 0 | Plus | Farmer reference (no deep P, no deep ripping) |
| 2 minus | 0 | Minus | Deep ripped* |
| 2 plus | 0 | Plus | Deep ripped* |
| 3 minus | 10 | Minus | Deep ripped* |
| 3 plus | 10 | Plus | Deep ripped* |
| 4 minus | 20 | Minus | Deep ripped* |
| 4 plus | 20 | Plus | Deep ripped* |
| 5 minus | 40 | Minus | Deep ripped* |
| 5 plus | 40 | Plus | Deep ripped* |
| 6 minus | 80 | Minus | Deep ripped* |
| 6 plus | 80 | Plus | Deep ripped* |

* Deep-ripped to 20 cm deep

\# Starter fertiliser Plus = 60 kg/ha Granulock®Z

## Results

### Grain yield

Using starter fertiliser resulted in a significant, 254% (64 kg/ha to 226 kg/ha), increase in yield across all treatments.

The highest yield was recorded where deep P was applied 20 kg P/ha (0.29 t/ha) together with starter fertiliser. Although there was a general trend of increasing yield with increasing rates of deep P, a significant increase in yield was not recorded in 2018, compared with the FR treatment (Figure 1).

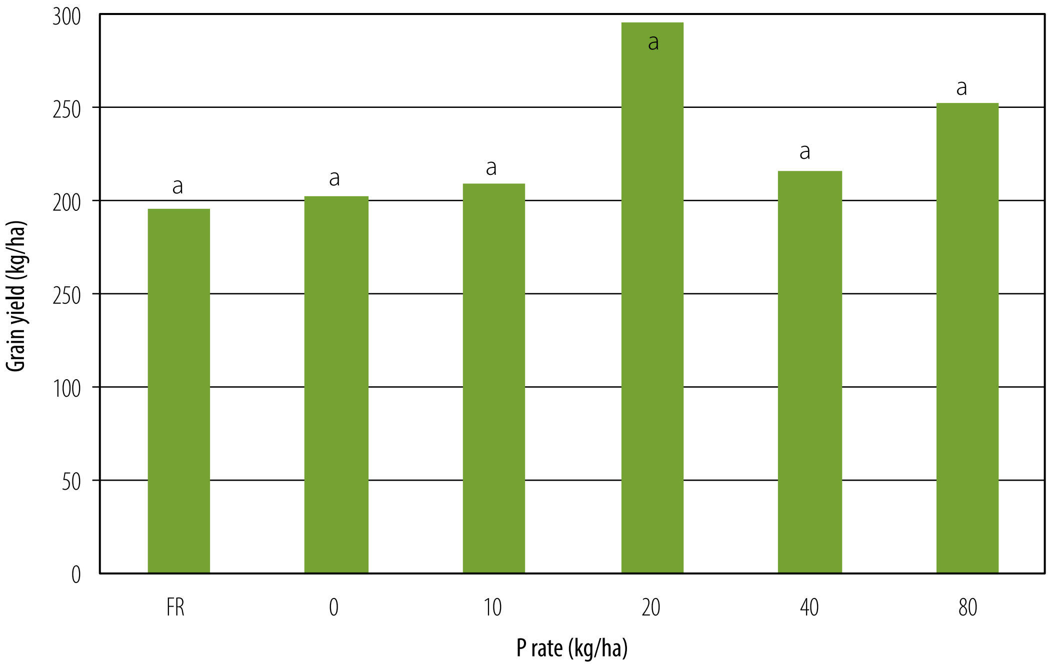

Figure 1 Yield response to deep P/tillage treatments plus starter fertiliser – Nyngan 2018. Bars with the same letter are not significantly different (*P*<0.05).

Deep P applied at 80 kg P/ha (without starter fertiliser) gave the highest yield at 0.12 t/ha.

This was the only significant increase in yield compared with the FR treatment (Figure 2).

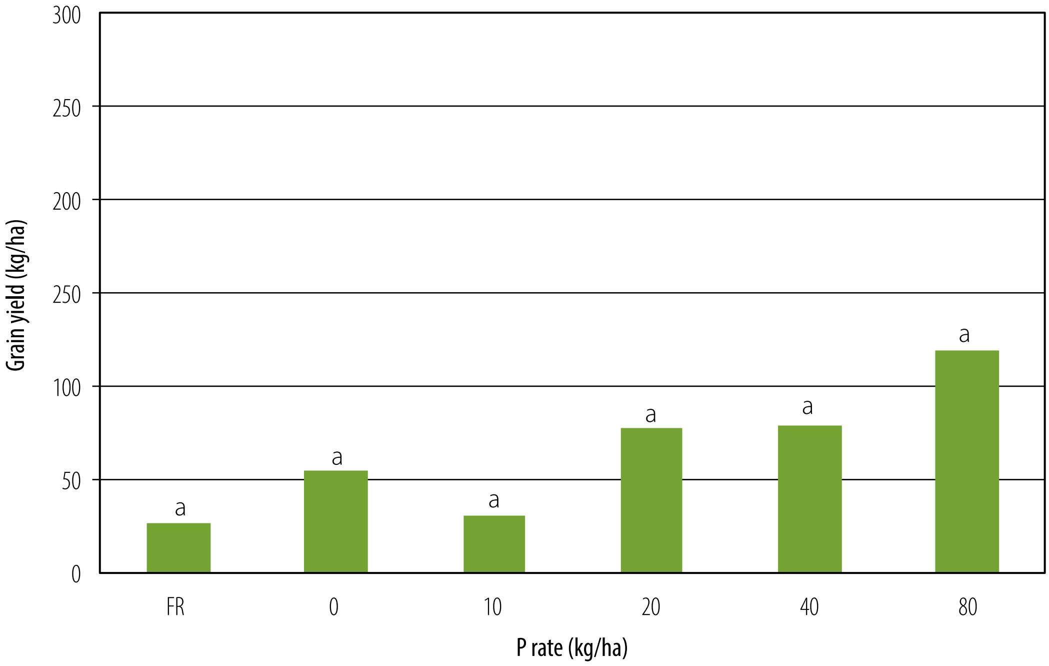

Figure 2 Yield response to deep P/tillage treatments without starter fertiliser – Nyngan 2018. Bars with the same letter are not significantly different (*P*<0.05).

### Crop P content

Crop tissue and grain analysis (ICP test) was only conducted on plants from the FR and 80 kg P/ha deep-P treatments. Within the FR treatments, crop P content significantly increased when starter fertiliser was applied (Table 2). The highest crop P content (6.3 kg/ha) was measured from the treatment where deep P was applied at 80 kg P/ha with starter fertiliser. Crop P content for this treatment was also significantly higher than the crop P content from the FR treatment where starter fertiliser was applied.

Table 2 Crop P content from the FR and 80 kg P/ha deep P treatments. Numbers with the same letter are not significantly different (*P*<0.05).

| Treatment | Crop P content (kg/ha), minus starter fertiliser | Crop P content (kg/ha), plus starter fertiliser |
|---|---|---|
| Farmer reference | 1.2$^{a}$ | 4.6$^{b}$ |
| 80 kg P/ha deep P | 3.1$^{ab}$ | 6.3$^{c}$ |

## Summary

In 2018, Nyngan experienced drought conditions with only ~120 mm of in-crop rainfall, with reasonable rainfall in October (data not shown). Rainfall at this stage of the season might have slightly aided grain fill, however, would have been too late to promote reasonable plant growth. These harsh conditions meant limited plant growth and resulted in yields ranging from 0.03 t/ha to 0.3 t/ha. In 2018 the state's wheat crop averaged 1.0 t/ha, reflecting these drought conditions, with many crops failing, if sown at all.

Although yields recorded at Nyngan in 2018 were limited, some trends emerged between treatments. Across all treatments, a large yield increase in response to starter fertiliser was recorded. Visually mature plants with the FR treatment plus starter fertiliser, had more biomass than plants with the FR treatment and no starter fertiliser. This response indicated that the plants relied heavily on the starter P applied with the seed. Efficient root access to deep P could have been restricted by the low in-crop rainfall.

There was a general trend of increasing grain yield with increasing rates of deep P (plus starter fertiliser), but this response was not significant compared with the FR treatment alone. The highest yield recorded in 2018 was where deep P was applied at 20 kg P/ha (0.3 t/ha).

There was a significant yield increase where deep P was applied at 80 kg P/ha without starter fertiliser, compared with the FR treatment (Figure 2). Yields increased where starter fertiliser was added, but where no deep P was applied, compared with the FR treatments. The treatments with starter fertiliser out-yielded the deep-P-only treatments compared with the control.

A significant response to deep ripping was not observed at Nyngan in 2018.

Nitrogen did not appear to limit grain yields; there was an average grain protein concentration across all treatments of ~17% (data not shown), which was above the industry minimum of 14% for APH1 wheat in 2017–2018. Grain and tissue nutrient analysis was limited to the FR and 80 kg P/ha deep-P treatments. Within the FR treatment, grain crop P content significantly increased where starter fertiliser was applied (Table 1), again indicating the efficient use of this source of P. Within the 80 kg P/ha deep-P treatments, a significant increase in P content was also recorded with added starter fertiliser. The highest crop P content was measured from this treatment.

## Conclusions

The yields obtained at Nyngan in 2018 reflected the 2018 drought conditions. Where deep P was applied with starter fertiliser, no significant increases in yield were recorded. Limited in-crop rainfall and stored soil moisture restricted crop growth and could have restricted plant access to the deep-placed P.

Results also indicated that deep-banded TSP might not be as efficient a source of P as other forms such as MAP. Deep P experiments at alternative sites in northern NSW and southern QLD have resulted in regular responses to deep-banded MAP compared with deep-banded TSP in previous seasons (Bell et al., 2018). Similar observations have been recorded in glasshouse studies (UQ00078). In early 2019, a new deep-P treatment was established where MAP was applied at 40 kg P/ha. This new treatment will allow yield comparisons where P is not limited and will provide a differing deep-P treatment to the high residual rates of TSP.

## References

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## Acknowledgements

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# Yield response of canola and wheat to nitrogen application – Tamworth 2018

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## Key findings

- Results from this experiment conducted during the 2018 season highlight canola's yield response to nitrogen (N) application.
- Relative to the zero N treatment, a significant increase in yield was recorded where N was applied at 50 kg N/ha (2.53 t/ha) and higher.
- Canola yield increased with higher rates of N application before the yield response plateaued at 150 kg N/ha.
- Canola protein levels increased with higher rates of N. A significant increase in protein was recorded where N was applied at 50 kg N/ha and higher, relative to the zero N treatment.
- Wheat yields also increased with higher rates of N in a more linear path than canola. The highest wheat yield was recorded where N was applied at 450 kg N/ha. Wheat protein concentrations remained below 13% across all treatments.

## Introduction

In 2016, a scoping study was undertaken to assess crop response data entered into the Better Fertiliser Decisions for Cropping (BFDC) database (www.bfdc.com.au/interrogator/frontpage.vm) for various crops and nutrients in the eastern Australian cropping zone, to identify knowledge gaps. In Northern NSW, gaps for nitrogen (N) were identified for a winter oilseed (canola), a summer cereal (maize) and a summer oilseed (sunflower). The NSW Department of Primary Industries (Tamworth Agricultural Institute, TAI) is conducting crop response experiments over multiple seasons, for these identified crops.

In 2017, an N-response yield curve was generated at TAI that highlighted the yield responsiveness of canola to N application.

The aim of this experiment was to generate another N-response yield curve for canola with various rates of applied N, during the 2018 season. Wheat was used as a control in this experiment. Data from this study will contribute towards N-response data for canola within the BFDC database in order to improve nutrient recommendations for optimising crop production.

## Site details

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| **Location** | Tamworth – Tamworth Agricultural Institute |
| **Soil type and nutrition** | Grey/brown vertosol.<br>$pH_{Ca}$ 6.2 (0–10 cm).<br>Starting N (available soil nitrate N) 43 kg N/ha (0–120 cm). |
| **Rainfall** | Annual rainfall at Tamworth in 2018 was 399.6 mm, compared with the long-term average (LTA) of 672.5 mm.<br>In-crop rainfall at the trial site was 163.8 mm, compared with the LTA of 366.1 mm for the same period.<br>Stored soil moisture before sowing was 71 mm (0–120 cm). |

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| **Trial design** | Ten N rates in a randomised block design.<br>Canola, Pioneer® 45Y86 (CL), and wheat, Elmore CL PLUS⊕, were grown as separate blocks to allow for appropriate weed management.<br>Eight replications of each treatment. |
| **Sowing** | Seed was direct-drilled into barley stubble on 11 May 2018.<br>Plots were 11.5 m long on 2 m centres, with five rows at 30 cm spacings. |
| **Fertiliser** | Phosphorus (P) fertiliser as single superphosphate at 200 kg/ha (17.6 kg P/ha) 44 days before sowing. |
| **Plant population** | Mean plant densities at maturity were 42 plants $m^2$ (canola) and 66 plants $m^2$ (wheat). |
| **Harvest date** | 6 November 2018 (canola).<br>7 November 2018 (wheat). |

## Treatments

Nitrogen rates are shown in Table 1. Treatments were applied as granular urea (46% N), side-banded using a twin-disk seeder 44 days before sowing.

Table 1 Nitrogen application treatments at Tamworth 2018.

| Treatment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Applied N (kg N/ha) | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 |

Yield response curves were generated using GenStat® for Windows, 19th Edition (VSN International), with curves fitted using the FITCURVE directive. The Mitscherlich function was used to fit relationships between yield and applied nutrient.

## Results

### Grain yield

#### Canola

The mean grain yield across all N treatments was 2.96 t/ha, with the nil treatment (no additional N) producing a yield of 1.89 t/ha (Figure 1). The highest yield was obtained where N was applied at 450 kg N/ha, resulting in a yield of 3.28 t/ha. Relative to the nil treatment, significant increases in yield were recorded where N was applied at 50 kg N/ha and higher.

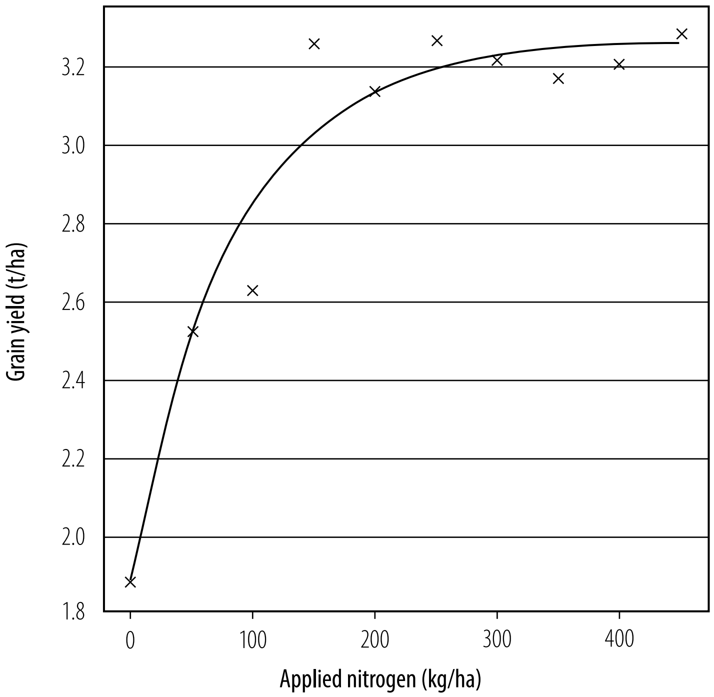

Figure 1 Relationship between applied nitrogen and canola grain yield.
l.s.d ($P<0.05$) = 0.39 t/ha

### Wheat

The mean grain yield across all N treatments was 4.04 t/ha, with the nil treatment producing a yield of 3.63 t/ha (Figure 2). The highest yield was obtained where N was applied at 450 kg N/ha, resulting in a yield of 4.32 t/ha. Relative to the no additional N treatment, significant increases in yield were recorded where N was applied at 150 kg N/ha and higher.

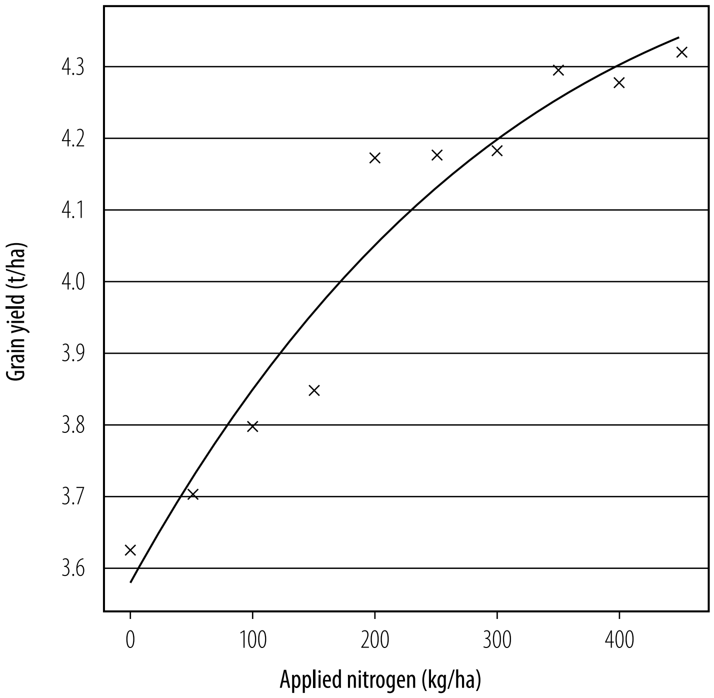

Figure 2 Relationship between applied nitrogen and wheat grain yield.
l.s.d ($P<0.05$) = 0.25 t/ha

## Grain protein concentration

### Canola

The mean grain protein concentration (GPC) across all N treatments was 21.0%, with the nil treatment producing a GPC of 18.6 % (Figure 3). The highest GPC of 22.2% was obtained where N was applied at 450 kg/ha.

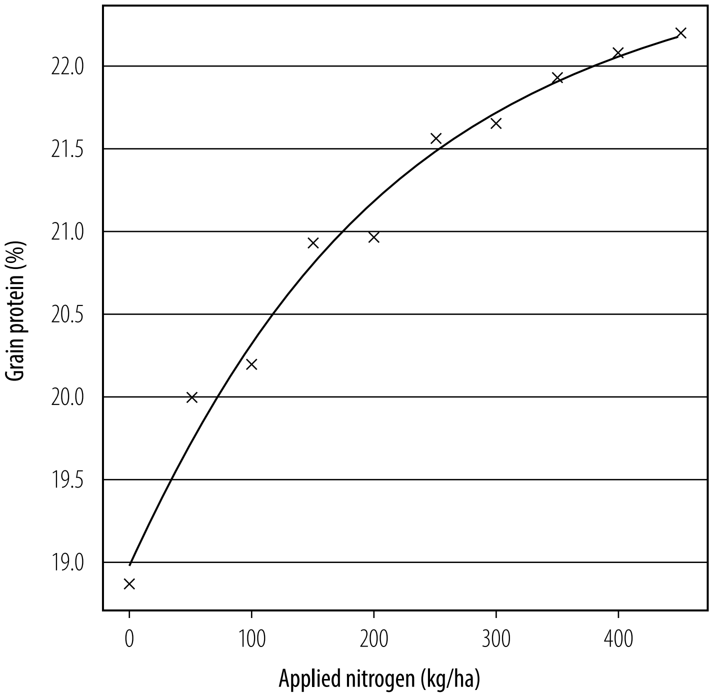

Figure 3 Relationship between applied nitrogen and canola grain protein concentration. l.s.d ($P$<0.05) = 0.63%

### Wheat

The mean GPC across all N treatments was 11.9%, with the nil treatment producing a GPC of 10.0% (Figure 4). The highest GPC of 12.95% was obtained where N was applied at 450 kg/ha.

### Canola oil concentration

The inverse relationship between canola oil concentration and increasing rates of N held true in this experiment where the mean oil concentration across all N treatments was 43%, with the highest oil concentration of 45.5% obtained where no additional N was applied (data not shown).

## Discussion

Canola yields increased with higher rates of N, before plateauing at 150 kg N/ha (Figure 1). At the highest rate of N (450 kg N/ha), grain yield increased by 1.38 t/ha (73%) over the nil treatment.

Nitrogen, alongside potassium (K) and P, is a key nutrient required for plant growth. Nitrogen increases plant growth, productivity, yield and quality. Applying urea to the soil increased available nitrate for crop uptake through nitrification. This increased nitrate availability was reflected in the increases in yields that were recorded with additional rates of urea. Significant increases in yield were recorded where additional N was applied at 50kg N/ha and higher. However, at rates of N above 150 kg N/ha, the yield response curve was relatively flat. Grain yields were not significantly different at N rates above 150 kg N/ha.

Even though the highest yield recorded was where N was applied at 450 kg N/ha, a significant increase in yield was recorded where N was applied at 50 kg N/ha, which indicated that a yield response can still be obtained with moderate levels of urea application. High rates of N application might not always be economically viable.

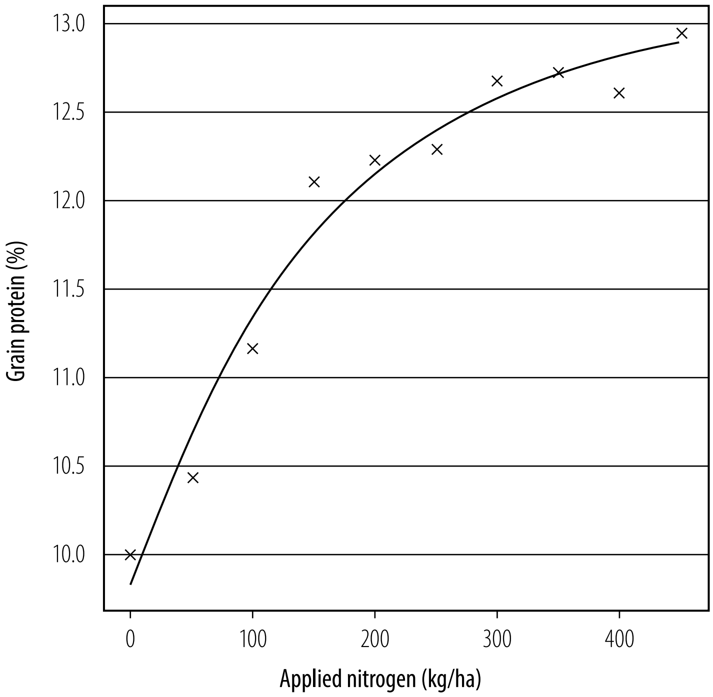

Figure 4 Relationship between applied nitrogen (kg N/ha) and wheat grain protein concentration. l.s.d. (*P*<0.05) = 0.45%

Higher rates of N were incorporated into this study in order to see whether a negative yield response would result at these levels. A negative yield response was not recorded in this experiment and the commonly encountered symptoms of excessively high rates of N were not observed.

The average canola yield obtained in this experiment was 2.95 t/ha. This was above the state average of 0.8 t/ha in 2018–19. Indeed, the yield obtained where no additional N was applied (1.89 t/ha) was itself higher than the state average. Even though decent grain yields were obtained in this experiment, yield potentials were most likely affected by the environmental conditions experienced in the 2018 growing season. In 2018, Tamworth received below average annual rainfall of 366.1 mm (compared with the long-term average of 672.5 mm) and 41 days below 0 °C during the growing season. Reduced moisture would have limited crop growth (yield) and frosts could have contributed to flower and pod abortion, both of which would have affected yield.

Similar to the trend recorded with yield, canola GPC also increased with increasing rates of N (Figure 3). Again, applying urea to soils would have resulted in increasing nitrate levels that the crop would have been able to use. Nitrogen is a key element of all amino acids, the building blocks of proteins. Grain protein concentration increased with increasing rates of N, however, oil concentration declined. This negative correlation has been consistently recorded in a number of studies across a wide range of environments, most likely as a consequence of the partitioning of oil, protein, water and residue in seeds. Significant reductions in oil concentrations relative to the nil treatment were recorded wherever additional N was applied (>50 kg N/ha, data not shown). Oil concentrations below the critical value of 42% (2018–19 base level) were recorded where N was applied at 250, 400 and 450 kg N/ha. These results highlight the inverse relationship in canola between GPC and oil, in response to increasing rates of N.

Wheat also responded to additional N application over the 2018 winter growing season. The yield-response curve generated from grain yield data demonstrated a near-linear response in yield with increasing rates of N. Significant increases in yield (relative to the nil treatment) were obtained when N was applied at rates of 200 kg N/ha and higher. Wheat yield peaked at 4.31 t/ha, where N was applied at 450 kg/ha. This increase of 0.69 t/ha corresponded to a 19% increase in yield over the nil treatment. Average wheat yields obtained in this experiment (4.04 t/ha) were above the state average in 2018–19 (1 t/ha).

Wheat GPC also increased with increasing rates of N application. The nil treatment produced grain with a GPC of 10%. The highest GPC was recorded where N was applied at 450 kg N/ha (12.95%). However, even at this rate of N, the protein level was still below the industry minimum for the 2018–19 seasons (H1, 13%). Grain protein is determined by the balance between the N requirement of the crop, the supply of N to that crop, as well as by environmental conditions. The wheat crop was supplied with moderate to high rates of N as urea. Therefore, it is likely that environmental factors limited GPC to the levels recorded in this experiment. Indeed, even though an increase in GPC was recorded with increasing rates of N, yield and GPC are often negatively correlated, with higher yields often diluting GPC.

## Conclusions

The aim of this experiment was to generate an N-response yield curve for canola subjected to various rates of N in 2018. Similar to results obtained in the winter of 2017, results from this experiment further highlighted canola's yield response to N application. Within a grey/brown vertosol and under dry seasonal conditions, grain yields of canola increased with increasing rates of N. Significant increases in yield were obtained wherever additional N was applied (≥50 kgN/ha), relative to where no additional N was applied. An inverse relationship between GPC and oil concentration in canola was also recorded, as is readily observed. Results from this experiment will contribute towards N-response data within the BFDC database to help develop improved soil test-crop response guidelines.

## Acknowledgements

This experiment is part of the project 'Updated nutrient response curves in the Northern and Southern Regions', UQ00082, a co-funded investment between the NSW Department of Primary Industries (NSW DPI) and the Grains Research and Development Corporation (GRDC), led by the University of Queensland. Technical assistance provided by additional members of the NSW DPI Tamworth Agronomy Team is gratefully acknowledged.

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# Linseed genotype growth and development response to varying sowing date – Narrabri 2015

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## Key findings

- Time to flowering progressively decreased in all genotypes when sown after mid April on all sowing dates (SD) with the exception of the early May SD.
- The Glenelg variety genotype was quickest to start flowering and the quickest to mature on all sowing dates. Croxton was the slowest to start flowering.
- The genotypes LM14 and LM17 showed no significant difference in the time to flowering. Differences between genotypes decreased as sowing was delayed beyond 28 May (SD3).
- Glenelg was the quickest to finish flowering when sown in April and May. Flowering ceased in all genotypes in late September and early–mid October for April and May SDs.
- Environmental conditions, principally high temperatures, halted flowering in all genotypes for SD4 (26 June) and SD5 (13 July). The flowering duration was greatest for SD4 and SD5, due to the short vegetative growth period.
- The flowering period was shortest in all genotypes for SD3 (28 May).
- LM14 and LM17 displayed no significant difference in growth and development traits and agronomic characteristics, including days to the start and end of flowering, plant height, height of lowest capsule, branching, number of seeds per capsule, and the number of infertile capsules per plant.
- Overall plant height and the height above ground of the lowest capsule decreased as SD was delayed. The Glenelg plant structure was the most compact of the genotypes tested.
- Sowing date had a significant effect on seed size. Linseed sown in July (SD5) was 22% smaller than that sown in April (SD1). Glenelg had the largest seed size at 5.34 g/1000 seeds.
- The data suggests that the optimal sowing window for the four genotypes was late April to early May at Narrabri.

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## Introduction

The 'Tactical agronomy of minor crops' (DAN00197) was a joint project between NSW DPI and the Grains Research and Development Corporation (GRDC). A major objective was to determine the agronomic constraints to yield potential in the oilseed crops linseed, safflower and sunflower.

Linseed is grown in the medium to high rainfall areas of northern NSW and grown in rotation with winter cereal crops. Linseed is recognised for its beneficial role as a cereal disease break crop in the northern farming systems. It has resistance to the root lesion nematodes *Pratylenchus thornei* and *P. neglectus*, which are major pathogens in the region. Linseed is also recognised as having frequently high grain prices, making it a profitable crop in its own right. Agronomic research had been extremely limited in linseed for many years until 2015.

The linseed variety Glenelg is the most widely grown variety in northern NSW, with small areas of the variety Croxton. New cultivars, available through licensing arrangements, have generated greater interest. Consultation with industry has identified a range of views regarding optimal sowing windows and a significant knowledge gap regarding the varieties' agronomic attributes.

A linseed phenology experiment was conducted in 2015 at Narrabri to evaluate the response of four linseed varieties to varying SDs, including characterising crop growth and development. This paper reports on the effects of SD on traits including time to flowering and yield components. The data forms the initial information needed to refine sowing time recommendations for northern NSW.

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| **Site details** | **Location** | Plant Breeding Institute (PBI), Sydney University – Narrabri |
| | **Soil type and nutrition** | Self-mulching grey vertosol with low sodicity. Di-ammonium phosphate (DAP) fertiliser was pre-drilled into seeding furrows at 80 kg/ha. |
| | **Experiment design** | Complete randomised block design; five replications. Plot size 8 × 1.65 m. |
| | **Plant population** | Experiments were sown into seedbed conditions suitable for even germination and emergence. Plant rows were hand-thinned to achieve the target plant population of 300 plants/$m^2$. |
| | **Seed quality** | Seed was tested before sowing. Germination percentages ranged between 91% and 97% and vigour (medium to high) 90–95%. Seed size expressed as the weight of 1000 seeds were Glenelg: 5.30 g, LM14: 5.20 g, LM17: 5.75 g and Croxton: 6.35 g. Seed quality information was used to calculate the sowing rate for each genotype. |
| | **Climate** | In 2015, growing season rainfall (GSR) for each SD ranged from 273 mm to 104 mm (Table 1). Long-term GSR (April to November) at Narrabri averages 306 mm (Bureau of Meteorology).<br>In 2015, average monthly temperatures were lower than the long-term average during the winter and early spring, but higher in mid to late spring. shows the daily minimum and maximum temperatures and rainfall at the experiment site. Rainfall in June, July, September and October were below the long-term average. |
| **Treatments** | **Genotypes** | Glenelg, LM14, LM17, Croxton |
| | **Sowing dates** | SD1: 17 April; SD2: 8 May; SD3: 28 May; SD4: 22 June; SD5: 13 July |

Table 1 Rainfall for the five sowing dates.

| Sowing date | In-crop rainfall (mm) | Wet days |
|---|---|---|
| 17 April (SD 1) | 273 | 33 |
| 8 May (SD 2) | 230 | 28 |
| 28 May (SD 3) | 222 | 26 |
| 26 June (SD 4) | 104 | 10 |
| 13 July (SD 5) | 151 | 17 |

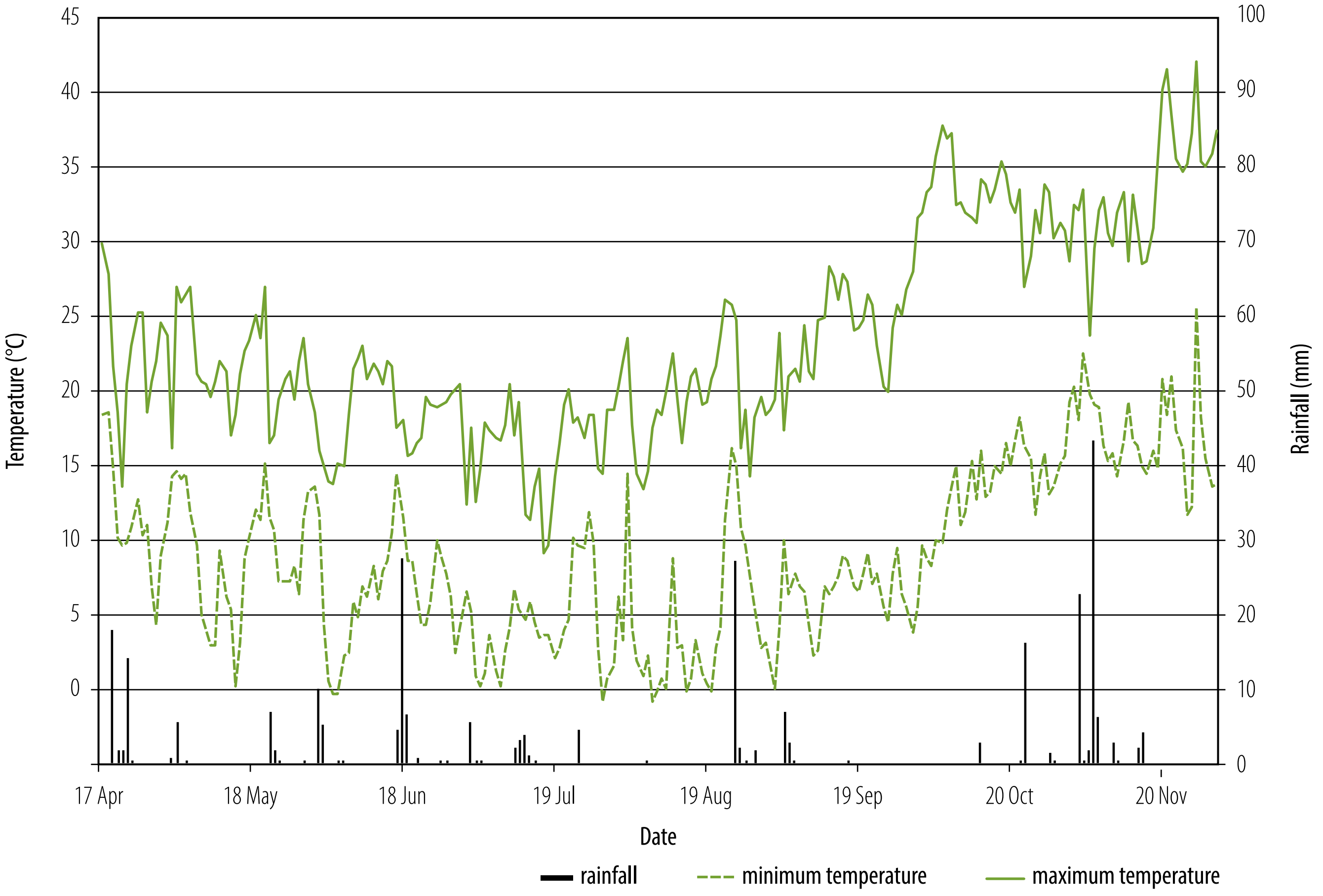

Figure 1 Temperature and rainfall at Narrabri in 2015.

## Results

### Start of flowering

The SD significantly affected the time taken to reach the start of flowering ( A). Flowering started 119 days after sowing (DAS) for SD2, which decreased to 85 DAS for SD5.

Genotypes showed distinct responses to SD. Glenelg was significantly quicker to flower than the three other genotypes, whilst Croxton was the slowest ( B). Glenelg started flowering 11 days earlier than Croxton for SD1. There was no significant difference between LM14 and LM17, but these genotypes were significantly slower than Glenelg. At SDs 1–4, they were significantly quicker to flower than Croxton.

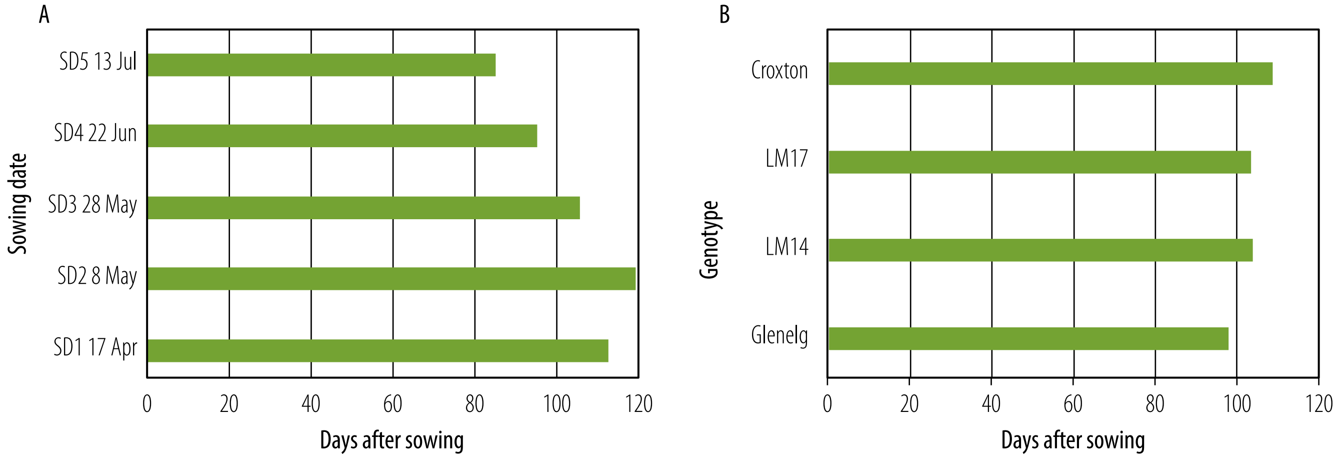

Figure 2 Linseed flowering response to (A) sowing date (l.s.d [*P*<0.001] = 3 days); and (B) genotype (l.s.d [*P*<0.001] = 1 day).

The interaction between SD and genotype ( ) significantly affected the start of flowering. Flowering started later in the season as SD was progressively delayed. Delaying sowing after SD2 hastened the start of the flowering phase by one to 1.3 days for every two days of delay in sowing. Sowing after SD3, reduced the number of days to the start of flowering by two days for every delay of two days.

For SD3, SD4 and SD5, differences between genotypes progressively decreased, with Glenelg flowering just six days earlier than Croxton for SD5. Croxton was the slowest to flower at all SDs except SD5, where LM14 was similar.

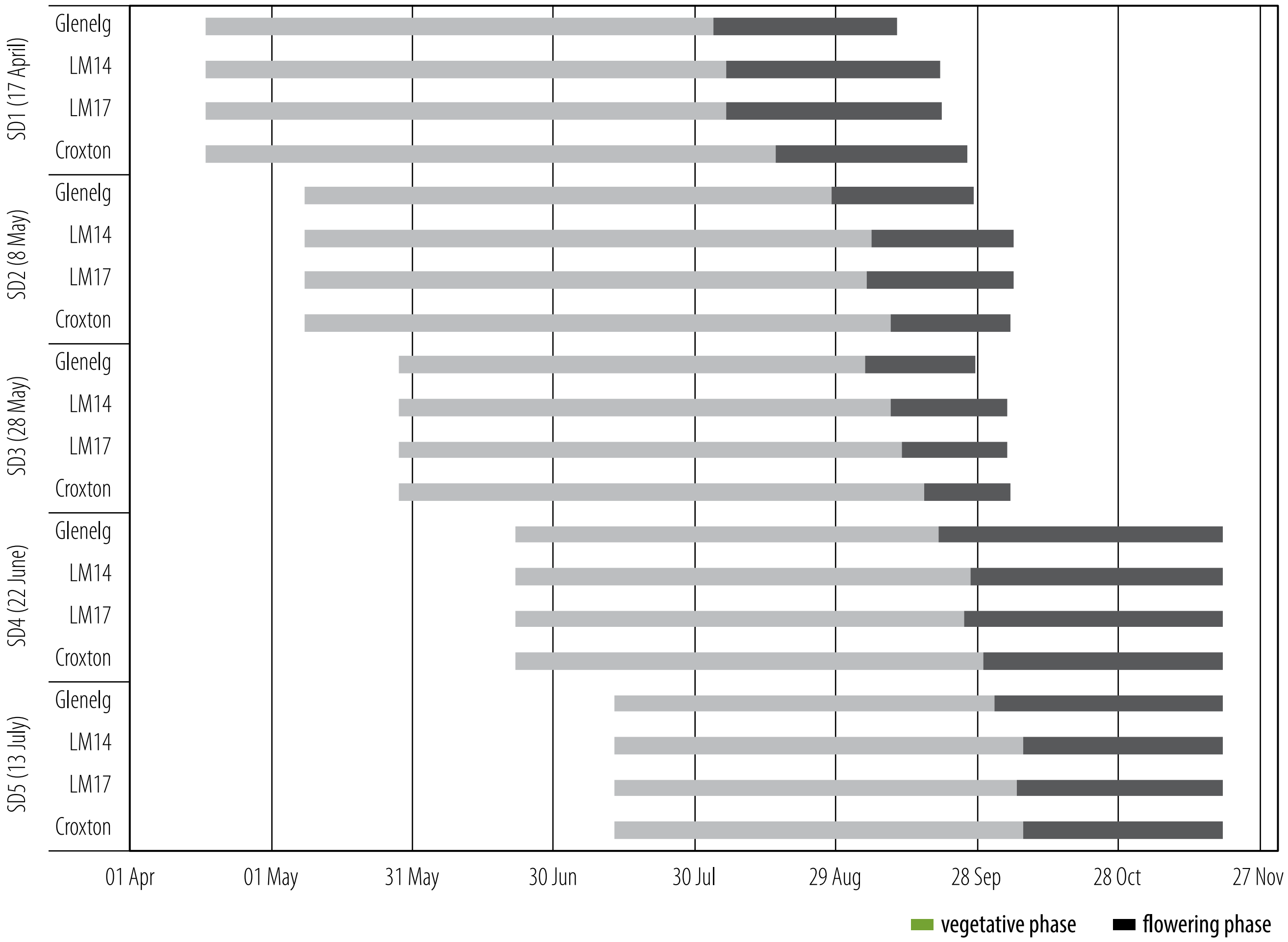

Figure 3 Effect of sowing date and genotype on the duration of linseed vegetative growth (light grey bars) and flowering (dark grey bars).

### End of flowering

Linseed is an indeterminate crop, with its flowering period overlapping with continued vegetative growth. Flowering continues until plant resources or environmental conditions are limiting. Sowing date significantly affected the flowering duration ( ).

For SDs 1–3, Glenelg ceased flowering significantly earlier than the other genotypes, but there was no significant difference between LM14 and LM17 ( ). Flowering in Croxton was the last to finish, but this was not significantly different from LM14 and LM17 for SD2–SD5. All genotypes finished flowering in early to mid October for SD1, and by the end of September and early October for SD2 and SD3.

There was no significant difference in the end of flowering between any genotypes for SD4 and SD5. All genotypes ceased flowering simultaneously at SD4 and SD5. These dates coincided with a rapid increase in maximum temperatures, exceeding 40 °C ( ). Plant available water (PAW) was not limiting at the time, with 83 mm of rainfall recorded since 1 November.

## Plant structure

### Plant height

Plant height decreased significantly as SD was delayed. Plant heights measured 92 cm, 85 cm, 88 cm, 80 cm and 75 cm respectively for SDs 1–5 (l.s.d. 9 cm; $P<0.05$) across all varieties. There was no significant difference in plant height between LM14, LM17 and Croxton, all measuring 86 cm at maturity. Glenelg was significantly shorter at 78 cm (l.s.d. 5 cm; $P<0.001$). There was no significant interaction between SD and genotype for plant height.

### Position of lowest capsule

The position of the lowest capsule was measured to assess potential harvest efficiency problems. Sowing date significantly affected the height above ground of the lowest seed capsule, measuring 79 cm, 66 cm, 71 cm, 60 cm and 54 cm respectively for SDs 1–5 (l.s.d. 8 cm; $P<0.001$).There were no significant differences between genotypes or the interaction between SD and genotypes (data not shown).

Figure 4 represents the overall plant structure for each SD, showing the seed capsule position on the plant and the stem length below the capsule. The effect of SD on the combination of overall plant height and the position of seed capsules was significant, but did not indicate any difficulties in seed capture during harvest.

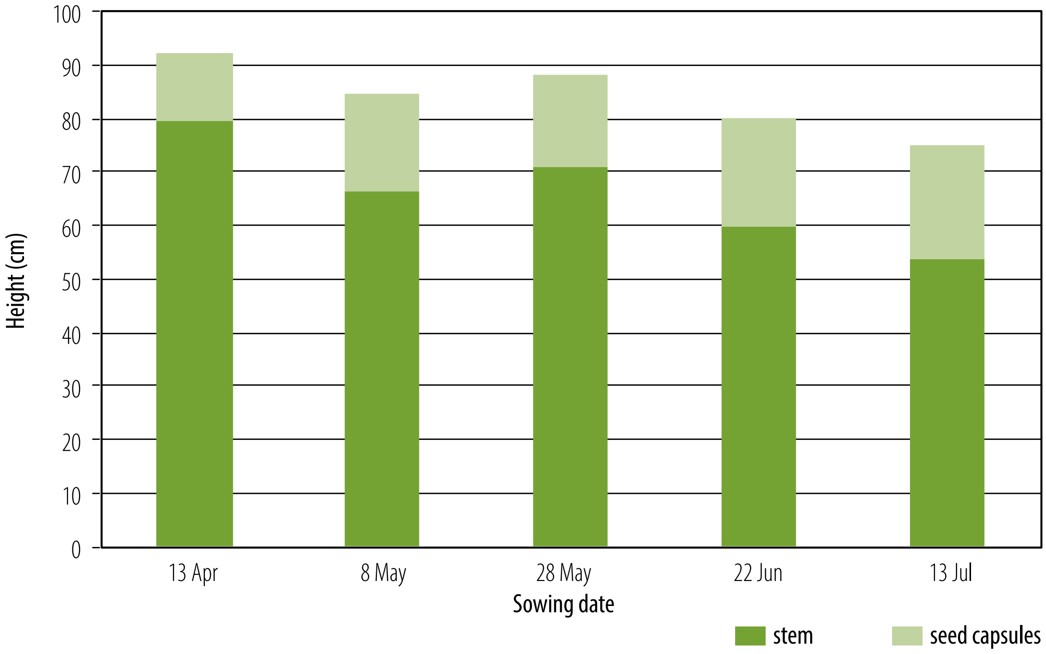

Figure 4 Effect of sowing date on height to the lowest capsule. Plant height (l.s.d [$P<0.05$] = 9 cm); height above ground of lowest capsule (l.s.d [$P<0.001$]

### Stem diameter

Stem diameter was measured to assess stem strength and susceptibility to lodging. The average stem diameter was 3.13 mm. Sowing date had no significant effect on stem diameter, however, small significant differences were measured between genotypes (l.s.d. 0.2 mm; $P<0.001$) (Table 2). No persistent lodging was observed in any treatment.

Table 2 Effect of linseed genotype on stem diameter at five sowing dates.

| | Glenelg | LM14 | LM17 | Croxton |
|---|---|---|---|---|
| Stem diameter (mm) | 3.2$^{ab}$ | 3.0$^{bc}$ | 3.4$^{a}$ | 2.9$^{c}$ |
| l.s.d. ($P<0.001$) | 0.2 | | | |

Note: Values with the same letter are not significantly different at 99.9% ($P<0.001$)

## Yield components

A range of plant characteristics commonly contribute positively to yield. Referred to as yield components, they are inter-related and can affect yield directly and indirectly. Some yield components correlated with crop yield include the number of capsules per plant, number of fertile and infertile capsules on the main stem, the number of branches per plant, seed size, number of seeds per capsule and the number of seeds per plant.

At physiological maturity, one linear metre row of plants were cut at ground level and dried. The above traits were measured; seed was removed from capsules, cleaned, and weighed for size.

### Number of capsules

Sowing date significantly affected the number of capsules per plant with SD2 and SD4 recording 77 capsules per plant, significantly more than at all other SDs (Table 3). There was no significant difference between genotypes (Table 4) or the interaction between SD and genotype (data not shown) on the total capsule number per plant.

### Fertile and infertile capsules

Sowing dates SDs 1–4 significantly affected the number of fertile capsules on the main stem, which produced the highest number of fertile capsules – between 24 per plant and 29 per plant.

- SD3 was not significantly different from SD5 (Table 3).
- Glenelg and LM17 produced significantly more fertile capsules than LM14 and Croxton on the main stem (Table 4).

Sowing date similarly affected the number of fertile capsules on branches compared with that on the main stem. The number of fertile capsules on branches was 4–6 times less (Table 3). Genotype did not significantly affect the number of fertile capsules on branches (Table 4).

- SD2 and SD4 recorded the highest number of infertile capsules on the main stem, however, SD2 was not significantly different from SD3 and SD4.
- SD1 and SD5 produced the fewest infertile capsules, 1.8 and 2.9 respectively (Table 3).
- Across genotypes, LM14 and LM17 recorded the fewest infertile capsules; 2.8 and 2.3 capsules, respectively.
- Glenelg had the highest number of infertile capsules at 6.6, significantly more than Croxton (Table 4).

Sowing date significantly affected the numbers of infertile capsules on branches, though total numbers did not exceed three capsules per branch (Table 3). Glenelg and Croxton had significantly more infertile capsules on branches than the other genotypes (Table 4).

### Branching

Varieties sown on SD4 had significantly more branches (3.2) than SD1, SD2 or SD3, which only had two branches per plant. There was no significant different between SD4 and SD5 (Table 3). Of the genotypes tested, there were no significant differences in branching (Table 4) or any significant interaction between genotype and sowing date (data not shown).

### Seeds per capsule

Each linseed capsule has the capacity to produce 10 seeds. On average, each capsule produced 7.3 seeds. Sowing date had no significant effect on the number of seeds per capsule ( ). There were small, but significant, differences between genotypes; for example LM14 produced significantly more seed per capsule than Glenelg (Table 4). There was a significant interaction between SD and genotype on the numbers of seeds per capsule (data not shown).

### Seeds per plant

Sowing date significantly affected the total number of seeds per plant. Seed numbers per plant from SD2, and SD4 were significantly greater than SD1 and SD5 (Table 3). There was no significant difference in seed numbers between SD1, SD3 and SD5. The average numbers of seeds per plant was 374 seeds. Genotype differences were not significant (Table 4). There was no significant interaction between SD and genotype (data not shown).

Table 3 Effect of sowing date on yield components.

| Sowing date | Capsules per plant | Fertile capsules on main stem | Infertile capsules on main stem | Branches per plant | Fertile capsules per branch | Infertile capsules per branch | Seeds per capsule | Seeds per plant |
|---|---|---|---|---|---|---|---|---|
| SD1 | 43$^{b}$ | 15.3$^{d}$ | 1.8$^{c}$ | 2.0$^{b}$ | 4.5$^{b}$ | 1.2$^{c}$ | 7.8$^{a}$ | 301$^{b}$ |
| SD2 | 77$^{a}$ | 29.3$^{a}$ | 4.9$^{ab}$ | 2.0$^{b}$ | 5.6$^{a}$ | 2.1$^{a}$ | 7.5$^{a}$ | 483$^{a}$ |
| SD3 | 56$^{ab}$ | 23.6$^{abc}$ | 4.1$^{b}$ | 2.0$^{b}$ | 4.8$^{ab}$ | 1.7$^{bc}$ | 7.1$^{a}$ | 344$^{ab}$ |
| SD4 | 77$^{a}$ | 27.3$^{ab}$ | 6.2$^{a}$ | 3.2$^{a}$ | 6.0$^{a}$ | 2.5$^{a}$ | 7.3$^{a}$ | 472$^{a}$ |
| SD5 | 47$^{b}$ | 20.6$^{c}$ | 2.9$^{c}$ | 2.6$^{ab}$ | 4.4$^{b}$ | 1.8$^{ab}$ | 6.7$^{a}$ | 272$^{b}$ |
| Site mean | 60 | 23.2 | 4.0 | 2.3 | 5.0 | 1.8 | 7.3 | 374 |
| l.s.d. ($P$<0.05) | 22** | 6.3** | 1.8** | 0.6** | 1.2* | 0.7** | ns* | 158* |

Note: values with the same letter are not significantly different at 99.9% ($P$<0.001)

Table 4 Effect of genotype on yield components.

| Genotype | Capsules per plant | Fertile capsules on main stem | Infertile capsules on main stem | Branches per plant | Fertile capsules per branch | Infertile capsules per branch | Seeds per capsule | Seeds per plant |
|---|---|---|---|---|---|---|---|---|
| Glenelg | 70$^{a}$ | 26.2$^{a}$ | 6.6$^{a}$ | 2.7$^{a}$ | 5.2$^{a}$ | 2.3$^{a}$ | 6.8$^{b}$ | 379$^{a}$ |
| LM14 | 54$^{a}$ | 21.2$^{b}$ | 2.8$^{c}$ | 2.2$^{a}$ | 4.9$^{a}$ | 1.6$^{b}$ | 7.8$^{a}$ | 385$^{a}$ |
| LM17 | 61$^{a}$ | 27.0$^{a}$ | 2.3$^{c}$ | 2.2$^{a}$ | 5.0$^{a}$ | 1.5$^{b}$ | 7.4$^{ab}$ | 416$^{a}$ |
| Croxton | 55$^{a}$ | 18.5$^{b}$ | 4.3$^{b}$ | 2.2$^{a}$ | 5.0$^{a}$ | 2.0$^{a}$ | 7.1$^{ab}$ | 318$^{a}$ |
| Site mean | 60 | 23.2 | 4.0 | 2.3 | 5.0 | 1.8 | 7.3 | 374 |
| l.s.d. ($P$<0.05) | ns* | 3.9** | 1.4** | ns* | ns* | 0.5** | 0.8 | ns* |

Note: values with the same letter are not significantly different at 99.9% ($P$<0.001)

## Grain yield and seed characteristics

### Seed size

Seed number and size are important contributors to yield. There was a significant interaction between SD and genotypes on seed size or thousand seed weight (TSW) (Figure 5). Seed size was the largest in all genotypes for SD1.

Seed size declined in all genotypes after SD1; Glenelg progressively declined with each successive SD.

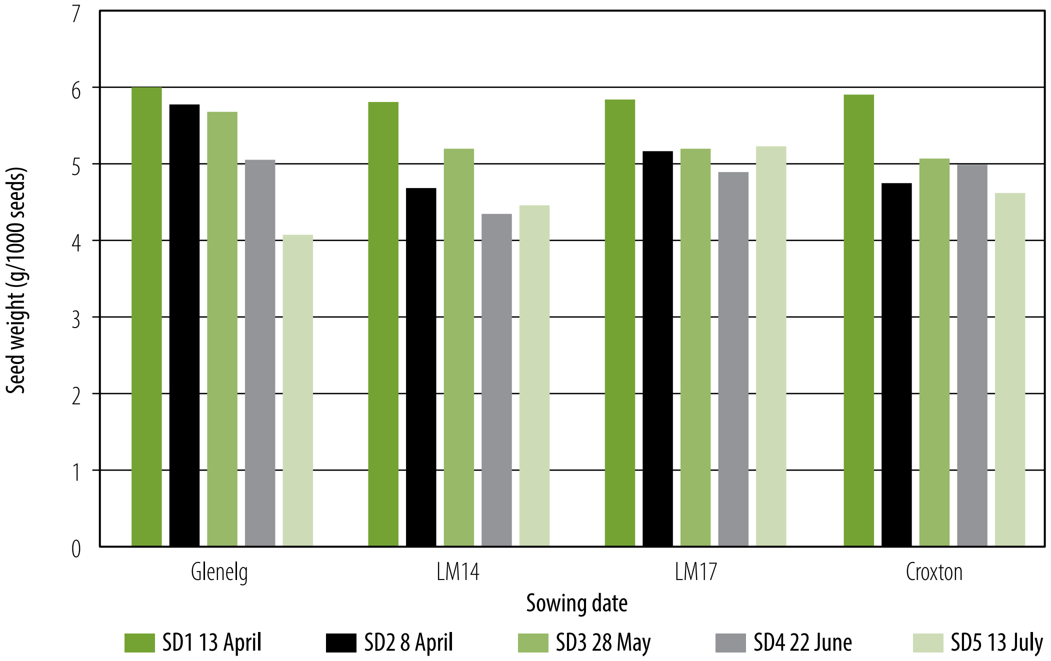

Figure 5 Seed size relationship with sowing date x genotype.
Sowing date × Genotype (l.s.d. [$P<0.05$] = 0.94 g).

### Yield

Yield was calculated from 1 m row hand cuts from each treatment. The average site yield was 1.81 t/ha. Sowing date significantly affected yield with SD4 yielding significantly more than SD5 (Table 5). There was no significant difference in yield for SD2, SD3 or SD4.

Table 5 Effect of sowing date on grain yield.

| **Sowing date** | **Yield (t/ha)** |
|---|---|
| SD 1 | 1.65$^{bc}$ |
| SD 2 | 2.13$^{ab}$ |
| SD 3 | 1.72$^{abc}$ |
| SD 4 | 2.30$^{a}$ |
| SD 5 | 1.27$^{c}$ |
| Site mean | 1.81 |
| l.s.d. ($P<0.05$) | 0.62 |

Note: values with the same letter are not significantly different at 99.9% ($P<0.001$)

There was no significant difference in yield between Glenelg and LM17, yielding 2.10 t/ha and 1.90 t/ha respectively. There was also no significant different between LM14, LM17 and Croxton (Table 6).

Table 6 Effect of genotype on grain yield.

| Sowing date | Yield (t/ha) |
|---|---|
| Glenelg | 2.10 a |
| LM14 | 1.57 b |
| LM17 | 1.90 ab |
| Croxton | 1.67 b |
| Site mean | 1.81 |
| l.s.d. (*P*<0.05) | 0.39 |

Note: values with the same letter are not significantly different at 99.9% (*P*<0.001)

There were significant interactions between SD and genotype (*P*<0.05). Glenelg sown at SD2 yielded significantly higher than all other genotypes at other SDs (data not shown).

### Harvest index

Harvest index (HI) is a measure of reproductive efficiency, calculated as the ratio of harvested grain to total shoot dry matter. HI was greatest for SD2 and SD4. There was no significant difference between SDs1, 3, 4 and 5 (Figure 6A).

The average site HI was 0.23. There was no significant difference in HI between Glenelg, LM14 and LM17. Croxton HI was significantly less (Figure 6B).

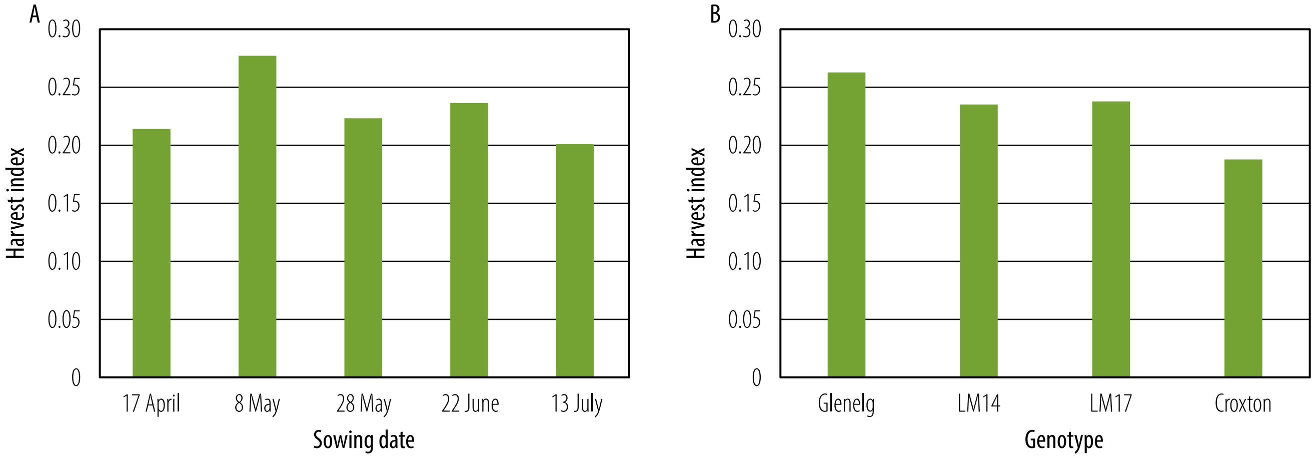

Figure 6 Harvest index relationship with (A) sowing date and (B) genotype. Sowing date (l.s.d = 0.04 [*P*<0.05]); Genotype (l.s.d. = 0.03, [*P*<0.001]).

## Conclusions

This experiment highlighted differences in flowering and maturity between four linseed genotypes and their responses to SD, genotypes, and SD × genotype interactions. These factors had significant effects on yield-contributing factors and plant structure.

The earliest sowing in mid April allowed flowering to be completed by mid to late September in all genotypes. This enabled seed fill to be largely completed before the likelihood of heat and/or moisture stress. Delaying sowing after late May moved sensitive crop phases such as flowering and seed-fill into periods when seasonal conditions are characterised by rapidly increasing temperatures and evapotranspiration rates in northern NSW. Sowing date had a much larger effect on plant yield components than genotype.

Glenelg was the earliest flowering and quickest maturing of the four genotypes. Croxton was the latest to start flowering and LM14 and LM17 in between. For most of the traits measured, there was no significant difference between LM14 and LM17.

The data suggests that the optimal sowing window at Narrabri for the four varieties of linseed was late April to early May. This assessment was based on the probabilities of environmental stresses, particularly heat and moisture stress during flowering and seed fill.

These findings were part of the research into determining key traits and characteristics of linseed genotypes and their optimum sowing date in northern NSW. The research demonstrated the first comparative data in northern NSW of commercially available linseed varieties. Additional experiments at geographically diverse locations and several seasons are required to better characterise these genotypes to refine crop growth response curves and agronomic management.

## Acknowledgements

This experiment was part of the project 'Tactical agronomy of minor crops (safflower, linseed, sunflower)', DAN00197, a joint investment between NSW DPI and the Grains Research and Development Corporation (GRDC).

Technical assistance provided by Stephen Morphett, Peter Formann, Jim Perfrement, Rosie Holcombe and Stacey Cunningham (all NSW DPI) is gratefully acknowledged. The IA Watson Plant Breeding Institute – Sydney University (Narrabri) is also acknowledged for providing the experiment site. Seed was kindly supplied by Austgrains (Moree). Leigh Jenkins (NSW DPI) helped to create Figure 3. Bernie Dominiak and Loretta Serafin reviewed and improved an earlier version of this manuscript (both NSW DPI).

# Row spacing × population effects on yield and seed size in linseed – 2015 and 2016

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## Key findings

- In most situations, the 17 cm row spacing resulted in optimum grain production.
- Crop establishment decreased as row spacing increased. Crop establishment was reduced by up to 49% when the row spacing increased to 66 cm.
- Crop establishment rates declined as seeding rates increased.
- Row spacings had mixed effects on yield. When sown before June with no pest pressure, yields were up to 62% higher at 17 cm row spacing than 33 cm and 66 cm spacings. Row spacing had no effect on yield where experiments were sown in July or where there was high pest pressure at seed fill.
- Plant population had no significant effect on yield at populations except where crop establishment was low, at populations less than 21 plants/m$^2$.
- Neither row spacing nor population affected seed size in 2015. Severe Rutherglen bug (*Nysius vinitor*) pressure during seed fill in 2016 could have affected results where row spacing and population individually and together significantly affected yield, harvest index and seed size.

## Introduction

The 'Tactical agronomy of minor crops (safflower, linseed, sunflower)' (DAN00197) was a co-funded project between NSW DPI and the Grains Research and Development Corporation (GRDC). A major objective was to determine the agronomic constraints to yield potential in oilseed crops, other than canola, in northern NSW.

Linseed production in northern NSW is primarily marketed for human consumption, particularly into health foods. Regarded as a valuable source of essential omega 3 and omega 6 fatty acids, lignans and fibre, linseed is widely sold as whole unprocessed seed in specialised health food shops as well as in supermarket health food sections. The seed is a common ingredient in multigrain products such as wholegrain snack bars and bread products. Linseed (flaxseed) oil production is a secondary market. No known market exists for linseed fibre in Australia.

Industry consultation with linseed growers in northern NSW at the beginning of the project identified wide-ranging views regarding optimal plant populations, row spacing and their effects on crop yield and other agronomic attributes. Industry seeding rates varied between 20 kg/ha and 40 kg/ha, with most crops sown closer to 40 kg/ha. Linseed is most commonly sown on 38 cm row spacing, with growers opting for 17 cm, 25 cm, 28 cm and 33 cm row spacings.

## Site details

Four experiments investigating optimal plant populations and row spacing were conducted in 2015 and 2016 in northern NSW. Details of the experiment locations are shown in Table 1.

Table 1 Site details in 2015 and 2016.

| | **Tulloona 2015** | **Breeza 2015** | **Terry Hie Hie 2016** | **Tamarang 2016** |
|---|---|---|---|---|
| Site | 'Myling,' Tulloona | 'Durante', Nea via Breeza, Liverpool Plains | 'Maneroo', Terry Hie Hie | 'The Point', Tamarang |
| GPS | S 25°52′39.4″;<br>E 150°05′13.0″ | S 31°18′12.9″;<br>E 150°34′26.8″ | S 29°39′38.8″;<br>E 150°05′04.0″ | S 31°24′46″;<br>E 150°18′41″ |
| Co-operator | Jack Gooderham | Alan Riordan | David & Rob Anderson | David Ronald |
| Variety | Glenelg | | | |
| Sowing date | 28 May 2015 | 10 July 2015 | 13 May 2016 | 30 June 2016 |
| Fertiliser | 111 kg/ha Granulock Z | 111 kg/ha Granulock Z | 111 kg/ha Granulock Z | 111 kg/ha Granulock Z |
| Starting soil water (mm to 120 cm) | 403 | 230 | 271 | 236 |
| Starting nitrogen to 120 cm (kg N/ha) | 101 | 137 | NA | 102 |
| Harvest date (days after sowing, DAS) | 11 November 2015 (167 DAS) | 1 December 2015 (143 DAS) | 14 December 2016 (214 DAS) | Not harvested |

## Treatments

The experiments consisted of three row spacings. Target populations were modified in the second year of testing based on difficulties in achieving higher target populations in 2015 experiments (Table 2).

Table 2 Treatment details in 2015 and 2016.

| **Treatment** | **Tulloona 2015** | **Breeza 2015** | **Terry Hie Hie 2016** | **Tamarang 2016** |
|---|---|---|---|---|
| Row spacing (cm) | 17<br>33<br>66 | 17<br>33<br>66 | 17<br>33<br>66 | 17<br>33<br>66 |
| Target population (plants/m$^2$) | 100<br>200<br>300<br>400<br>500<br>600 | 100<br>200<br>300<br>400<br>500<br>600 | 50<br>100<br>200<br>300 | 50<br>100<br>200<br>300 |

## Trial design

The experimental design was split plots with row spacing as the main block, with three replications.

## Seed quality

The seed used in the 2015 and 2016 experiment was tested for germination and vigour before sowing. The variety Glenelg was used, which is a relatively large seed at 5.2 g/1000 seeds (thousand seed weight (TSW)). The germination rate was 97%.

Seeding rates are shown in Table 3. These were calculated according to TSW, germination and establishment percentage. Seeding rates were calculated on an 80% assumed establishment.

Table 3 Experiment target populations and equivalent seeding rates in 2015 and 2016.

| Target population (plants/m²) | Seeding rate (kg/ha) |
|---|---|
| 50 | 3.5 |
| 100 | 7 |
| 200 | 13 |
| 300 | 20 |
| 400 | 27 |
| 500 | 34 |
| 600 | 40 |

## Sowing

At all sites, experiments were sown into favourable seedbed moisture. Follow-up rainfall occurred within one to 21 days after sowing at all experiment locations. Seeding depth was between 10 mm and 20 mm. Residual insecticide was applied after sowing.

## Site climate details

Total in-crop rainfalls at the sites were: Tulloona – 178 mm (16 wet days); Breeza – 165 mm (37 wet days); Tamarang – 322 mm (21 wet days) and Terry Hie Hie – 391 mm (49 days) (Figure 1A, Figure 1B, Figure 1C and Figure 1D).

The average minimum and maximum temperatures were: Tulloona: – 8.5 °C and 23.7 °C; Breeza– 9.0 °C and 24.4 °C, Tamarang– 7.3 °C and 24.2 °C and Terry Hie Hie– 7.3 °C and 22.4 °C.

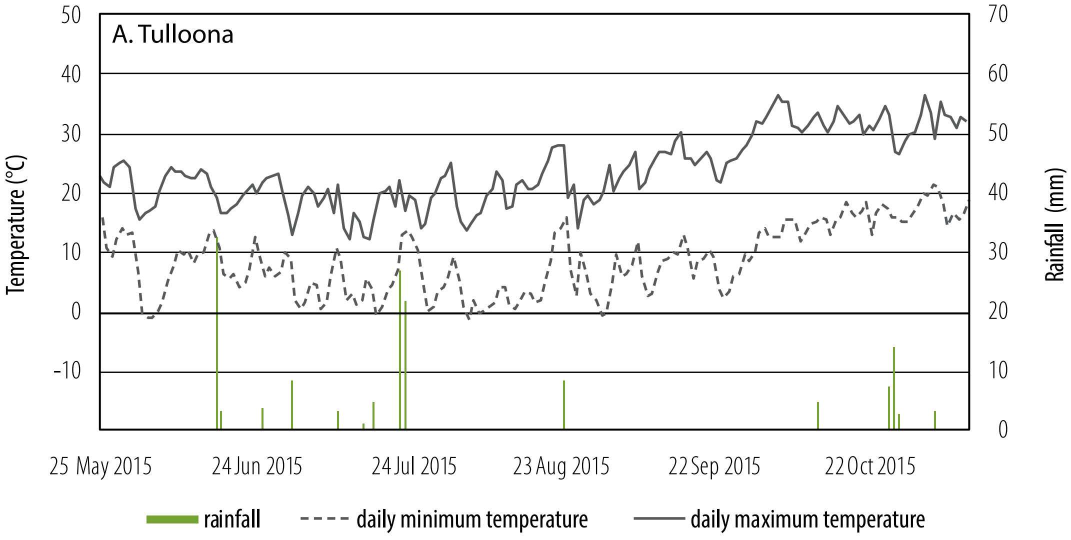


Figure 1A Experiment climate information at Tulloona 2015.

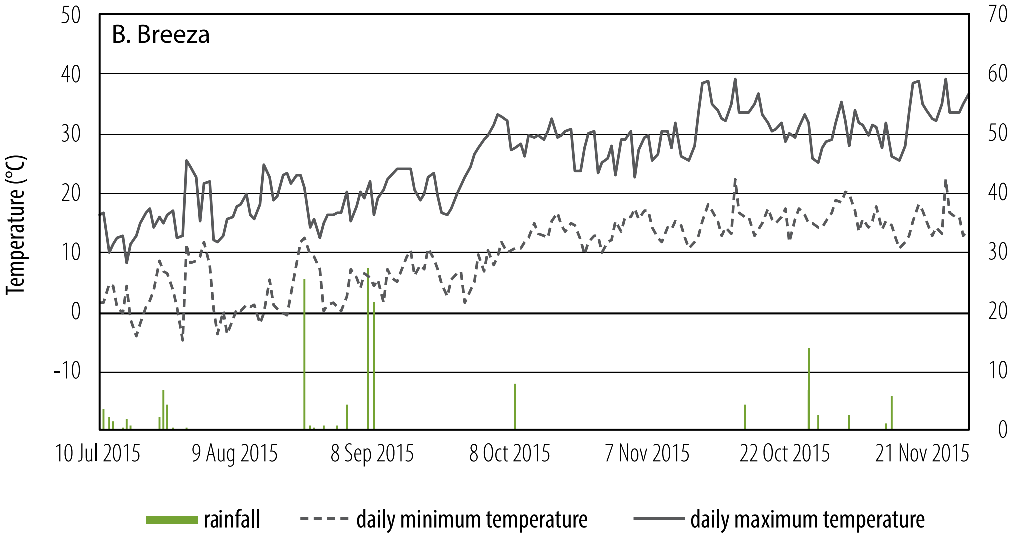


Figure 1B Experiment climate information at Breeza 2015.

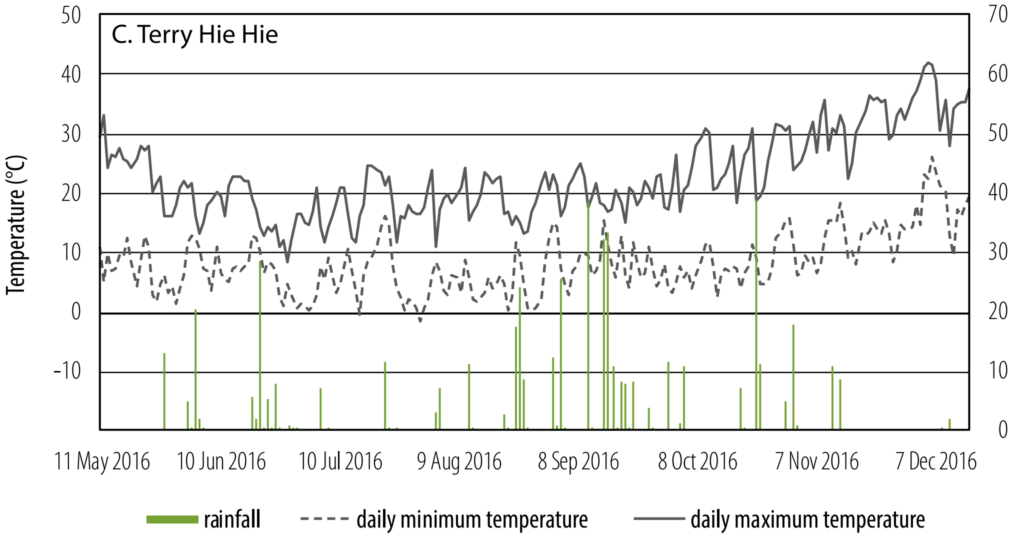


Figure 1C Experiment climate information at Terry Hie Hie 2016.

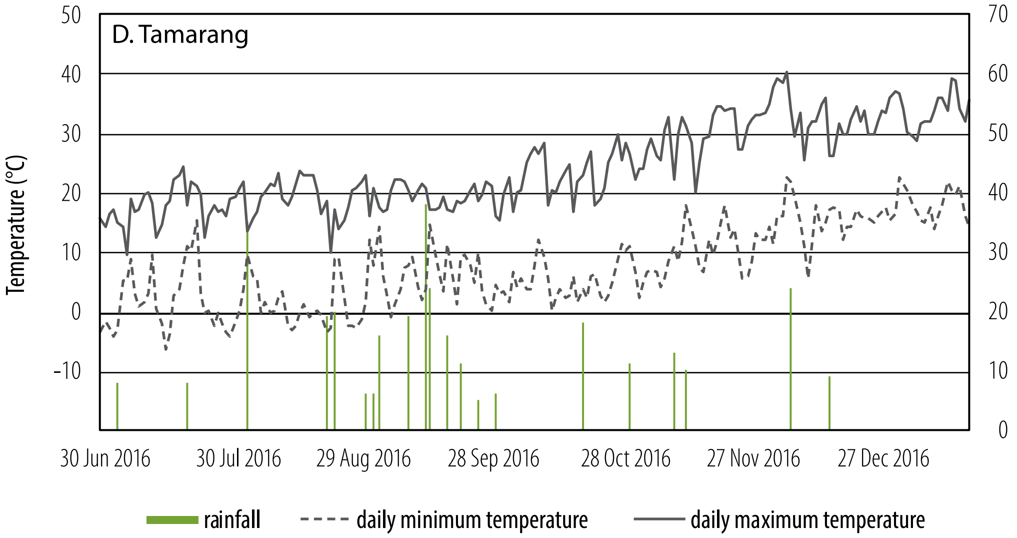


Figure 1D Experiment climate information at Tamarang 2016.

## Results

## Effects from row spacing

### Crop establishment

Row spacing significantly affected crop establishment in all experiments (Table 4). Crop establishment declined as row spacing increased. Compared with the 17 cm row spacing, crop establishment in 66 cm row spacing treatments was reduced by up to 49%.

Table 4 Effect of row spacing on linseed establishment in 2015 and 2016.

| **Row spacing (cm)** | **Established plant population (plants/m$^2$)** | | | |
|---|---|---|---|---|
| | **Tulloona 2015** | **Breeza 2015** | **Terry Hie Hie 2016** | **Tamarang 2016** |
| 17 cm | 348 $^{a}$ | 239 $^{a}$ | 67 $^{a}$ | 103 $^{ab}$ |
| 33 cm | 242 $^{b}$ (−30) | 217 $^{b}$ (−9) | 44 $^{bc}$ (−34) | 84 $^{bc}$ (−18) |
| 66 cm | 139 $^{c}$ (−40) | 135 $^{c}$ (−43) | 34 $^{c}$ (−49) | 70 $^{c}$ (−32) |
| Site mean | 243 | 197 | 49 | 86 |
| l.s.d. | 69 ** | 19 ** | 21 * | 20 * |
| Correlation | $R^2 = 1.00$ | $R^2 = 0.90$ | $R^2 = 0.95$ | $R^2 = 0.99$ |

** Values with the same letter are not significantly different at 99.9% ($P<0.001$)

* 95% ($P<0.05$) confidence levels.

Note: Figures in brackets represent the percentage reduction in crop establishment compared to that measured at 17 cm row spacing.

Note: Herbicide drift caused significant crop damage at the Tamarang experiment site during the growing season. The site was abandoned for experiment data after the start of flowering.

## Crop production

### Yield

Yields were higher from the 17 cm row spacing compared with the wider row spacings at Tulloona (Table 5). There was no significant difference in yield between the 17 cm and 66 cm row spacings at Breeza in 2015 or between all row spacings at Terry Hie Hie in 2016.

### Harvest index

Harvest index is a measure of crop reproductive efficiency, calculated as the ratio of grain to above-ground dry matter. The average harvest index at Tulloona, Breeza and Terry Hie Hie were 0.30, 0.25 and 0.23 respectively.

Harvest index was significantly higher in the 66 cm row spacing treatments at 0.32, than for the 17 cm and 33 cm row spacings at Tulloona, which were 0.28 and 0.29 respectively (l.s.d. 0.01; $P<0.001$). Row spacing had no significant effect at the remaining sites (data not shown).

### Seed size

Row spacing had no significant effect on seed size at Tulloona and Breeza in 2015. Average TSW at each site was 4.97 g and 4.39 g respectively.

Significant differences in seed size between row spacings were measured at Terry Hie Hie. The average TSW was the lowest (3.39 g) of the three experiments. At Terry Hie Hie, the highest TSW was 3.39 g from the 17 cm row spacing, which was significantly higher than for the 66 cm row spacing at 3.21 g. There was no significant difference in TSW from the 33 cm row spacing with other spacings at 3.34 g (l.s.d. 0.14 g; $P<0.001$).

This experiment was affected by prolonged severe damage from repeated incursions of migratory native Rutherglen bugs during much of the seed-filling period in 2016 (Figure 2 and Figure 3). Numerous control efforts were foiled by recurring invasions.

Table 5 Effect of row spacing on linseed yield, harvest index and seed size in 2015 and 2016.

| Row spacing (cm) | Yield (t/ha) @ 12% moisture | | |
|---|---|---|---|
| | Tulloona 2015 | Breeza 2015 | Terry Hie Hie 2016 |
| 17 cm | 1.62 [a] | 0.58 [a] | 0.86 [a] |
| 33 cm | 1.01 [b] | 0.39 [b] | 0.76 [a] |
| 66 cm | 1.08 [b] | 0.64 [a] | 0.69 [a] |
| Site mean | 1.23 | 0.53 | 0.77 |
| l.s.d. | 0.11 ** | 0.19 * | ns * |

** Values with the same letter are not significantly different at 99.9% ($P<0.001$)

* 95% ($P<0.05$) confidence levels

Figure 2 Severe infestation of Rutherglen bugs in linseed at Terry Hie Hie in 2016

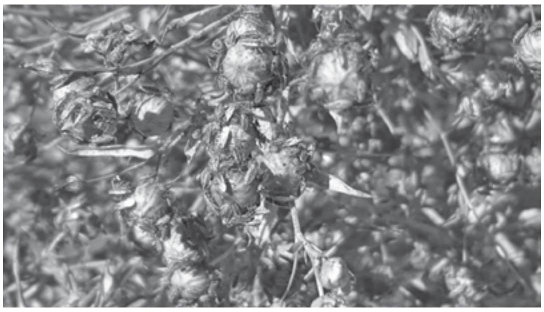


Figure 3 Rutherglen bugs in maturing linseed at Terry Hie Hie in 2016

## Effects of crop population

### Crop establishment

Crop establishment was strongly correlated with target populations in all experiments: Tulloona $R^2 = 0.97$; Breeza $R^2 = 0.99$; Terry Hie Hie $R^2 = 0.99$ and Tamarang $R^2 = 0.99$. As target population increased, crop establishment declined (Figure 4). In 2015 the highest establishment rate was 61%. This was the equivalent of 24.4 kg of the total of 40 kg seeding rate establishing.

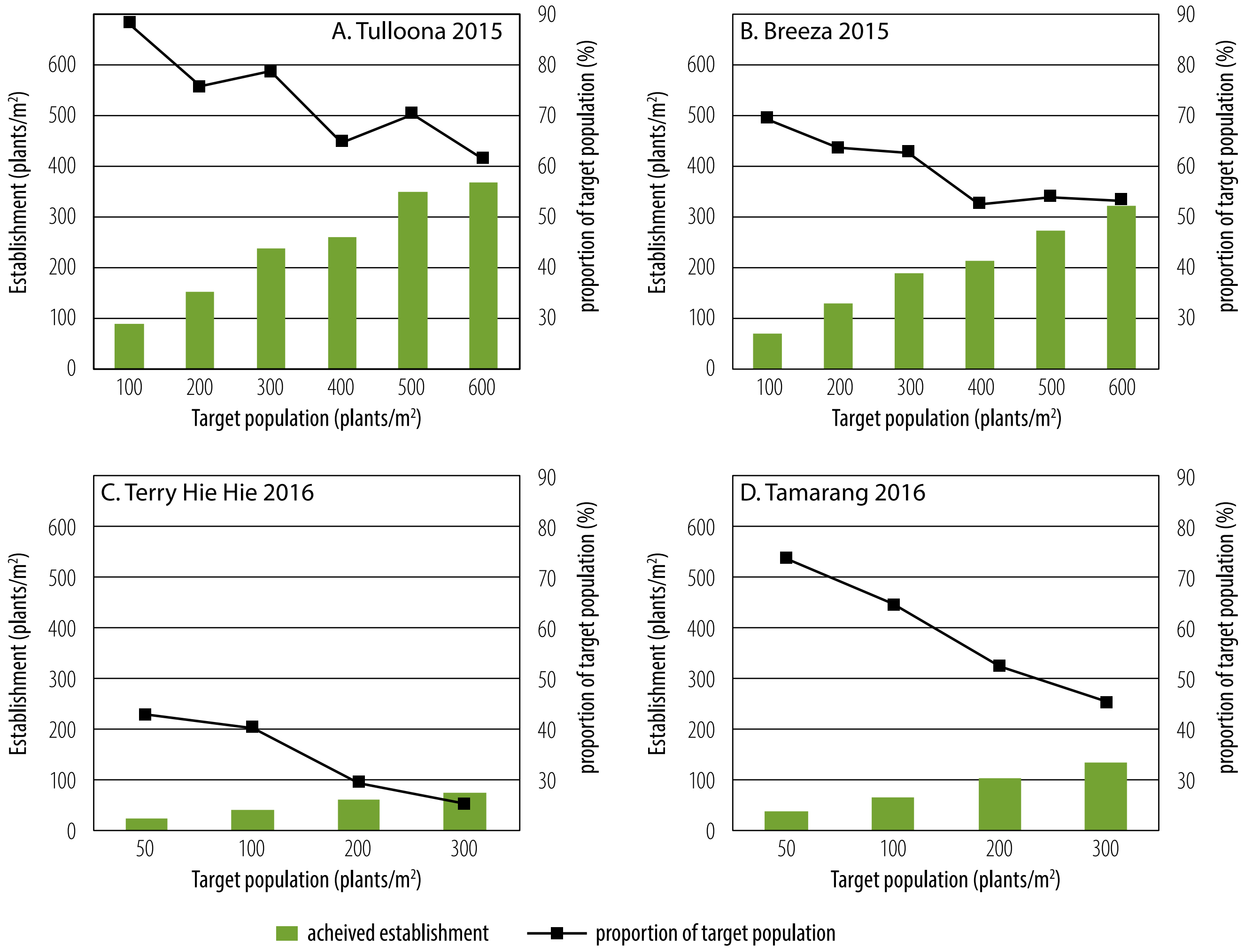


Figure 4 Achieved crop establishment compared with target populations in 2015 and 2016.
(A) Tulloona 2015 (l.s.d. [$P<0.001$] = 43 plants/m$^2$); (B) Breeza 2015 (l.s.d. [$P<0.001$ = 55 plants/m$^2$);
(C) Terry Hie Hie 2016 (l.s.d. [$P<0.001$] = 13 plants/m$^2$); (D) Tamarang (l.s.d. [$P<0.001$] = 13 plants/m$^2$).

The interaction between row spacing and seeding rates on crop establishment showed similar patterns of decline as row spacing and target populations increased (Figure 5). The percentage of seeds sown that germinated and successfully established declined as target populations increased. There was considerable variation in crop establishment at equivalent target populations between sites and seasons despite suitable seedbed moisture, seeding depth and residual pest control measures.

Air temperatures at sowing and within the three weeks following sowing at all sites varied between –1 °C to 25.3 °C at Tulloona, –4 °C to 26.8 °C at Breeza, 1.6 °C to 33.4 °C at Terry Hie Hie and –6.6 °C to 24.1 °C at Tamarang. Soil temperatures were not measured at any site.

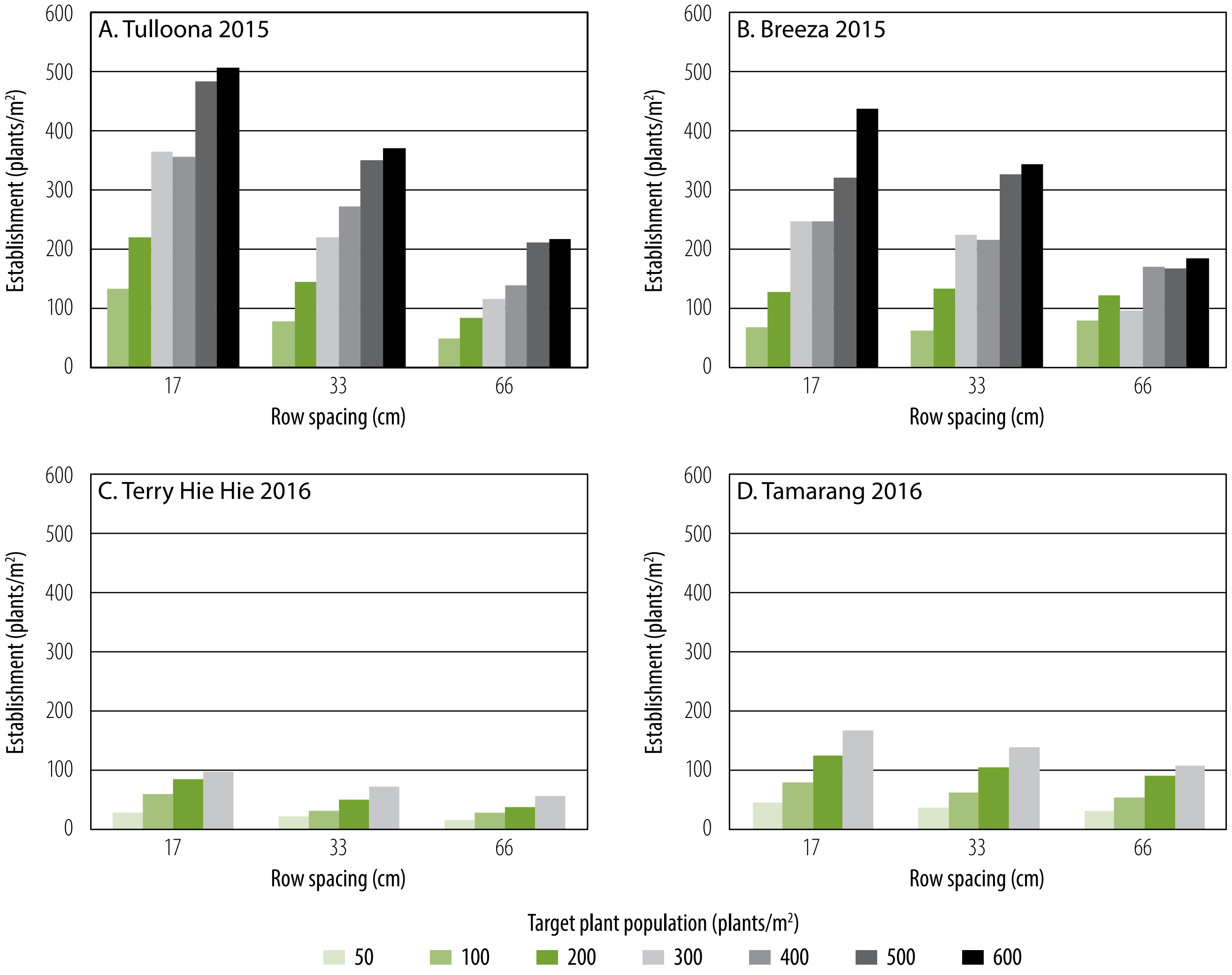


Figure 5 Interaction of row spacing and target population on achieved crop establishment in 2015 and 2016. (A) Tulloona 2015 (l.s.d. [$P<0.05$] = 86 plants/$m^2$); (B) Breeza 2015 (l.s.d. [$P<0.05$] = 88 plants/$m^2$); (C) Terry Hie Hie 2016 ([$P<0.05$] = ns); (D) Tamarang ([$P<0.05$] = ns).

### Crop production

The sowing date (SD) at each location was primarily determined when rain fell. This resulted in sites being sown late in regular sowing windows (Tulloona), or what would be considered to be well outside a suitable sowing window (Terry Hie Hie). Usually this would affect yield potential.

### Yield

Population had no significant effect on yield at either the Tulloona or Breeza site in 2015 where site averages were 1.23 t/ha and 0.53 t/ha respectively. The populations achieved were well below target (Figure 4A and B). The significant yield response to population at Terry Hie Hie in 2016 was attributed to the very low populations present. Yield from a population of 21 plants/$m^2$ was significantly lower than that from populations of 40 plants/$m^2$ (l.s.d. 0.10 t/ha; $P<0.001$).

### Harvest index

The average site harvest index at Tulloona, Breeza and Terry Hie Hie was 0.30, 0.25 and 0.23 respectively. Only at the Tulloona site were there significant differences of the effect of population on harvest index. Harvest indexes for the target populations of 100 plants/$m^2$ and 200 plants/$m^2$ were not significantly different at 0.33 and 0.31 respectively (l.s.d. 0.02; $P<0.001$).

### Seed size

Seed size was not affected by population in 2015. In 2016 at Terry Hie Hie, seed size was significantly greater at 50 plants/m$^2$ compared with 100 plants/m$^2$, measuring TSWs of 3.39 g and 3.37 g respectively (l.s.d. 0.07 g; $P<0.05$).

In 2016 at Terry Hie Hie, the effects of Rutherglen bugs during seed fill would have affected yield, harvest index and seed size.

The interaction between row spacing and plant population on yield and harvest index were not significant in any of the experiments (data not shown). Similarly there was no significant effect on TSW with the exception of the Terry Hie Hie experiment, where the effects of the Rutherglen bugs would have contributed to the seed filling capacity of the plants (data not shown).

## Conclusions

Increasing row spacing and seeding rates consistently decreased the rate of crop establishment. This effect is well known and has been shown to be attributed to interplant competition. Decreasing row spacing and seeding rates changes the spatial arrangement of seedlings and their access to space, moisture, nutrients and sunlight and can reduce interplant competition (Kemp et al. 1983).

Linseed is a small-seeded crop with sowing rates of 30–40 kg/ha being equivalent to sowing 700–900 seeds/m$^2$. This created a highly competitive environment for moisture and space during germination that continued with intense competition for nutrients and sunlight after emergence and throughout the growing season. Widening row spacing further increases this competition for resources because plants are concentrated within rows that occupy a smaller spatial area in the paddock.

These results suggest linseed should be sown at row spacing as narrow as is practically possible to improve rates of establishment and reduce inter-plant competition. In these experiments, rates of crop establishment were greatest at 17 cm spacings, progressively declining as row spacing increased. This evidence suggests reducing seeding rates by as much as half of current industry sowing rates, from 40 kg/ha to 20 kg/ha, resulting in an improved crop establishment rate. Targeting lower populations with wider row spacing would maximise crop establishment but would likely incur yield penalties when populations are below 21 plants/m$^2$.

Linseed yield was highest at the narrowest row spacing when sown before the end of May. Row spacing had less effect on yield when confounding factors like late sowing and late season pest pressure existed.

The lack of yield response to populations between 88 plants/m$^2$ and 369 plants/m$^2$ at Tulloona and 69 plants/m$^2$ and 320 plants/m$^2$ at Breeza suggested that linseed has considerable compensatory capacity across a wide population and SD range. The decline in yield at a population of 21 plants/m$^2$ indicates a lower population threshold where linseed is unable to compensate to maintain yield. An upper population threshold where yield declines has not been determined.

These experiments aimed to determine optimal plant populations and row spacing for linseed. They have provided some insight into the plasticity of linseed to spatial arrangement in the field and highlighted levels of seedling mortality at currently accepted industry seeding rates.

Crops are grown on wide rows for reasons including stubble management, crop placement for disease management, canopy manipulation for disease management, and moisture conservation. This data suggests that small reductions in row spacing while maintaining the practical advantages of increased row spacings, are likely to improve establishment rates and enable seeding rates to be reduced with no loss in yield potential.

Sowing date had major effects on yields. SD, in some experiments, was late or well outside appropriate sowing windows. This subsequently dominated production responses above that of population and row spacing.

Further research is required to quantify the effects of row spacing and population in linseed sown within optimal sowing windows.

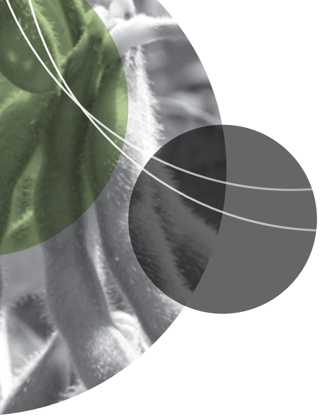
## Reference

Kemp DR, Auld BA and Medd RW (1983). Does optimizing plant arrangements reduce interference or improve the utilization of space? Agricultural Systems 12, 31–36.

## Acknowledgements

This experiment was part of the project 'Tactical agronomy of minor crops (safflower, linseed, sunflower)', DAN00197, a joint investment between NSW DPI and GRDC.

Technical assistance from Stephen Morphett, Peter Formann, Jim Perfrement, Rosie Holcombe and Stacey Cunningham (all NSW DPI) is gratefully acknowledged. Thank you to Jack Gooderham, 'Myling' Tulloona, Alan Riordan, 'Nullabean' Nea via Breeza, Robert and David Anderson, 'Maneroo', Terry Hie Hie and David Ronald, 'The Point' Tamarang for hosting the experiments. Seed was kindly supplied by Austgrains, Moree. This report was reviewed by Bernie Dominiak (NSW DPI).



# Crop protection

## Crown rot resistance rating does not necessarily reflect yield performance when disease is present – six sites in 2017

Steven Simpfendorfer[1], Greg Brooke[2], Rick Graham[1] and Robyn Shapland[1]

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### Key findings

- Average yield loss from crown rot across the six field sites in 2017 ranged from 16% (0.46 t/ha) in the bread wheat variety Sunguard$^{\phi}$ to up to 50% (1.32 t/ha) in the durum variety DBA Bindaroi$^{\phi}$.
- A variety's resistance rating was not a good reflection of its yield performance when infected with crown rot as tolerance level also dictates the rate of yield loss from this disease.
- Variety choice resulted in an 8–34% yield benefit over growing the standard bread wheat variety EGA Gregory$^{\phi}$ when infected with crown rot.
- Variety choice is not the sole solution to crown rot.
- Variety choice can maximise profit in the current season, but does not reduce inoculum levels for subsequent cereal crops as all are susceptible to crown rot infection.

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### Introduction

Crown rot (CR), caused predominantly by the fungus *Fusarium pseudograminearum*, remains a major constraint to winter cereal production in the northern grains region. Cereal varieties differ in their resistance to CR, which can significantly affect their relative yield in the presence of this disease by limiting the severity of infection that develops within a season. However, recent research has demonstrated that varieties also differ in their tolerance to CR. Tolerant varieties have a lower level of yield loss when infected, which appears to be independent of their resistance rating.

Six replicated field experiments were conducted in 2017 across central/northern NSW extending into southern Qld, to examine CR effects on the yield of four barley, four durum and 12 bread wheat varieties. Sites varied in their sowing date (SD), plant available soil water (PAW) at sowing and in-crop rainfall (Table 1), which interacted with CR expression.

## Site details

Details of the six experiment sites are in Table 1

Table 1 Crown rot experiment site details – 2017.

| Site | Location | Sowing date | PAW at sowing (0–120 cm) | In-crop rainfall (mm) |
|---|---|---|---|---|
| Wongarbon | Central west NSW | 23 May | 145 mm | 122 |
| Gilgandra | Central west NSW | 11 May | 120 mm | 63 |
| Edgeroi | North eastern NSW | 31 May | 295 mm | 164 |
| Rowena | North western NSW | 7 June | 185 mm | 103 |
| Westmar | Southern Qld | 22 May | 170 mm | 157* |
| Meandarra | Southern Qld | 18 May | 195 mm | 204* |

* Majority fell in October

## Treatments

### Varieties (20)

Four barley varieties:

- susceptible–very susceptible (S–VS) = La Trobe$^{\phi}$
- susceptible (S) = Commander$^{\phi}$, Compass$^{\phi}$, and Spartacus CL$^{\phi}$.

Four durum varieties:

- VS = Jandaroi$^{\phi}$
- S–VS = DBA Lillaroi$^{\phi}$, DBA Bindaroi$^{\phi}$ and the numbered line AGD043 which is not currently rated.

Twelve bread wheat varieties:

- S = EGA Gregory$^{\phi}$
- moderately susceptible–susceptible (MS–S) = Suntop$^{\phi}$, LongReach Mustang$^{\phi}$, LongReach Lancer$^{\phi}$, LongReach Gauntlet$^{\phi}$, LongReach Flanker$^{\phi}$, Coolah$^{\phi}$ and Sunmate$^{\phi}$
- moderately susceptible (MS) = Sunguard$^{\phi}$, Mitch$^{\phi}$, LongReach Reliant$^{\phi}$ and LongReach Spitfire$^{\phi}$.

### Pathogen treatment

Added or no added CR at sowing using sterilised durum grain colonised by at least five different isolates of *F. pseudograminearum* at a rate of 2.0 g/m of row at sowing.

## Results

### Yield

Averaged across the 20 cereal entries, yield with no added CR inoculum ranged from 3.82 t/ha at Wongarbon down to 2.15 t/ha at Rowena in 2017 (Figure 1). Crown rot infection (added CR) significantly reduced yield at all sites ranging from a 20% reduction at Gilgandra and Edgeroi, to 26% at Wongarbon and Meandarra, up to 43% at Westmar and 45% at Rowena.

An across-site analysis of the six sites was conducted to examine the yield response of the 20 cereal entries to CR infection in 2017. Average yield in the no added CR treatment ranged from 2.26 t/ha in the durum variety Jandaroi$^{\phi}$ up to 3.27 t/ha in the barley variety Compass$^{\phi}$ (Figure 2). The four durum entries were, on average, 0.40–0.53 t/ha lower yielding than the bread wheat or barley entries, respectively.

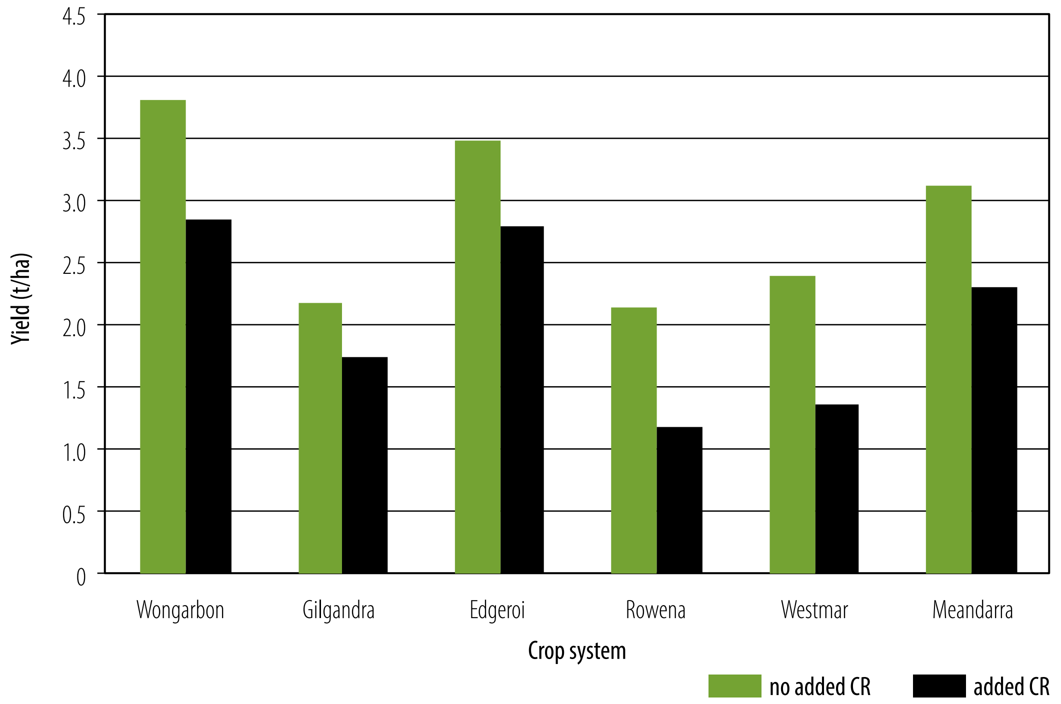

Figure 1 Average yield of cereal entries at six sites in 2017 with no added and added crown rot inoculum (l.s.d. ($P$<0.01) = 0.115 t/ha).

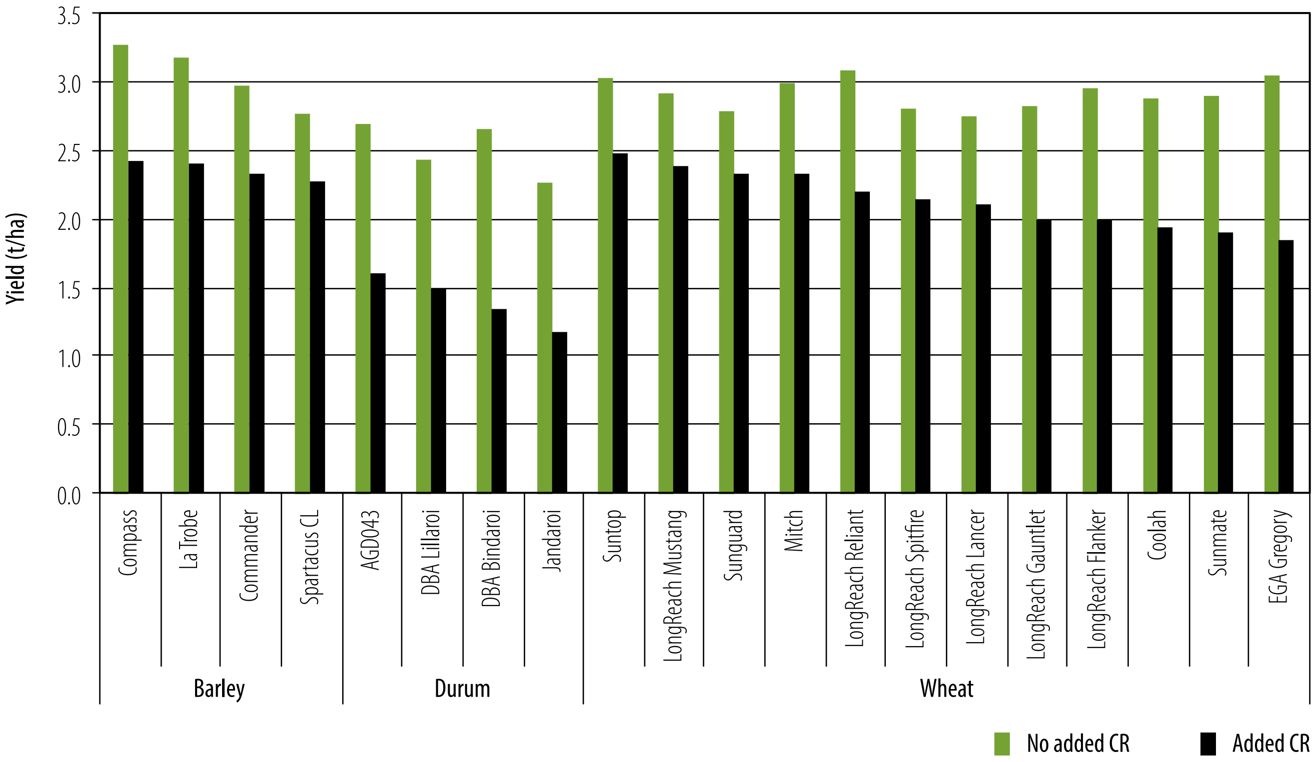

Figure 2 Average yield of four barley, four durum and 12 bread wheat varieties across six sites in 2017 with no added and added crown rot inoculum (l.s.d. ($P$<0.01) = 0.142 t/ha).

Adding CR inoculum at sowing significantly reduced the yield in all entries, which ranged from an average of 16% (0.46 t/ha) in the bread wheat variety Sunguard$^{\phi}$ up to 50% (1.32 t/ha) in the durum variety DBA Bindaroi$^{\phi}$ (Figure 2). Yield loss was highest in the four durum entries (average 44%, range 39% to 50%), followed by the 12 bread wheats (average 27%, range 16% to 39%) and lowest in the four barley entries (average 22%, range 17% to 26%).

Within the bread wheat entries, seven were rated MS–S to CR. However, their average extent of yield loss varied from 18% in Suntop$^{\phi}$ and LongReach Mustang$^{\phi}$ up to 24% in LongReach Lancer$^{\phi}$, 29% in LongReach Gauntlet$^{\phi}$, 32% in Coolah$^{\phi}$, 33% in LongReach Flanker$^{\phi}$ and 35% in Sunmate$^{\phi}$ (Figure 2).

Suntop$^{\phi}$, although being MS–S to CR infection has been demonstrated in other studies to have a level of tolerance to CR that reduces the extent of yield loss. It appears that LongReach Mustang$^{\phi}$ could also have a level of improved tolerance to CR.

In the four MS bread wheat varieties, average yield loss ranged from 16% in Sunguard$^{\phi}$ up to 28% in LongReach Reliant$^{\phi}$, which overlapped with that measured in the MS–S entries.

The resistance ratings also do not appear to be a good reflection of yield loss when comparing across some of the cereal types, especially with barley. Three of the barley varieties are rated S while La Trobe$^{\phi}$ is rated S–VS. However, their average yield loss ranged from 17% in Spartacus CL$^{\phi}$ up to 26% in Compass$^{\phi}$ (Figure 2). This was around half the extent of yield loss experienced in the S–VS and VS durum varieties of 39–50%. Barley tends to mature earlier than bread wheat or durum, which can provide an escape from later season moisture/temperature stress that exacerbates the expression of the disease. As seen in these six field experiments, this escape from stress reduces the yield loss from CR even though barley is still quite susceptible to infection.

## Conclusions

Cereal crop species and variety choice affected yield in the absence and presence of CR infection, which differed by 1.01 t/ha and 1.30 t/ha, respectively between the best and worst entries when averaged across the six sites in 2017. Yield loss associated with increased CR infection in the added CR treatment ranged from 16% in the bread wheat variety Sunguard$^{\phi}$ up to 50% in the durum variety Jandaroi$^{\phi}$.

Comparing varieties in terms of percentage yield loss can be potentially misleading for growers and advisers as it masks the actual yields obtained in the presence of CR. An alternate method is to compare yield performance with a standard variety such as EGA Gregory$^{\phi}$.

In the no added CR treatment, the bread wheat varieties Coolah$^{\phi}$, LongReach Gauntlet$^{\phi}$, LongReach Spitfire$^{\phi}$, Sunguard$^{\phi}$ and LongReach Lancer$^{\phi}$ were 0.17 t/ha to 0.29 t/ha lower yielding than EGA Gregory$^{\phi}$. The other six bread wheat entries had an equivalent yield to EGA Gregory$^{\phi}$ in the no added CR treatment averaged across the six sites in 2017. All four durum entries were between 0.35 t/ha to 0.78 t/ha lower yielding than EGA Gregory$^{\phi}$ in the no added CR treatment. With the four barley varieties, only Compass$^{\phi}$ was higher yielding (0.23 t/ha) than EGA Gregory$^{\phi}$, La Trobe$^{\phi}$ and Commander$^{\phi}$ had equivalent yield and Spartacus CL$^{\phi}$ was 0.28 t/ha lower yielding.

The comparison between varieties was markedly different in the presence of added CR. With the 12 bread wheat varieties, only LongReach Flanker$^{\phi}$, Coolah$^{\phi}$ and Sunmate$^{\phi}$ had an equivalent yield to EGA Gregory$^{\phi}$. The remaining eight bread wheat varieties were between 0.15 t/ha (LongReach Gauntlet$^{\phi}$) and 0.63 t/ha (Suntop$^{\phi}$) higher yielding than EGA Gregory$^{\phi}$ in the presence of CR. This represents an 8–34% yield benefit. All four durum varieties were between 0.24 t/ha to 0.68 t/ha lower yielding than EGA Gregory$^{\phi}$ where CR was added, representing a 13–37% yield penalty. In contrast, all four barley varieties were 0.43–0.57 t/ha higher yielding than EGA Gregory$^{\phi}$, a 23–31% yield benefit.

These crop or variety choices could have maximised profit in this growing season but will not reduce inoculum levels for subsequent crops, because all winter cereal varieties are susceptible to CR infection. Winter cereal crop and variety choice is therefore not the sole solution to CR, but rather just one element of an integrated management strategy to limit losses from this disease.

Crown rot resistance ratings are based on the extent of basal browning which develops during the season in infected plants and should **not** be confused by growers as necessarily reflecting the yield performance of a variety in the presence of this disease. Growers should consult relative yield performance data, as presented here, to provide a better indication of how different varieties are likely perform in their paddocks that have a medium–high risk of crown rot infection.

## Acknowledgements

This project was co-funded by NSW DPI and Grains Research and Development corporation (GRDC) under the 'National crown rot management and epidemiology project' (DAN00175).

Thanks to the grower cooperators Kevin Kilby, James Coggan, Angus Kelly, Cameron Williams, Chris Cook and Will Winston-Smith for providing the experiment sites. Peter Matthews (NSW DPI) for helping to organise operations at the Gilgandra site, Douglas Lush (DAFQ) for the Westmar and Meandarra sites, Matt Gardner (AMPS) for the Rowena site and Jim Perfrement, Mick Dal Santo, Stephen Morphett (all NSW DPI) for the Edgeroi site. Thanks to Chrystal Fensbo (NSW DPI) for grain quality assessments and to Jason Lowien (GrainCorp) for use of an NIR machine to determine grain protein levels.

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# Crown rot stubble inoculum levels within season and further growth after harvest

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## Key findings

- A preliminary survey in 2017 found that in the northern region (NSW and Qld) the crown rot fungus was, on average, present in 46% of crowns, with 19% having fungal growth of up to 18 cm within tillers at harvest.
- A laboratory experiment showed that moist conditions promoted further fungal growth postharvest in inoculated cereal stubble (growing almost 1 cm per day over five days at 100% humidity).
- Inoculum levels in postharvest stubble can fluctuate with differing weather patterns.
- Postharvest crown rot fungus growth did not differ between bread wheat, durum wheat or barley stubble.

## Introduction

Crown rot, caused by the fungus *Fusarium pseudograminearum* (*Fp*), is a significant disease of winter cereal crops in northern NSW and southern Qld. The fungus infects through a growing plant's roots, crown, lower stem or leaf sheaths. Once infection has been established, fungal mycelium can colonise the entire stem (Mudge et al., 2006) and survive in these residues for at least three years after the initial infection (Summerell and Burgess, 1988).

To date, a large effort has been made to investigate the pathogenic (infectious) phase of crown rot in winter cereals in Australia (e.g. disease mechanisms, disease impacts, yield loss analyses, breeding etc.). However, stubble-borne pathogens such as *Fp* spend the majority of their life-cycle in their saprophytic phase (i.e. surviving in stubble after the plant matures and dies). This phase has received much less research attention over the years, even though inoculum survival is a major challenge for crown rot management. Specifically, there is limited knowledge about what drives *Fp* saprophytic growth. For example, early studies suggested that moisture can promote fungal growth within standing stubble (Summerell and Burgess, 1988). However, it is unknown exactly what environmental conditions favour vertical growth in standing stubble, and how far or fast the fungus will colonise residues under these conditions.

Two experiments were conducted to investigate *Fp* inoculum within stubble:

1. Preliminary survey: to determine how far the crown rot fungus has progressed naturally within tillers at harvest (vertical colonisation) across the major grain growing regions in Australia.
2. Controlled environment experiment: to identify if specific cereal stubble types (durum wheat, bread wheat or barley) or moisture conditions (wet, wet then dry and dry) promote *Fp* growth in postharvest stubble.

## Methods

### Preliminary experiment – vertical colonisation of cereal stubble at harvest

A total of 59 cereal stubble samples from the 2017 harvest were obtained through the National Paddock Survey (BWD000025) and National Variety Trials (NVT). To assess vertical colonisation, 1.5 cm segments were taken from the main tillers at 4 cm intervals up to harvest height (which differed for each sample). Segments were surface sterilised and plated on laboratory media to assess *Fp* presence at the different heights. This data was used to approximate how far, on average, the fungus had progressed within stubble in northern region (NSW and Qld), southern region (Vic and SA) and western region (WA) regions (Table 2).

### Controlled environment experiment – saprophytic growth in stubble

The effect of different cereal stubble types (e.g. durum wheat, bread wheat or barley) and moisture conditions on saprophytic growth was investigated. The following factors were used:

1. Moisture conditions (Table 1)
2. Cereal type. Stubble from durum wheat (DBA Bindaroi⁽ᶲ⁾), bread wheat (Suntop⁽ᶲ⁾) and barley (Commander⁽ᶲ⁾) collected from paddocks at the Tamworth Agricultural Institute in 2017.
3. Isolate type (isolate A from Wongarbon, NSW and isolate B from Horsham, Vic).

Table 1 Average relative humidity and temperature conditions for each moisture treatment (wet, wet then dry and dry).

| Moisture treatment | Relative humidity (%) | Days exposed | Temperature (°C) |
|---|---|---|---|
| Wet | 100.0 | 0–5 | 24.7 |
| Wet then dry | 100.0<br>55.4 | 0–2.5<br>2.5–5 | 24.6<br>24.6 |
| Dry | 53.4 | 0–5 | 24.6 |

Moisture treatments were randomly assigned to humidity chambers (main plots), while combinations of cereal type and isolate were randomly assigned to plates (sub plots) within each humidity chamber. Each treatment, being the combination of moisture treatment, cereal type and isolate, was replicated four times.

Stubble pieces cut to 8.5 cm in length were sterilised (autoclaved on two consecutive days) and the base inoculated with an agar plug of an isolate (Figure 1a) before being inserted upright onto nail plates to simulate standing stubble (Figure 1b). Each nail plate consisted of four stubble pieces of the same cereal type, infected with the same isolate. Nail plates were subsequently placed into one of three humidity chambers set up as per Table 1 and run in a room with alternating ultra-violet light (12 hour light/12 hour dark) at a constant 25 °C. Tinytag data loggers (Gemini Data Loggers, Chichester UK) were used to log temperature and relative humidity.

After five days, tillers were removed and trimmed into eight individual 1 cm sections, with the inoculated end (0.5 cm of base) discarded. These 1 cm sections were sequentially plated on laboratory media (Figure 1c) and incubated under alternating ultra-violet light (12 hour light/12 hour dark) at 25 °C. Tiller segments were assessed for *Fp* presence at each height (1 cm–8 cm) to determine fungal growth up the length of the tillers.

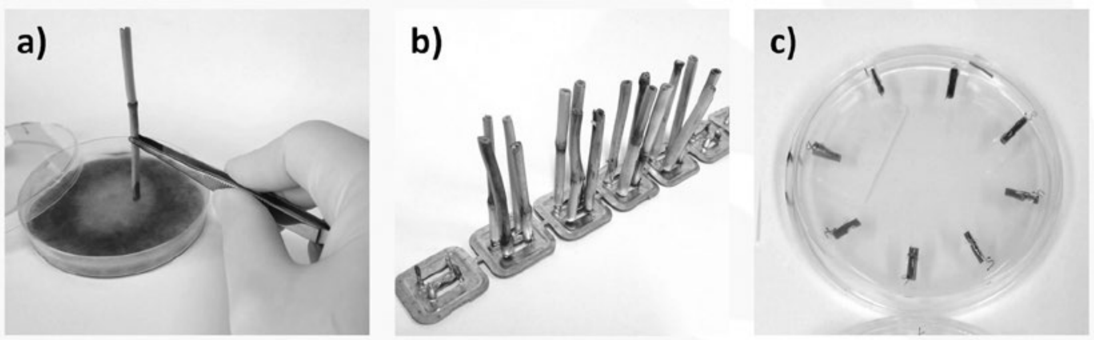

Figure 1 (a) Sterile stubble inoculated with an *Fp* agar plug. (b) Stubble pieces on nail plates after inoculation. (c) Stubble 1 cm pieces on agar for culturing after moisture treatment.

## Results

### Preliminary survey

The northern region sites had a higher incidence of inoculum at all stubble heights in 2017, than the other two regions (Table 2). This ranged from 46% in the crown section (0–1.5 cm) and gradually declined to 19% at 16.5–18 cm. Inoculum was found as high as 33 cm on the tallest sample received. Inoculum assessment in postharvest stubble is routinely isolated from the crown and/or 5 cm up the stem. This preliminary survey shows that inoculum is not just retained within stubble at the base (0–5 cm), but substantially higher up the tiller.

Table 2 Vertical incidence of *Fp* (%) in 2017 cereal stubble, averaged across all sites (n) for each region.

| Stubble sample height (cm) | Northern (n = 27) | Southern (n = 6) | Western (n = 26) |
|---|---|---|---|
| 0–1.5 (crown) | 46 | 25 | 17 |
| 5.5–7 | 40 | 7 | 16 |
| 11–12.5 | 26 | 8 | 7 |
| 16.5–18 | 19 | 0 | 3 |

### Controlled environment experiment

Moisture conditions significantly affected *Fp* colonisation in stubble (Figure 2). The wet treatment (Table 1) resulted in the highest fungal growth, with a maximum extent of colonisation ranging from 3.8 cm to 4.2 cm (isolate A) and 4.3–4.6 cm (isolate B) (Figure 2).The wet then dry treatment resulted in approximately half the growth compared with the wet treatment, with the fungus progressing an average of 1.7–2.2 cm (isolate A) and 1.8–2.4 cm (isolate B). The dry treatment promoted the least fungal growth, with an average colonisation of 0.4–0.5 cm (isolate A) and 0.3–0.6 cm (isolate B). The *Fp* growth rate was equal to almost 1 cm per day under high (100%) humidity in the wet treatment. Temperature was unlikely to have affected colonisation as conditions were similar across treatments (Table 1).

Although the moisture treatments in this experiment show the largest effect on saprophytic growth, the interaction between isolate, moisture treatment and cereal type was also significant ($P = 0.0364$, Figure 2). However, trends are difficult to ascertain for isolates or cereal types. Both isolates still produced a substantial rate of vertical growth (almost 1 cm per day at 100% humidity) over the five days, with moisture significantly driving saprophytic *Fp* fitness.

## Conclusions

### Preliminary survey

Almost one in five tillers collected in the north contained inoculum at 16.5–18 cm (Table 2). Inoculum retained in stubble at this height could become problematic when pulses such as chickpea are used as break crops due to their lower harvest height requirements. Harvesting shorter stature break crops could potentially spread the infected cereal residues from the previous year into 'clean' inter-row spaces where the fungus can more readily infect a newly sown cereal crop. One way to restrict the *Fp* saprophytic growth within stubble after harvest could be to reduce stubble length (e.g. by lowering the harvest height). This would limit the suitable substrate and resources available for the fungus to colonise, even if moisture conditions are suitable for growth. Further controlled environment experiments and validating field results is required before specific recommendations can be developed.

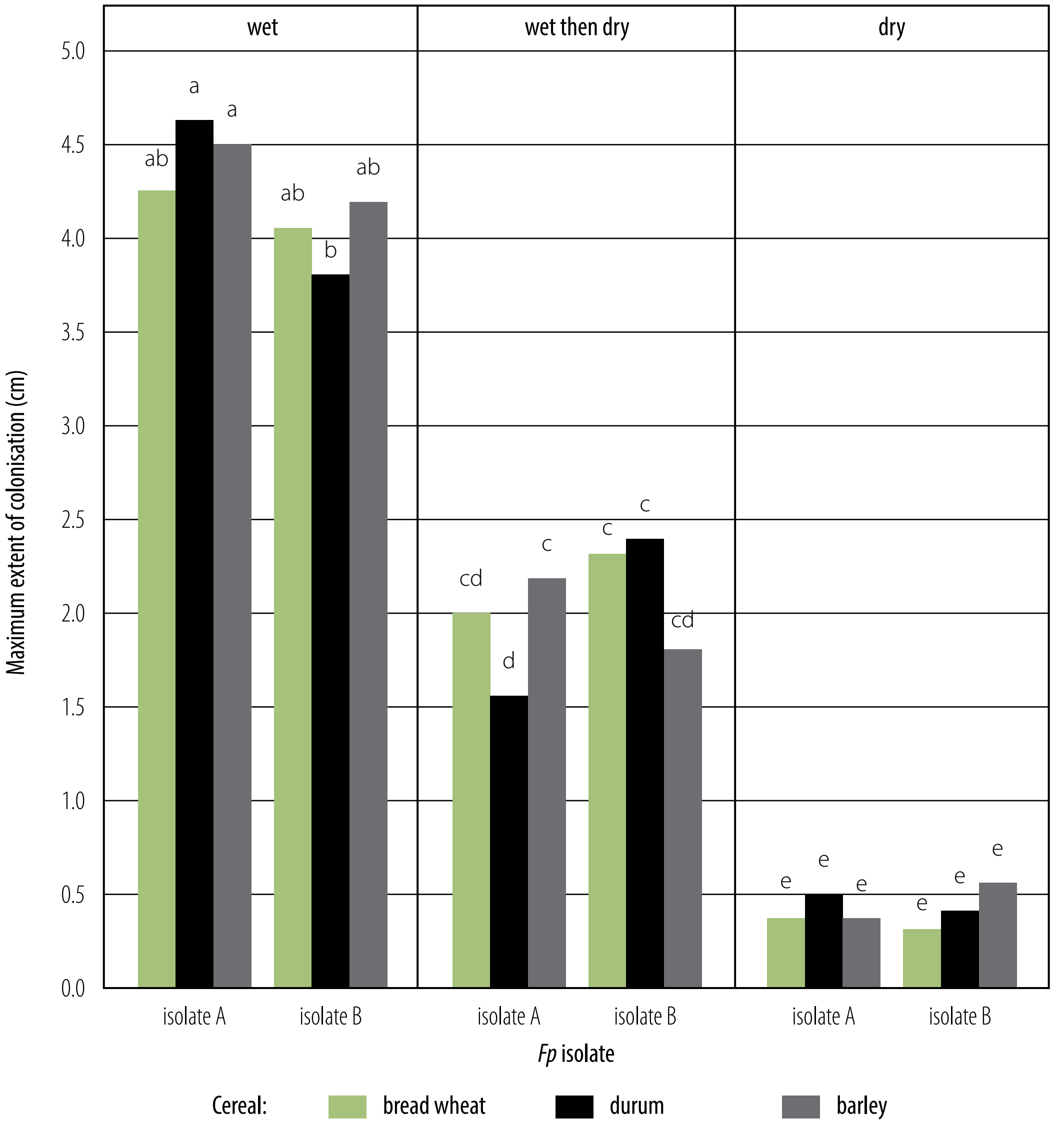

Figure 2 The saprophytic colonisation of cereal stubble inoculated with *Fp* after five days. Bars with the same letter are not statistically different.

## Controlled environment experiment

Wet conditions (i.e. high humidity) appear to have the potential to cause explosive *Fp* saprophytic growth in cereal stubble. This reinforces that inoculum levels are not static within stubble, and they can fluctuate with different weather patterns during fallow or break crop periods. Furthermore, if moisture conditions allow, *Fp* is likely to progress up the stem after harvest regardless of stubble type. This means that any yield advantages shown by different cereal types (e.g. crown rot tolerance in barley) with crown rot infection present are unlikely to slow saprophytic growth in postharvest stubble. This supports existing recommendations that cereal or variety selection can increase yield, but not reduce inoculum levels, under crown rot pressure.

Growers need to be aware of the presence of crown rot inoculum in retained cereal stubble to inform disease management strategies. Some seasons (e.g. wet finish) and varieties (e.g. barley) are not always conducive to crown rot expression even when infection is present. This means inoculum can be found in stubble without observing obvious symptoms (e.g. whiteheads or extensive stem browning). This 'silent inoculum' could lead growers to believe they have clean stubble, when in reality there is *Fp* inoculum waiting to infect the next cereal crop. These experiments show that inoculum can also move up stems if moisture conditions allow, increasing inoculum levels and potentially interfering with current disease management strategies. At present, crown rot diagnostic services through NSW DPI and risk predictors such as PREDICTA®B can be used to determine the presence of crown rot inoculum in suspect paddocks to guide disease management decisions.

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## 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 Grains Research and Development Corporation (GRDC); the authors would like to thank them for their continued support. Ms Petronaitis would like to thank both the GRDC and NSW DPI for co-funding her position under Capacity Building (DAN00200), and further funding this research topic under a GAPP PhD scholarship. Ms Petronaitis would like to thank Jenny Wood, Joop van Leur, Gururaj Kadkol and Rick Graham from NSW DPI for providing materials and equipment for experiments. Technical assistance provided by Chrystal Fensbo, Finn Fensbo and Karen Cassin is gratefully acknowledged.

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# Impact of durum and bread wheat variety choice on final root lesion nematode soil populations – Wongarbon 2018

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## Key findings

- Winter cereal crop and variety choice can have a large impact on the build-up of the nematode *Pratylenchus thornei* (*Pt*) population within paddocks which can then impact on the performance of following crops and/or varieties in the rotation.
- Significant differences were evident amongst varieties with a 5.3 fold difference in final *Pt* populations between the best (PBICR-08-012TC-3) and worst (Mitch$^{(\phi)}$).
- Very susceptible varieties (e.g. Mitch$^{(\phi)}$) should be avoided in paddocks where *Pt* is known to be present at any level as they can increase the population to high risk levels in one season.
- *Pratylenchus neglectus* (*Pn*) was also present at the site at a much lower density than *Pt* with varietal differences in final populations evident. However, all varieties either maintained or lowered starting *Pn* levels at this site in 2018 which remained at a low level of risk.

## Introduction

The root lesion nematode (RLN) *Pratylenchus thornei* (*Pt*) is widespread in cropping soils throughout northern NSW and southern Qld where it feeds on root systems throughout the soil profile. A second RLN species, *P. neglectus* (*Pn*) is also present but at lower frequency and population densities across the region and mainly feeds on roots in the 0–15 cm soil layer. Winter cereal varieties differ in their extent of yield loss from either *Pt* and *Pn* (tolerance) and the numbers of nematodes that multiply in their root systems within a season (resistance). Interestingly, an individual variety can differ markedly in their resistance or tolerance to these two RLN species. Resistance to RLNs is an important consideration as it dictates a variety's effect on subsequent crops in the rotation. That is, more susceptible varieties allow greater RLN multiplication in their root systems over a season. The higher the resulting RLN population left in the soil, the greater the potential for a negative effect on the yield of subsequent crops.

The effect of four durum and 16 bread wheat entries on final *Pt* and *Pn* populations was determined in a replicated field experiment near Wongarbon in central-west NSW in 2018.

## Site details

| | |
|---|---|
| **Location** | 'Hillview', Wongarbon, Latitude 32°33' 50.87" S, Longitude 148°71' 49.83" E |
| **Co-operator** | The Kelly family |
| **Sowing date** | 29 May 2018 |
| **Fertiliser** | 80 kg/ha Granulock Z Extra (10.5 N:19.7 P:8.0 S:5 Zn) at sowing |
| **Starting nitrogen (N)** | 95 kg N/ha to 120 cm |
| **PAWC** | ~90 mm plant available soil water (0–120 cm) |
| **Rainfall** | The growing season rainfall was 222 mm |

| | |
|---|---|
| **PreDicta B** | 14.6 *Pt*/g soil (medium risk), 2.2 *Pn*/g soil (low risk) at sowing (0–30 cm) |
| **Post-harvest soil sampling date** | 9 April 2019 with a bulk of 15 cores (0–30 cm) per plot |

## Treatments

### Varieties (20)

- Four durum entries: DBA Lillaroi$^{\Phi}$, DBA Bindaroi$^{\Phi}$ plus the numbered lines AGTD090 and TD1602.
- Sixteen bread wheat entries: EGA Gregory$^{\Phi}$, Coolah$^{\Phi}$, LongReach Lancer$^{\Phi}$, LongReach Reliant$^{\Phi}$, LongReach Spitfire$^{\Phi}$, LongReach Mustang$^{\Phi}$, LongReach Oryx$^{\Phi}$, Mitch$^{\Phi}$, Suntop$^{\Phi}$, Sunguard$^{\Phi}$, Sunprime$^{\Phi}$ and numbered lines LPB14-3634, PBICR-08-012TC-3, PBICR-10-108-29, PBICR-10-011-3 and PBICR-10-109-24.
- All entries sown to achieve a target plant population of 100 plants/m$^2$.

### Pathogen treatment

Added or no added crown rot at sowing using sterilised durum grain colonised by at least five different isolates of *Fp* at a rate of 2.0 g/m of row at sowing.

## Results

Inoculation with crown rot at sowing had no impact on final soil *Pt* or *Pn* densities measured after harvest. There was a 5.3 fold difference in final *Pt* densities between the lowest (PBICR-08-012TC-3) and highest (Mitch$^{\Phi}$) entry (Figure 1). Generally, there was lower variation in final *Pt* populations with the four durum entries, which were on the lower end compared with many of the bread wheat entries. The *Pt* population across the site was measured as 14.6 *Pt*/g soil which was just below the high risk threshold of >15 *Pt*/g. All four durum entries lowered the *Pt* population when measured post-harvest. However, there was considerable variation between the 16 bread wheat entries with PBICR-08-012TC-3 and Suntop$^{\Phi}$ roughly halving the starting *Pt* population whilst Mitch$^{\Phi}$ more than doubled it (Figure 1).

The starting *Pn* population was considerably lower than that of *Pt* at only 2.2 *Pn*/g soil which is consistent with previous paddock surveys across the northern region. All entries either maintained or reduced the starting *Pn* population at this site in 2018 which all remained at a low level of risk. However, there was still a 3.2 fold difference in final *Pn* densities between the lowest (LongReach Reliant$^{\Phi}$) and highest entry (LongReach Lancer$^{\Phi}$).

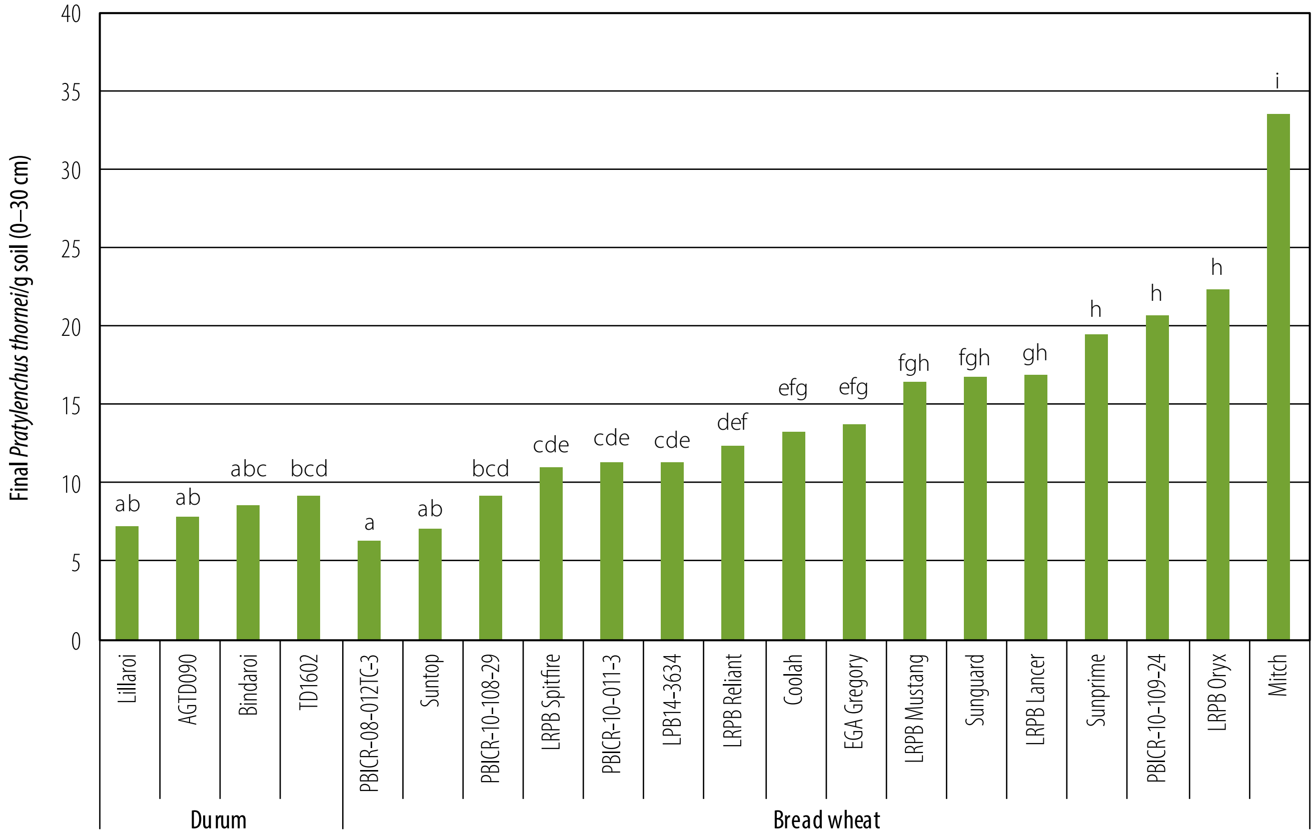

Figure 1 Final *Pratylenchus thornei* soil populations (*Pt*/g soil; 0–30 cm) produced by four durum and 16 bread wheat entries – Wongarbon 2018.
Bars with the same letter are not significantly different (*P*=<0.001) based on transformed data (ln(x + 1)). Back-transformed values are presented in figure 1.

## Conclusions

Cereal crop and variety choice can significantly affect *Pt* build-up within paddocks. There was a 5.3 fold difference in populations between the best and worst entry at Wongarbon in 2018. In the northern grains region, starting *Pt* populations of below 2.0 *Pt*/g soil are considered low risk; populations between 2.0 and 15.0 *Pt*/g soil are considered medium risk; and above 15.0 *Pt*/g soil is considered high risk for yield loss in intolerant crops or varieties. Seven bread wheat entries (LongReach Mustang$^{(\phi)}$, Sunguard$^{(\phi)}$, LongReach Lancer$^{(\phi)}$, Sunprime$^{(\phi)}$, PBICR-10-109024, LongReach Oryx$^{(\phi)}$ and Mitch$^{(\phi)}$) elevated the *Pt* population to a high risk level, all other entries either maintained or decreased *Pt* soil densities to within a medium risk level for yield loss in a subsequent crop in 2019.

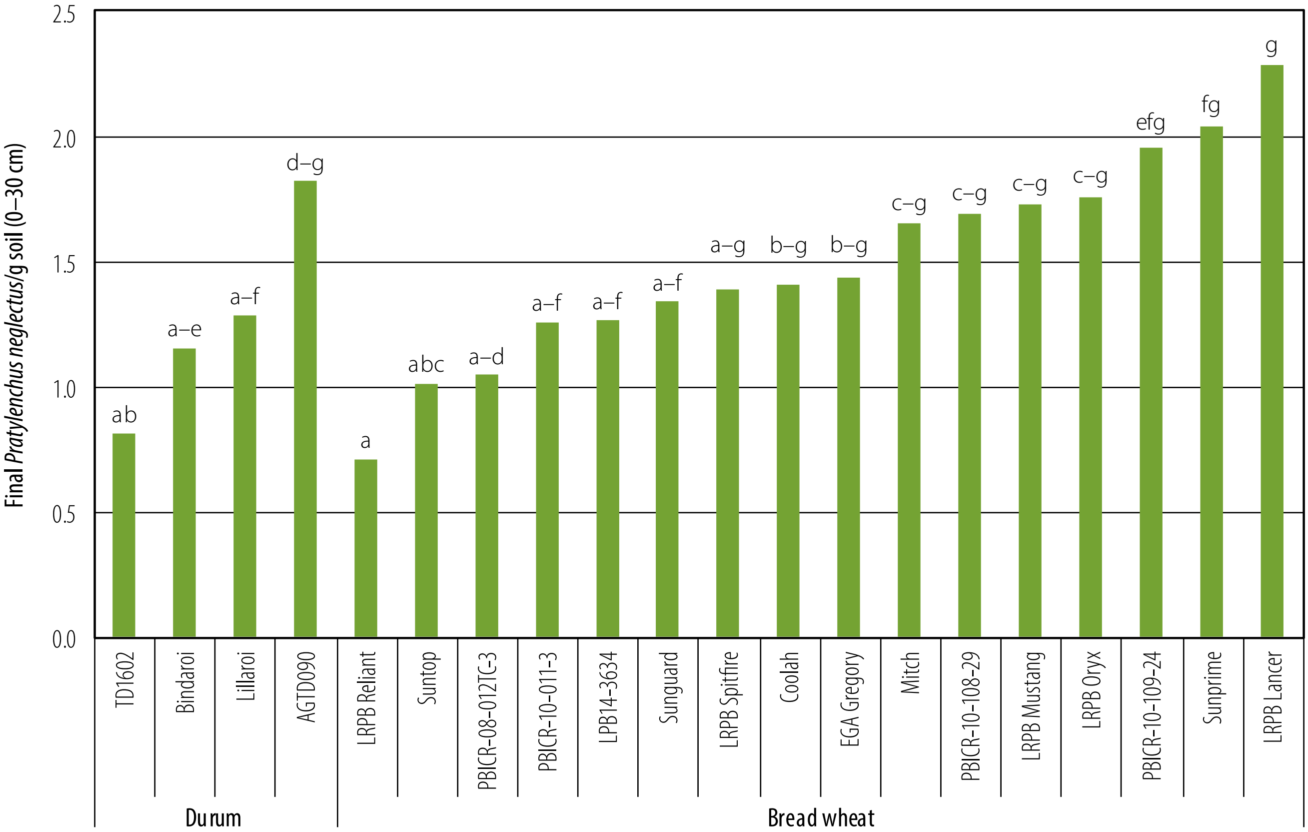

Figure 2 Final *Pratylenchus neglectus* soil populations (*Pn*/g soil; 0–30 cm) produced by four durum and 16 bread wheat entries – Wongarbon 2018.
Bars with the same letter are not significantly different (*P*=0.072) based on transformed data (ln(x + 1)). Back-transformed values are presented in figure 2.

**Acknowledgements**

This experiment was part of the project 'National Nematode Epidemiology Management Program' (DAV00128) a joint investment between NSW DPI and the Grains Research and Development Corporation (GRDC).

Thanks to the Kelly family for providing the trial site and Robyn Shapland, Jason McCulloch, Patrick Mortell and Chrystal Fensbo (NSW DPI) for collecting post-harvest PREDICTA B soil samples. Root lesion nematode levels were determined using the DNA-based soil test service PREDICTA B provided by the South Australian Research and Development Institute (SARDI).

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# Phytophthora root rot–reduced yield losses in crosses with wild *Cicer* relatives – Warwick 2018

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## Key findings

- Crosses between chickpea and wild *Cicer* species, such as the breeding lines CICA1328, CICA1718 and CICA1812, offer improved levels of resistance to phytophthora root rot (PRR).
- Avoid paddocks prone to waterlogging, with poorly drained areas, or a history of lucerne, medics or chickpea PRR.
- Use the most PRR-resistant varieties (rated MR) where there is a disease risk.
- A higher number of chickpea varieties now have improved resistance to PRR, but substantial yield losses (40–68%) can still occur, even in a relatively dry season, if one soil saturation rainfall event occurs.

## Introduction

*Phytophthora medicaginis*, which causes PRR in chickpea, is endemic and widespread in southern Queensland and northern NSW. The pathogen carries over from season to season on infected chickpea volunteers, lucerne, native medics and as resistant structures (oospores) in the soil. Although registered for use on chickpeas, metalaxyl seed treatment is expensive, does not provide season-long protection and is not recommended as a general management tool for PRR. There are no in-crop control measures for PRR – reducing losses from the disease are based on avoiding risky paddocks and choosing the right chickpea variety.

This annually-occurring experiment aims to compare the yields of established chickpea varieties and advanced (CICA) breeding lines for differences in yield losses due to PRR disease. This information will be used to produce PRR yield loss information for advanced breeding lines (if they are released as varieties) and provide information on the current PRR resistance in established chickpea varieties.

## Site details

| | |
|---|---|
| **Location** | Warwick QLD – Hermitage Research Facility |
| **Trial design** | Trials consist of two treatments being:<br>1. Plus PRR – seed treated with thiram + thiabendazole only, plots inoculated at planting with a mixture of oospores from 10 *P. medicaginis* isolates and receive no metalaxyl soil drenches.<br>2. Minus PRR – seed treated with thiram + thiabendazole + metalaxyl and plots received regular soil drenches with metalaxyl. (Note: metalaxyl is not currently registered as a soil drench in chickpea). This metalaxyl treatment prevents infection by the PRR pathogen. The difference in yield between the metalaxyl-treated plots and untreated plots is used to calculate the PRR-caused yield loss. |

| | | |
|---|---|---|
| | **Rainfall and irrigation** | Fifty millimetres of irrigation was applied before sowing in 2018. There was below average rainfall in July, August and September (total 15 mm). However, 22 mm of dripper-tape-applied irrigation in late September and frequent October rainfall (128 mm) favoured PRR development later in the season. |
| | **Sowing date** | 16 July 2018 |
| | **Fertiliser** | 25 kg/ha Granulock Z (nitrogen:phosphorus:sulfur:zinc; 11:21.8:4:1) placed in-furrow with seed. |
| | **Sowing rate and established plant population** | Target 35 plants/$m^2$. Once emergence is complete, seedlings are hand thinned to provide common plant density across varieties and breeding lines. In 2018, plants were thinned to 28 plants/$m^2$. |
| | **Weed management** | Post plant pre-emergent herbicide: 500 g/ha Simazine 900 (900 g/kg simazine) plus 1043 g/ha Terbyne® (750 g/kg terbuthylazine) plus 50 g/ha Balance® 750 WG (750 g/kg isoxaflutole) applied on 20 July. |
| | **Insect management** | Targeting *Helicoverpa* spp: 70 g/ha Dupont™ Altacor® (350 g/kg chlorantraniliprole) applied on 23 October and 9 November. |
| | **Disease management** | Targeting ascochyta blight: 1 kg/ha Mancozeb 750 SC (750 g/L mancozeb) applied on 23 August and 26 September; and 500 ml/ha Howzat (500 g/L carbendazim) applied on 24 October and 9 November. |
| | **Harvest date** | 4 December 2018. |
| **Treatments** | **Varieties (10)** | CICA1328, CICA1521, CICA1718, CICA1811, CICA1812, Kyabra$^{(\phi)}$, PBA Drummond$^{(\phi)}$, PBA HatTrick$^{(\phi)}$, PBA Seamer$^{(\phi)}$, Yorker$^{(\phi)}$. |

## Results

### Grain yield

The level of PRR disease that developed in 2018 was lower than that in 2017, reducing the extent of the yield loss. In 2017, losses ranged from 29% for CICA1328 to 95% for PBA Boundary$^{(\phi)}$ (rated S). However, in 2018, CICA1328 had no significant yield loss from PRR, while the most susceptible entry, PBA Drummond$^{(\phi)}$ (S), lost 68% (Table 1).

The lower yield losses in the 2018 experiment reflect low early season levels of PRR resulting from below average rainfall in July, August and September. However, 22 mm of irrigation applied in late September and frequent October rainfall (128 mm) favoured PRR development later in the season, caused moderate yield losses in the more susceptible entries.

In the presence of PRR, the high yields of the advanced breeding lines (crosses between a chickpea (*Cicer arietinum*) line and a wild *Cicer* species) was a highlight of this experiment. Three lines in particular, CICA1328, CICA1718 and CICA1812, produced over 2 t/ha in the plus-PRR treatment and correspondingly had the lowest yield losses. These three lines yielded significantly higher than all other entries, which lacked non-wild *Cicer* genetics, with the exception of PBA HatTrick$^{(\phi)}$ and Yorker$^{(\phi)}$ (Table 1). The breeding lines CICA1718 and CICA1812 are being multiplied as possible new variety releases.

Table 1 Yield of chickpea varieties and breeding lines plus or minus PRR.
l.s.d. ($P = 0.047$) yield = 0.77 t/ha

| Variety/line | Yield (t/ha) | | PRR yield loss (%) |
|---|---|---|---|
| | Minus PRR | Plus PRR | |
| CICA1328A | 2.40 | 2.58 | –7.2 (ns) |
| CICA1521A | 1.94 | 1.19 | 38.7 (ns) |
| CICA1718A | 2.51 | 2.02 | 19.6 (ns) |
| CICA1811A | 2.54 | 1.43 | 44.0 |
| CICA1812A | 2.84 | 2.08 | 26.7 (ns) |
| Kyabra | 2.22 | 1.17 | 47.4 |
| PBA Drummond | 2.49 | 0.79 | 68.1 |
| PBA HatTrick | 2.28 | 1.36 | 40.5 |
| PBA Seamer | 2.81 | 1.08 | 61.5 |
| Yorker | 2.84 | 1.70 | 40.1 |

A these lines are crosses between chickpea (*C. arietinum*) and a wild *Cicer* species

Hundred seed weights of samples showed that all breeding lines and varieties produced good seed size in 2018 despite PRR infection (Table 2). In addition, two entries that had lower than average seasonal yields (CICA1521 and Kyabra(b)) also had significantly larger seed when PRR was present. This larger seed reflects reduced seed number per plant, plant recovery from PRR during dry spells and lower plant density (due to PRR losses) that provided greater soil moisture during pod fill.

Table 2 Hundred seed weights (HSD, g) of chickpea varieties and breeding lines plus or minus PRR.
l.s.d. ($P = 0.030$) HSD = 1.525 g

| Variety/line | Minus PRR (g) | Plus PRR (g) |
|---|---|---|
| CICA1328A | 22.82 | 21.50 |
| CICA1521A | 22.22 | 23.79 |
| CICA1718A | 21.51 | 22.81 |
| CICA1811A | 24.64 | 23.54 |
| CICA1812A | 25.99 | 26.57 |
| Kyabra | 25.50 | 27.51 |
| PBA Drummond | 24.17 | 23.46 |
| PBA HatTrick | 23.36 | 23.57 |
| PBA Seamer | 22.85 | 24.09 |
| Yorker | 21.96 | 22.87 |

A These lines are crosses between chickpea (*C. arietinum*) and a wild *Cicer* species

## Conclusions

This experiment showed that a number of advanced breeding lines (CICA1328, CICA1718 and CICA1812), which are crosses between a chickpea (*Cicer arietinum*) line and a wild *Cicer* species can have high yields when PRR is present. This was the highlight in the 2018 experiment with these lines also producing good sized seed. These varieties that can produce high yields under PRR disease pressure indicates that the chickpea breeding program is successfully producing material with improved PRR resistance.

The experiment also demonstrated that substantial yield losses from PRR can occur in both S (47–68%) and MR (40–61%) resistance-rated varieties. This finding reinforces the need to minimise the risk of PRR disease losses in chickpea crops by choosing low risk sites (no history of PRR, good drainage, and free of medic weeds).

## Acknowledgements

This experiment was part of the project 'Improving management of phytophthora root rot of chickpea', the subproject BLG205 in DAN00213, which is funded through the Grains Research and Development Corporation (GRDC) and NSW DPI's Grains Agronomy and Pathology Partnership (GAPP).

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# Chickpea root DNA tool to identify chickpea root distribution

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## Key findings

- A new, advantageous DNA-based chickpea root measurement method was developed as an alternative to other root quantification methods that allows large numbers of soil cores to be analysed over a short time period.
- Field results showed the DNA method could be used to determine chickpea root depth distribution.
- The results also showed that differences in root dry matter distribution and soil water extraction exist among chickpea varieties and breeding lines.
- Comparing genotypes using the DNA method is complex due to differences in DNA copy number between genotypes; currently the method is most readily used to determine factors affecting root distribution in a single chickpea genotype.

## Introduction

Currently there is a lack of knowledge about the basic root traits in Australian chickpea varieties under field conditions. This means it is difficult to select varieties with shallow or deep root distributions that might provide production advantages to growers. Traditional root sampling methods are both laborious and time consuming, which limits the ability to sample comprehensive field experiments. Alternative methods such as the mini-rhizotron have been developed, but still require extensive analysis of images and do not allow for opportunistic sampling outside the viewing fixed point access tube.

The soil DNA was evaluated through extraction and the qPCR method, which is used to quantify chickpea root DNA concentrations and was developed by SARDI. Importantly this method allows hundreds of samples to be processed per day and requires no root separation from soil before analysis. Root dry weight to root DNA values in both glasshouse and field studies were compared. This paper presents the key findings of the field experiment and identifies the key advantages and limitations of the DNA method.

## Site details

| | |
|---|---|
| **Location** | Tamworth – Tamworth Agricultural Institute. |
| **Rainfall** | A total of 635 mm of rain was recorded at the experiment site during 2017. The growing season rainfall was 148 mm, with the majority occurring in October (90 mm).<br>The long-term average rainfall for Tamworth is 671.5 mm. |
| **Experiment design** | Randomised complete block design with four replicates. |
| **Sowing date** | 11 May 2016. |
| **Fertiliser** | 50 kg/ha Granulock Z (nitrogen:phosphorus:sulfur:zinc; 11:21.8:4:1) placed in furrow with seed. |
| **Plant population** | Target 32 plants/m$^2$. |

| | |
|---|---|
| **Weed management** | Post plant pre-emergent herbicide: 1 kg/ha Terbyne® 750 WG (750 g/kg terbuthylazine) plus 80 g/ha Balance® 750 WG (750 g/kg isoxaflutole) applied on 12 May.<br>Grass weed management: 100 mL/ha Verdict™ 520 (520 g/L haloxyfop) applied on 5 June and 27 June. |
| **Insect management** | Targeting *Helicoverpa* spp: Dupont™ Steward® EC 300mL/ha (150 g/L indoxacarb) applied on 21 September, 11 and 24 October. |
| **Disease management** | Targeting ascochyta blight: 2 L/ha Unite 720 (720 g/L chlororthalonil) applied on 18 July, 1 August, 1 September and 6 October. |

## Treatments and sampling regime

### Varieties (5)

04067-81-2-1-1(B) C, Kyabra$^{\Phi}$, PBA HatTrick$^{\Phi}$, PBA Seamer$^{\Phi}$, and Sonali.

### Soil sampling

Hydraulic coring (core diameter 45 mm) was used to collect soil cores. The root DNA levels were assessed in the five genotypes at four depths (0–15, 15–30, 30–60 and 60–90 cm) and three time points (vegetative [one core/plot], flowering [one core/plot] and physiological maturity [two cores/plot]). Soil cores were sent to SARDI for chickpea root DNA analysis. For the cores taken at flowering one set of cores had the chickpea roots extracted by washing the soil samples over sieves and the dry weight (DW) of roots recorded after drying the samples at 65 °C for 48h. A separate core was also collected at each time point from each plot to determine the gravimetric soil moisture content at each sample depth, including at 90–120 cm.

## Results

### Establishment

Post-emergence counts showed some variation in populations between genotypes, although the differences were not significant. The average plant density was 30 plants/m$^2$, with a range of 25–32 plants/m$^2$.

### Root DNA and dry weight results

Chickpea DNA concentration analysis showed significant effects from depth at each of the three time points, with lower DNA concentrations as depth increased (Table 1). Root DW at flowering, was also significantly higher in the 0–15 cm soil layer than the three deeper depths, but there was no statistical difference between the three deeper depths. It was noted that the DNA results were less variable, as indicated by the % the coefficient of variation, as the season progressed (data not presented).

Table 1 Sampling depth effects on chickpea DNA concentrations at flowering.

| Sample depth | Root DNA concentration (Log kilo copies/g soil/cm core depth) | | | Root dry weight (DW, mg/cm core depth) |
|---|---|---|---|---|
| | Vegetative $^{A}$ | Flowering $^{A}$ | Physical maturity $^{B}$ | Flowering $^{A}$ |
| 0–15 cm | 5.75 | 6.53 | 6.88 | 1.840 |
| 15–30 cm | 2.89 | 5.71 | 5.54 | 0.294 |
| 30–60 cm | 0.36 | 4.30 | 4.76 | 0.249 |
| 60–90 cm | -2.55 | 2.36 | 3.87 | 0.122 |
| l.s.d. ($P$<0.001) | 1.252 | 0.798 | 0.301 | 0.2987 |

$^{A}$ Results for one core analysed per plot; $^{B}$ Average results of 2 cores analysed per plot.

The genotype did not have a significant effect on DNA concentrations at the vegetative or flowering growth stages (Table 2). However, at physiological maturity, the variety Sonali showed significantly higher DNA concentrations than the other entries.

Although not the primary focus of this field experiment, results showed that there are significant differences in the root DW distribution in chickpea genotypes. For example, there was a significant genotype effect on root DW values in samples collected at flowering (Table 2). Kyabra$^{\phi}$, PBA HatTrick$^{\phi}$ and PBA Seamer$^{\phi}$ all had higher DW values than either 04067-81-2-1-1(B) or Sonali.

These results included a significant genotype-by-depth interaction whereby at the 0–15 cm soil depth both PBA Seamer$^{\phi}$ and Kyabra$^{\phi}$ had higher values than the three other genotypes. PBA HatTrick$^{\phi}$ had an intermediate DW value that was also significantly higher than either 04067-81-2-1-1(B) or Sonali (data not presented). Differences were also found between genotypes at physiological maturity in November. For a separate set of 0–10 cm samples, PBA Seamer$^{\phi}$ had a higher fine root DW value than 04067-81-2-1-1(B) (data not presented).

Table 2 Genotype effects on chickpea root DNA concentration at flowering.

| Genotype | Root DNA concentration (Log kilo copies/g soil/cm core depth) | | | Root dry weight (DW, mg/cm core depth) |
|---|---|---|---|---|
| | Vegetative $^{A}$ | Flowering $^{A}$ | Phys. maturity $^{B}$ | Flowering $^{A}$ |
| 04067-81-2-1-1(B) $^{C}$ | 2.05 | 4.82 | 5.039 | 0.456 |
| Kyabra | 2.33 | 4.59 | 5.226 | 0.754 |
| PBA HatTrick | 1.56 | 4.74 | 4.999 | 0.758 |
| PBA Seamer | 0.91 | 4.75 | 5.232 | 0.801 |
| Sonali | 1.20 | 4.74 | 5.823 | 0.362 |
| *P* value | 0.241 | 0.990 | <0.001 | 0.010 |
| l.s.d. | 1.40 | 0.892 | 0.3364 | 0.2672 |

$^{A}$ Results for one core analysed per plot, $^{B}$ Average results of 2 cores analysed per plot; $^{C}$ this line is a cross between chickpea (*C. arietinum*) and a wild *Cicer* species

The gravimetric soil moisture results from the field experiment showed there are significant differences in the extraction of soil water among genotypes, particularly at depth (>30 cm) where 04067-81-2-1-1(B) and Sonali left more soil water than other genotypes, and Kyabra$^{\phi}$ had superior water use at the 60–90 cm depth (Table 3).

Table 3 Field experiment gravimetric soil moisture content (%) genotype by depth interaction. l.s.d. = 2.06.

| Genotype | Depth, cm | | | |
|---|---|---|---|---|
| | 0–15 | 15–30 | 30–60 | 60–90 |
| 04067-81-2-1-1(B) $^{A}$ | 18.8 | 24.9 | 24.2 | 19.1 |
| Kyabra | 20.2 | 25.7 | 23.6 | 16.6 |
| PBA HatTrick | 19.9 | 24.1 | 23.5 | 20.0 |
| PBA Seamer | 19.4 | 25.2 | 22.4 | 18.9 |
| Sonali | 20.8 | 25.6 | 25.0 | 22.4 |

$^{A}$ this line is a cross between chickpea (*C. arietinum*) and a wild *Cicer* species

## Conclusions

The findings in the field that Australian varieties and breeding lines differ in root dry weight values are supported in both controlled environment and overseas studies. Significant variation exists in root traits, including root depth distribution, between chickpea genotypes. Further, both the DW and gravimetric soil moisture data reinforces the need for high throughput methods for studying chickpea root distribution. This will enable varieties and breeding lines to be identified that have superior traits. This knowledge can then be used to support improved production in specific environments.

The DNA results showed significant differences in root distribution across soil depths at each sampling time, but genotype DNA results only differed at the final sample time at physiological maturity. In contrast, there were significant differences in root DW among genotypes at flowering. Further, due to differences in root DNA concentrations among genotypes, high DNA results did not correlate with root DW results for some genotypes, such as Sonali.

Due to genotype DNA concentrations not reflecting root DW values for some genotypes such as Sonali, currently this method is most readily used to determine factors affecting root distribution in a single chickpea genotype rather than for comparing genotypes.

Through careful implementation, the DNA chickpea root method, including adequate sampling regimes, could be used by industry (land managers, agronomists, breeders, research scientists) to determine the vertical and lateral root distribution of chickpea roots in soil. This will enable varieties to be selected with either shallow or deep root distributions, where such traits will provide agronomic advantages in specific growing environments. Further, the method can be used to identify sites where soil constraints, such as sodicity and acidity, are affecting vertical or lateral chickpea root distribution. Plant pathologists and breeders might be able to use the method to identify which genotypes have superior compensation abilities (root replacement) in the presence of different abiotic or biotic constraints. The DNA test could also be used to simultaneously co-quantify root pathogen populations (e.g. PRR) and chickpea roots, which might facilitate identification of disease management practices or chickpea genetics with superior resistance or tolerance to chickpea root diseases.

## Acknowledgements

This experiment was part of the project 'Chickpea root quantification' subproject BLG101 within DAN00213: Grains Agronomy & Pathology Partnership – A strategic partnership between the Grains Research and Development Corporation (GRDC) and NSW DPI. Technical assistance provided by Matthew Grinter and Mike Nowland (NSW DPI) is gratefully acknowledged.

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# Glyphosate-resistant annual ryegrass (*Lolium rigidum*) control with non-conventional herbicides: Using repeated applications to control large weed sizes – Tamworth (glasshouse) 2018

Tony Cook, Bill Davidson and Bec Miller
NSW DPI, Tamworth

## Key findings

- Repeated applications of Non-Tox® herbicide can significantly suppress young (early tillering) annual ryegrass.
- This herbicide desiccates weeds and is likely to work more effectively on smaller broadleaf weeds (open growing point) and not as effective on grasses as the growing point is protected by the leaf sheath and stems.

## Introduction

Herbicide resistance is becoming more widespread in the northern grains region. Furthermore, no new herbicides with novel modes-of-action have been developed since the 1980s. This reducing number of effective conventional herbicides has necessitated investigation into alternative herbicides.

This experiment aimed to measure the success of repeated applications (twice) of Non-Tox® herbicide. Repeated applications of conventional desiccant herbicides are known to improve weed control across a broader range of growth stages; this experiment is trying to prove this scenario with Non-Tox®.

## Site details

| | |
|---|---|
| **Location** | Tamworth – Tamworth Agricultural Institute |
| **Soil type and nutrition** | Potting mix for containerised plants. Scotts® Osmocote Premium Potting Mix. |
| **Irrigation** | Plants watered regularly; soil was near field capacity for the duration of the experiment. |
| **Experiment design** | Randomised complete block design with weed growth stage as the only treatment factor; five replications and thus five pots per treatment (one plant per pot). |
| **Plant population** | One plant per pot (5 cm diameter pots – Figure 1). |
| **Weed growth stages (3)** | Annual ryegrass:<br>• 2–4 tillers – sprayed 6 and 14 September 2018<br>• 5–7 tillers – sprayed 18 and 24 September 2018<br>• 10 or more tillers – sprayed 24 and 28 September 2018. |
| **Spraying conditions – over the various times of application** | Range of temperatures: 21–24 °C; relative humidity: 74–88%. |
| **Assessment date** | 3 October 2018. |

## Treatments

| | |
|---|---|
| **Spraying volumes** | Spraying was set at 1000 L/ha. This spray volume was both the rate of chemical and total spray volume as the product is a ready-to-go formulation and therefore does not need dilution with water. |

## Results

### Desiccation and plant recovery – ideal time for a second treatment

Non-Tox® herbicide did not control annual ryegrass as effectively as flax-leaf fleabane (findings from previous rate-response experiments). Annual ryegrass plant recovery is common with this herbicide as the growing points are protected by the leaf sheaves and new leaf emergence from this point (Figure 1). Occasional plant death can be seen at the smaller growth stages, however suppression is more common

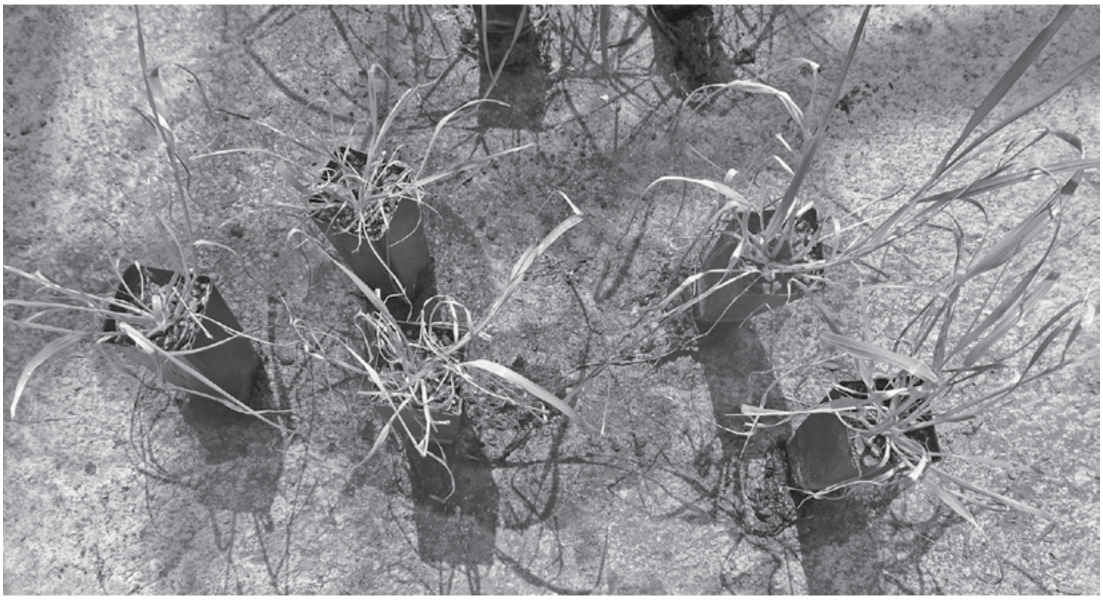

Figure 1 Recovery and emergence of new foliage on annual ryegrass six days after treatment with Non-Tox®. For this example, plants were re-treated to desiccate the new foliage, aiming to significantly suppress weed growth. Lower foliage is necrotic from the previous treatment.

### Repeat application and weed growth stage interaction

Annual ryegrass was substantially controlled (98% reduction in biomass) following sequential treatment to plants between the two and seven tiller stage (Table 1). However, the repeated application of Non-Tox® for the next larger growth stage (≥10 tillers) resulted in significantly lower control ($P<0.05$) (Table 1 and Figure 2). Although biomass reduction was considered excellent for the two smallest growth categories, four out of the five treated plants survived and were capable of recovery and producing seed. Occasional plant death can be seen at the smaller growth stages, however suppression is more common

Table 1 Effect on annual ryegrass growth stage on efficacy of Non-Tox® herbicide (applied twice), Tamworth (2018). Assessed 3 October 2018.

| Weed growth stage | Percentage of dead plants per pot (0–100%) | Estimated reduction in weed biomass (0–100%) |
|---|---|---|
| 2–4 tillers | 20 | 98 |
| 5–7 tillers | 20 | 98 |
| 10 or more tillers | 0 | 72 |
| Untreated control | 0 | 0 |
| l.s.d. ($P = 0.05$) | 10 | 14 |

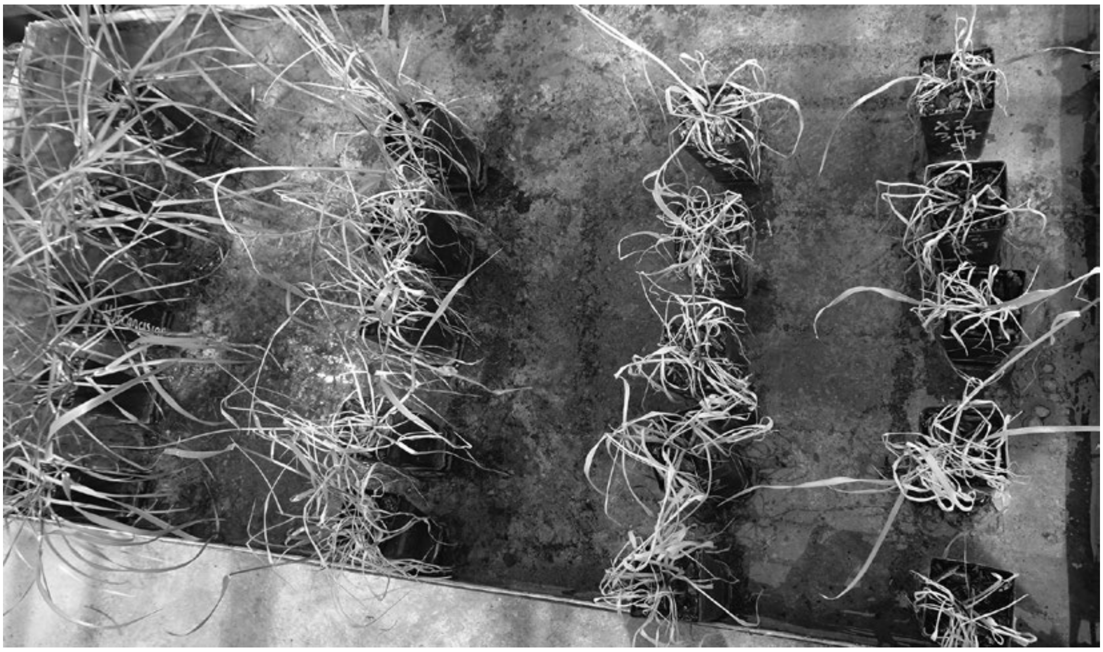

Figure 2 Effects on various annual ryegrass growth stages from Non-Tox® efficacy after treating with sequential applications. Increasing growth stages from right to left.

## Conclusions

Non-Tox® herbicide is a salt-based non-selective herbicide that has mainly suppressive and occasionally lethal effects against annual ryegrass, including glyphosate-resistant strains, at the smaller growth stages (2–7 tillers).

Non-Tox® treatment is best suited as a spot treatment on very light patchy weeds due to the large volume of solution required. It has not been researched as a potential treatment using camera detector sprayers or robotic devices, however, it has much potential with these technologies. It might have a fit in broadacre agricultural systems in fallow paddocks or potential in non-agricultural areas. The product's desiccating properties could be used for glyphosate resistance management.

Flaxleaf fleabane will be investigated in a similar experiment. It was selected because it is another widespread glyphosate-resistant weed that is problematic in fallows and in non-cropped areas.

In summary, the findings from this research show that Non-Tox® could be used as a suppression treatment for annual ryegrass if the weed's size is in the early to mid tillering phase (2–7 tillers); however, it needs to be applied twice for good suppression. Currently it is not registered for this use pattern. The second application must be made when the new foliage is soft and expanding, usually about 4–8 days after the first treatment.

## Acknowledgements

This experiment was part of the NSW DPI GATE (Global Ag-Tech Ecosystems) initiative with in-kind contributions from NSW DPI. The contributing work from NSW DPI staff members Bill Davidson (Technical Officer) and Bec Miller (Technical Assistant) was an integral part of this research.

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# Glyphosate-resistant annual ryegrass (*Lolium rigidum*) control with alternative, non-conventional herbicides: Comparison of spray volumes – Tamworth (glasshouse) 2018

Tony Cook, Bill Davidson and Bec Miller

NSW DPI, Tamworth

## Key findings

- The optimum spray volume of Non-Tox® herbicide needs to be more than 800 L/ha.
- There is limited potential to use this alternative, non-conventional herbicide as a spot treatment option for isolated patchy grass weeds such as annual ryegrass.
- This herbicide desiccates the weed and is likely to work more effectively on smaller broad leaf weeds. A follow-up experiment will investigate how growth rate affects the herbicide's efficacy.

## Introduction

Herbicide resistance is becoming more widespread in the northern grains region. No new herbicides with novel modes-of-action have been developed since the 1980s. This reducing number of effective conventional herbicides has necessitated investigation into alternative herbicides.

This experiment aimed to determine the most practical spray volume of Non-Tox® herbicide. This product is a ready-to-go formulation needing no dilution with water, so the spray volume is the product rate per hectare. The current recommendation for application is a spray volume of 1000 L/ha. It would be more advantageous to reduce this spray volume for large scale broadacre agriculture to minimise application time and costs.

## Site details

| | |
|---|---|
| **Location** | Tamworth – Tamworth Agricultural Institute |
| **Soil type and nutrition** | Potting mix for containerised plants. Scotts® Osmocote Premium Potting Mix. |
| **Irrigation** | Plants watered regularly, soil near field capacity for the duration of the experiment. |
| **Experiment design** | Randomised complete block design with spraying volume as the only treatment factor; five replications. |
| **Spraying date** | 6 September 2018. |
| **Spraying conditions** | Temperature : 22 °C, relative humidity : 88%, with full sunlight. |
| **Plant population** | One plant per pot (5 cm diameter pots – Figure 1). |
| **Weed growth stage** | Annual ryegrass treated at the 2–4 tiller stage (Figure 1). |

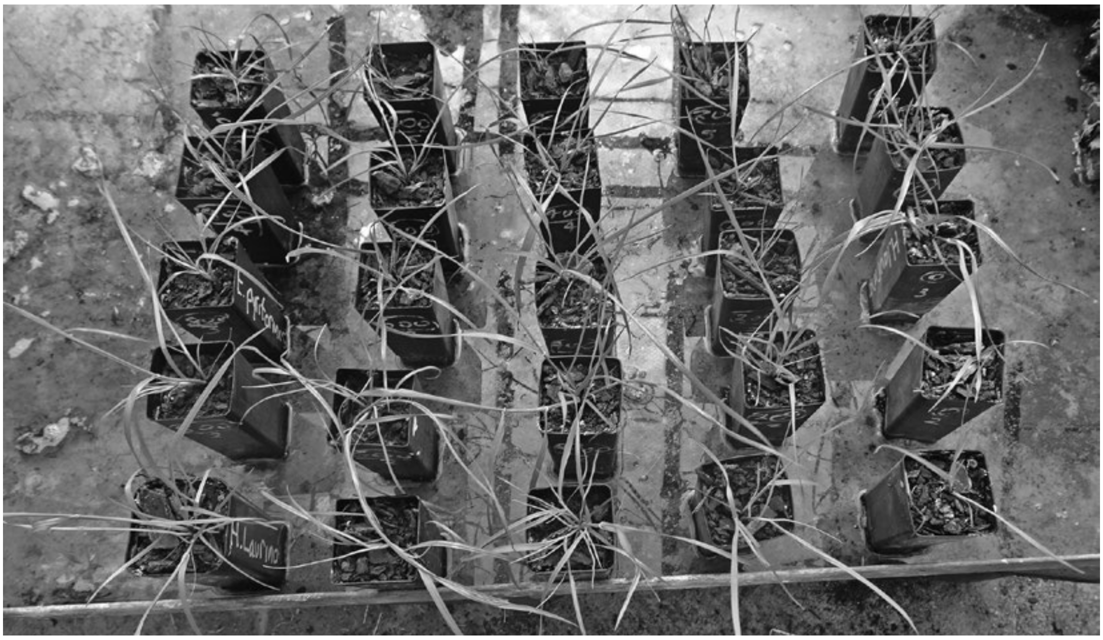

Figure 1 Annual ryegrass growth stage and glasshouse conditions at the time of application.

| | |
|---|---|
| **Assessment date** | 17 September 2018 |
| **Treatments** | Spraying volumes (5) Spraying volumes: 0, 200, 400, 600 and 800 L/ha. These are equivalent to product rates as the product is not diluted with water. |

## Results

### Rapid weed control

Non-Tox® herbicide's rapid action was apparent one day after treatment with leaves wilting (Figure 2).

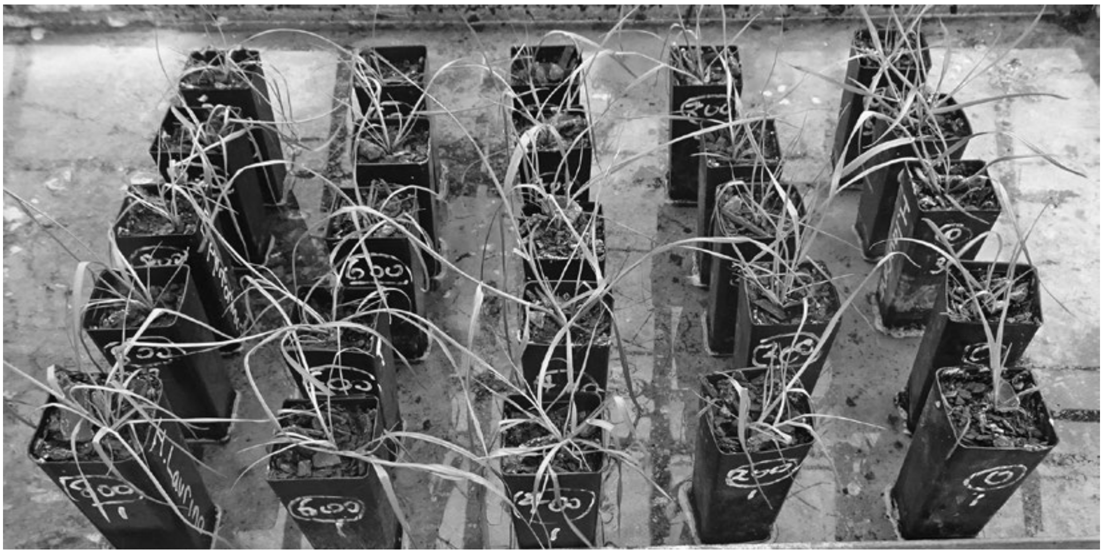

Figure 2 Rapid wilting of annual ryegrass one hour after treatment due to the product's drying nature: Increasing spray volumes from right to left (0–800 L/ha).

### Rate response

Weed biomass steadily reduced as spray volume rates increased (Table 1). The percentage of dead plants only increased significantly ($P<0.05$) when comparing the highest rate (800 L/ha) with the remaining treatments (Table 1 and Figure 3).

Table 1 Rate response from Non-Tox® herbicide application on annual ryegrass, Tamworth (2018). Assessed 11 days after treatment.

| Spray volume (L/ha) | Percentage of dead plants per pot (0–100%) | Estimated reduction in weed biomass (0–100%) |
|---|---|---|
| 0 | 0 | 0 |
| 200 | 0 | 8 |
| 400 | 0 | 24 |
| 600 | 0 | 46 |
| 800 | 60 | 94 |
| l.s.d. ($P = 0.05$) | 10 | 17 |

NOTE: A 1000 L/ha spray volume was not included in this research as other preliminary evidence demonstrated that lower volumes could result in satisfactory results (results not shown).

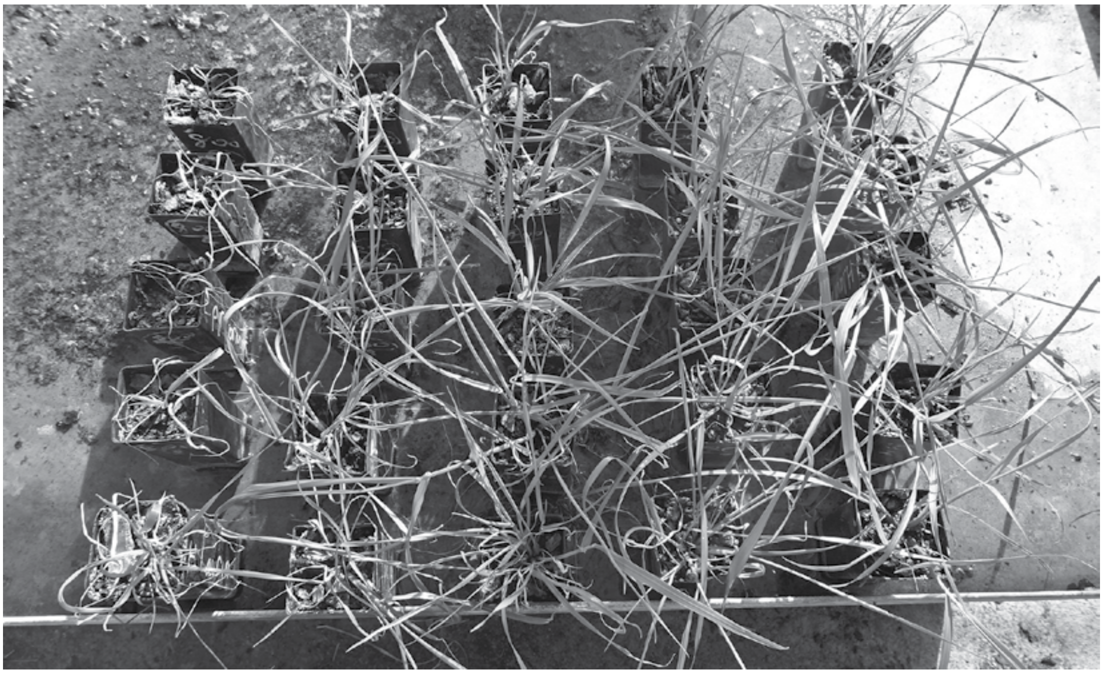

Figure 3 Affects of the various spray volumes on Non-Tox® efficacy, eleven days after treatment. Only the highest spray volume tested (800 L/ha) resulted in some plant death. Increasing spray volumes from right to left (0–800 L/ha).

## Conclusions

Non-Tox® herbicide is a salt-based non-selective herbicide. It has some suppressive and lethal effects against annual ryegrass, including glyphosate-resistant strains, at the higher spray rate tested (800 L/ha). These weeds were relatively small (2–4 tillers) and thus further research is required to better understand and improve control at the larger weed growth stages.

The practicalities of applying 800 L/ha of spray volume means that Non-Tox® can only be applied as a spot spray treatment on patchy weeds due to the large volume of solution required. It has not been researched as a potential treatment using camera detector sprayers or robotic devices, however, it has potential with these technologies. It might have a fit in broadacre agricultural systems in fallow paddocks or potential in non-agricultural areas. The product's desiccating properties could be used for glyphosate resistance management.

Flaxleaf fleabane will be investigated in a similar experiment. Fleabane was selected because it is another widespread glyphosate-resistant weed that is problematic in fallows and in non-cropped areas.

The recommended spray volume on the label is 1000 L/ha. It appears from this research that this recommended application rate should remain; reducing this rate is likely to be detrimental since 800 L/ha did not control all annual ryegrass. It might be feasible that this spray volume could be applied to weeds using camera detector sprayers or robotic devices. The travelling speed will need to be significantly slower than commercial standards and the number of weeds in the paddock will need to be extremely light to accommodate for this treatment's spray volume.

## Acknowledgements

This experiment was part of the NSW DPI GATE (Global Ag-Tech Ecosystems) initiative with in-kind contributions from NSW DPI. The contributing work from NSW DPI staff members Bill Davidson (Technical Officer) and Bec Miller (Technical Assistant) was an integral part of this research.

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# Glyphosate-resistant flaxleaf fleabane (*Conzya bonariensis*) control with alternative non-conventional herbicides: Using repeated applications to control large weed sizes – Tamworth (glasshouse) 2018

Tony Cook, Bill Davidson and Bec Miller
NSW DPI, Tamworth

## Key findings

- Repeated applications of Non-Tox® herbicide are not required for small rosette fleabane control.
- Repeated applications of Non-Tox® herbicide are required when treating fleabane at the stem elongating development stage.
- This experiment has shown that Non-Tox® herbicide has greater efficacy on smaller broadleaf weeds compared with grasses (alternative experiment).

## Introduction

Herbicide resistance is becoming more widespread in the northern grains region. Furthermore, no new herbicides with novel modes-of-action have been developed since the 1980s. This reducing number of effective conventional herbicides has necessitated investigation into alternative herbicides.

This experiment aimed to measure the success of repeated applications (twice) of Non-Tox® herbicide. Repeated applications of conventional desiccant herbicides are known to improve weed control across a broader range of growth stages, this experiment is trying to prove this scenario with Non-Tox®.

## Site details

| | |
|---|---|
| **Location** | Tamworth – Tamworth Agricultural Institute |
| **Soil type and nutrition** | Potting mix for containerised plants. Scotts® Osmocote Premium Potting Mix. |
| **Irrigation** | Plants watered regularly, soil was near field capacity for the duration of the experiment. |
| **Experiment design** | Randomised complete block design with weed growth stage as the only treatment factor; five replications. A total of five pots per treatment. |
| **Plant population** | One plant per pot (5 cm diameter pots – Figure 1). |
| **Weed growth stages (4)** | Flax-leaf fleabane:<br>• 5 cm diameter – sprayed 17 September 2018, no need for another spray as 100% control achieved with the first spray.<br>• 10 cm diameter – sprayed 28 September 2018, no need for another spray as 100% control achieved with the first spray.<br>• Very early stem elongation – sprayed 16 October 2018, no need for another spray as 100% control achieved with the first spray.<br>• Mid stem elongation – sprayed 26 and 30 October 2018. |

| | | |
|---|---|---|
| | Spraying conditions – over the various times of application | Temperature range: 22–26 ºC, relative humidity: 71–88%. |
| | Assessment date | 5 November 2018. |
| Treatments | Spraying volumes | Spraying was set at 1000 L/ha. Since the product is formulated as a ready-to-go (no dilution required), the spraying volume is the same as the product rate. |

## Results

### Desiccation and plant recovery – ideal time for a second treatment

Non-Tox® herbicide is a more effective control for fleabane than annual ryegrass (findings from previous rate-response experiments). The first three growth stages did not require a repeat application. However, the mid stem elongating fleabane required two applications, which resulted in significant ($P<0.05$) suppression in biomass, but did not kill the plant. The upper canopy leaves protect the lateral growing points on the stem, which results in new leaves emerging from these points (Figure 1).

Figure 1 Recovery and emergence of new foliage on fleabane five days after Non-Tox® treatment. In this example, the plants had been treated twice. Lower foliage is necrotic from the previous treatment and upper growing points are dead, however, protected lateral buds on the stem are the source of new growth.

### Repeat application and weed growth stage interaction

Fleabane was completely controlled with one application of Non-Tox® at 1000 L/ha (5 cm to very early stem elongation). Once plants attained a protected semi-woody stem, i.e. the mid stem elongating stage, sequential treatments only achieved suppression (Table 1). This interaction is strongly related to the protection of secondary growing points at this stage. (Table 1 and Figure 1 and Figure 2). The first three growth stages were fully controlled with one application of Non-Tox® with a second application not required. Survival is strongly related to fleabane stem and lateral bud development

Table 1 Effect on flaxleaf fleabane growth stage from Non-Tox® herbicide (applied twice only for mid stem elongating plants), Tamworth (2018). Assessed 5 November 2018.

| Weed growth stage | Percent dead plants per pot (0–100) | Estimated reduction in weed biomass (0–100%) |
|---|---|---|
| 5 cm diameter | 100 | 100 |
| 10 cm diameter | 100 | 100 |
| Very early stem elongation | 100 | 100 |
| Mid stem elongation | 0 | 83 |
| Untreated control | 0 | 0 |
| l.s.d. ($P = 0.05$) | 20 | 11 |

Figure 2 Effects from Non-Tox® on various flaxleaf fleabane growth stages after treating with sequential applications. Increasing growth stages from left to right.

## Conclusions

Non-Tox® herbicide is a salt-based non-selective herbicide that has lethal effects against flaxleaf fleabane, including glyphosate-resistant strains, at the smaller growth stages before stem development.

Non-Tox® herbicide is best suited as a spot treatment of very light patchy weeds due to the large volume of solution required. It has not been researched as a potential treatment using camera detector sprayers or robotic devices, however, it has much potential with these technologies. It might have a fit in broadacre agricultural systems in fallow paddocks or potential in non-agricultural areas. The product's desiccating properties could be used for glyphosate resistance management.

Annual ryegrass will also be investigated in a similar experiment. Ryegrass was selected because it is another widespread glyphosate-resistant weed that is problematic in fallows and in non-cropped areas.

In summary, the findings from this research show that Non-Tox® could be used to control flaxleaf fleabane if the size of the weed is in the rosette stage (10 cm diameter or smaller). Non-Tox® needs to be applied twice for good suppression (greater than 80% biomass reduction) for weeds that have a stem. The second application must be made when the new foliage is soft and expanding, usually about 4–8 days after the first treatment.

## Acknowledgements

This experiment was part of the NSW DPI GATE (Global Ag-Tech Ecosystems) initiative with in-kind contributions from NSW DPI.

The contributing work from NSW DPI staff members Bill Davidson (Technical Officer) and Bec Miller (Technical Assistant) was an integral part of this research.

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# Glyphosate resistant flaxleaf fleabane (*Conzya bonariensis*) control with alternative non-conventional herbicides: Comparison of spray volumes – Tamworth (glasshouse) 2018

Tony Cook, Bill Davidson and Bec Miller
NSW DPI, Tamworth

## Key findings

- The optimum spray volume of Non-Tox® herbicide was 800 L/ha.
- There is the potential to use this alternative non-conventional herbicide as a spot treatment for isolated patchy weeds such as flaxleaf fleabane.
- This herbicide desiccates the weed and is likely to work more effectively on smaller weeds. A follow-up experiment will investigate how growth stage affects the herbicide's efficacy.

## Introduction

Herbicide resistance is becoming more widespread in the northern grains region. Furthermore, no new herbicides with novel modes-of-action have been developed since the 1980s. This reducing number of effective conventional herbicides has necessitated investigation into alternative herbicides.

This experiment aimed to determine the most practical spray volume of Non-Tox® herbicide. The product does not need dilution as it is a ready-to-go formulation, so product rate and the spray volume are the same. The current recommendation for application is a spray volume of 1000 L/ha. It would be more advantageous to reduce this spray volume for large scale broadacre agriculture to minimise application time and costs.

## Site details

| | |
|---|---|
| **Location** | Tamworth – Tamworth Agricultural Institute |
| **Soil type and nutrition** | Potting mix for containerised plants. Scotts® Osmocote Premium Potting Mix. |
| **Irrigation** | Plants watered regularly, soil was near field capacity for the duration of the experiment. |
| **Experiment design** | Randomised complete block design with spraying volume as the only treatment factor; five replications. A total of five pots per treatment were required. |
| **Spraying date** | 17 September 2018. |
| **Spraying conditions** | Temperature: 22 ºC relative humidity: 85%, with full sunlight. |
| **Plant population** | One plant per pot, 5 cm diameter pots (Figure 1). |
| **Weed growth stage** | Flaxleaf fleabane treated when 5 cm in diameter (Figure 1). |

Figure 1 Flaxleaf fleabane growth stage and glasshouse conditions at the time of application.

| | | |
|---|---|---|
| | **Assessment date** | 22 September 2018 |
| **Treatments** | **Spraying volumes (5)** | Spraying volumes were 0, 200, 400, 600 and 800 L/ha. |

## Results

### Rapid weed control

The Non-Tox® herbicide's rapid action was apparent one day after treatment. The symptoms were necrotic lesions, which were more prominent around the leaf margins. The weed's central growing points were less affected, especially with the low spray rates (Figure 2).

Figure 2 Rapid brownout of flaxleaf fleabane one day after treatment due to the product's desiccant nature: Increasing spray volumes from right to left (0 to 800 L/ha).

### Rate response

Weed biomass was reduced as product rate increased (Table 1). The percentage of dead plants increased significantly ($P<0.05$) when the rate was increased from 400 L/ha to 600 L/ha and then again when 800 L/ha was applied (Table 1 and Figure 3).

Table 1 Rate response of Non-Tox® herbicide on flaxleaf fleabane control, Tamworth (2018). Assessed five days after treatment.

| Spray volume (L/ha) | Percent dead plants per pot (0–100%) | Estimated reduction in weed biomass (0–100%) |
|---|---|---|
| 0 | 0 | 0 |
| 200 | 0 | 25 |
| 400 | 0 | 82 |
| 600 | 60 | 95 |
| 800 | 80 | 98 |
| l.s.d. ($P = 0.05$) | 10 | 13 |

NOTE: The recommended rate of 1000 L/ha was not included in this research as other preliminary evidence demonstrated that lower volumes could result in satisfactory control (results not shown).

Figure 3 How Non-Tox® at various spray volumes affects flaxleaf fleabane five days after treatment. Only the two highest spray volumes tested (600 L/ha and 800 L/ha) resulted in some plant death. Increasing spray volumes from right to left (0 L/ha to 800 L/ha).

## Conclusions

Non-Tox®, is a salt-based, non-selective herbicide, which has commercial potential against flaxleaf fleabane, including glyphosate-resistant strains, at the higher spray rate tested (800 L/ha). These weeds were relatively small (5 cm diameter) and thus further research is required to better understand the interactions between larger weeds and the product.

The practicalities of applying 800 L/ha of spray volume means that Non-Tox® can only be applied as a spot spraying treatment on patchy weeds due to the large volume of solution required. It has not been researched as a potential treatment using camera detector sprayers or robotic devices, however, it has potential with these technologies. It might have a fit in broadacre agricultural systems in fallow paddocks or potential in non-agricultural areas. The product's desiccating properties could be used for glyphosate-resistance management.

Annual ryegrass will be investigated in a similar experiment. It was selected because it is another widespread glyphosate-resistant weed that is problematic in fallows and in non-cropped areas.

The recommended spray volume is 1000 L/ha (product label) and that will be used accordingly in research investigating the effect on weed growth stage. It appears from this research that the recommended application rate of 1000 L/ha should remain; reducing this rate is likely to be detrimental since 800 L/ha did not control all flaxleaf fleabane.

## Acknowledgements

This experiment was part of the NSW DPI GATE (Global Ag-Tech Ecosystems) initiative with in-kind contributions from NSW DPI.

The contributing work from NSW DPI staff members Bill Davidson (Technical Officer) and Bec Miller (Technical Assistant) was an integral part of this research.

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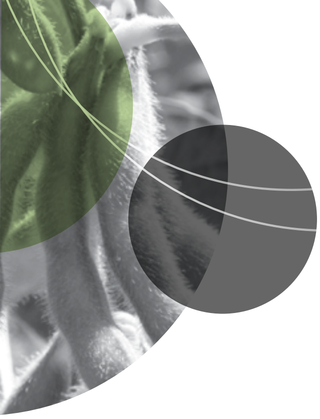

# Summer crops

## The changing face of sorghum planting windows – Breeza dryland 2018/19

Loretta Serafin, Mark Hellyer and Andrew Bishop

NSW DPI Tamworth

### Key findings

- The planting time for sorghum can be moved earlier than the traditional 16–18 °C soil temperature without negatively affecting crop establishment and grain yield.
- Defining the minimum soil temperature required is still tenuous as temperatures are variable in late winter–early spring and there is still the risk of mild and severe frosts.
- Planting sorghum earlier (September as opposed to late October) at Breeza moved the flowering window forward and resulted in improved grain yields in 2018/19.
- Varying plant population did not affect final grain yield at this site in this season. This was primarily due to there being more primary heads as the plant population increased, but this was offset by fewer fertile tillers being produced.

### Introduction

Dryland grain sorghum producers are focused on the need to produce high yields to achieve positive gross margins. One of the major limiting factors to increasing yields is the hot temperatures that commonly occur during flowering and grain fill.

On the Liverpool Plains, the sorghum planting window is considered to open in mid–late October, with a strong preference for a November planting. This traditional planting window is based on avoiding soil temperatures below the recommended 16–18 °C level and frosts in the early growth stages. The combination of high temperatures and flowering has increased in frequency for crops planted in the traditional October–November planting window across the Liverpool Plains in the past 10 years. This has meant the need to consider alternative planting dates to avoid this impact on crop yield potential.

Earlier than traditional planting dates (PD) are being evaluated through this research, where soil temperatures as low as 12 °C are being tested. Lower soil temperatures at planting would be tolerated if uniform, rapid plant establishment could still be achieved, frosts damage avoided and, importantly, the flowering and grain fill period was moved forward. The effects from planting rotational sorghum earlier than normal also need consideration as this can result in an earlier harvest and thus a longer period to refill the soil profile or consider a double crop.

In 2018/19, three experiments were established in this project, a dryland and an irrigated experiment at Breeza and a dryland experiment north of Moree. This report provides the results from the dryland Breeza experiment only.

### Site details

| | |
|---|---|
| **Location** | Liverpool Plains Field Station, Breeza. 31°10'S, 150°25'E |
| **Co-operator** | NSW DPI |

| | |
|---|---|
| **Soil type and nutrition** | The site was soil cored to establish starting nutrition levels (Table 1); 141 kg/ha of nitrogen to 120 cm deep. |
| **Starting soil water & rainfall** | The site was soil cored before each PD to measure the amount of plant available water. PD1 had 127 mm; PD2 200 mm and PD3 152 mm PAW to 120 cm deep. A total of 368 mm rainfall was recorded at the site during between September 2018 and March 2019 (Table 2). In-crop rainfall varied across the three planting times. PD1 and PD2 received 222.9 mm of in crop rainfall and PD3 received 170 mm (Table 2). |
| **Experiment design** | Split, split plot with PD as the main plot and then plant population as a sub plot. Hybrids were randomly allocated to plots. Three replications. |
| **Fertiliser** | Granulock Supreme Z (43 kg/ha) was applied with the seed at planting. |
| **Harvest dates** | PD1: 24 January 2019<br>PD2: 5 February 2019<br>PD3: 28 February 2019 |

Table 1 Site soil chemical characteristics for 0–120 cm depth at Breeza in 2018.

| Characteristic | Depth (cm) | | | | |
|---|---|---|---|---|---|
| | 0–10 | 10–30 | 30–60 | 60–90 | 90–120 |
| $pH_{Ca}$ | 7.7 | 7.9 | 8.0 | 8.1 | 8.2 |
| Nitrate nitrogen (mg/kg) | 29 | 11 | 6 | 8 | 5 |
| Sulfur (mg/kg) | 10.1 | 8.2 | 14.7 | 15.5 | 29.4 |
| Phosphorus (Colwell) (mg/kg) | 37 | 13 | 19 | 28 | 35 |
| Organic carbon (OC) (%) | 1.00 | 0.53 | 0.45 | 0.35 | 0.32 |

Table 2 In-crop rainfall at Breeza in 2018/19.

| Month | September | October | November | December | January | February | March |
|---|---|---|---|---|---|---|---|
| Rainfall (mm) | 22.0 | 56.6 | 62.0 | 29.0 | 27.0 | 39.0 | 132.4 |

## Treatments

### Planting dates (3)

Three PDs to target different soil temperatures, recorded as the seven-day average at 8 am AEST.

- PD1: 6 September 2018; soil temperature 11.2 °C.
- PD2: 17 September 2018; soil temperature 10.3 °C.
- PD3: 23 October 2018; soil temperature 18.8 °C.

### Planting rate (4)

Four target plant populations on 100 cm solid plant rows on raised beds (Figure 1).

- 3.0 plants/$m^2$ (30 000 plants/ha)
- 6.0 plants/$m^2$ (60 000 plants/ha)
- 9.0 plants/$m^2$ (90 000 plants/ha)
- 12.0 plants/$m^2$ (120 000 plants/ha)

### Hybrids (6)

MR Buster, MR Apollo, G33, Cracka, HGS114 and Agitator.

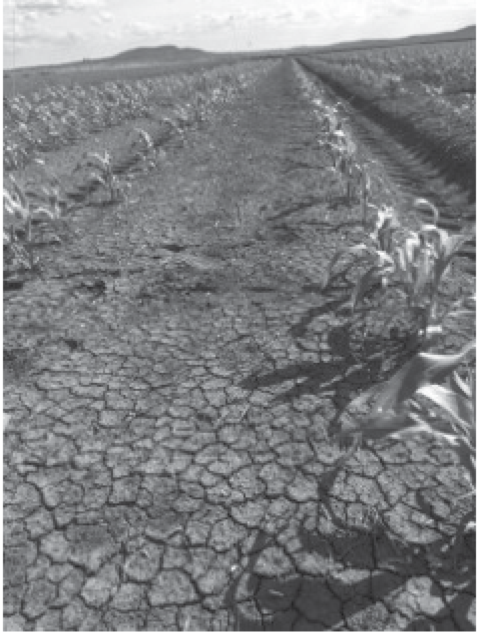

Figure 1 Breeza dryland experiment planted on one metre raised beds.

## Results

### Establishment

At Breeza the soil temperatures rose nearly to 12 °C during early September, which prompted PD1 and then continued to rise, which led to PD2. However, immediately after PD2, soil temperatures cooled to a seven-day average of 10.3 °C. At these cooler soil temperatures, PD significantly affected plant establishment. PD1 and PD2 had significantly reduced plant establishment compared with the standard (PD3) planting date, representing one of the risks of planting early.

Most hybrids did not achieve the four target plant populations of 3 plants/m$^2$, 6 plants/m$^2$, 9 plants/m$^2$ and 12 plants/m$^2$ for PD1 or PD2. PD3, which established in soil temperatures closer to 19 °C, was better (data not shown).

There were a couple of small differences between hybrids for plant establishment. Agitator had a significantly lower establishment than all other hybrids and G33 established fewer plants than MR Buster (Figure 2).

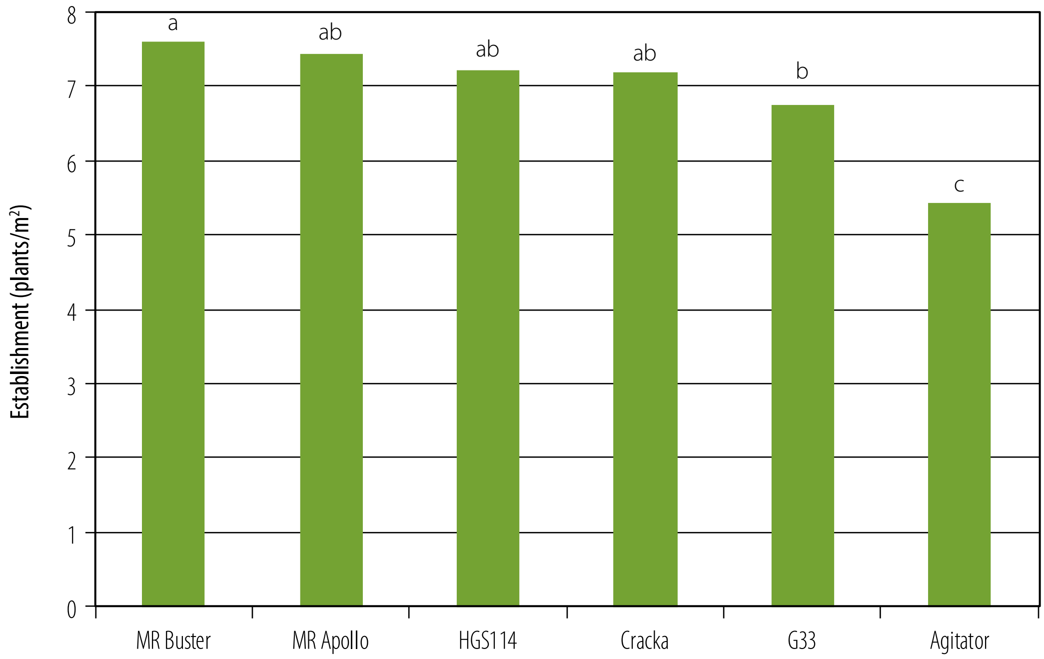

Figure 2 Hybrid establishment (plants/$m^2$) averaged across planting dates and plant populations.

### Planting date and plant population effects on crop development

There was a significant interaction between PD and plant population. The number of fertile tillers declined as the plant population increased for all PDs. PD3 had much lower levels of tillering than PD1 or PD2 (Figure 3).

Planting date did not affect 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).

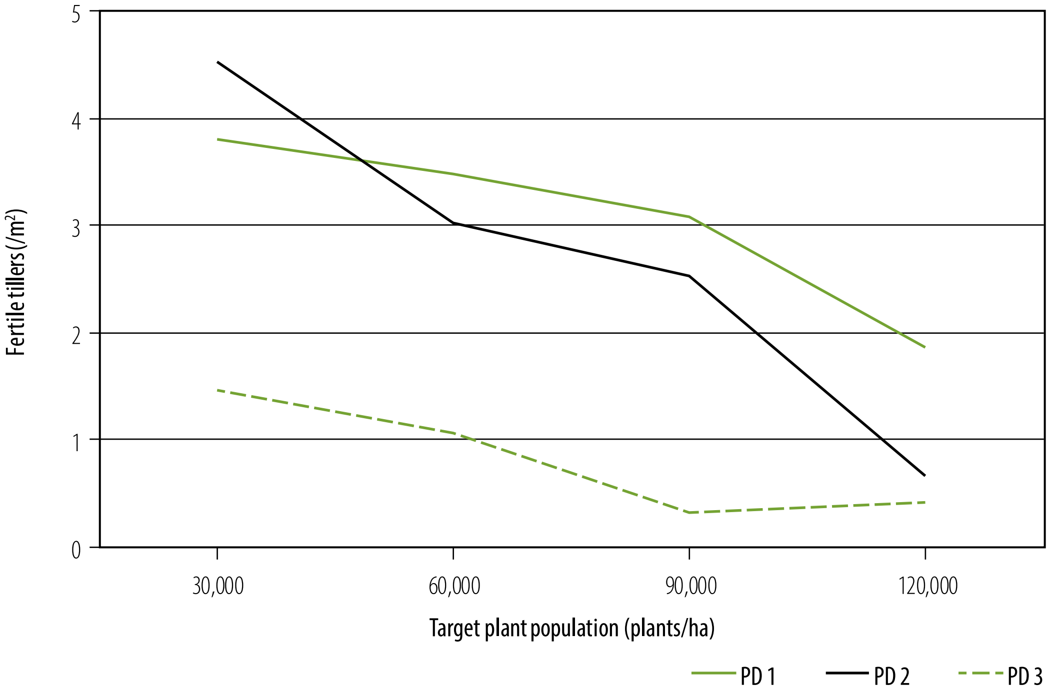

Figure 3 Interaction between planting date and target plant population effect on fertile tiller number (tillers/$m^2$).

### Did planting earlier affect the flowering date?

The number of days taken to reach 50% flowering reduced as PD was delayed. For PD1 it was 95 days, PD2 was 10 days faster at 85 days and it was 69 days for the standard planting date of PD3. Between PD1 and PD2, delaying planting by 15 days resulted in a 10-day difference in flowering. PD3 developed in much warmer conditions, so though there was a 30-day difference in planting between PD2 and PD3, there was only a 16 day difference to flowering.

There was a much smaller difference between the hybrids for time to flowering at Breeza compared with Moree in 2018/19. However, Agitator was the quickest hybrid to start flowering for all PDs, although by PD3, MR-Buster flowered in a comparative number of days. MR-Apollo remained the slowest of the hybrids evaluated (Figure 4).

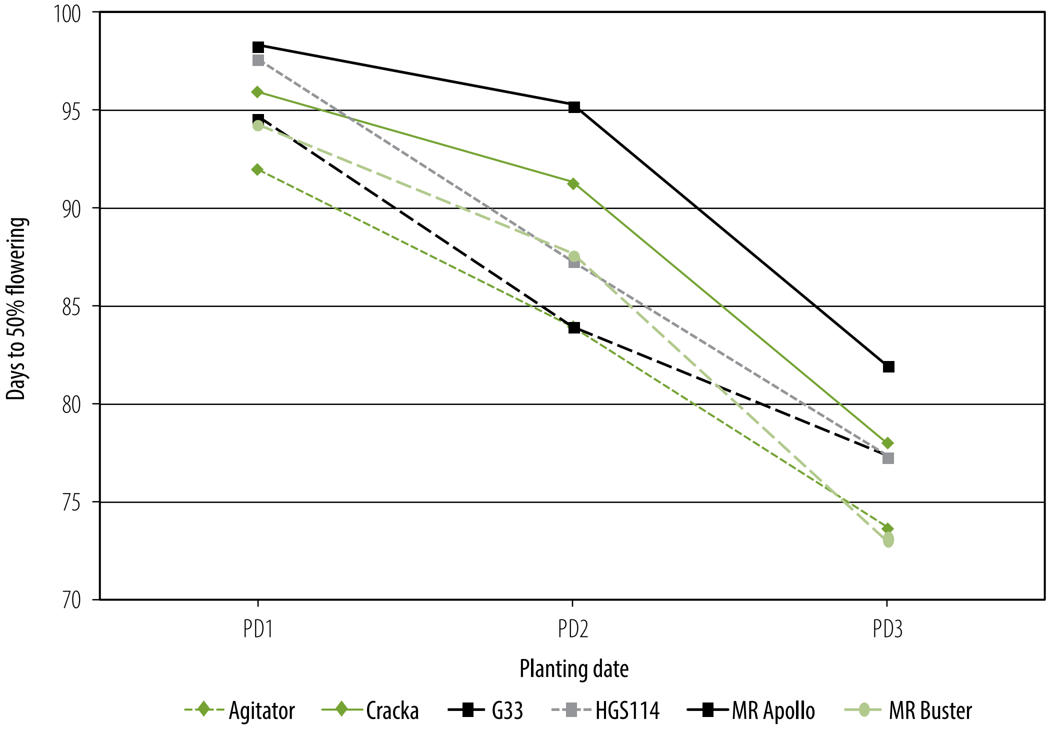

Figure 4 Days to 50% flowering at Breeza – dryland at six plants/m$^2$ target plant population.

### How did varying planting date affect grain yield and quality?

The site mean yield was 1.73 t/ha at Breeza in 2018/19. There was a significant impact of PD and hybrid on final grain yield (Table 3). PD1 (2.23 t/ha) and PD2 (2.12 t/ha) had significantly higher grain yield than PD3 (0.85 t/ha), averaged across hybrids and plant populations. There was no significant impact of plant population on grain yield.

The quicker maturing hybrids tended to have better yields in this season for PD1 and PD2 as opposed to PD3. That is Mr Buster, G33 and Agitator were significantly better than HGS114, Cracka and MR Apollo. MR Apollo performed poorly for all three PDs.

Table 3 How planting date and hybrid affected grain yield (t/ha) at 13.5% moisture.

| Hybrid | PD1 | PD2 | PD3 |
|---|---|---|---|
| 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. (P<0.05) | 0.75 | | |

Test weights were significantly lower for PD3 (54.8 kg/hl) compared with PD1 (62.7 kg/hl) and PD2 (62.8 kg/hl), although neither made sorghum grade 1. Similarly, no hybrid produced the required test weight to achieve grade 1 sorghum (>71 kg/hl).

Planting date, plant population and hybrid affected screenings at Breeza with all levels being relatively high. PD1 and PD2 had significantly lower screenings at 12.6% and 13.2 % than PD3 at 27.4%. The hybrid interaction was also significant with Agitator and Cracka producing the lowest screenings at 15.3% and 15.7% respectively. G33 had the highest screenings at 21.5%. Higher screenings also occurred as plant population increased (data not shown).

## Conclusions

Planting into slightly cooler temperatures (10–11 °C) at Breeza significantly affected sorghum establishment, resulting in lower plant establishment. However, planting earlier in this season moved the flowering window forward. This helped to ensure flowering occurred before the peak of heat and moisture stress. The earlier planting date resulted in improved yields, even though average yields at Breeza were not high due to the dry conditions.

Varying the target plant population, from three plants/m$^{2}$ to 12 plants/m$^{2}$ did not affect 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 planting sorghum earlier than traditionally recommended appear to be improved grain yield and grain quality, the risks have not yet been fully evaluated. Plant establishment losses were higher, meaning additional seed costs for no resulting plants. The effect of frost in particular also needs to be further assessed including determining the actual temperature and duration that cause plant death.

## Acknowledgements

This experiment was part of the project 'Optimising sorghum agronomy project (UOQ 1808-001RTX)' a collaborative initiative between the Grains Research and Development Corporation (GRDC), University of Queensland, NSW Department of Primary Industries and Qld Department of Agriculture and Fisheries.

Thanks to Scott Goodworth and Steve Jengos, NSW DPI Breeza for assistance with the experiment site. Technical assistance provided by Delphi Ramsden and Natalie Aquilina (NSW DPI) is gratefully acknowledged.

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# The changing face of sorghum planting windows – Ponjola, Moree, dryland 2018/19

Loretta Serafin, Mark Hellyer and Andrew Bishop

NSW DPI, Tamworth

## Key findings

- Planting time for sorghum can be moved earlier than the traditional 16–18 °C soil temperature without negatively affecting crop establishment and yield.
- Defining the minimum soil temperature required is tenuous as temperatures are variable in the late winter–early spring with the risk of mild and severe frosts.
- Planting sorghum earlier (August as opposed to September) at Moree moved the flowering window forward and resulted in improved yields in 2018/19.
- Varying plant population did not affect the final yields at this site in this season. This was primarily due to there being more primary heads as the plant population increased, which resulted in fewer fertile tillers being produced.

## Introduction

Dryland grain sorghum producers need to produce high yields to achieve positive gross margins. One of the major limiting factors for increasing yields in the northern grains region (NGR) is hot temperatures during flowering and grain fill.

In the Moree region, the sorghum planting window is considered to open in mid–late September. There is a strong preference for avoiding planting during November and ensuring planting has been completed by the end of December. This traditional planting window is based on avoiding soil temperatures below the recommended 16–18 °C and the risk of frosts in the early growth stages. The crossover of high temperatures and flowering has increased in frequency for crops planted in the traditional September–October planting window across the Moree region in the past 10 years. This has resulted in reduced yields, higher screenings and a greater incidence of crop failure in the western areas.

Earlier than traditional planting times are being evaluated through this research where soil temperatures as low as 12 °C are being tested as the base level for starting planting. Lower soil temperatures at planting would be tolerated if uniform, rapid plant establishment could still be achieved, frost damage avoided, and importantly, the flowering and grain fill period was moved forward out of the high risk period.

The rotational effects from planting sorghum earlier than normal also need consideration as earlier planting can result in an earlier harvest and thus a longer period available to refill the soil profile or consider a double crop.

In 2018/19, three experiments were established in this project: a dryland and an irrigated experiment at Breeza and a dryland experiment north of Moree. This report provides the results from the dryland Moree experiment only.

## Site details

| | |
|---|---|
| **Location** | Ponjola, Moree (~40 kms north). 29°15'S, 150°06'E. |
| **Co-operator** | Geoff Manchee and J.R. McDonald. |

| | |
|---|---|
| **Soil type and nutrition** | The site was soil cored to establish starting nutrition levels (Table 1): 263 kg/ha of nitrogen (N) to 120 cm deep. |
| **Starting soil water and rainfall** | The site was soil cored at each planting date (PD) to measure the amount of plant available water (PAW). PD1 had 160 mm; PD2 had 172 mm and PD3 had 172 mm PAW to 120 cm deep.<br>A total of 191.4 mm rainfall was recorded at the site between August 2018 and February 2019. The amount of in-crop rainfall received varied between the three PDs. PD1 received 199 mm of in-crop rainfall plus 33 mm of drip irrigation at planting – a total of 232 mm, while PD2 and PD3 received 153.2 mm of rainfall only (Table 2). |
| **Experiment design** | Split, split plot with planting date as the main plot and plant population as a sub plot. Three replications. Hybrids were randomly allocated to plots. |
| **Fertiliser** | Granulock Supreme Z (43 kg/ha) was applied with the seed at planting. |
| **Harvest dates** | PD1: 29 January 2019<br>PD2: 29 January 2019<br>PD3: 30 January 2019 |

Table 1 Site soil chemical characteristics for 0–120 cm depth at Ponjola, Moree in 2018.

| Characteristic | Depth (cm) | | | | |
|---|---|---|---|---|---|
| | 0–10 | 10–30 | 30–60 | 60–90 | 90–120 |
| $pH_{Ca}$ | 6.7 | 7.4 | 8.0 | 7.8 | 7.2 |
| Nitrate nitrogen (mg/kg) | 63 | 20 | 15 | 10 | 4 |
| Sulfur (mg/kg) | 7.2 | 4.6 | 12.7 | 773.4 | 1594.9 |
| Phosphorus (Colwell) (mg/kg) | 17 | 5 | <2 | 2 | 3 |
| Organic carbon (OC) (%) | 0.87 | 0.57 | 0.44 | 0.39 | 0.17 |

Table 2 In-crop rainfall at Moree in 2018/19.

| Month | August | September | October | November | December | January |
|---|---|---|---|---|---|---|
| Rainfall (mm) | 31.0 | 24.5 | 71.5 | 51.4 | 13.0 | 0.0 |

## Treatments

### Planting dates (3)

Three PDs to target different soil temperatures, recorded as the seven-day average at 8 am AEST.

- PD1: 7 August 2018, however this was not watered until 14 August; soil temperature 12.3 °C.
- PD2: 11 September 2018; soil temperature 17.1 °C.
- PD3: 27 September 2018; soil temperature 18.9 °C.

### Planting rate (4)

Four target plant populations on 100 cm solid plant rows (Figure 1).

- 3.0 plants/$m^2$ (30 000 plants/ha)
- 6.0 plants/$m^2$ (60 000 plants/ha).
- 9.0 plants/$m^2$ (90 000 plants/ha).
- 12.0 plants/$m^2$ (120 000 plants/ha).

### Hybrids (8)

MR Buster, MR Apollo, MR Taurus, G33, HGS114, Cracka, Agitator and A66.

## Seasonal conditions

The planting season started off dry with PD1 planted on 7 August into dry soil. Due to the lack of seedbed moisture, dripper lines were used to apply 33 mm of water over the plant rows. This enabled germination to start at the targeted soil temperature. The following two plantings were established using seedbed moisture.

Temperatures rose very rapidly during October and early November resulting in the first 40 °C+ recording in mid November (Figure 1). From the end of November, the maximum temperatures were above 30 °C consistently until the end of January. This was combined with minimum temperatures rarely below 20 °C for the same period, coupled with low rainfall in December and no rainfall in January.

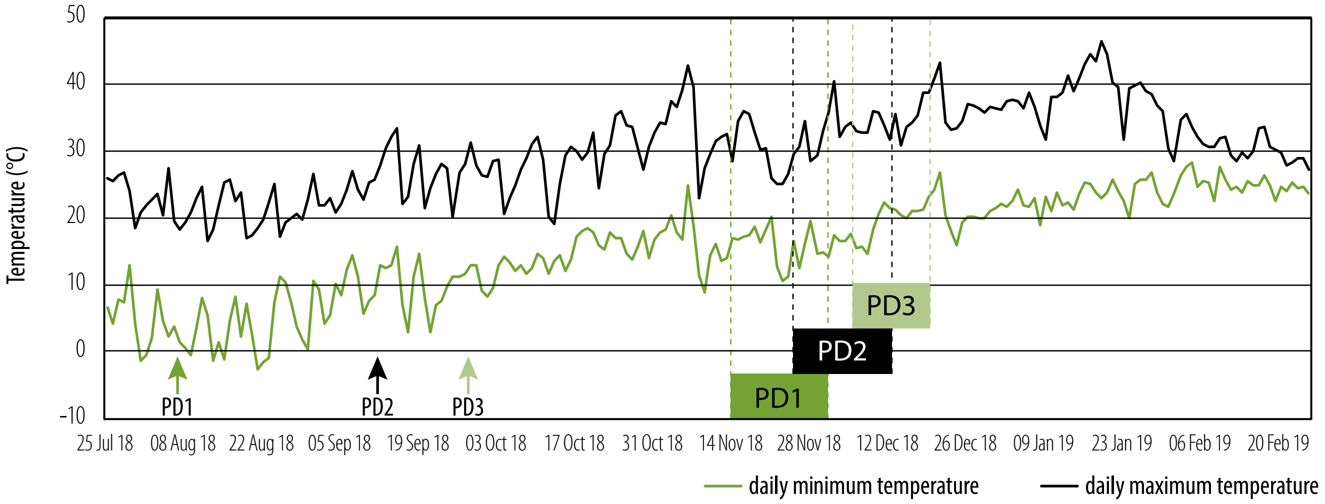

Figure 1 Daily maximum and minimum temperature at Ponjola, Moree during the 2018/19 season. The flowering window for PD 1, 2 and 3 are indicated by dashed lines and actual planting date by arrows.

## Results

### Establishment

There was an effect of PD, hybrid and plant population on plant establishment. The four target plant populations of three, six, nine and 12 plants/m$^2$ were not achieved from any of the planting times, however, there were differences between each treatment.

The first establishment counts, on 31 August, recorded plants emerging three weeks post planting and two weeks post watering. Plants emerged slowly from PD1, however, PD2 and PD3 had a more even and quicker establishment.

When comparing the three PDs, only in the 12 plants/m$^2$ population are there differences in establishment. PD1 recorded 8.94 plants/m$^2$ compared with 10.80 plants/m$^2$ and 11.83 plants/m$^2$ for PD 2 and PD3 respectively (Table 3).

Table 3 The effect of planting date on actual plant establishment.

| Target plant pop (plants/m$^2$) | Planting date | | |
|---|---|---|---|
| | PD1 (7 Aug) | PD2 (11 Sep) | PD3 (27 Sep) |
| 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$^a$ |

There was an interaction between PD and hybrid. Across all PDs, Agitator had the poorest establishment. PD2 and PD3 had improved establishment for all hybrids when compared with PD1 (Table 4).

Table 4 Effect of planting date on hybrid establishment (averaged across populations) in plants/m$^2$.

| Hybrid | Planting date | | |
|---|---|---|---|
| | PD1 (7 Aug) | PD2 (11 Sep) | PD3 (27 Sep) |
| MR Buster | $5.79^{fgh}$ | $7.72^{ab}$ | $7.89^{ab}$ |
| MR Taurus | $5.79^{efgh}$ | $6.98^{bcd}$ | $8.26^{a}$ |
| MR Apollo | $6.55^{cdefg}$ | $7.25^{abc}$ | $6.58^{cdefg}$ |
| G33 | $6.83^{bcdefg}$ | $6.46^{cdefgh}$ | $7.17^{abc}$ |
| A66 | $6.81^{bcdefg}$ | $7.11^{bc}$ | $6.23^{bcde}$ |
| Cracka | $5.70^{gh}$ | $6.75^{bcdefg}$ | $7.01^{bc}$ |
| HGS114 | $6.42^{cdefgh}$ | $6.32^{cdefgh}$ | $6.91^{bcdef}$ |
| Agitator | $4.49^{i}$ | $5.86^{defgh}$ | $5.34^{hi}$ |

The effect of planting date, hybrid and plant population on crop development

### Tiller production

More tillers were produced from PD1 and PD2 than PD3. PD1 also resulted in more fertile tillers: 4.34 tillers/m$^2$ compared with 2.88 tillers/m$^2$ for PD2 and 1.78 tillers/m$^2$ for PD3 (data not shown).

Increasing plant population reduced the number of fertile tillers produced. There were differences in the number of fertile tillers produced by each hybrid (Table 5). Agitator, which had the lowest plant establishment, had the highest number of fertile tillers. MR Apollo had the lowest number of fertile tillers.

Table 5 Hybrid differences in fertile tillers and head production/m$^2$ (across planting dates and plant populations).

| Hybrid | Fertile tillers (number/m$^2$) | Heads produced (number/m$^2$) | Primary heads produced (number/m$^2$) |
|---|---|---|---|
| Agitator | $4.17^{a}$ | $9.09^{ab}$ | $4.92^{b}$ |
| G33 | $3.45^{b}$ | $9.91^{a}$ | $6.45^{a}$ |
| Cracka | $3.22^{bc}$ | $9.25^{ab}$ | $6.04^{a}$ |
| A66 | $3.16^{bc}$ | $9.53^{ab}$ | $6.37^{a}$ |
| HGS114 | $3.16^{bc}$ | $9.36^{ab}$ | $6.21^{a}$ |
| MR Buster | $2.80^{bc}$ | $9.27^{ab}$ | $6.47^{a}$ |
| MR Taurus | $2.69^{c}$ | $8.82^{b}$ | $6.13^{a}$ |
| MR Apollo | $1.34^{d}$ | $6.35^{c}$ | $5.02^{b}$ |

### Head production

The PD, plant population and hybrid all affected the number of heads produced per plant. More heads were produced from PD1 than PD3. The differences between PD1 and PD2 were not significant.

As the established plant population increased, so did the number of primary heads produced. Agitator produced the highest number of fertile tillers, but had the lowest number of primary heads as a result of the initial poor stand. MR Apollo and Agitator produced the lowest numbers of primary heads (Table 5). There was no significant difference between the other hybrids in the number of primary heads produced.

The total number of heads produced showed a similar trend. PD1 produced the highest number of heads/m$^2$ compared with PD2 and PD3. Similarly, the number of heads produced rose as the plant population increased. MR Apollo produced the lowest number of total heads (Table 5).

### Affects from planting date on days to 50% flowering

PD, population and hybrid significantly affected the number of days taken to reach to 50% flowering. Planting date significantly increased the days to flowering, with the earlier PDs taking longer to reach this point. It took PD1 an average of 106 days to reach flowering, reducing to 82 days for PD2 and 75 days for PD3. The four-week delay in planting from PD1 to PD2 reduced the time to 50% flowering by 26 days. The difference between PD2 and PD3 was much smaller, with only a seven-day difference.

There were significant interactions between plant population and hybrids. Higher plant populations flowered sooner than the lower plant populations for most hybrids, even though the difference was, at most, five days. Some hybrids such as MR Apollo and Agitator were largely unaffected by plant population. MR Apollo was consistently slow to reach flowering and Agitator was consistently the quickest.

The PD produced differences in maturities between the hybrids. At PD1, the slowest to reach 50% flowering was MR Apollo in 115 days, and the quickest was Agitator at 99 days, a spread of 16 days over the eight hybrids. In contrast by PD3, MR Apollo flowered in 81 days, while Agitator was 70 days, a difference of 11 days.

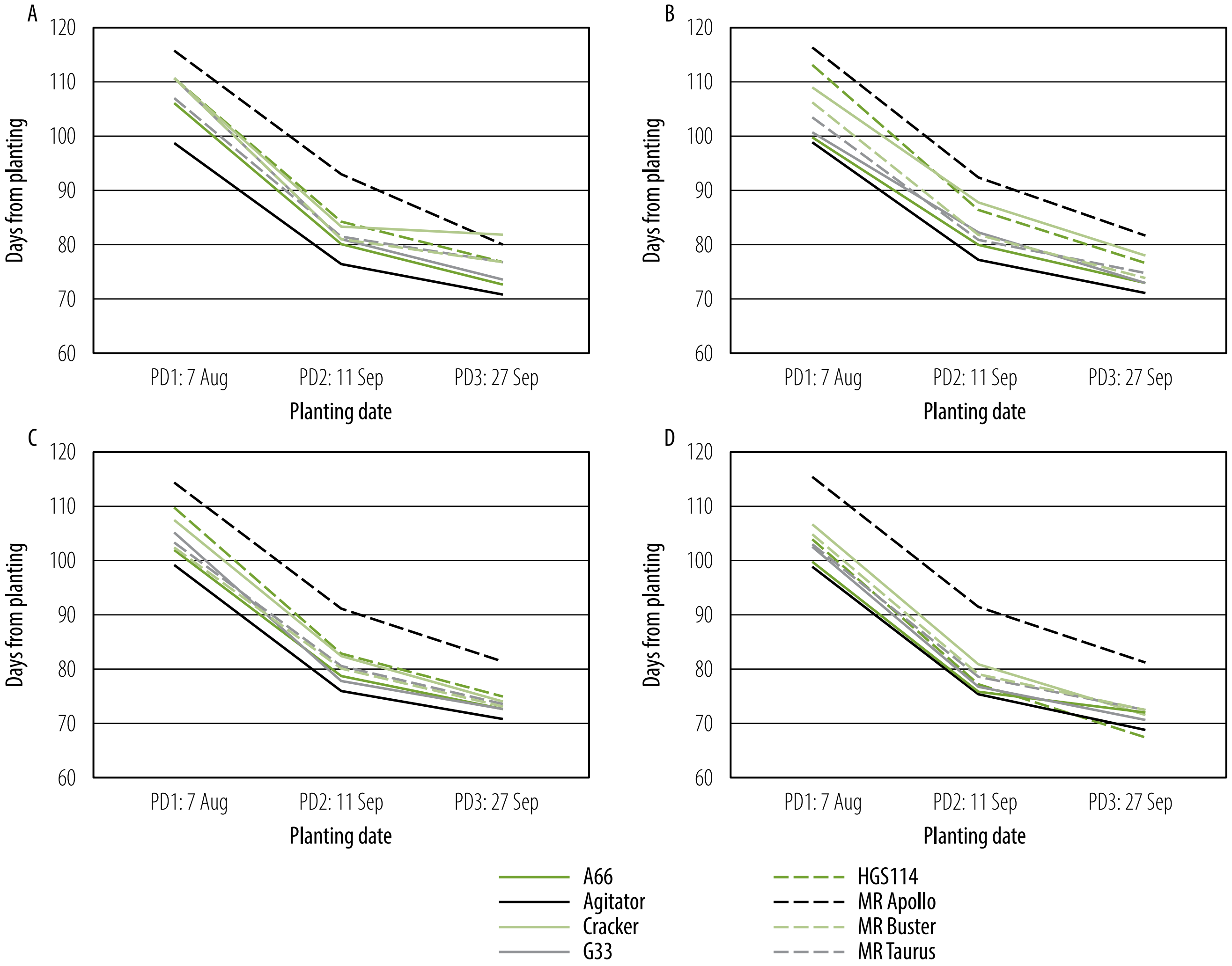

Figure 2 Days to 50% flowering at A) 3 plants/m$^2$, B) 6 plants/m$^2$, C) 9 plants/m$^2$, D) 12 plants/m$^2$.

For PD1, the flowering window was moved forward for all hybrids by around three weeks, compared with planting at the recommended soil temperature (PD3). Figure 1 shows that this meant flowering was completed before the very high temperatures at the beginning of December.

### Dry matter production

The PDs and plant populations affected dry matter production, but no differences were detected between hybrids.

PD1 averaged 7.7 t/ha, which was significant higher than PD2 (6.2 t/ha) or PD3 (5.7 t/ha). The 12 and nine plant population treatments produced significantly more biomass than both the six and three plant populations.

### Harvest index

Harvest index (HI) is used as a measure of efficiency within the plant. It is a ratio comparing the amount of grain produced against the amount of biomass produced. In this study, plants were separated into primary stems and tiller stems for each sample collected.

The HI for the primary stems was quite variable ranging from 61.75% down to 28 % across the three PDs. Agitator consistently had a high HI and MR Apollo consistently had a low HI (Figure 2).

The HI for tiller stems varied between hybrids. Agitator consistently produced high HI's and MR Apollo was the lowest at 7% for PD2 and PD3. A66 showed an interesting relationship between planting times, with a much higher HI for PD1 compared to PD2 or PD3. The HI for tiller stems was lower for all PDs compared with the primary stems. Most hybrids produced a lower HI from PD3 for their tiller stems.

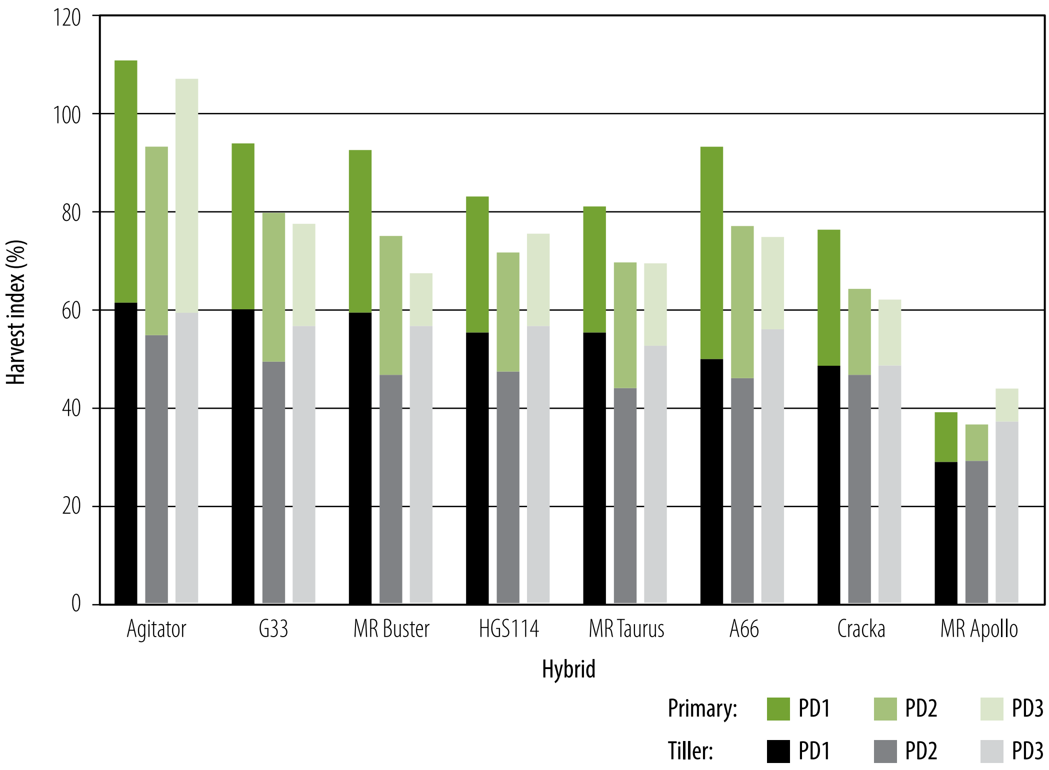

Figure 3 Harvest index of primary stems and tillers on plants at three planting dates (averaged across plant population).

## What was the impact of varying planting date on grain yield and quality?

### Grain yield

The site mean yield was 1.78 t/ha at Ponjola in 2018/19. There was a significant interaction between PD and hybrid yields. Plant population differences were not significant.

PD1 had the highest yield with a mean of 2.14 t/ha. There was no significant difference in the yields of PD2 and PD3, yielding 1.51 t/ha and 1.68 t/ha respectively.

The hybrids performed differently, but there was no correlation between hybrid maturities. MR Apollo was the slowest maturity hybrid and produced the lowest yields from all three PDs. However Agitator, the quickest hybrid, did not produce the highest yields. This could be related to the poor plant establishment and the variety's lower tillering habit. These two factors combined meant the hybrid could not use tillering to fully compensate for the lack of plants. Hybrids that performed consistently well across planting times included MR Buster, MR Taurus, A66 and HGS114.

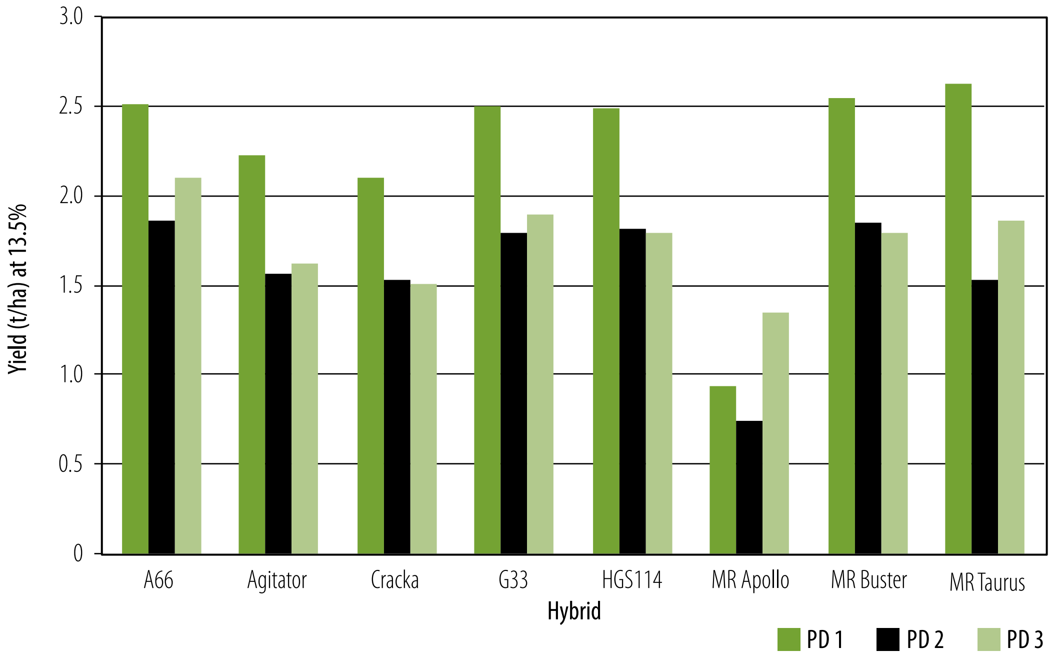

Figure 4 Grain yield at Ponjola, 2018/19.

### Grain quality

Grain protein was significantly less for PD1 (10.7%) compared with PD2 and PD3, at 11.1% and 11.2% respectively. Hybrids varied in their grain protein levels, Agitator produced the lowest protein at 10.7%; MR Apollo the highest at 11.49%; with a range of <1% across hybrids (data not shown). As the population increased, the protein increased, with the 12 plants/m$^2$ population having the highest protein content of 11.2%.

In 2018/19, test weights were generally low and screenings were high. No hybrid produced the required test weight to achieve Sorghum No 1 grade (>71kg/hL). The only treatment to achieve the Sorghum No 1 quality was Cracka at PD3 with 71.3 kg/hL (data not shown).

PD, population and hybrid affected screening percentages. PD1 had significantly lower screenings of 10% than PD2 at 16.6% and PD3 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 12 plants/m$^2$ population was the only treatment to show significantly higher screenings at 15.9% compared with the other populations, which were between 14–15% when averaged across hybrids and PDs.

PD, population and hybrid significantly affected the thousand grain weight. PD1 was significantly higher than both PD2 and PD3. MR Apollo produced the highest weights at 22.7 g in contrast to most of its other traits this season. HGS114 was the lowest, averaging 17 g. MR Apollo was also the most consistent, performing the highest PD.

## Conclusions

At Ponjola in 2018/19 planting earlier than recommended into sub optimal soil temperatures of around 10.8°C for PD1 had little effect on plant establishment of. Final plant establishments were slightly lower than for PD2 and PD3, but this did not affect the final yield results. PD1 yielded significantly better than PD2 and PD3 (where yields were comparable).

The site was only exposed to seven days where the minimum fell below 0 °C and only for PD1. All of these frosts occurred before seedlings emerged. There was a minor amount of post emergence death recorded for plants, which might have been caused by one event where temperatures of 2 °C were recorded at screen height.

Sorghum establishment at Ponjola was not statistically different between PD1, PD2 or PD3. This gives greater confidence in the ability to plant and establish sorghum at soil temperatures less than currently recommended.

PD1 moved the flowering window forward by close to three weeks compared with PD3, which meant avoiding additional heat during December and January.

PD1 produced the best yields of the three planting times at 2.14 t/ha (averaged across hybrids and populations). Grain quality was also improved by planting earlier; PD1 had significantly less screenings, and higher test weight than PD 2 and 3.

## Acknowledgements

This experiment was jointly funded by University of Queensland (UQ), Grains Research and Development Corporation (GRDC) and NSW DPI under project UOQ 1808-001RTX – 'Optimising sorghum yield through agronomic management'.

Technical assistance provided by Delphi Ramsden, Natalie Aquilina, Bronwyn Clarendon, Mitchell Clifton and Mathew Dunn (NSW DPI) is gratefully acknowledged. Thanks to J.R. McDonald and Geoff Manchee, of Ponjola, Moree for hosting the trial and to Rob Holmes, HMAg, for assistance with the site.

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# Soybean variety evaluation – Tabulam 2018/19

Nathan Ensbey, Nguyen Nguyen, Natalie Moore and Sam Blanch

NSW DPI Grafton

## Key findings

- The two new lines T171A-2 (2.74 t/ha) and NK94B-25 (2.51 t/ha) had yields that were statistically similar to the industry standard variety Richmond$^{\Phi}$ (2.28 t/ha).
- RichmondA had a grain protein concentration of 45.2% on a dry matter (DM) basis, which was significantly higher than the varieties T171A-2 (43.0 %) and NK94B-25 (43.4%).
- There was significant difference in seed size between varieties. Richmond$^{\Phi}$ produced the largest seed size (25.7 g/100 seeds), followed by T171A-2 (23.4 g/100 seeds) and NK94B-25 (21.3 g/100 seeds).
- No significant difference in grain oil concentration, plant height, and lodging score was observed between the three lines.
- Downy mildew, a leaf disease, was identified in the experiment, but not at an economically significant level.
- Adaptation of the two unreleased lines to the North Coast region of New South Wales (NSW) was validated through this experiment.

## Introduction

In recent decades, the Australian Soybean Breeding Program (ASBP) has transformed Australian soybean (*Glycine max*) varieties in response to industry calls for varieties with superior quality grain traits. These include high protein, large seed size and clear hilum for supply the high value human consumption markets in Australia and internationally. In 2017, the Grower Variety Selection Committee (GVSC) was formed, and in consultation with the ASBP re-focused on the selection of high yielding lines for northern NSW. Data from past seasons were assessed and several high yielding lines with adequate levels of grain quality were chosen for on-farm evaluation in the summer of 2018/19.

The GVSC was formed to allow growers greater involvement in the selection of new varieties from the breeding program and to participate in data review and on-farm evaluation. It consists of six grower members from the north coast region of NSW, and three NSW DPI representatives. The growers include Kevin Twohill (Murwillumbah), Paul Fleming (Codrington), Kate Dowley (Tabulam), Ben Clift (Codrington), Shane Causley (Warregah Island) and Alan Munro (Woodford Island). The NSW DPI representatives are Dr Natalie Moore (Research Agronomist), Nathan Ensbey (Technical Officer) and Sam Blanch (Technical Assistant).

A replicated, on-farm experiment was conducted at Kendall and Kate Dowley's property at Tabulam in northern NSW to assess two advanced, unreleased high yielding lines against the known Australian industry standard variety Richmond$^{\Phi}$.

## Site details

| | |
|---|---|
| **Location** | Growvale Trust, Plains Station Road, Tabulam, NSW 2469 (Latitude 28°57'23.2"S, Longitude 152°32'52.0"E) |
| **Co-operator** | Kendall and Kate Dowley, Growvale Trust |

| | |
|---|---|
| **Paddock history** | Summer 2017/18: soybean; Winter 2018: wheat |
| **Soil type and nutrition** | Brownish loam $pH_{Ca}$ 5.6<br>Subsoil constraints were not evident at this site. The soil chemical analysis is presented in Table 1. |
| **Rainfall and temperature** | Total rainfall from November 2018 to April 2019 was 346.2 mm, which is 53% less than the long term average of 742.3 mm for this location. There was no rainfall in January 2019, with the remaining months receiving substantially less than long term rainfall averages (March excluded) (Figure 1). Higher average temperatures were recorded during the growing season, which may have negatively affected plant growth. |
| **Experimental design** | Randomised complete block design<br>Three replicates and three varieties<br>Each plot was 4.87 m (6 rows) wide and approximately 95 m long<br>Row spacing was 0.8 m. |
| **Planting date** | 29 December 2018 |
| **Fertiliser** | 400 mL/ha Como® (cobalt 1% and molybdenum 6%) applied over crop rows on 4 February 2019 |
| **Target plant population** | 20 plants/$m^2$ |

Table 1 Soil analysis of Growvale Trust site at Tabulam – 2018/19.

| Measurement | Value |
|---|---|
| Soil pH (1:5 water) | 5.6 |
| Estimated organic matter (% OM) | 2.9 |
| Sulfur (mg/kg) | 5.6 |
| Nitrate Nitrogen (mg/kg) | 17.4 |
| Ammonium Nitrogen (mg/kg) | 2.2 |
| Phosphorus (mg/kg) [Bray 1 test] | 33 |
| Phosphorus (mg/kg) [Bray 2 test] | 63 |
| Phosphorus (mg/kg) [Colwell test] | 71 |
| Potassium (%) | 5.4 |
| Calcium (%) | 75.3 |
| Magnesium (%) | 17.2 |
| Sodium - ESP (%) | 0.7 |
| Aluminium (%) | 0.5 |
| Electrical conductivity (dS/m) | 0.062 |
| Effective cation exchange capacity (ECEC) ($cmol_+$/kg) | 8.2 |
| Zinc (mg/kg) | 4.8 |
| Copper (mg/kg) | 0.6 |
| Iron (mg/kg) | 195 |
| Manganese (mg/kg) | 14 |
| Silicon (mg/kg) | 33 |

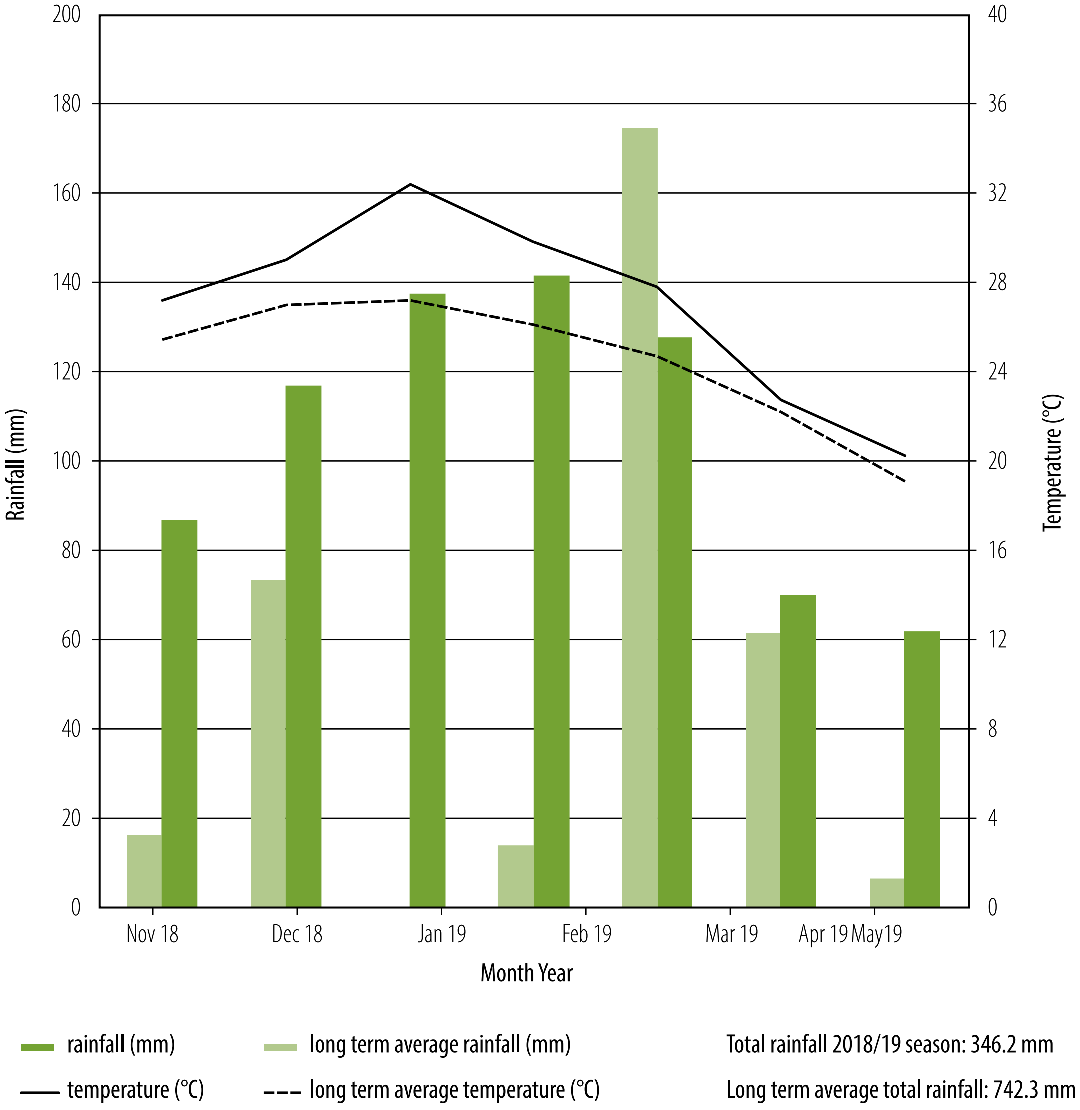

Figure 1 Comparison of growing season rainfall and temperature at Tabulam, NSW 2018/19 with long term average rainfall and temperature data.
*Raw data was obtained at http://www.bom.gov.au/climate/data/ (BOM 2019)*

| | |
|---|---|
| **Weed management** | Starane™ Advanced 450 mL/ha (333 g/L fluroxypyr), fallow weed control.<br>Weedmaster® Argo® 1.8 L/ha (540 g/L glyphosate) was applied on 23 November 2018<br>Spinnaker® 140g/ha (700 g/kg imazethapyr) and Dual Gold® 2.0 L/ha (960 g/L s-metolachlor) was banded over at planting<br>Weedmaster® Argo® 1.8 L/ha (540 g/L glyphosate), mixed with enhance oil at 500 mL/100 L and applied on 6 February 2019<br>Reglone® 2.2.0 L/ha (200 g/L diquat) applied on 5 May 2019 prior to harvest |
| **Insect management** | Targeting larvae of *Helicoverpa armigera*: ViVus® Gold 375 mL/ha (polyhedral inclusion bodies of the nucleopolyhedro virus of *Helicoverpa armigera*) applied 5 February 2019 over rows<br>Targeting brown eggs and hatchling to small larvae of *Helicoverpa* spp: DuPont™ Steward® EC 400 mL/ha (150 g/L indoxacarb) applied on 18 February 2019<br>Controlling Lepidopteran species: DuPont™ Altacor® (350 g/kg chlorantraniliprole) at 70 g/ha applied on 7 March 2019 |

| | |
|---|---|
| **Disease management** | No diseases of economic significance developed in the experiment.<br>Some downy mildew (*Peronospora manshurica*) was present but not at an economically significant level. |
| **Harvest date** | 10 May 2019 |

## Treatments

### Varieties (3)

Commercial standard Richmond$^{\Phi}$ and unreleased lines NK94B-2 and T171A-2. A short description of variety traits and reason for inclusion in trial are listed in Table 2.

Table 2 Description of soybean varieties in the experiment at Tabulam – 2018/19.

| Variety | Variety traits and reason for inclusion in trial |
|---|---|
| Richmond | Industry standard with high weathering tolerance, high protein, clear hilum and high yield, suited to an early-mid planting date in the North Coast and northern slopes regions of NSW. |
| NK94B-25 | Unreleased line with high yield potential, clear hilum, suited to an early-mid planting date. |
| T171A-2 | Unreleased line with high yield potential, clear hilum, suited to an early planting date, resistant to soybean leaf rust, narrow leaf shape. |

## Results

### Establishment

The planting date was three weeks later than planned due to prolonged dry weather, however, all varieties established well and evenly in the experiment (Figure 2).

The established plant population ranged from 243,000 plants/ha to 270,000 plants/ha, within the target range. The unreleased line NK94B-25 developed the bushiest growth habit and line T171A-2 appeared to adapt well to the hot, dry weather with a dense canopy and good pod set (Figure 3). As the grower inadvertently planted over Replicate 2 of line T171A-2, data was only taken from two replicates of this treatment, not from three replicates as for the other treatments.

Figure 2 An on-farm evaluation of unreleased soybean lines was conducted at Growvale Trust, Kendall and Kate Dowley's property at Tabulam. The farming system uses wide (0.8 m) row spacing and double cropping of soybean with winter cereal.
*Photo N. Ensbey NSW DPI*

Figure 3 Soybean line T171A-2 in the on-farm evaluation at Tabulam.
*Photo N. Moore NSW DPI*

### Lodging, leaf diseases and maturity

All soybean varieties in the experiment showed high stand-ability with no lodging observed. Downy mildew leaf disease was detected but there was no significant damage to soybean plants that would results in yield loss. All varieties matured at an acceptable time for harvest.

### Plant height at maturity

Plant height was measured at crop maturity. Line NK94B-25 was the tallest variety at 54.8 cm, followed by line T171A-2 at 51.37 cm and the commercial variety Richmond$^{(b)}$ being the shortest at 45.43 cm (Table 3). There was no significant difference in the data for plant height.

### Grain yield

The data was analysed by Stephen Morris (Biometrician, NSW DPI Wollongbar) using spatial analysis with an asreml package (Butler et al. 2017) in the R environment (R Development Core Team 2017). Differences between results that exceed the estimate of least significant difference (l.s.d.) can be regarded as statistically significant at the 5% critical value ($P<0.05$).

Line T171A-2 yielded 9% higher than line NK94B-25 and 17% higher than variety Richmond$^{(b)}$ (Table 3), however, when analysed there was no statistically significant difference between the yields of the three varieties in this experiment. Figure 4 gives a visual representation of the variation in yield of the field replicates in the experiment.

Table 3 Analysed data of soybean variety evaluation at Tabulam – 2018/19.

| Soybean variety | Grain yield (t/ha) | Seed size (g/100 seed) | Grain oil content (% DM) | Grain protein content (% DM) | Plant height (cm) |
|---|---|---|---|---|---|
| T171A-2 | 2.74$^{a}$ | 23.4$^{c}$ | 20.3$^{a}$ | 43.0$^{b}$ | 51.4$^{a}$ |
| NK94B-25 | 2.51$^{a}$ | 21.3$^{b}$ | 20.8$^{a}$ | 43.4$^{b}$ | 54.8$^{a}$ |
| Richmond | 2.28$^{a}$ | 25.7$^{a}$ | 19.8$^{a}$ | 45.2$^{a}$ | 45.4$^{a}$ |
| l.s.d. ($P<0.05$) | 1.16 | 1.8 | 1.1 | 1.2 | 10.2 |

l.s.d. = least significant difference at the 5% critical value ($P<0.05$)
Note: values with the same letter are not significantly different

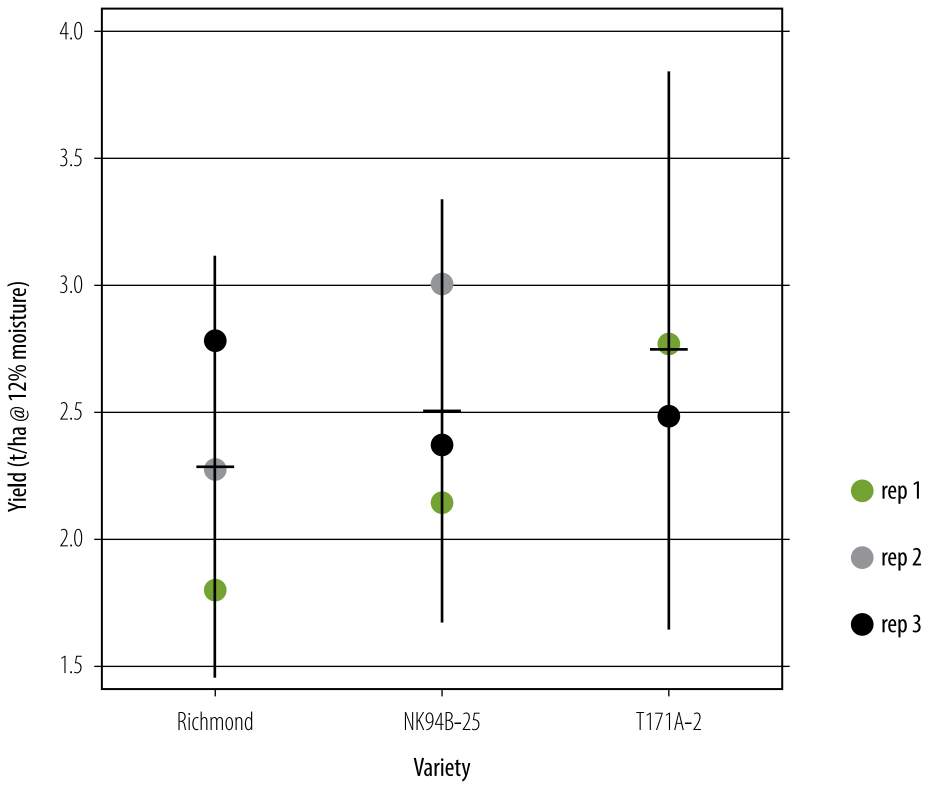

Figure 4 Average yields of the three varieties plotted with the mean of three replicates (replicate 2 of T171A-2 is not included) at Tabulam, NSW 2018/19.

### Seed size

Seed size was measured as the weight of 100 seeds at 12% moisture content. The difference of seed size between three lines was significant, ranging from the largest for standard variety Richmond⊕ (25.7 g/100 seeds) to the smallest, NK94B-25, at 21.3 g/100 seeds. T171A-2 was the second largest seed size recorded at 23.4 g/100 seeds (Table 3).

### Grain protein and oil content

All varieties produced protein content above the industry standard of 40% DM. The protein content of variety Richmond⊕ (45.0% DM) was significantly higher than the two unreleased lines NK94B-25 (43.4% DM) and T171A-2 (43.0% DM) (Table 3). There was no statistically significant difference between the protein content of NK94B-25 and T171A-2.

In relation to grain oil content, the three treatments NK94B-25 (20.8% DM), T171A-2 (20.3% DM), and Richmond⊕ (19.8% DM) were statistically similar (Table 3).

## Conclusions

Average rainfall during the growing season was 53% of the long term average rainfall for the region. This, combined with the higher temperature during the growing season, may have negatively affected plant growth and decreased the overall yield of the experiment. The collaborating grower confirmed that soybean yield was lower than average for their farm this season. However, the two unreleased lines and Richmond⊕ adapted well to the unfavourable conditions and established evenly. Results indicate that the two unreleased soybean lines (NK94B-25 and T171A-2) performed similarly to the high yielding commercial variety Richmond⊕ and produced acceptable protein content and seed size, confirming their adaptation to the North Coast region of NSW. The growers commented favourably on the establishment and yield of line T171A-2, and expressed interest in evaluating the variety again. Although no soybean leaf rust developed in this experiment, the resistance of line T171A-2 to this disease is considered as a valuable trait to protect yield in seasons with high rainfall and, therefore, high yield potential.

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## Acknowledgements

The assistance of Growvale Trust (Kendall and Kate Dowley) in conducting and maintaining this trial is gratefully acknowledged. Statistical analysis performed by Stephen Morris, NSW DPI, Wollongbar is gratefully acknowledged.

This regional on-farm evaluation was an objective of the Australian Soybean Breeding Program, which is a co-investment by NSW DPI, CSIRO and Grains Research and Development Corporation (GRDC), project number 9175421.

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# Soybean variety evaluation – Oakwood 2018/19

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## Key findings

- Two unreleased soybean lines, T171A-2 and NK94B-25, had the highest yield in this experiment (2.15 t/ha and 2.04 t/ha, respectively) followed by the two commercial standard varieties Richmond$^{\phi}$ (1.94 t/ha) and Moonbi$^{\phi}$ (1.73 t/ha).
- Line T171A-2 had the highest plant height at maturity (61.3 cm), while the lowest height recorded was for variety Moonbi$^{\phi}$ (48.7 cm). There was no significant difference in plant height between Richmond$^{\phi}$ (53.7 cm) and NK94B-25 (59.7 cm).
- The two unreleased lines appear to be well adapted to the northern slopes production region of New South Wales (NSW) in terms of yield, lack of leaf diseases and suitable maturity compared with current commercial cultivars.

## Introduction

In recent decades, the Australian Soybean Breeding Program (ASBP) has transformed Australian soybean (*Glycine max*) varieties. This was in response to industry calls for varieties with superior quality grain (high protein, large seed size, clear hilum) to supply the high value, human consumption markets in Australia and internationally. In 2017, the Grower Variety Selection Committee (GVSC) was formed, and in consultation with the ASBP, has re-focused on selecting high-yielding lines for northern NSW. Data from past seasons were assessed and several high-yielding lines with adequate grain quality were chosen for on-farm evaluation in the summer of 2018/19.

The GVSC was formed to allow growers greater involvement in selecting new varieties from the breeding program and to participate in data review and on-farm evaluation. It consists of six grower members from the north coast region of NSW, and three NSW DPI representatives. The growers include Kevin Twohill (Murwillumbah), Paul Fleming (Codrington), Kate Dowley (Tabulam), Ben Clift (Codrington), Shane Causley (Warregah Island) and Alan Munro (Woodford Island). The NSW DPI representatives are Dr Natalie Moore (Research Agronomist), Nathan Ensbey (Technical Officer) and Sam Blanch (Technical Assistant).

A replicated, on-farm experiment was conducted at Brad and Kyeron Schwark's property, Oakwood NSW to assess two advanced unreleased high-yielding lines against two known Australian industry standards, Moonbi$^{\phi}$ and Richmond$^{\phi}$.

## Site details

| | |
|---|---|
| **Location** | Narallen, 1306 Dintonvale Road, Oakwood, NSW 2360 (Latitude 29°36'31.55"S, Longitude 151°02'42.96" E) |
| **Paddock history** | Summer 2017/18: maize. Cultivation included strip-tilling on 76 cm row spacing. |
| **Co-operators** | Brad and Kyeron Schwark |
| **Soil type and nutrition** | Brownish clay loam. The three important nutrients for growing soybean, nitrogen (N), phosphorus (P), and potassium (K) were slightly low (Table 1). |

Table 1 Soil analysis of the trial site at Schwark's property at Oakwood – 2018/19.

| Soil measurement | Value |
|---|---|
| Soil pH (1:5 water) | 6.7 |
| Estimated organic matter (% OM) | 2.9 |
| Sulfur (mg/kg) | 16 |
| Nitrate nitrogen (mg/kg) | 12 |
| Ammonium nitrogen (mg/kg) | 0.1 |
| Phosphorus (mg/kg) [Bray 1 test] | 3.1 |
| Phosphorus (mg/kg) [Bray 2 test] | 10 |
| Phosphorus (mg/kg) [Colwell P test] | 19 |
| Potassium (%) | 0.6 |
| Calcium (%) | 51.9 |
| Magnesium (%) | 46.9 |
| Sodium – ESP (%) | 0.6 |
| Aluminium (%) | 0 |
| Electrical conductivity (dS/m) | 0.1 |
| Effective cation exchange capacity (ECEC) (cmol+/kg) | 53.6 |
| Zinc (mg/kg) | 4.6 |
| Copper (mg/kg) | 2.8 |
| Iron (mg/kg) | 45 |
| Manganese (mg/kg) | 26 |
| Silicon (mg/kg) | 82 |

| | |
|---|---|
| **Rainfall and temperature** | From November 2018 to April 2019, the site received 289.7 mm of rain. This was 40% less than the long-term average (488.6 mm) for this location (Figure 1). To maintain the experiment, the growers irrigated the area twice using a lateral boom irrigator, applying approximately 40 mm total additional irrigation water. Lower than average rainfall, combined with higher than average temperatures (Figure 1), had a negative effect on soybean growth rates through the vegetative and reproductive stages of the crop. Growth was even across the site and enabled useful yield data acquisition. |
| **Experiment design** | A randomised complete block design with four treatments (varieties) and three replicates was used. Each plot was 9 m wide and 63 m long with 12 rows per plot and 0.76 m row spacing to fit with the grower's farming system. |
| **Planting date** | 11 December 2018 |
| **Fertiliser** | A mixture of Incitec Pivot fertilisers with 50% MAP (mono-ammonium phosphate) and 50% DAP (di-ammonium phosphate) was applied at 200 kg/ha to supply N and P as per the grower's usual practice. |
| **Target plant population** | 30 plants/m$^2$ |
| **Weed management** | Weed control at the site was adequate. Chipping was required later in the season to remove some Noogoora burr (*Xanthium occidentale*) before harvest. Desiccation was not required. |

| | |
|---|---|
| **Insect management** | Legion® Insecticidal Seed Treatment (fipronil 500 g/L) as a seed dressing for control of lucerne crown borer (*Zygrita diva*) at 200 mL/100kg of seed.<br>ViVus® Gold (polyhedral inclusion bodies of the nucleopolyhedro virus of *Helicoverpa armigera*) at 375 mL/ha to manage larva of *Helicoverpa armigera*.<br>DuPont™ Altacor® (chlorantraniliprole 350 g/kg) at 70 g/ha to control Lepidopteran species. |
| **Disease management** | No diseases of economic significance were detected in the crop. |
| **Harvest date** | 25 April 2019 |

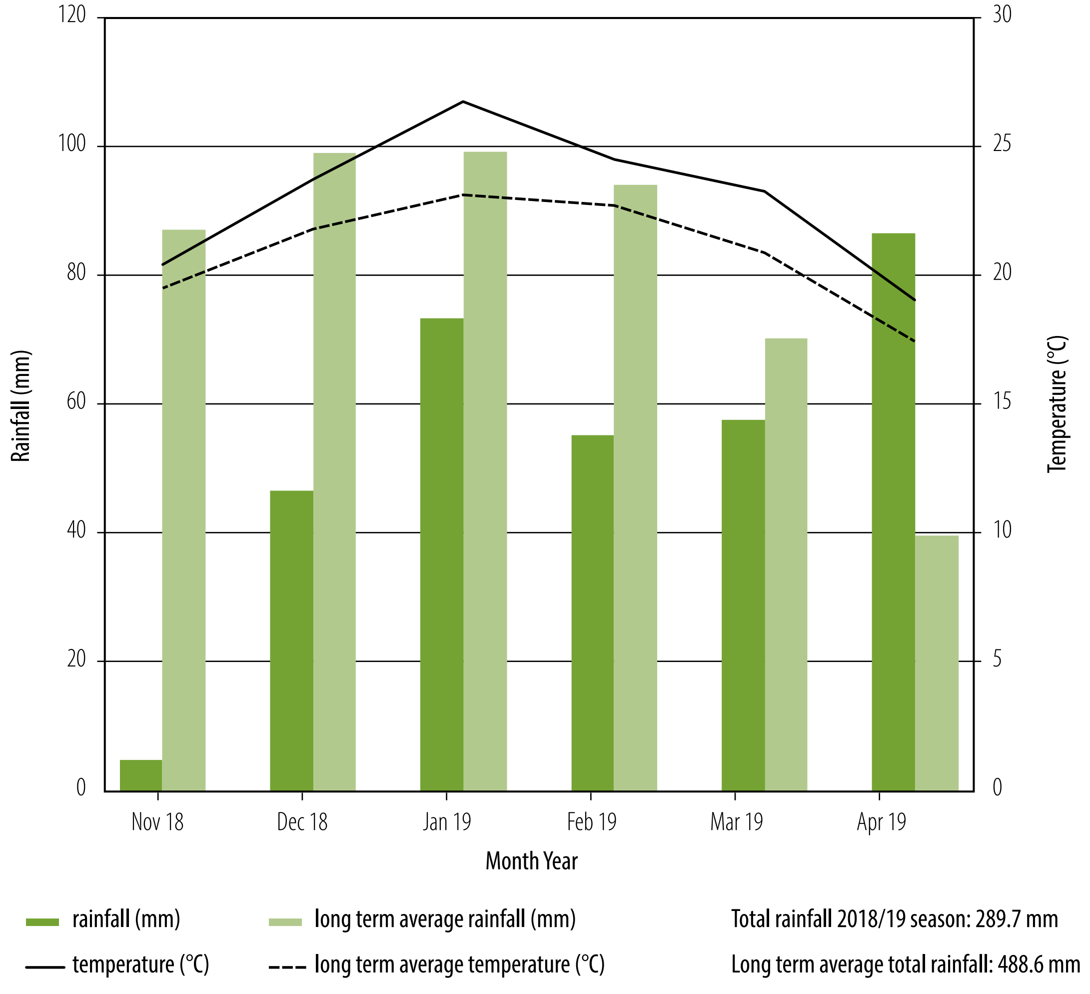

Figure 1 Comparison of growing season rainfall and temperature at Oakwood in 2018/19 with long term average rainfall and temperature.
*Raw data was obtained at http://www.bom.gov.au/climate/data/ (BOM 2019)*

## Treatments

### Varieties (4)

Commerical standards Moonbi$^{\Phi}$ and Richmond$^{\Phi}$ and unreleased lines NK94B-2 and T171A-2. A short description of variety traits and reason for inclusion are listed in Table 2.

Table 2 Description of the soybean varieties in the on-farm evaluation at Oakwood – 2018/19.

| Variety | Variety traits and reason for inclusion in the on-farm evaluation |
|---|---|
| Moonbi$^{(\phi)}$ | Industry standard with compact plant shape, quick maturing, clear hilum, high protein, suited to early planting dates in the northern slopes region of NSW. |
| Richmond$^{(\phi)}$ | Industry standard with high weathering tolerance, high protein, clear hilum and high yield, suited to an early–mid planting date in the northern slopes region of NSW. |
| NK94B-25 | Unreleased line with high yield potential, clear hilum, suited to an early–mid planting date in northern NSW. |
| T171A-2 | Unreleased line with high yield potential, clear hilum, suited to an early planting date in northern NSW, resistant to soybean leaf rust, narrow leaf shape. |

## Results

### Establishment

Frequent crop scouting was undertaken to record plant parameters and to prevent early insect and disease damage. The plant population ranged from 285,000 plants/ha to 340,000 plants/ha, within the target. New line T171A-2 adapted well to the harsh hot and dry conditions with impressive pod set and grain fill (Figure 2).

Figure 2 Pod set and grain fill of experimental soybean line T171A-2.
*Photo: N. Moore*

### Maturity

Rainfall in mid April confounded the time to reach harvest maturity in this experiment, therefore accurate maturity data was not available. However, it is estimated at approximately 135 days after planting for the unreleased lines T171A-2, NK94B-25 and Richmond$^{(\phi)}$. Moonbi$^{(\phi)}$ matured earlier than the other varieties (approximately 128 days after planting; Figure 3).

Figure 3 Early maturing soybean variety Moonbi$^{\phi}$ (left, 1.73 t/ha) was out-yielded by experimental line T171A-2 (right, 2.15 t/ha).
*Photo taken on 11 April, 2019 by N. Moore*

### Grain yield and plant height

Stephen Morris (Biometrician, NSW DPI Wollongbar) analysed the data using spatial analysis with the asreml package (Butler et al., 2017) in the R environment (R Development Core Team 2017). Differences that exceed the estimate of least significant difference (l.s.d.) can be regarded as statistically significant at the 5% critical value ($P<0.05$).

Moonbi$^{\phi}$ was significantly lower yielding (1.73 t/ha) than the two unreleased soybean lines NK95B-25 (2.04 t/ha) and T171A-2 (2.15 t/ha), and statistically similar to the Richmond$^{\phi}$ yield of 1.94 t/ha (Table 3). There was no statistically significant difference between Richmond$^{\phi}$ and the two unreleased lines.

Table 3 Yield and plant height data.

| Soybean variety | Grain yield (t/ha) | Plant height (cm) |
|---|---|---|
| T171A-2 | 2.15 | 61.3 |
| NK94B-25 | 2.04 | 59.7 |
| Richmond | 1.94 | 53.7 |
| Moonbi | 1.73 | 48.7 |
| s.e. | 0.07 | 2.0 |
| l.s.d. ($P<0.05$) | 0.24 | 6.9 |

s.e. = standard error
l.s.d. = least significant difference at the 5% critical value ($P<0.05$)

The average grain yields of Richmond$^{\phi}$, NK95B-25, and T171A-2 were consistent between the treatments. The yield of variety Moonbi$^{\phi}$ was low in field replicate one, which accounted for the variety's reduced average yield in the experiment (Figure 4).

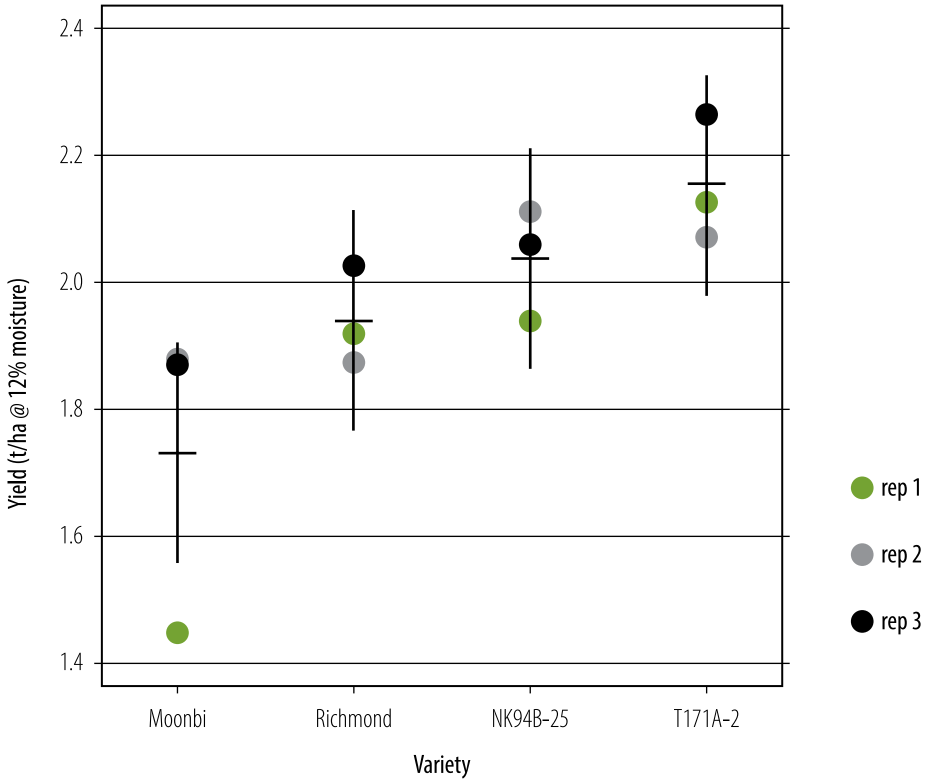

Figure 4 Average grain yields of the four varieties plotted with the mean.

All the varieties in the trial reached acceptable plant height for ease of harvest. The unreleased lines, NK94B-25 (59.67 cm) and T171A-2 (61.33 cm), resulted in the highest plant heights at maturity whereas variety Moonbi⁽ᶲ⁾ (48.7 cm) was the shortest (Table 3). There was no significant difference in plant height between Moonbi⁽ᶲ⁾ and Richmond⁽ᶲ⁾ (53.67 cm), or between Richmond⁽ᶲ⁾ and NK94B-25 (59.67 cm). Plant height differences between the treatments can result from different phenotypes and, according to Diondra et al., (2008), higher plant height is not necessarily correlated to an increase in soybean yield.

## Conclusions

Results from this on-farm experiment indicated that the two unreleased soybean lines, T171A-2 and NK94B-25, produced higher yields than the industry standard Moonbi⁽ᶲ⁾ and have the potential to outperform variety Richmond⁽ᶲ⁾ in terms of yield. The very dry and hot conditions during the summer of 2018–19, combined with a later than usual planting date, was likely to have decreased the yield of all varieties in the experiment. No leaf diseases of economic significance were observed in any of the varieties during the experiment.

The growers commented that both of the unreleased lines in this experiment were suited to their farming system, although neither was as fast to mature as variety Moonbi⁽ᶲ⁾. In their experience, Moonbi⁽ᶲ⁾ is usually ready to harvest 7–10 days earlier than Richmond⁽ᶲ⁾ and up to two weeks earlier than variety Soya791 when planted on the same date. Early maturity is beneficial for minimising the risk of early frost damage and avoiding delays in sowing winter crops in a double-cropping farming system.

These results give the GVSC confidence that the new varieties T171A-2 and NK94B-25 are suitable to northern NSW. The GVSC will continue to participate in on-farm evaluations of high-yielding soybean lines from the ASBP and make recommendations for release.

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## Acknowledgements

This regional on-farm evaluation was an objective of the Australian Soybean Breeding Program (GRDC Project number 9175421), which is a co-investment by NSW DPI, Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Grains Research and Development Corporation (GRDC).

The assistance of Brad and Kyeron Schwark in conducting and maintaining this experiment is gratefully acknowledged. Statistical analysis performed by Stephen Morris, NSW DPI, Wollongbar is gratefully acknowledged.

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# Manipulating maize genetics and agronomy for improved yield and reliability in northern NSW – Breeza 2017/18

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## Key findings

- Early planting into a soil temperature of less than 10 °C, which is lower than the industry recommendation of 12° C, did not affect plant establishment at this site in this season. Further research is needed to validate these results and allow for consideration of the effects in different seasons when frosts can occur around sowing.
- Varying the sowing date from early August to late August or to mid-September did not affect grain yield.
- There was no significant difference in grain yield between the three hybrids included in this experiment: Pioneer® P1467, Pioneer® P1756 and PAC 606IT.
- The optimum plant density for all hybrids was determined as 8.4 plants/m$^2$ where the predicted yield for the three times of sowing was 7.2–7.7 t/ha.

## Introduction

Dryland maize is a minor summer grain crop in northern NSW, due to the high risk of crop failure or un-economic yields due to variable seasonal conditions. The major challenges that growers currently face relate to a lack of information on how to mitigate these risks through optimising agronomic decisions such as sowing time, plant population, hybrid type and crop nutrition. Ensuring that the crop can reliably produce an economic yield is a critical factor influencing growers' decisions to plant maize and also affects industry size.

This research focuses on two key factors that influence crop reliability and performance:

1. silking and tasselling synchronisation in an environment prone to extreme heat and moisture stress during the summer
2. trying to manipulate the interactions between crop genetics and agronomic decisions to improve grain yield and quality.

This experiment was designed to evaluate options to manipulate pollination and grain fill timing to avoid peak heat windows. It also aimed to provide information on ways to improve the crop's harvest index (HI – the ratio of grain produced compared with the amount of dry matter produced) through managing unproductive biomass accumulation and water used.

The experiment can be posed as the following question: Can maize reliability and yield be improved through selecting more suitable hybrid types (e.g. varying multi-cobbing and tillering propensity) and biomass management (e.g. through varying sowing time and plant population)?

The same experiment was conducted at Mallawa, west of Moree and Gurley, east of Moree to provide data on the responses to varying sowing time, population and hybrid type in different environments.

## Site details

| | |
|---|---|
| **Location** | Breeza – Liverpool Plains Field Station |
| **Co-operator** | NSW Department of Primary Industries. |

### Soil type and nutrition

The site was cored before sowing to establish starting nutrition and water. The starting soil water was 188, 220 and 218 mm of plant available water for times of sowing date (SD) one, two and three respectively.

Table 1 Site soil chemical characteristics – Breeza 2017/18.

| Characteristic | Depth (cm) | | | | |
|---|---|---|---|---|---|
| | 0–10 | 10–30 | 30–60 | 60–90 | 90–120 |
| pH$_{Ca}$ | 7.7 | 7.4 | 8.0 | 8.0 | 8.2 |
| Nitrate nitrogen (mg/kg) | 11 | 18 | 11 | 5 | 4 |
| Phosphorus (Colwell) (mg/kg) | 37 | 17 | 14 | 20 | 27 |
| Potassium (Colwell) (mg/kg) | 454 | 268 | 226 | 234 | 265 |
| Sulfur (mg/kg) | 4.9 | 10.8 | 13.0 | 16.3 | 26.6 |
| Organic carbon (OC) (%) | 1.11 | 0.77 | 0.68 | 0.56 | 0.39 |

### Rainfall

A total of 272 mm rainfall was recorded at the site from August 2017 through to the end of February 2018 (Table 2). There was very little rain during August and September, so there was little difference in the in-crop rainfall regardless of the sowing date. SD1 and SD2 received 258 mm of in crop rain, whilst SD3 received 253 mm.

Table 2 Rainfall (mm) during the growing season – Breeza 2017/18.

| Month | Aug 2017 | Sept 2017 | Oct 2017 | Nov 2017 | Dec 2017 | Jan 2018 | Feb 2018 | Total (mm) |
|---|---|---|---|---|---|---|---|---|
| Rainfall (mm) | 14.0 | 5.0 | 92.0 | 56.0 | 54.0 | 10.0 | 41.0 | 272.0 |

### Experiment design

A split, split plot design was used with sowing date blocked, plant population blocked and hybrid randomly allocated. Three replications were used.

### Fertiliser

50 kg/ha Granulock Supreme Z was applied with the seed at planting.
200 kg/ha urea applied as a side band at planting.

### Harvest dates

SD1: 9 March 2018
SD2: 9 March 2018
SD3: 12 March 2018

## Treatments

### Sowing time (3)

Three target soil temperatures at sowing: 10 °C, 14 °C and 16–18 °C were used. This resulted in the following sowing dates and soil temperatures (presented as an average of seven days post sowing) in 2017.

SD1: 9 August 2017 at 9.7 °C
SD2: 28 August 2017 at 10.8 °C
SD3: 20 September 2017 at 15.8 °C

### Plant populations (4)

Four plant populations targeting 1.5, 3.0, 6.0 and 12.0 plants/m$^2$.

### Hybrids (3)

Pioneer® P1467, Pioneer® P1756, PAC 606IT

## Results

### Plant establishment

There was no difference in plant establishment between sowing date or hybrids. Established populations were higher than the target except for the 12 plants/m$^2$ treatment, which achieved 9.3 plants/m$^2$ (Figure 1). The reduced establishment for the highest population target was due to an inability to achieve a higher sowing rate on the planter, so only 11 seeds/m$^2$ could be sown with the highest setting.

The lack of statistical difference in plant establishment between the three SDs indicates that soil temperatures as low as 10 °C can be successfully used to establish maize.

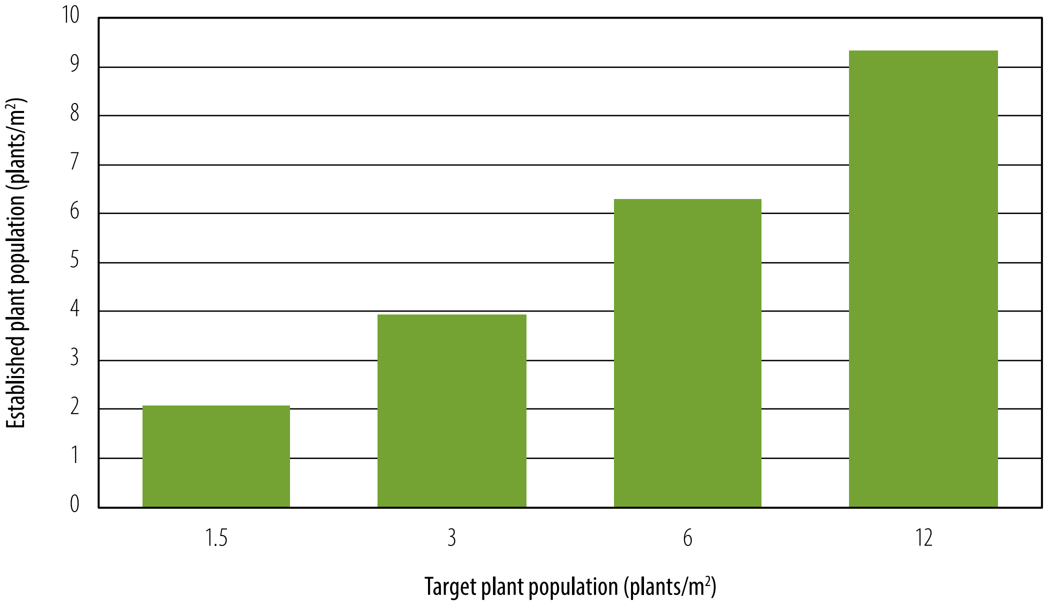

Figure 1 Target versus established plant population in maize – Breeza 2017/18.

Frost risk needs to be considered for the next stage of plant growth – from seedlings to flowering. Planting earlier in the season could expose the crop to higher frost risks, thereby increasing the chances of plant damage or death. In this season, there were 21 frosts (below 0 °C at screen height) in the 40 days following SD1 (Figure 2). There was no effect on maize plants, even though a −2.2 °C frost was recorded on 15 September, 10 days after the first plants from SD1 were starting to emerge.

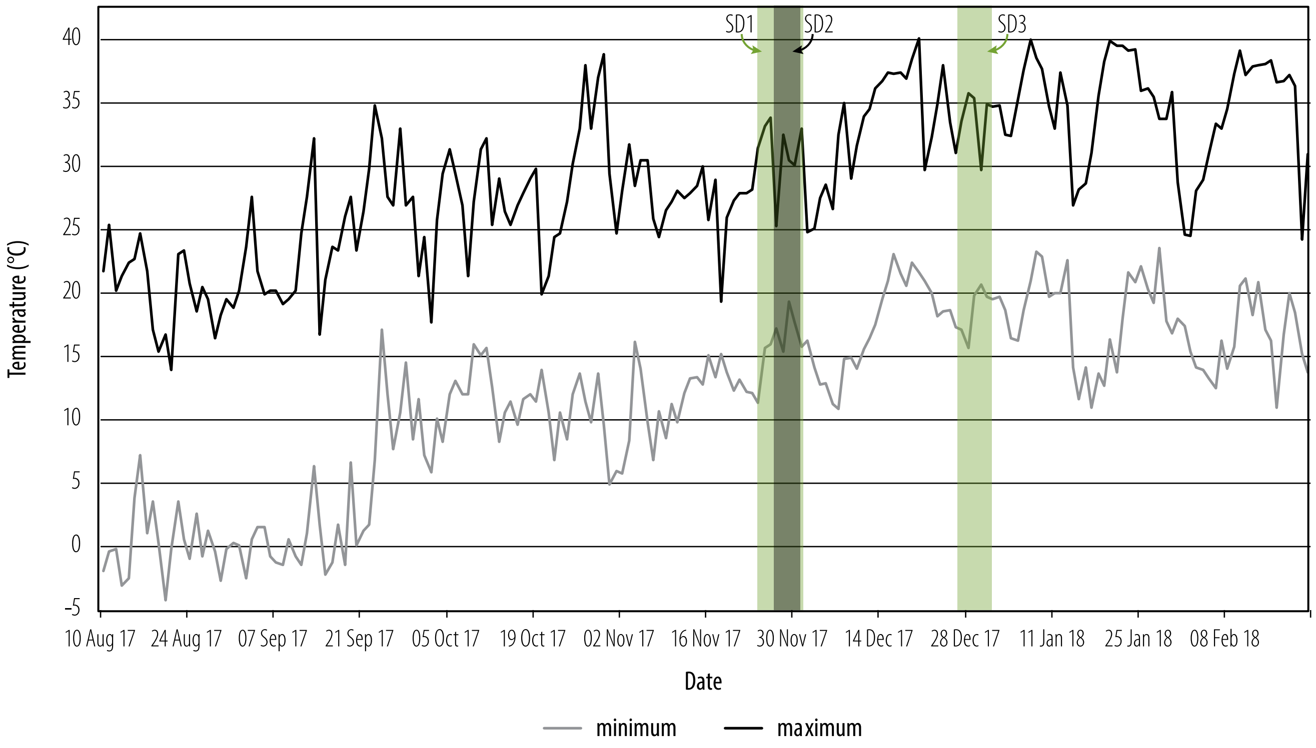

Figure 2 Maximum and minimum temperatures at screen height – Breeza 2017/18.

## Flowering

The number of days taken to reach 50% flowering was recorded for each treatment (Table 3). There was a significant reduction in the time taken to reach flowering between SD1 and SD2 from 112 days to 97 days respectively, and then a lengthening for SD3 back to an average of 102 days. The three hybrids differed in their length to flowering with PAC 606IT being the quickest.

Table 3 Days to 50% flowering of maize treatments – Breeza 2017/18.

| Sowing date | Target plant population (plants/m$^2$) | Pioneer® P1467 | Pioneer® P1756 | PAC 606IT |
|---|---|---|---|---|
| SD1 | 1.5 | 118 | 112 | 109 |
| | 3 | 117 | 112 | 108 |
| | 6 | 117 | 115 | 109 |
| | 12 | 115 | 109 | 109 |
| SD2 | 1.5 | 98 | 98 | 94 |
| | 3 | 98 | 95 | 93 |
| | 6 | 98 | 98 | 95 |
| | 12 | 98 | 98 | 97 |
| SD3 | 1.5 | 105 | 104 | 98 |
| | 3 | 105 | 104 | 98 |
| | 6 | 105 | 102 | 99 |
| | 12 | 105 | 101 | 99 |

Sowing at either SD1 or SD2 allowed the crop to flower before the peak heat of the season as shown by the shaded boxes in Figure 2. For SD3 however, the critical stages of silking and tasselling were reached during the heat of late December when temperatures were in the mid to high °C 30s.

## Grain yield

There was no difference in grain yield between the three SDs or between the hybrids. However, there was a significant response to plant density for all treatments (Figure 3). Based on this, a common optimum plant density was determined at 8.4 plants/m$^2$ at this yield level for the three SDs, which were predicted to yield between 7.2–7.7 t/ha. Established populations above or below the optimum produced reduced yields.

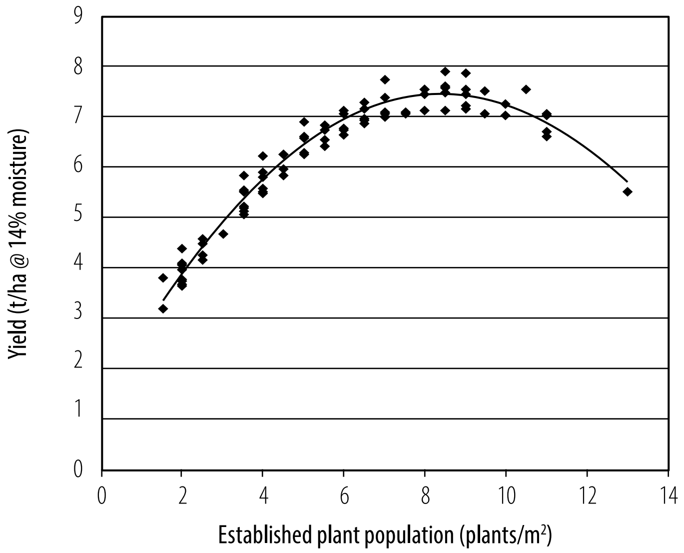

Figure 3 Grain yield response to varying plant population and sowing time in maize – Breeza 2017/18.

## Grain quality

Grain quality testing was conducted for the following factors: protein content, screenings, test weight and 1000 grain weight.

### Protein

Sowing dates had a significant effect on grain protein, with the protein content declining as the sowing date became earlier. Sowing in September produced a significantly higher protein of 11.3% than sowing in early or late August, which produced grain of 10.7% and 11.0% protein respectively. There was also an interaction between hybrid and plant population on grain protein, with protein levels declining as population increased (Figure 4).

### Screenings and 1000 grain weight

Sowing date had no effect on screenings levels; however, there was a response to plant population (data not shown). The highest population, a target of 12 plants/m$^2$ had significantly higher screenings levels than all other plant populations, however, all levels were still below 1%. Similarly, there were differences between the hybrids tested, with Pioneer® P1756 having higher screenings, but again all screenings were below 1%. The highest population also had significantly higher 1000 grain weight.

### Test weight (kg/hL)

There was an interaction between SD, hybrid and plant population. Pioneer® P1756 had the highest test weight of the three hybrids and PAC 606IT the lowest. Test weight also tended to increase with plant population up to 6 plants/m$^2$ and then reached a plateau, with the exception of PAC 606IT, which showed a trend of continued increase (Figure 5).

### Harvest index (HI)

There was a very strong correlation between HI and grain yield; as grain yield increased so did HI (Figure 6). There was no clear correlation between either SD, plant population or hybrid to explain the HI results.

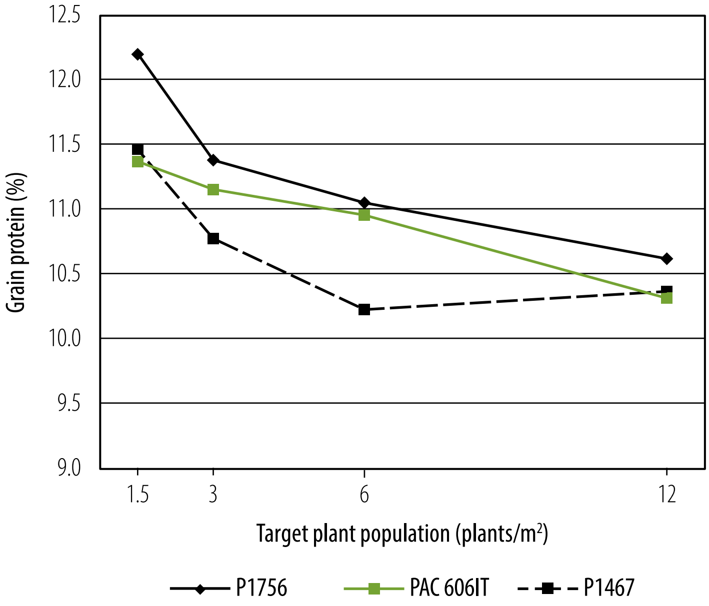

Figure 4 Effect of plant population and hybrid on grain protein – Breeza 2017/18.

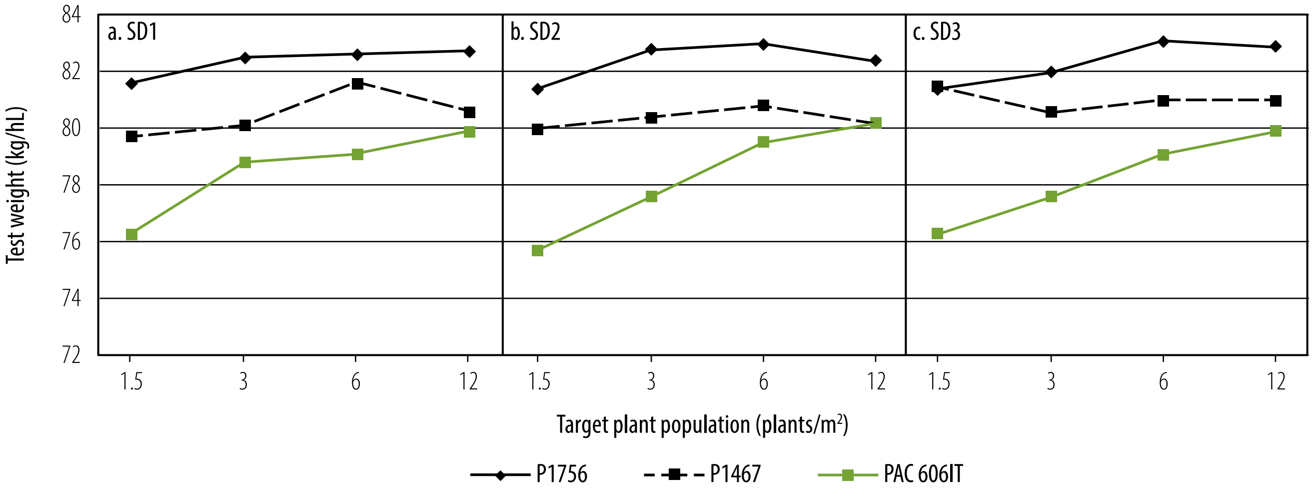

Figure 5 Interaction between hybrid and target plant population at each sowing date: (a. SD1, b. SD2, c. SD3) – Breeza 2017/18.

## Conclusions

The results from the Breeza site support the possibility of moving the sowing window for maize forward to allow planting in cooler soil conditions than currently recommended, without suffering establishment losses. Additional experiments conducted over multiples seasons with more frosts and having greater intensity would help to build confidence in these results.

In this environment in this season, moving the sowing window forward did not affect grain yield. Therefore, the decision to plant earlier this year would be largely based on access to good sowing moisture without needing to wait for soil temperatures to reach 12° C and rising. The experiment produced a significant response to varying plant population with grain yield being optimised at 8.4 plants/m$^2$.

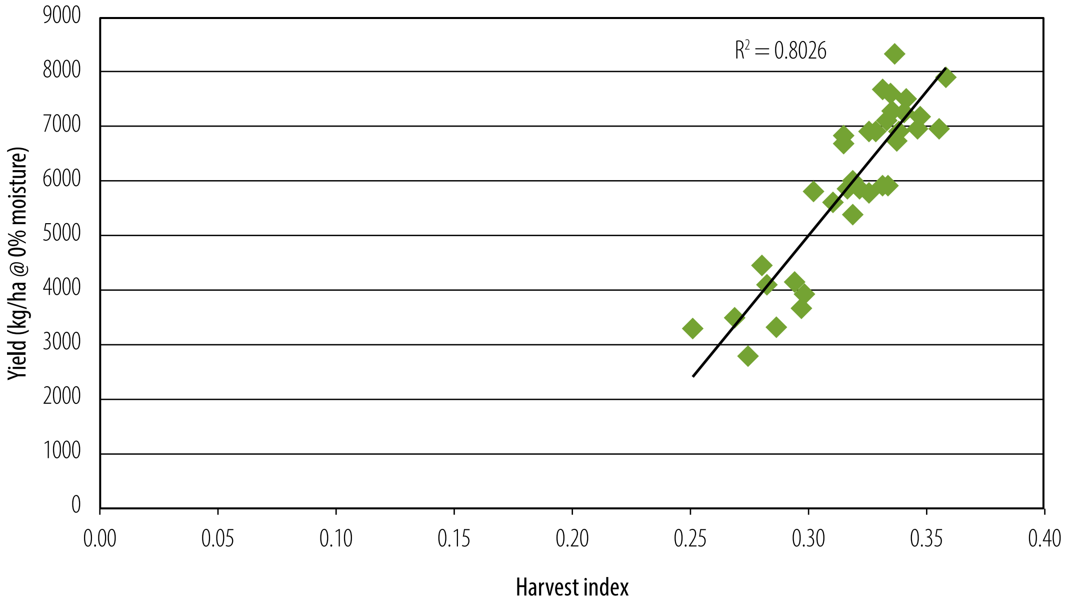

Figure 6 Correlation between grain yield and harvest index – Breeza 2017/18.

Varying plant population did affect grain quality attributes, with screenings and test weight being higher at the target population of 12 plants/m$^2$.

There was also an effect on grain protein, with levels increasing as sowing was delayed from early to the recommended time. There was a range in the HIs found at this site; however, no trends with SD, plant population or hybrid could be identified.

Importantly, these results show that sowing earlier than traditionally planned moved the flowering and grain fill window forward to late November/early December, which allowed the crop to avoid the main period of high temperatures. Long-term seasonal data indicates generally lower temperatures in late November than in late December. Realistically however, climate variability means there is no guarantee of average conditions in every season.

## Acknowledgements

This experiment was part of the project 'Tactical Sorghum and Maize Agronomy in the northern region – NSW component' DAN00195 which was a joint investment by NSW DPI and Grains Research and Development Corporation (GRDC).

Thanks to Scott Goodworth and Steve Jengos, NSW DPI for assisting with the experiment site. Technical assistance provided by Delphi Ramsden, Bailey Skewes (NSW DPI) and Alice Bowler (formerly NSW DPI) is gratefully acknowledged. Thanks to Pioneer and Pacific seeds for supplying the hybrid seed.

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# Manipulating maize genetics and agronomy for improved yield and reliability in northern NSW – Gurley 2017/18

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## Key findings

- Early planting into a soil temperature of 10 °C, which is lower than the recommended 12° C at this site in this season, did not affect plant establishment. Further research is needed to validate these results and allow for consideration of the affects in different seasons when frosts can occur around sowing.
- Harvest index (HI) was highest from the earliest sowing date (SD) – the beginning of August.
- There was little effect from hybrid or plant population on harvest index at SD1 (2 August) or SD2 (22 August). In contrast, differences in HI resulted from varying plant populations at SD3 (17 October), with the results varying between hybrids.
- There was an interaction between plant population and SD for yield.
- The earliest SD produced the highest yields. Two of the hybrids, Pioneer® P1467and Pioneer® P1756 were unresponsive to varying plant population. In contrast, PAC 606IT produced the highest yields when its population was 44,000 plants/ha.
- The third SD suffered from heat stress during the critical growth stages of pollination and grain fill, producing the lowest yields.

## Introduction

Dryland maize is a minor summer grain crop in northern NSW, due to the high risk of crop failure or un-economic yields. The major challenges that growers currently face relate to a lack of information on how to mitigate these risks through optimising agronomic decisions such as sowing time, plant population, hybrid type and crop nutrition. Ensuring the reliability of the crop to produce an economic yield is a critical factor influencing growers' decisions to plant maize and the effects this has on industry size.

Two key factors which influence crop reliability and performance have been the focus of this research:

1. Ensuring synchronisation of silking and tasselling in an environment prone to extreme heat and moisture stress during the summer.
2. Trying to manipulate the interactions between crop genetics and agronomic decisions to improve grain yield and quality.

This experiment was designed to evaluate options to manipulate pollination and grain fill timing to avoid peak heat windows. It also aimed to provide information on ways to improve the crop's HI (the ratio of grain produced compared with the amount of dry matter produced) through managing unproductive biomass accumulation and water used.

The experiment can be posed as the following question: Can maize reliability and yield be improved through selecting more suitable hybrid types (e.g. varying multi-cobbing and tillering propensity) and biomass management (e.g. through varying sowing time and plant population)?

The same experiment was replicated at Mallawa, west of Moree and Breeza on the Liverpool Plains to provide data on the responses to varying SD, population and hybrid type in different climates.

## Site details

| | |
|---|---|
| **Location** | Gurley – 'Koreen' |
| **Co-operator** | Paul Slack |
| **Soil type and nutrition** | Cores were taken pre-plant to establish starting nutrition and water. The starting soil water was 209 mm, 246 mm and 321 mm of plant available water for SD 1, 2 and 3 respectively. |

Table 1 Site soil chemical characteristics – Gurley 2017/18

| Characteristic | Depth (cm) | | | | |
|---|---|---|---|---|---|
| | 0–10 | 10–30 | 30–60 | 60–90 | 90–120 |
| $pH_{Ca}$ | 7.2 | 7.5 | 7.9 | 8.3 | 8.5 |
| Nitrate nitrogen (mg/kg) | 26 | 26 | 13 | 2 | 2 |
| Phosphorus (Colwell) (mg/kg) | 14 | 4 | 3 | 8 | 7 |
| Potassium (Colwell) (mg/kg) | 471 | 248 | 216 | 178 | 119 |
| Sulfur (mg/kg) | 4.4 | 2.7 | 4.9 | 26.4 | 53.1 |
| Organic carbon (OC) (%) | 1.34 | 0.99 | 0.84 | 0.38 | 0.20 |

**Rainfall**

A total of 234.5 mm of rain was recorded at the experiment site during the 2017–18 season (Table 2). Planting moisture was good for SD1 and SD2, but then a dry September meant SD3 was delayed until mid-October when rainfall was received. Ideally, the SD3 would have occurred in early September. The trial suffered a period of extreme heat from mid-December till early January. This combined with low January rainfall, limited the yield potential of the third SD.

Table 2 Rainfall (mm) during the growing season – Gurley 2017/18

| Month | Aug 17 | Sept 17 | Oct 17 | Nov 17 | Dec 17 | Jan 18 | Feb 18 | Total |
|---|---|---|---|---|---|---|---|---|
| Rainfall (mm) | 17 | 0.5 | 76.0 | 68.0 | 49.5 | 11.0 | 12.5 | 234.5 |

**Experiment design**

A split, split plot design was used with time of sowing blocked, plant population blocked and hybrid randomly allocation with three replications

## Treatments

**Sowing dates (SD, 3)**

There were three target soil temperatures at sowing: 10 °C, 14 °C and 16–18°C. This resulted in three SD in 2017.

SD1: 2 August
SS2: 22 August
SD3: 17 October

**Plant populations (4)**

Four plant populations – targeting 1.5, 3.0, 4.5 and 6.0 plants/$m^2$.

**Hybrids (3)**

Pioneer® P1467, Pioneer® P1756, PAC 606IT

**Fertiliser**

43 kg/ha Granulock Supreme Z was applied with the seed at planting.

| | |
|---|---|
| **Harvest dates** | SD1 harvested on 7 February 2018<br>SD2 harvested on 7 February 2018<br>SD3 harvested on 22 February 2018. |

## Results

### Plant establishment

Established populations were higher than the target for all sowing times, except the 6.0 plants/m$^2$ in SD1. This data supports the possibility of sowing maize at sub optimal (<12 °C) soil temperatures with maize established at ~11 °C at this site with no adverse effect on plant establishment.

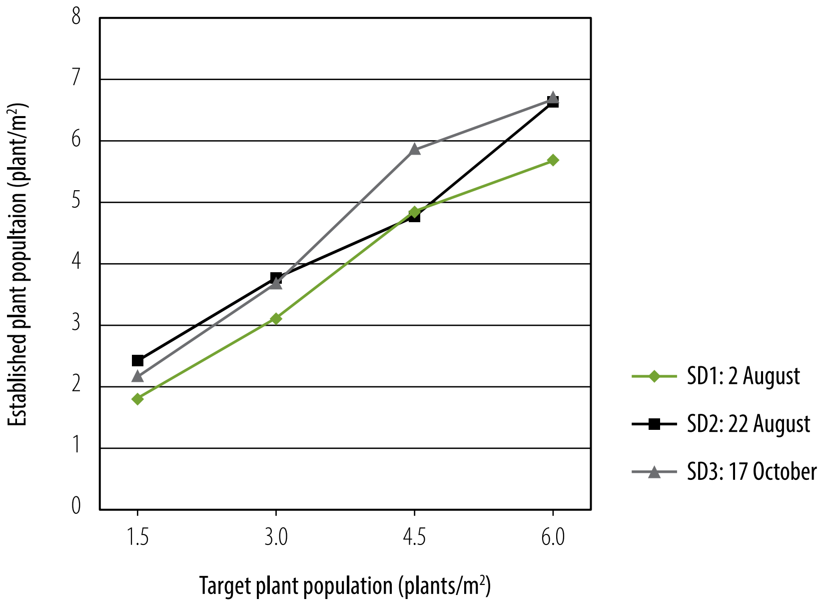

Figure 1 Target versus established plant population in maize – Gurley 2017/18.
*l.s.d. = 0.658 when comparing between sowing times. l.s.d = 0.597 when comparing within sowing times*

### Harvest Index (HI)

The later sowing dates (SD2 and SD3) had a negative effect on the HI, which reduced from SD1 to SD2 and to SD3. There was also an increased spread of HI values for the later sowings (Figure 2). For SD1 there was less variation in HI, regardless of the hybrid or plant population. In contrast, there was a much larger spread in HI for SD3 between hybrids and plant populations.

Increased plant populations in SD1 and SD2 had little effect on HI. However, a larger variation was seen in SD3, but the response was not linear.

### Grain yield

Grain yield from SD1 reached just under 6.0 t/ha. There was a significant hybrid × plant density interaction within each SD (Figure 3). Grain yield declined at this site over the later sowing dates.

#### SD1

The two hybrids, Pioneer® P1467 and Pioneer® P1756 were unresponsive to varying plant populations. Pioneer® P1467 produced a higher yield than Pioneer® P1756 at 4.9 t/ha versus 4.5 t/ha with a plant population of 30,000/ha. In contrast, PAC 606IT showed a strong response to plant population with yield optimised at 44,000 plants/ha.

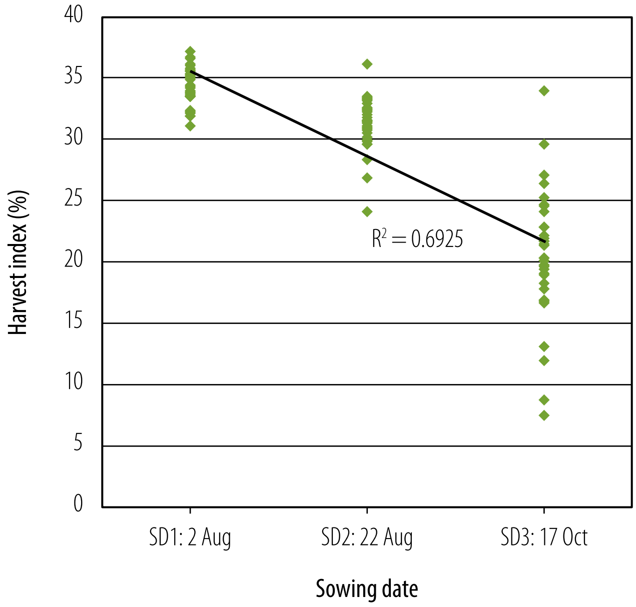

Figure 2 Impact of time of sowing on harvest index – Gurley 2017/18.

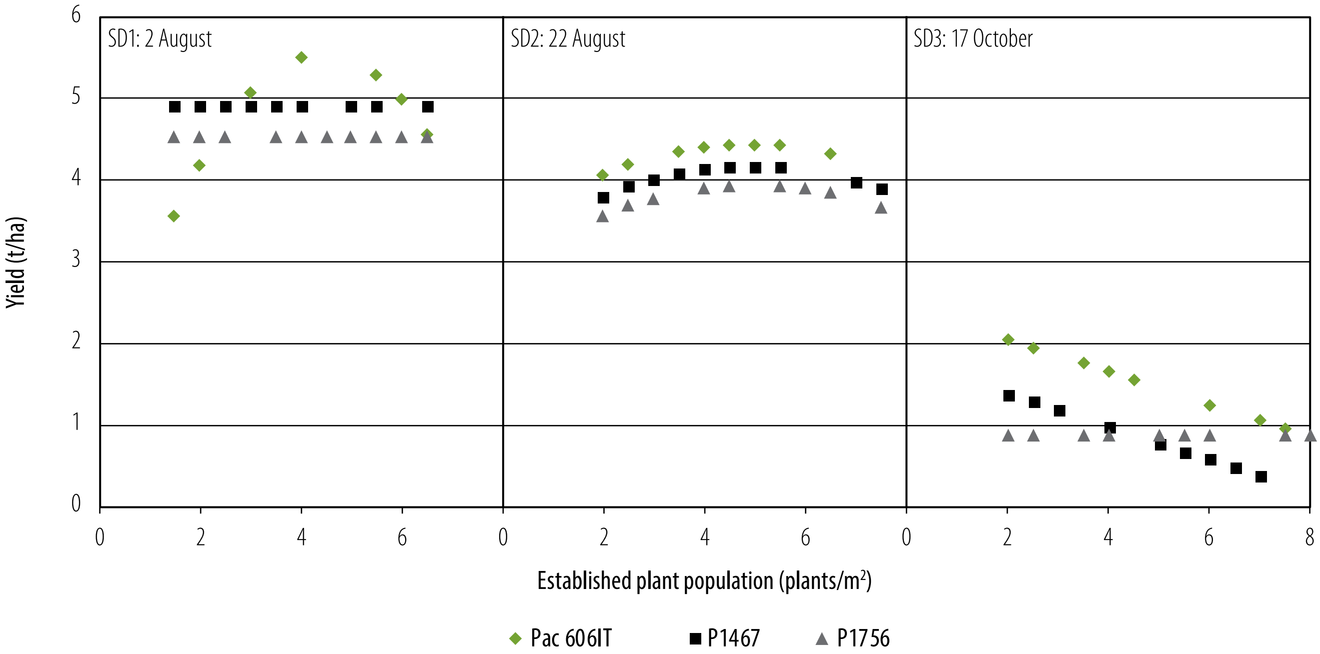

Figure 3 Grain yield response to varying plant population and sowing time in maize – Gurley 2017/18.

**SD2**

When soil temperatures were at the ideal 12 °C, grain yields showed a similar curved response for all three hybrids, reaching a peak and then declining as plant populations increased. However, PAC 606IT still yielded higher than the other two hybrids (Figure 3, centre). This sowing time produced the highest yields at an established population of 49,000 plants/ha. At this optimum plant density, PAC 606IT yielded 4.44 t/ha, Pioneer® P1467 produced 4.2 t/ha and Pioneer® P1756 was the lowest with a 3.9 t/ha yield.

### SD3

Grain yields were lower (<2.0 t/ha) than SD2 and SD3 .There was a similar response at the Mallawa site for PAC 606IT and Pioneer® P1467 for this SD. A decrease in yield of around 200 kg/ha occurred for every additional plant/m$^2$ above the base population of 3.0 plants/m$^2$ for Pioneer® P1467 and PAC 606IT. In contrast, there was no response to plant density for Pioneer® P1756. PAC 606IT had a significantly higher yield of 1.85 t/ha than Pioneer® P1467, which yielded 1.18 t/ha (Figure 3, right).

## Conclusions

Earlier sowing provided positive grain yield responses in this season which supports the idea of moving the sowing window earlier to allow maize planting in cooler than currently recommended soil temperatures. However, additional experiments in this environment are required to build greater confidence in the results and to allow for experiments to be conducted in seasons where frosts occur during early plant development.

In this season, the first sowing time in early August produced the highest yields at just under 6.0 t/ha. The latest time of sowing in mid-October produced disappointing yields.

Hybrid responses to varying plant population varied depending on the yield potential at each time of sowing. The mid-October sowing produced yields less than 2.0 t/ha for all treatments and the hybrids either had a negative correlation of decreased yield with increased plant population (PAC 606IT and Pioneer® P1467) or were unresponsive (Pioneer® P1756). In contrast at the higher yielding times of sowing from August most of the hybrids response to increasing population was either flat or showed a typical curve.

Of the three hybrids included in this experiment, PAC 606IT produced the highest yields. Pioneer® P1756 yield was largely unresponsive to changes in plant population, unlike the other two hybrids.

Harvest index at this site reduced as the SD was delayed further into the spring months. This was most likely due to yields being limited by the hotter, drier conditions during grain fill. There was little effect from hybrid or plant population on HI at the earliest sowing time; however, there was a much larger and overall lower HI range from SD3.

Overall it was seen that there is scope to increase yields in maize by combining specific hybrids and plant populations with their expected yield targets. Moving the sowing window forward also has merit towards improving yields through avoiding pre- and post anthesis heat and moisture stress.

## Acknowledgements

This experiment was part of the project Tactical Sorghum and Maize Agronomy in the Northern Region – NSW component (DAN00195) which was a joint investment by NSW DPI and Grains Research and Development Corporation (GRDC).

Thanks to Paul Slack and his team for providing the experiment site. Thanks to Tony Lochery, AMPS Moree for assistance with the site. Technical assistance provided by Delphi Ramsden, Alice Bowler and Stephen Morphett (NSW DPI) is gratefully acknowledged. Thanks to Pioneer and Pacific seeds for supplying the hybrid seed.

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