NSW GOVERNMENT

Department of Primary Industries

Northern NSW research results 2018

RESEARCH & DEVELOPMENT – INDEPENDENT RESEARCH FOR INDUSTRY

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

www.dpi.nsw.gov.au

Department of
Primary Industries

Northern NSW research results 2018

RESEARCH & DEVELOPMENT – INDEPENDENT RESEARCH FOR INDUSTRY

an initiative of Northern Cropping Systems

Editors: Carey Martin, Development Officer Information Delivery, Agriculture NSW, Orange;
Don McCaffrey, Technical Specialist Oils & Pulses, Agriculture NSW, Orange;
Penny Heuston, Project Officer – Publications, Agriculture NSW, Trangie.

Reviewers: Steven Simpfendorfer, Cereal Pathologist, Agriculture NSW, Tamworth;
Loretta Serafin, Research Officer Northern Cropping Systems, Agriculture NSW, Tamworth;
Lisa Bird, Cotton Entomologist, Agriculture NSW, Narrabri; and Mathew Dunn, Research Officer, Agriculture NSW, Narrabri.

Cover image: Peter Formann, Agriculture NSW, Tamworth.

ISSN 2208-8199 (Print)

ISSN 2208-8202 (Online)

jn 14780

Copyright

© State of NSW through Department of Industry, 2019

You may copy, distribute, display, download and otherwise freely deal with this publication for any purpose, provided that you attribute the Department of Industry as the owner. However, you must obtain permission if you wish to:

- charge others for access to the publication (other than at cost)
- include the publication in advertising or a product for sale
- modify the publication
- republish the publication on a website.

You may freely link to the publication on a departmental website.

Disclaimer

The State of New South Wales, including the NSW Department of Industry (" the Department"), does not give any warranty, guarantee or representation about the accuracy, currency or completeness of any information contained in this document [or DVD, film, material, etc.] (including, without limitation, any information included in the document which was provided by third parties). The State of New South Wales (including the Department) provides this document [or DVD, film, material, etc.] without assumption of a duty of care to any person.

To the fullest extent permitted by law, the State of New South Wales (including the Department) excludes all liability in relation to the information contained in this document [or DVD, film, material, etc.] or for any injury, expense loss, or damage whatsoever (including without limitation liability for negligence and consequential losses) suffered or incurred by any person acting, or purporting to act in reliance upon any information contained herein.

Always read the label

Users of agricultural or veterinary chemical products must always read the label and any permit before using the product and strictly comply with the directions on the label and the conditions of any permit. Users are not absolved from compliance with the directions on the label or the conditions of the permit by reason of any statement made in this publication.

Foreword

The NSW Department of Primary Industries (NSW DPI) Northern Cropping Systems Unit 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 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 collaboration with the Grains Research and Development Corporation (GRDC), using grower's funds to address key production constraints and opportunities facing growers.

The NSW DPI Northern Cropping Systems Unit is based throughout the Northern Grains Region of NSW with the key research hubs at Trangie, Tamworth, Narrabri and Grafton and satellite sites at Breeza and numerous farms locations. This geographical spread allows work to be replicated throughout differing rainfall and climatic scenarios creating greater rigour across the experiments.

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 to pathology, along with phenology, soils and nutrition work. This is the 8th 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 grower solution groups, universities, CSIRO 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 patience 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

Contents

Farming systems

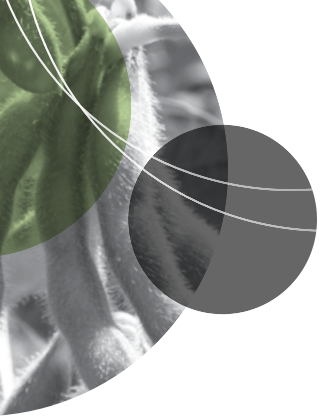
Winter crops

Crop protection

Cotton

Soybean

Mungbean



Farming systems

Farming systems site report – Narrabri 2015–2017

Jon Baird and Gerard Lonergan

NSW DPI Narrabri

Key findings

- Between 2015 and 2017 the baseline, high nutrient, high intensity and high legume treatments produced significantly higher cumulative grain yield, and crop water use efficiency than the low intensity and high diversity systems.
- The high intensity system resulted in the highest treatment gross margin with $2407/ha or $802/ha/year.
- From 2015–2017, the low intensity system, which contained a summer cotton crop, had a lower water use efficiency than the high diversity treatment (17% compared with 25.5%), but had a greater gross margin per millimetre ($0.85/mm compared with $0.55/mm).
- *Pratylenchus thornei* (*P.thornei*) numbers were higher in 2017 after the 2016 chickpea crop than after faba bean and field pea. Canola and cotton reduced *P. thornei* numbers in 2017. The higher *P. thornei* numbers after the 2016 chickpea crop have continued through to December 2017.

Introduction

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

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

Can systems performance be improved by modifying farming systems in the northern region?

The 'Northern farming systems initiative' is addressing this question at two levels:

1. systems performance across the whole grains region
2. providing rigorous data on local farming systems' performance at key locations.

The following report details the systems being studied in Narrabri and their local implementations along with the results after the first three years.

Site details

Location

The University of Sydney research farm – 'Llara', Narrabri

Farming systems treatments implemented at Narrabri

- Baseline – The baseline system was designed to represent a standard cropping system for the local north-western grains region. The planting trigger will be 50% of full profile. The area has both winter and summer crops with a diverse range of cropping options.

- High nutrient – This system duplicates the crop sequence for the baseline system, but examines the economics and system performance of high fertiliser inputs. Fertilising will be targeting a higher yield (90% of seasonal yield potential for nitrogen and 100% replacement for phosphorus).
- High crop intensity – the trigger for planting will be soil moisture at 30% of full profile. The selection of crops and cultivars will be determined by the period of the year when planting triggers are met.
- High crop diversity – This system is investigating alternative crop options to help manage and reduce nematode populations, disease and herbicide resistance. The profitability of these alternative systems will be critical. A wider range of profitable crops might enable growers to maintain soil health and sustainability as their cropping lands age and nutrients are depleted.
- High legume – The high legume system is focused on soil fertility and reducing the amount of nitrogen input required through fertiliser. One in every two crops must be a legume. Crops will be planted at an average moisture trigger (50% full soil moisture profile).
- Low crop intensity – This lower intensity system is designed to plant at a lower frequency when the profile is greater than 80% full. High value crops are targeted and the crops included are wheat, barley, chickpea, sorghum and cotton.

Site characteristics

'Llara' is a chocolate vertosol with plant available water content (PAWC) of 210 mm to 120 cm deep.

Table 1. 'Llara' soil characteristics.

Characteristic	Soil depth (cm)				
	0–15	15–30	30–60	60–90	90–120
pH ($CaCl_2$)	7.44	7.93	8.21	8.43	8.55
Organic carbon (%)	0.79	0.63	0.54	0.39	0.25
Exchangeable sodium percentage (ESP)	3.3	5.8	11.0	16.0	23.0
Colwell-P (mg/kg)	24	8	10	16	20
Conductivity (dS/m)	0.12	0.15	0.22	0.29	0.34

Cropping sequence at the Narrabri farming systems site

Wheat was sown in the 2015 winter (Figure 1) across all systems to establish a consistent base before sowing various crops in 2016. Early rain provided good establishment and plant vigour, but the dry finish of the 2015 winter affected grain yield.

In winter 2016 treatments were:

- Baseline – chickpea (in line with local growers who planted above average hectares of chickpea to take advantage of the commodity's high grain price).
- High nutrient – chickpea.
- High diversity – field pea
- High legume –faba bean
- High intensity – canola
- Low intensity – winter fallow and, after receiving high rainfall during the winter of 2016, the treatment was planted to cotton in November 2016

In winter 2017 treatments were:

- Low intensity system – cereal cover crop sown following the 2016/17 cotton crop.
- Baseline, high nutrient, high intensity and high legume systems returned to cereal crops
- High diversity – was sown to canola following the 2016 field pea.

All systems were sown with ideal soil available water for optimum crop sowing dates, except the cover crop (77 PAW mm) which was sown for stubble retention purposes. The winter of 2017 received considerably less in-crop rainfall compared with 2016 (184 mm vs 450 mm) and received over 20 days of minimum temperatures of less than 0°C (2016 received one day in contrast) which greatly affected the 2017 canola yield.

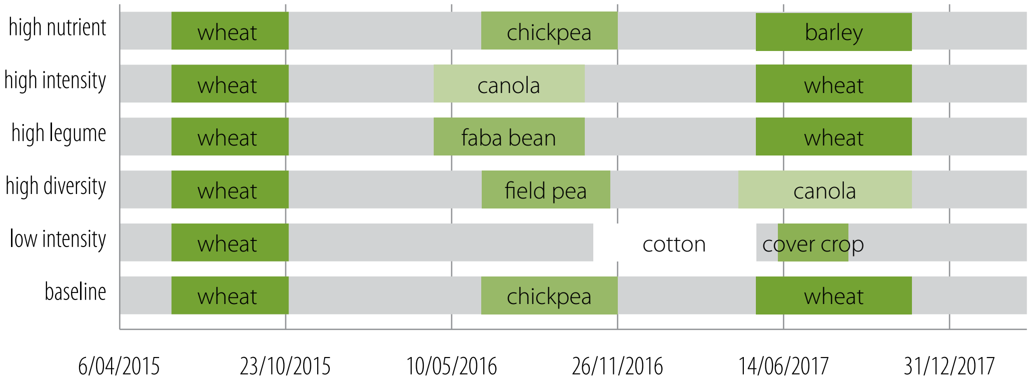


Figure 1. Cropping sequence and fallow length of the six farming systems at Narrabri.

Results

Grain yield

The cumulative grain yield of the six systems (Figure 2) highlight the similar productivity of the baseline, high nutrients, high legume and high intensity systems (9.3, 9.1, 9.3, and 9 t/ha respectively). The four systems (baseline, high nutrients, high legume and high intensity) produced significantly more total grain (or grain + lint) than both the greater diversity and low intensity systems (5.95 and 3.4 t/ha respectively). The lower yielding systems received unfavourable growing conditions during 2017. The low intensity system, which had cotton in the 2016/17 summer, received large yield penalties due to the extreme heat during the important boll development stage. In 2017 the canola crop (high diversity system) received a number of frosts during late August/early September during the flowering/pod fill stage, that devastated the final yield.

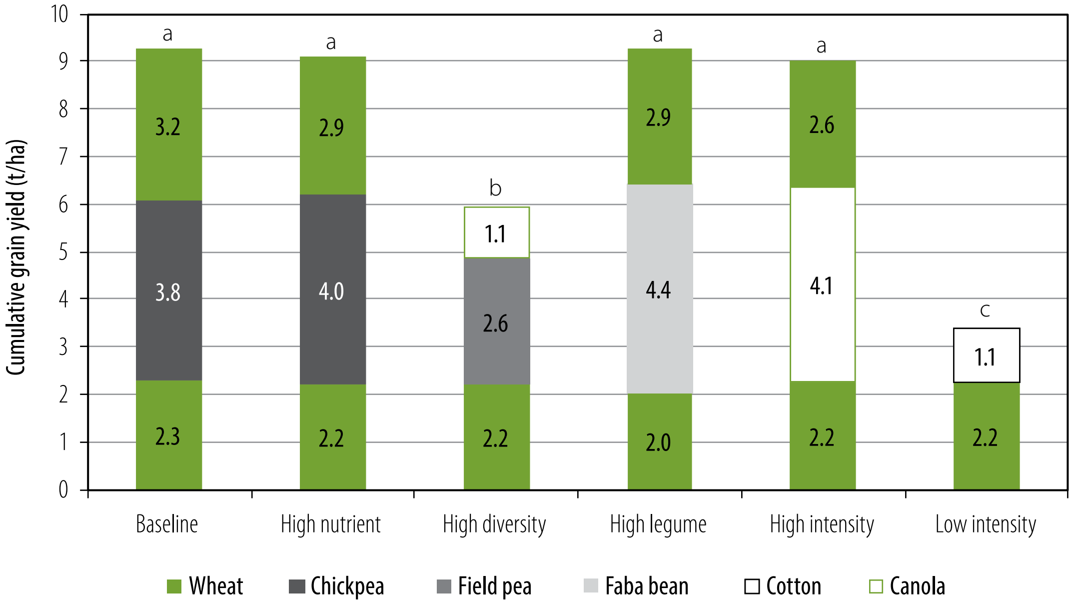


Figure 2. Cumulative grain yields of the six systems at the Narrabri farming systems trial. Labels a, b, c denote significance groups, l.s.d. = 1.2, *P*<0.001.

System economics

After the first three seasons (2015–2017) of the farming systems trial at Narrabri, the treatment cumulative gross margins were:

- High intensity system – the greatest cumulative gross margin with $2407/ha or $802/ha/year (Figure 3).
- Baseline system – similar to the high intensity system with a gross margin of $2339/ha.
- High nutrient system – $133/ha less than the baseline system due to the extra cost of the higher applied fertiliser.
- High legume – gross margin of $2165/ha.
- Low crop intensity – second lowest gross margin at $1232/ha: two crops grown in the three seasons, one less than the other five farming systems.
- High diversity treatment – lowest gross margin of the six farming systems ($858/ha) due the system containing the two lowest returning crops: field peas ($320/ha in 2016) and canola ($158/ha in 2017).

The grain value of the crops planted in 2016 determined the difference in gross margins of the top four systems.

Grain prices used for the project's gross margin analysis are a 10 year median price (Brisbane port), less transport costs ($40/t) across all sites. This was to ensure that there was no confusion between biophysical characterisations of each site and changes in transportation/market costs between sites.

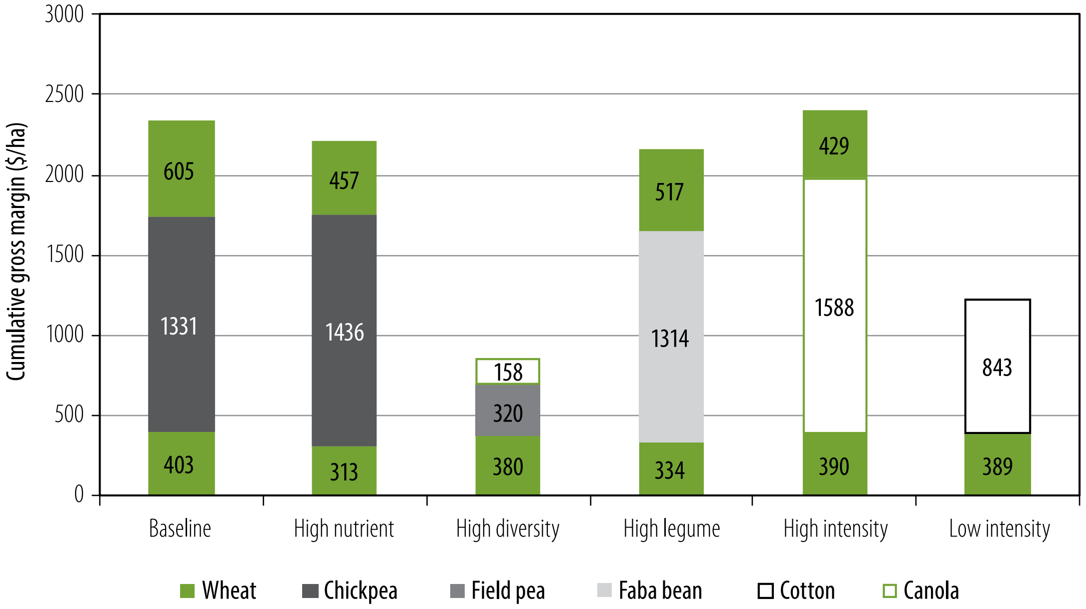


Figure 3. Cumulative gross margins of the six farming systems at Narrabri (includes crop and fallow costs). Prices used at Narrabri: wheat – $269/t, faba bean – 382/t, canola – $503/t, chickpea – $504/t, field pea – $350/t and cotton – $1037/t (includes lint and seed).

Water use efficiency

In 2016 the low intensity system sown to cotton, had the poorest fallow efficiency with 19% (the proportion of fallow rainfall available to the next crop) and lowest WUE (kg yield/mm crop water use) of 2 kg/mm (Figure 4). There was no difference in WUE between faba bean (high legume), chickpea (baseline & high nutrient), canola (high intensity) and field pea (high diversity) during the 2016 winter. There was difference between chickpea (baseline and high nutrients) and field pea (high diversity) for fallow efficiency through the 2016/17 summer fallow – 30%, 21% and 6% respectively.

The crop's WUE of 4.5 kg/mm highlights the effect from the 2017 frost damage on the greater diversity system (canola), which had the lowest efficiency rating for crops harvested in 2017. This is in comparison with the high intensity canola crop (2016), which had 7 kg/mm WUE (Figure 4).

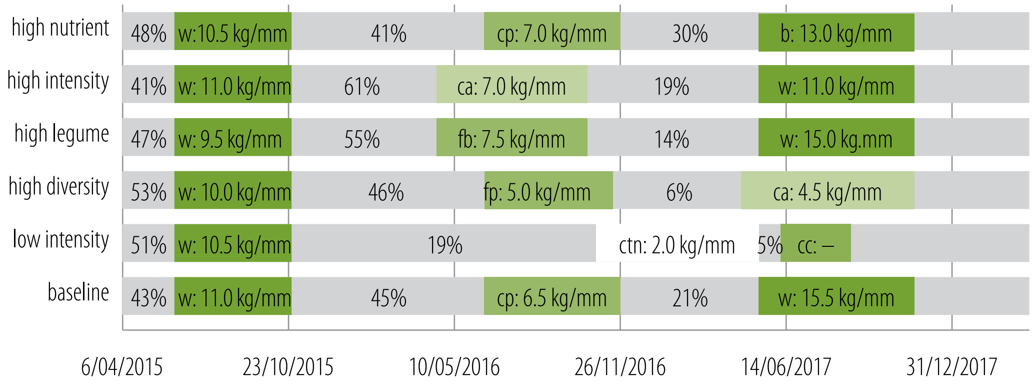


Figure 4. Crop water use efficiency, fallow efficiency and system gross margin per mm of rainfall for the six Narrabri farming systems up to the harvest of the last crop.
Note: w = wheat; b = barley; ca = canola; cp = chickpea; fb = faba bean; fp = field pea; ctn = cotton; cc = cover crop.

Baseline, high nutrient, high legume and high intensity systems all had similar system water use efficiency (cumulative grain yield per mm and system gross margin per mm of rainfall), which was greater than the low intensity and high diversity systems. The high diversity system had the lowest GM water use efficiency ($0.57 ha/mm) due to the poor gross margin of its 2016 field pea crop and the frost-affected 2017 canola crop.

The long fallow periods in the low intensity treatments did reduce the system water use efficiency ($0.85 ha/mm) and the aggregate fallow efficiency (25%), but it must be noted that the system had the highest plant available moisture (>40 mm) than the other five of the six systems at the completion of the 2017 cropping season in mid-December following the desiccation of the 2016 cover crop.

Table 2. System aggregate fallow efficiency and water use efficiency (grain yield/accumulated rainfall and gross margin/accumulated rainfall).

System treatment	Fallow efficiency (%)	System WUE (kg/mm)	GM WUE ($/mm)
Baseline	36	5.8	1.6
High nutrient	40	5.6	1.5
High legume	38	5.9	1.5
High diversity	35	3.7	0.55
High intensity	40	5.7	1.55
Low intensity	25	2.1	0.85

Soil pathogens

Eighteen soil pathogens were DNA tested pre and post each crop within the farming system project with *Pratylenchus thornei* (*P. thornei*) numbers showing the strongest system trends for the first three seasons. Crop choice during 2016 had the biggest impact on *P. thornei* numbers. Chickpea (PBA HatTrick$^{(b)}$) was grown in the baseline and high nutrient systems increasing *P. thornei* numbers by up to five times the 2016 pre-sown numbers. The other legumes sown in 2016 – field pea (PBA Oura$^{(b)}$) in the high diversity plots and faba bean (PBA Warda$^{(b)}$) in the high legume system, also increased *P. thornei* numbers, but not to the extent of chickpea. Although *P. thornei* did increase to moderate levels in 2016 within the baseline and high nutrient systems, no yield effect was recorded as chickpea yield equalled 3.8 t/ha for the baseline and 4 t/ha for the high nutrient system (Table 3).

While *P.thornei* numbers across all six systems did reduce during the 2016/17 summer fallow, *P.thornei* numbers in both the baseline and high nutrient systems increased slightly during the 2017 wheat crop (LRPB Lancer$^{(\text{D})}$). As a result, both these systems had more than three times the *P.thornei* numbers than the other four farming systems at the end of 2017.

Conversely the other four farming systems continued to reduce *P. thornei* numbers during 2017 and had less than1.3 nematodes/g soil (Table 3) by the end of 2017. To date, the higher nematode numbers in the baseline and high nutrient systems have not affected yield, but future cultivar selection should take into account pathogen levels (Table 3).

Table 3. Root lesion nematodes (*P. thornei*) population at Narrabri (nem./g soil).

System	12 Nov 2015	10 Mar 2016	12 Dec 2016	1 May 2017	20 Dec 2017	10 July 2018
Baseline	1.82	1.74	8.68	3.44	4.25	3.75
High nutrient	1.11	1.69	10.60	5.45	6.25	7.50
Greater diversity	2.03	1.66	4.19	2.15	1.33	2.75
High legume	1.79	1.30	3.17	1.77	1.00	2.00
High intensity	1.87	1.60	1.40	0.81	0.75	2.00
Low intensity	1.40	1.30	0.82	0.71	0.75	1.50
Probability	ns	ns	<0.001	ns	<0.001	<0.01

Conclusions

For the first three seasons, 2015–2017, crop choice in the 2016 winter had the biggest effect on system gross margins and productivity. The wheat–chickpea–wheat sequence and wheat–canola–wheat rotation resulted in the highest grain yield and largest gross margins. This result is due to the 2016 winter crops being significantly higher yielding than both the 2015 and 2017 winters, and the high value of chickpea and canola in 2016. This resulted in higher gross margins for the baseline and high intensity systems compared with the other four farming systems at Narrabri.

Although the wheat–chickpea sequence within the baseline and high nutrients systems resulted in the highest grain production and system gross margins, this continuing rotation is not conducive to best management practices for the region. Of particular concern are long-term implications on crop disease and nematode numbers (in particular *P. thornei*). Future crop selections for the baseline and high nutrient systems will need to take into account the varieties' susceptibility to *P. thornei*.

Acknowledgements

This experiment was part of the project 'Northern farming systems initiative', CSA00050 DAQ00190 and. The project was a collaboration between state agencies in Queensland and NSW with jointly investment by NSW DPI, QDAF, CSIRO and GRDC.

We would like to specifically thank the trial host at 'Llara', The University of Sydney research farm, who have assisted us in implementing the trial.

Contact

Jon Baird
Australian Cotton Research Institute, Narrabri
jon.baird@dpi.nsw.gov.au
02 6799 1500

Investigating the effect from rain-fed cotton on grain production in northern farming systems – 2016/17

Jon Baird and Gerard Lonergan
NSW DPI Narrabri

Key findings

- No-till wheat (0.97 t/ha) produced the highest grain yield compared with the full cultivation and plant line cultivation wheat treatments (0.67 and 0.70 t/ha respectively).
- No-till chickpea (0.64 t/ha) yielded higher than the plant line cultivation chickpea (0.37 t/ha).
- No-till chickpea resulted in the highest gross margin of the double-cropped treatments ($131/ha).
- Wheat had a greater water use efficiency (WUE) than chickpea, and also had higher grain production.
- Cultivating (either plant line or full cultivation) after the dryland cotton crop decreased cotton volunteers and ratoons by >100 plants/ha (184 days after cotton harvest) compared with no-till treatments.

Introduction

Rain-fed cotton production is an integral part of dryland farming systems in the northern grain regions of NSW and southern Queensland. New cultivars with greater lint yield potential, high commodity prices and improved moisture management, along with minimum-till farming adoption, have resulted in greater areas purposely kept for growing dryland cotton. As a result, questions are being raised about the sustainability of growing a long-season summer crop in an unpredictable rainfall climate, and its effect on growers farming systems.

Issues for growing cotton in a dryland farming system include:

- How to sequence back into grain crops?
- What crop to grow after the cotton crop?
- Does cultivating the cotton ratoons affect yield potential, and if so, for how long?
- If cultivation does not occur, what is the effect from ratoon and volunteer cotton control?

GRDC-funded farming systems projects are investigating issues such as planting moisture opportunities, gross margins, rainfall efficiency and their effects on crop sequencing. In collaboration with the Queensland Department of Agriculture and Fisheries (QDAF), CSIRO and the NSW Department of Primary Industries (NSW DPI), the farming systems program is focused on developing systems to better use available rainfall to increase productivity and profitability. This report presents results that investigate the options for transitioning from a cotton crop back to a grain crop and the legacy effects on subsequent crops in a dryland farming system.

Site details

Location	The University of Sydney research farm – 'Llara', Narrabri
Soil type	Chocolate vertosol (see Table 1)
Plant available water capacity (PAWC)	210 mm to 120 cm deep

Rainfall	The experiment site received 185 mm in-crop rainfall (long-term average for the site is 201 mm)
Note:	The site is representative of Northern NSW cropping soils, but of particular note is the high sodicity at depth

Table 1. 'Llara' soil characteristics.

Characteristic	Soil depth (cm)				
	0–15	15–30	30–60	60–90	90–120
pH_{Ca}	7.44	7.93	8.21	8.43	8.55
Organic carbon (%)	0.79	0.63	0.54	0.39	0.25
Exchangeable sodium percentage (ESP)	3.3	5.8	11.0	16.0	23.0
Colwell-P (mg/kg)	24	8	10	16	20
Conductivity (dS/m)	0.12	0.15	0.22	0.29	0.34

Experiment treatments

Tillage operations

- No–till: Zero cultivation, followed by crops sown directly into cotton stubble with a no-till planter. Only herbicides were used to control cotton regrowth or volunteers.
- Plant-line ripping: Ripping tynes cultivated along the plant line of the cotton crop to a depth of 30 cm deep. No cultivation occurred between the plant lines.
- Full cultivation: Offset discs were used twice to ensure full disturbance.

Crop choice

- Wheat: LRPB Lancer$^{\phi}$
- Chickpea: PBA HatTrick$^{\phi}$
- Cover crop: barley (sprayed out before booting)

Following a rain-fed cotton crop grown in the 2016–17 summer, tillage occurred approximately one month after cotton harvest; subsequent crops were planted on 26 June with PAWC approximately 42%.

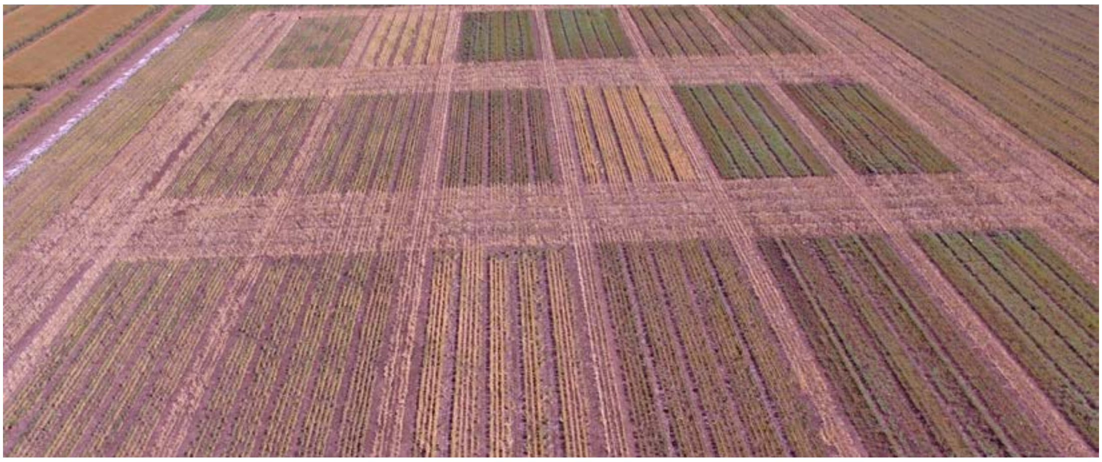


Figure 1. Experiment site 17 October 2017.

Results

Grain yield

After the 2016–17 dryland cotton crop there was low residual moisture left in the profile (77 mm plant available moisture to 120 cm deep). The low starting moisture and the decline in moisture from the cultivation, along with below average in-crop rainfall affected the grain yield potential for the experiment's treatments.

The no-till treatment resulted in the highest yield for both chickpea and wheat. The no-till wheat treatment yielded 0.28 t/ha higher than the plant line cultivated treatment, while the chickpea no-till yielded 0.28 t/ha higher than the plant line cultivated treatment (Figure 2). This equated to a yield difference of 38% for wheat and 42% for chickpea. Crop choice also affected final yield, with the wheat no-till treatment yielding 34% higher than the chickpea no-till treatment (0.97 t/ha and 0.64 t/ha respectively).

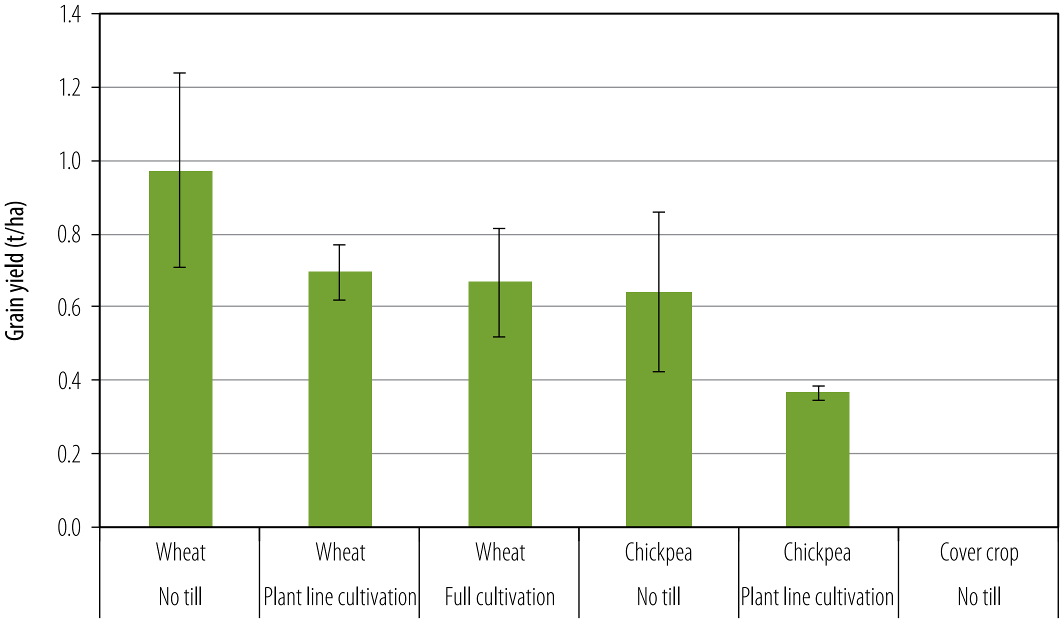


Figure 2. Yield of treatments double cropped after dryland cotton. Error bars signify standard deviation of means.

Treatments gross margins

An important aspect of this study was to evaluate the economics of implementing the various management treatments. Due to the low yields, only two treatments were profitable after the 2017 winter harvest – no-till chickpea and no-till wheat (Figure 3). The no-till chickpea treatments resulted in the highest gross margin with a return of $132/ha, $88/ha greater than the no-till wheat treatment (which resulted in a gross margin of $44/ha). The results show that both cultivation and crop choice affected the gross margin for the grain crop following cotton.

For growers considering the value of sowing a strategic cover crop after a dryland cotton crop, the farming system's 2017 cover crop (barley) resulted in a cost of $100/ha. The cost includes planting cost, seed purchase and herbicide applications and fallow maintenance up to December 2017.

Grain values used for gross margin analysis are 10 year median prices at port, minus transport costs. Prices used at Narrabri: wheat $269/t, chickpea $504/t, and cotton $1037/t (includes lint and seed).

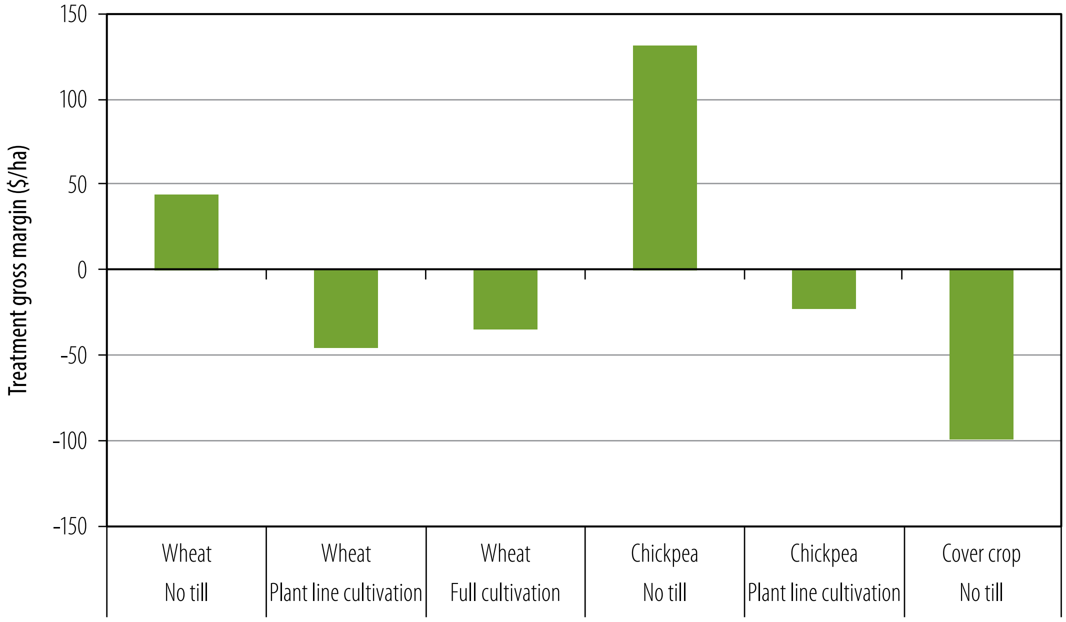


Figure 3. Treatment gross margins at Narrabri – 2017, gross margins include pre-sowing cultivation and herbicide costs.

Cultivation and crop choice effects on crop water use and WUE

After the 2016–17 rain-fed cotton crop, there was 77 mm of plant available water (PAW) at the Narrabri farming systems site, which equates to 42% of PAWC.

As expected, soil disturbance due to cultivation treatments led to a loss in soil water. The full cultivation reduced PAW by 21 mm (27%), while the plant line cultivation reduced PAW by 12 mm (15%) (Table 2). As a result, the no-till treatments had higher PAW at planting. The no-till chickpeas had the greatest crop water use for all the treatments planted in 2017 (189 mm, $P<0.05$). The three wheat treatments highlighted the effects from cultivation:

- no-till (178 mm) used more moisture than the plant line cultivated (161 mm)
- plant line cultivated (161 mm) used more moisture than the fully cultivated (144 mm).

The post-harvest soil moistures show that there was no benefit to growing a cover crop after the rain-fed cotton crop. The residual moisture was comparable to the no-till wheat treatment, 54.9 mm and 55.3 mm respectively.

Table 2. Treatment effect on PAW and water use efficiency.

Cultivation treatment	Crop choice	Post cotton PAW (mm)	Post cultivation pre-plant PAW (mm)	Post harvest PAW (mm)	Crop water use (mm)	Water use efficiency (kg/mm/ha)
No-till	Wheat	78.0	78.0	55.3	177.7	5.5
Plant line cultivation	Wheat	78.0	67.0	60.6	161.4	4.3
Full cultivation	Wheat	77.3	56.0	66.8	144.2	4.6
No-till	Chickpea	75.0	74.0	40.3	188.7	3.4
Plant line cultivation	Chickpea	77.0	64.0	45.3	173.7	2.1
No-till	Cover crop	76.0	79.0	54.9	179.1	na
Probability					<0.05	<0.001

Wheat had a higher WUE (kg grain/mm crop water use) than chickpea, 4.6 and 3.4 respectively in the experiment. The no-till operation resulted in a greater WUE than the plant line cultivation treatment for both crops (*P*<0.001).

Cotton regrowth and volunteer control

A major concern for growing rain-fed cotton is the number of ratoon and volunteer cotton plants that occur after harvest. Controlling ratoon and volunteers can be expensive and they can become hosts for pests and diseases. Weeds counts conducted 184 and 300 days after the harvest (DAH) show the longevity of the volunteers and ratoon plants.

The cultivation treatments did reduce cotton ratoon and volunteers at the first sampling date (184 DAH), with the plant line cultivation resulting in the lowest ratoon/volunteer numbers. Although minor, the difference between the plant line cultivation and the full cultivation is the plant line cultivator was able to remove 99% of cotton stumps from the field (0 and 3 ratoons/ha at 184 DAH respectively), whereas the full cultivation treatment removed less cotton stumps from the plant line (26 plants/ha at 184 DAH). Due to the high number of ratoons and cotton volunteers in the three no-till treatments, (wheat, chickpea and cover crop) two extra herbicide applications were applied pre-sowing and 190 DAH.

It should be noted that there are no registered or consistently reliable herbicide options available for controlling cotton ratoon.

Table 3. Residual ratoon and volunteer cotton plant numbers (plants/ha) at Narrabri, at 184 and 300 days after cotton harvest.

Cultivation	Crop choice	24 Nov 2017 184 (DAH)	19 Mar 2018 300 (DAH)
No-till	Wheat	153	90
No-till	Chickpea	103	11
No-till	Cover crop	156	36
Plant line	Wheat	0	4
Plant line	Chickpea	3	1
Full cultivation	Wheat	26	33
Standard error (s.e.)		80	45

Conclusions

There are many challenges for sequencing cotton in a dry land farming system. Firstly, growers need to evaluate the effect and risk of growing a long-season summer crop in a variable climate with unreliable summer rainfall. Northern NSW and south-eastern Queensland do have a high probability of favourable spring–summer planting conditions, especially after a long fallow with good ground cover. The events leading to suitable planting conditions might occur later than the ideal sowing date for cotton to reach its full yield potential.

The opportunity to sow a double crop after cotton in optimum conditions is limited, with chances for profitability increased if the following crop can better use the residual moisture. At Narrabri, chickpeas stood out as the ideal second crop in a double-cropping sequence, as they were able to extract a greater amount of soil moisture in a low moisture environment, which resulted in the greatest gross margin. Wheat and the cover crop (barley) did have greater biomass accumulation and did result in greater residual stubble cover, which might have a beneficial effect on future grain crops.

Cultivating had benefits such as reducing the cotton ratoons and volunteer numbers, but the implementation cost on soil moisture caused significant yield reduction. If growers are able to defoliate their cotton before 3 March and are able to control ratoon and volunteer numbers, the ideal treatment is to leave the field in a no-till situation.

It is noted that Bollgard 3 cotton is under the Monsanto product stewardship program, cotton growers must abide by the company's management plan: http://www.monsantoglobal.com/global/au/products/Documents/Bollgard-3-Resistance-Management-Plan.pdf

Acknowledgements

This experiment was part of the project 'Northern farming systems initiative', CSA00050 and DAQ00190. The project is a collaboration between state agencies in Queensland and NSW, with joint investment by NSW DPI, QDAF, CSIRO and GRDC.

We would like to specifically thank the experiment host at 'Llara', The University of Sydney who have assisted us in implementing the experiment.

Contact

Jon Baird
Australian Cotton Research Institute, Narrabri
jon.baird@dpi.nsw.gov.au
02 6799 1500

Managing heavy clay soils to improve grain production in a high rainfall environment: Investigating soil amendments on soil properties and soybean yield – Codrington 2017/18

Nathan Ensbey[1], Natalie Moore[1] and Robert Aitken[2]

[1]NSW DPI Grafton
[2]Soil scientist and private consultant, Yamba NSW

Key findings

- Surface and subsurface soil tests showed very high magnesium (Mg) levels of 43.3% exchangeable Mg and cation exchange capacity (CEC) of 26 at 0–10 cm. Seven soil amendment treatments were applied before a soybean crop was sown over the site in December 2017.
- Treatments containing lime resulted in a significant increase in soybean yield in the first season.
- All treatments reduced the detrimental dispersion and slaking properties of the soil.
- Assessment of the soil chemical and physical properties, and grain yield will continue in 2018/19.

Introduction

Heavy clay soils have provided many challenges for grain growers in the high rainfall zone of north-eastern NSW. These soils typically have a high clay content, a very high bulk density and low soil permeability to water. This creates an environment where plant roots struggle to penetrate the soil and rainfall tends to run off rather than infiltrate the soil profile.

A troublesome heavy clay soil was identified at Paul Fleming's property at Codrington in north eastern NSW. Initial soil tests (0–30 cm depth) indicated that the surface soil was not sodic (2.1% exchangeable sodium). However, the surface soil was highly magnesic (43.3% exchangeable Mg), possibly explaining the poor soil structure. Subsequent soil tests taken deeper in the soil profile (30–60 cm) indicated elevated sodium (Na) levels (7.7% exchangeable sodium). Gypsum ($CaSO_2H_2O$) and lime ($Ca(OH)_2$) and combinations of the two were assessed to evaluate the efficacy of calcium-based amendments. Compost treatments were also included to evaluate organic amendments with combinations of organic matter and lime.

A replicated field experiment was conducted to measure the effect of soil amendments on soybean yield and on soil chemical and physical properties. This experiment aimed to identify a surface-incorporated soil amendment that can ameliorate a difficult-to-manage soil type and thereby increase crop productivity. The investigation of these amendments was prioritised by the *Advisory Group for the Coastal and Hinterland Grower Solutions* project to identify strategies to improve the productivity of grain crops in this region. This experiment was the first in a three-year project with on-going measurements this site.

Site details

A commercial grain farm with a heavy clay soil type was selected for the experiment. This is a dryland (rain-fed) production system in a rotation of maize, barley and soybean. Details of the site location and general attributes of the experimental design are described below. Soil chemical properties at the site are shown in Table 1.

Location	Casino–Coraki Road, Codrington, NSW Latitude: 153°12′53.62″E, Longitude: 29°25′01.39″S
Soil type	Heavy clay soil
Co-operator	Paul Fleming, Codrington, Coraki, NSW Australia
Soil type and nutrition	Red clay loam, pH_{Ca} 5.6 (0–10 cm), see Table 1 for soil chemical properties
Irrigation	Nil (rain-fed)
Trial design	Randomised block design, seven soil amendment treatments with three replicates
Row spacing	Two rows on a raised bed at 0.9 m row spacing, furrows at 1.8 m spacing.
Variety	Richmond$^{\Phi}$
Sowing date	15 December 2017
Plant population	300,000 plants/ha (bed top population)
Harvest date	23 April 2018
Farming system and bed preparation	The farming system uses a minimum tillage (strip-tillage) unit that incorporates stubble and forms a bed with furrows at 1.8 m spacing. Due to the wet harvest of the previous barley crop, the paddock was chisel ploughed and cultivated with a Lilliston® rolling cultivator twice before bed-forming and applying ameliorants. Two rows of soybean variety Richmond$^{\Phi}$ were sown into each bed using a disc opener Kinze® planter (90 cm row spacing). Trimble® GPS guidance was used when planting the experiment.
Fertiliser	Incitec Pivot Pasture 13® (0% N, 6.6% P, 12.5% K, 8.3% S, 15.0% Ca) was applied at planting at 110 kg/ha. Soybean seed was inoculated using liquid inoculant injected at planting.
Weed management	Dual Gold® at 1.4 L/ha (960 g/L S–metolachlor) was banded post planting the soybean crop and Spinnaker® at 100 g/ha (700 g/kg imazethapyr) was applied before canopy closure. A shielded sprayer was used mid-season to apply 2.5 L/ha of glyphosate to control weeds in the inter-row.
Rainfall and temperature	The growing season was favourable for soybean growth. Although January was a particularly dry month (Figure 1), there was sufficient soil moisture for the crop to continue growing.

Table 1. Soil chemical properties for Codrington before soil amendment application – December 2017.

Analysis	**Soil depth (cm)**	
	0–10	**30–60**
pH (1:5 water)	5.7	6.3
pH_{Ca}	4.61	5.05
Electrical conductivity (1:5 water) dS/m	0.08	0.10
Electrical conductivity (saturated extract) dS/m	0.4	–
Chloride mg/kg	58	157
Organic carbon %	2.3	–
Nitrate nitrogen (as N) mg N/kg	14	7.0
Ammonium nitrogen mg/kg	<4	<4
Phosphorus (P) (Colwell) mg/kg	107	34
Phosphorus buffer index (PBI-Col)	374	237
Sulfur (S) as sulfate (MCP) mgS/kg	9.6	23
Cation exchange capacity (CEC) cmol(+)/kg	26	30
Aluminium (Al) (Amm-acet.) % of CEC	0.4	0.3
Aluminium (Amm-acet.) cmol(+)/kg	<0.1	<0.1
Calcium (Ca) (Amm-acet.) % of CEC	49.3	42.7
Calcium (Amm-acet.) cmol(+)/kg	16	14
Magnesium Mg) (Amm-acet.) % of CEC	46	45
Magnesium (Amm-acet.) cmol(+)/kg	13.3	13.5
Sodium (Na)(Amm-acet.) % of CEC	2.5	7.7
Sodium (Amm-acet.) cmol(+)/kg	0.65	2.31
Potassium (K) (Amm-acet.) % of CEC	1.7	0.7
Potassium (Amm-acet.) cmol(+)/kg	0.52	0.20
Available potassium mg/kg	201	77
Calcium/magnesium ratio	1.07	0.85
Potassium/magnesium ratio	0.04	0.01
Zinc (Z) (DTPA) mg/kg	4.4	–
Copper (Cu) (DTPA) mg/kg	2.8	–
Iron (Fe) (DTPA) mg/kg	476	–
Manganese (Mn) (DTPA) mg/kg	22.1	–
BSES phosphorus mg/kg	44.70	23.64
Potassium permanganate oxidisable carbon mg/kg	485	302

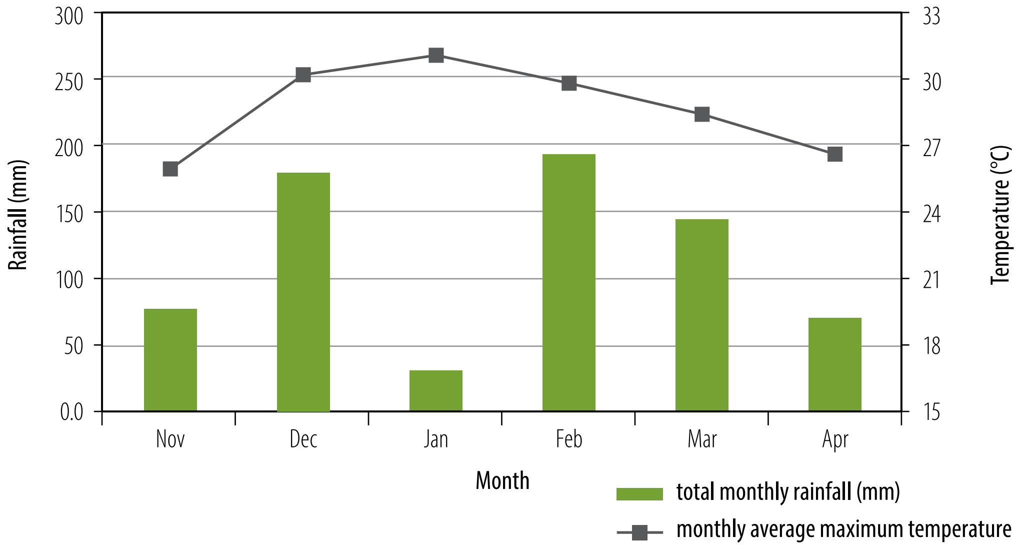


Figure 1. Average maximum temperature and monthly rainfall for Codrington, NSW, 2017/18.

Treatments

The experiment consisted of seven treatments, described in Tables 2 and 3, with three replications in a randomised complete block design. Individual plots consisted of three beds (5.4 m) wide and 12 m long. Treatments two, three and four were chosen to evaluate how effective calcium (Ca) amendments were on the soil and treatments six and seven were included to evaluate an organic matter amendment and the combination of organic matter and lime.

Table 2. Soil amendment treatments.

Treatment number	Soil amendment
1	Control (no amendment applied)
2	Gypsum (2.5 t/ha) + lime (5 t/ha)
3	Gypsum (5 t/ha)
4	Lime (5 t/ha) per annum (3 years)
5	Gypsum (5 t/ha) annually (3 years)
6	Compost (15 t/ha)
7	Compost (15 t/ha) + lime (5 t/ha)

Table 3. Soil amendments specific properties.

Amendment	Specific properties
Gypsum	21% calcium; 15.5% sulfur as sulfate
Lime	% calcium; neutralising value; fineness
Compost	11.3% organic carbon; 24.9% organic matter, 1.21% total nitrogen; 39.4% moisture

Figure 2. The experiment site after amendments applied and before incorporation (13 December 2017). Photo: N. Ensbey, NSW DPI.

Results and conclusions

Soil analysis – treatment pre-application

Soil analysis confirmed that the surface soil at the site (0–10 cm depth) was not sodic (Table 1), however, Mg accounted for 43% of the CEC. In some clay soils a high Mg value can result in poor soil physical properties with the Mg acting in a similar way to Na. The tendency of the soil to form a surface crust was evident. The subsoil at the site (30–60 cm depth) is sodic (7.7% exchangeable Na, Table 1) and this was associated with a high Mg percentage of the CEC. These subsoil characteristics indicate poor soil physical properties in the subsoil with reduced permeability and poor internal drainage.

Calcium-based amendments are typically used as ameliorants on sodic soils and act by the Ca replacing Na and Mg on the cation exchange complex. On neutral to alkaline soils, gypsum is typically used. On acidic soils lime, or a combination of lime and gypsum, are applied to ameliorate acidity.

Because the surface soil is strongly acidic and the subsoil is mildly to moderately acidic (Table 1), lime treatments were included, as lime increases soil pH as well as supplying Ca. A yield response to lime could be attributed to one or both of these effects. Gypsum treatments were also included for comparison.

Plant biomass, grain yield and quality

The site was assessed on 16 January (31 days after sowing) for emergence and visual effects from the treatments. Germination and emergence were even across the site. There were no clear effects on growth, except that the treatments containing lime (treatments two, four and seven) appeared to have slightly more vigorous growth than the control plots. No quantitative measurements were made at this stage.

There was a high standard of crop management across the site and the crop was harvested on 23 April 2018. Analysed results of yield, quality and crop biomass are presented in Table 4.

Table 4. Soybean yield (@ 12% moisture), seed quality and peak crop biomass.

Treatment number, description		Yield (t/ha)	Seed size (g/100 seeds)	Protein[#] (%)	Oil[#] (%)	Peak crop biomass[#] (t/ha)
4	Lime 5 t/ha	4.43	21.6	40.1	22.4	7.14
7	Compost 15 t/ha + lime 5 t/ha	4.33	21.6	39.2	22.9	7.59
2	Gypsum 2.5 t/ha + lime 5 t/ha	4.12	20.6	40.2	22.5	7.95
1	Control – no amendment	3.80	19.5	39.4	22.9	7.07
3	Gypsum 5 t/ha once	3.76	19.8	40.1	22.6	7.65
5	Gypsum 5 t/ha annually	3.70	19.3	39.8	22.9	7.98
6	Compost 15 t/ha	3.65	19.8	40.8	22.1	7.69
	standard error	0.11	0.33	1.0	0.52	0.36
	l.s.d. (*P*<0.05)	0.32	1.03	ns	ns	ns
	NHST	0	0	0.92	0.93	0.47

[#] dry matter basis

ns: not significant; NHST: nil hypothesis sum total value for spatial analysis. Differences between values 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).

Statistical analysis by Stephen Morris, Biometrician NSW DPI.

There was no significant difference in crop biomass between treatments, but there was for yield. All treatments containing lime produced significantly higher yields than the control treatment. The gypsum and the compost alone treatments did not yield more than the control. Grain protein and oil content were not significantly different between treatments.

Both lime and gypsum supply Ca, however, as an increase in yield was only observed in the treatments containing lime, it is unlikely that this is due to a Ca response. The response to lime could be due to either a response to the amelioration of potential toxicities, such as Al and/or Mn, or a response to an increase in the soil pH level. Since soil test results for the unamended soil indicated low levels of exchangeable Al (Al value of 0.3% of the effective CEC), amelioration of Al toxicity is unlikely to be the reason for the response to lime. Additionally, the soybean plants in the control plots showed no symptoms of Mn toxicity. Therefore, it appears that the yield increase is likely due to an increase in soil pH due to applying and incorporating lime.

The responses recorded in this experiment could have implications for soybean production on the predominantly acidic cropping soils of the NSW north coast.

Soybean yield in this experiment was only weakly correlated with soil $\mathrm{pH_{water}}$ as shown in Figure 3.

Post-harvest chemical soil properties – surface layer (0–10 cm)

After the crop was harvested, soil samples 0–10 cm and 10–30 cm deep were collected (August 2018). For each depth, five soil cores from each plot were composited, mixed and a subsample taken for soil chemical and physical properties. All plots, except those from treatment 5, were sampled as, at this stage of the experiment, treatments three and five were identical in the amount of gypsum applied. Soil physical properties were assessed using the Emerson dispersion test, slaking test and cone penetrometer readings.

In the 0–10 cm surface soil layer, all the treatments containing lime (treatments two, four and seven) significantly increased soil pH (i.e. ≥0.5 for $\mathrm{pH_{water}}$ and ≥0.62 for $\mathrm{pH_{Ca}}$, Table 5) compared with the untreated control. Compost and gypsum treatments had no significant effect on soil pH. There was no significant effect from the treatments on organic carbon, a measure of organic matter content. For the rate of compost applied in this experiment (15 t/ha) the amount of organic matter applied is very small in relation to the amount of organic matter already present in the soil, therefore, an increase in soil organic carbon from these compost treatments was not expected at this stage of the experiment.

The significant increases in plant available sulfate sulfur, CEC and exchangeable calcium are consistent with the treatments imposed.

Although there was no significant effect from the treatments on the Ca:Mg ratio in the unamended soil (Table 1), there was a trend for the ratio to increase in treatments where Ca was applied as lime (Table 5).

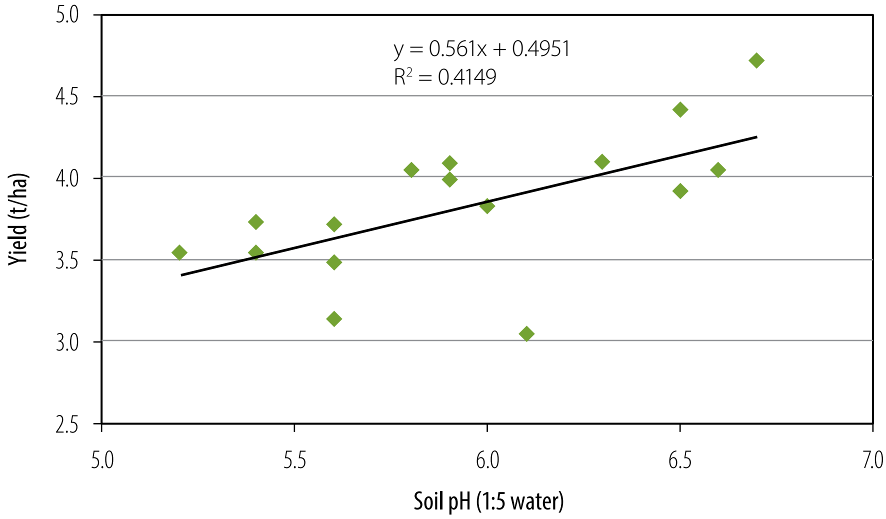


Figure 3. Relationship between soil pH and soybean yield.
Note plotted values are for individual plots.
Analysis by Dr Bob Aitken, consultant soil scientist.

Table 5. Effect of soil amendments on soil surface (0–10 cm), taken after harvest (August 2018) and eight months after treatment application.

Soil property (0–10 cm)	**Treatment**						**l.s.d.**	***P***
	1 Control	**2 Gypsum (2.5 t/ha) + lime (5 t/ha)**	**3 Gypsum (5 t/ha)**	**4 Lime (5 t/ha) annually**	**6 Compost (15 t/ha)**	**7 Compost (15 t/ha) + lime (5 t/ha)**		
pH_{water}	5.7	6.2	5.3	6.5	5.9	6.3	0.50	0.0015
pH_{Ca}	4.61	5.26	4.62	5.58	4.94	5.44	0.62	0.0205
Organic C %	2.3	2.2	2.0	2.0	2.1	2.2	–	ns
EC (1:5 water) (dS/m)	0.08	0.08	0.17	0.07	0.10	0.08	0.06	0.0286
S (mg/kg)	27	22	88	8	31	20	24.0	0.003
CEC (cmol(+)/kg)	26	25	22	28	26	29	2.90	0.0073
Al (%CEC)	0.4	0.4	0.5	0.4	0.4	0.3	–	ns
Ca (%CEC)	49.3	56.1	51.7	55.2	50.8	55.3	–	ns
Exch. Ca	12.8	14.3	11.6	15.4	13.1	16.1	2.80	0.0365
Mg (%CEC)	46.4	39.6	44.5	40.7	44.0	40.5	–	ns
Exch. Mg	12.0	10.0	10.0	11.4	11.3	11.8	–	ns
Na (%CEC)	2.5	2.0	2.1	1.9	2.7	2.3	–	ns
Exch. Na	0.646	0.491	0.474	0.540	0.688	0.668	–	ns
Ca/Mg ratio	1.07	1.43	1.17	1.37	1.13	1.37	–	ns
Labile C (mg/kg)	367	400	376	413	376	396	–	ns

ns: not significant
Soil chemical analyses were conducted by Dr Bob Aitken, consultant soil scientist

Treatment three, gypsum-only (5 t/ha), significantly increased the electrical conductivity from 0.08 dS/m to 0.17 dS/m in the surface soil layer (Table 5). This, in conjunction with gypsum being a soluble source of Ca, explains the effect of this treatment in reducing the tendency for dispersion (Table 8).

There was no significant effect from the treatments on labile carbon (potassium permanganate oxidisable carbon), but there was a trend for increased labile carbon where lime was applied (Table 5).

Post harvest chemical soil properties – subsoil layer (10–30 cm)

In the 10–30 cm subsoil layer, there were few significant effects from treatments on soil chemical properties (Table 6). This highlights the difficulty in ameliorating subsoils, particularly heavy clay soils. Lime application had no effect on soil pH in the 10–30 cm layer. It is possible that the amendments were only incorporated to a depth of around 10 cm to 15 cm despite the appearance of deeper incorporation during cultivation.

Treatment three, gypsum-only (5 t/ha), significantly lowered the soil pH_{water} value to 5.8 compared with 6.3 in the untreated control. This was likely to be due to a salt effect on the measurement of pH_{water}. The significant increase in sulfate sulfur in the 10–30 cm layer to 102 mg/kg in the gypsum-only treatment compared with 39 mg/kg in the untreated control (Table 6), suggests that sulfate sulfur moved deeper into the soil layer. As gypsum is used to supply sulfur and the mobility of sulfur in soil, this result is not unexpected.

The sub soil layer (10–30 cm) is sodic with an exchangeable Na percentage of 6% (Table 6). This explains the management difficulties the grower encountered with soil physical characteristics at the site.

Table 6. Effect of treatments on subsoil properties (10–30 cm), taken after harvest (August 2018) and eight months after treatment application.

Soil property (10–30 cm)	**Treatment**						**l.s.d.**	***P***
	1 Control	**2 Gypsum (2.5 t/ha) + lime (5 t/ha)**	**3 Gypsum (5 t/ha)**	**4 Lime (5 t/ha) annually**	**6 Compost (15 t/ha)**	**7 Compost (15 t/ha) + lime (5 t/ha)**		
pH_{water}	6.3	6.0	5.8	6.4	6.1	6.2	0.27	0.0037
pH_{Ca}	5.05	4.84	4.85	5.02	4.92	4.87	ns	ns
EC (1:5 water) (dS/m)	0.09	0.11	0.19	0.08	0.11	0.09	0.04	0.0012
S (mg/kg)	39	48	102	22	51	34	30	0.0022
CEC (cmol(+)/kg)	30.2	26.4	27.3	29.3	27.2	27.3		ns
Al (%CEC)	0.3	0.4	0.4	0.3	0.4	0.4		ns
Ca (%CEC)	42.7	43.2	44.0	42.7	43.2	46.0		ns
Exch. Ca	12.9	11.4	12.0	12.5	11.7	12.5		ns
Mg (%CEC)	50.4	50.0	49.4	50.3	49.9	47.5		ns
Exch. Mg	15.3	13.2	13.5	14.7	13.6	13.0		ns
Na (%CEC)	6.0	6.2	6.0	6.2	6.3	5.9		ns
Exch. Na	1.82	1.62	1.64	1.83	1.73	1.61		ns
Ca/Mg ratio	0.85	0.87	0.89	0.85	0.87	0.96		ns
Labile C (mg/kg)	253	243	283	245	220	256		ns

ns: not significant
Soil chemical analyses were conducted by Dr Bob Aitken, consultant soil scientist.

Post-harvest physical soil properties

Ten cone penetrometer measurements were made in the middle bed of each plot (16 August 2018). These readings measured the maximum pressure (kPa) attained while pushing the cone to a depth of 15 cm. The readings for each plot were averaged to give a mean. Plot means were then used for an ANOVA (analysis of variance) analysis for a randomised complete block experiment design. Although there was no statistically significant treatment effect ($P = 0.05$), there was a trend for the treatments with Ca amendments (treatments two, three, four and five) to have lower values than the untreated control and the compost only treatment (treatments one and six respectively; Table 7). Lower values indicate softer soil due to less resistance.

Table 7. Treatment effects on cone penetrometer readings.

Treatment No.	Treatment	Mean cone penetrometer reading (kPa)
1	Control	2500
2	Gypsum (2.5 t/ha) + lime (5 t/ha)	1600
3	Gypsum (5 t/ha)	1300
4	Lime (5 t/ha) annually (3 years)	1700
5	Gypsum (5 t/ha) annually (3 years)	1700
6	Compost (15 t/ha)	2200
7	Compost (15 t/ha) + lime (5 t/ha)	1800

No significant treatment effect ($P = 0.05$)

Air-dried aggregates (or peds) from the 0–10 cm soil depth from each plot were assessed using the Emerson slaking and dispersion test. All aggregates slaked to some degree, that is, their physical structure slumped and fell apart in water. There was minimal to no dispersion in the water around the peds (Figure 4, left) in the untreated control plots and there were no discernible differences between the treatments. The test was repeated using soil samples remoulded at field capacity moisture to simulate working the soil in a wet condition. The results for remoulded soil are shown in Table 8 and Figure 4, right, showing strong slaking and dispersion.

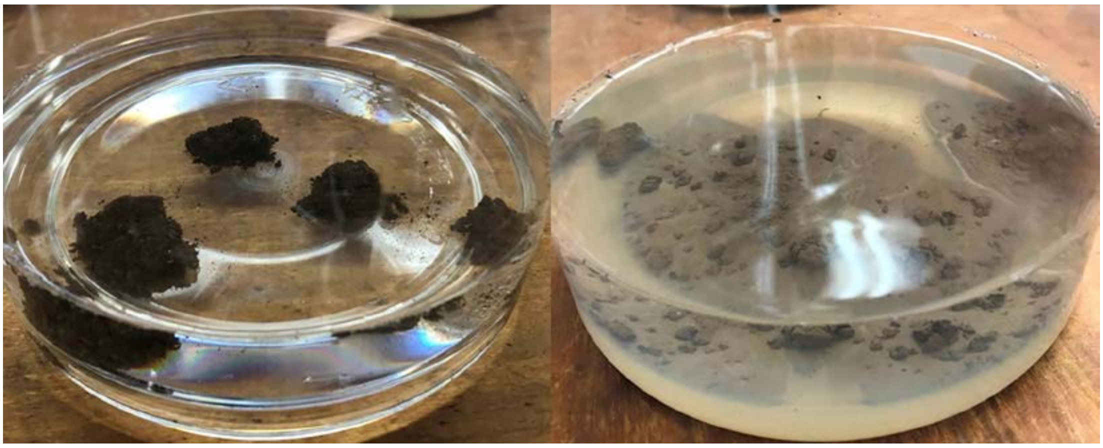


Figure 4. Air-dried soil aggregates (peds) showing a small amount of dispersion and little to no slaking (left) compared with a remoulded sample of the untreated control displaying a high degree of dispersion and slaking of remoulded peds (right).
Photos: N. Moore, NSW DPI.

Table 8. Treatment effects on dispersion score for remoulded soil samples.

Treatment No	Treatment	Remoulded aggregate dispersion score
1	Control	Strong to complete dispersion
2	Gypsum (2.5 t/ha) + lime (5 t/ha)	Moderate dispersion
3	Gypsum (5 t/ha)	Slight dispersion
4	Lime (5 t/ha) annually (3 years)	Strong dispersion
5	Gypsum (5 t/ha) annually (3 years)	–
6	Compost (15 t/ha)	Strong dispersion
7	Compost (15 t/ha) + lime (5 t/ha)	Strong dispersion

Differences between treatments occurred, with only the gypsum treatments showing a lower tendency to disperse after remoulding (Table 8). Relative to lime, gypsum is a more soluble source of Ca and these observations are consistent with the relative solubility of lime and gypsum.

In winter 2018, a cereal crop was intended to be sown over the site, however, due to a change by the grower, a chickpea crop was sown. Grain yield of the chickpea crop and soil chemical and physical properties will be measured before additional amendments are applied and soybean is sown on the site in 2018–19. Treatment effects will continue to be measured over three summer and three winter seasons, along with calculating the cost/benefit of the soil amendments in relation to grain production.

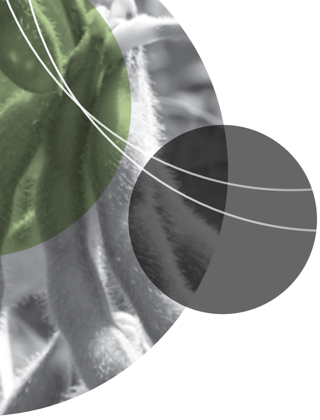
Acknowledgements

This research is an initiative of the NSW North Coast node of the 'Growers Solutions project for Coastal/Hinterland Queensland and NSW North Coast', DAQ00204, 2017–20, with joint investment by NSW DPI, QDAF and GRDC.

The assistance of Paul and Nicole Fleming, Joe Fleming and David Hall in conducting this field experiment is gratefully acknowledged. Technical assistance from Sam Blanch, Meg Cameron and Rodney Ellem, NSW DPI Grafton and statistical analysis by Stephen Morris, NSW DPI Wollongbar is gratefully acknowledged.

Contact

Nathan Ensbey
Grafton Primary Industries Institute, Grafton
nathan.ensbey@dpi.nsw.gov.au
02 6640 1600



Winter crops

Wheat response to deep placement of phosphorus – Gurley 2017

Rick Graham[1] Mike Bell[2], Thomas Tendo Mukasa Mugerwa[1] and Peter Formann[1]

[1]NSW DPI Tamworth
[2]University of Queensland, Gatton

Key findings

- There were significant yield responses to both starter phosphorus (P) use and deep P application.
- The lack of a significant interaction between starter P and deep P indicates that starter P and deep P act independently of each other. Thus implying that it is not practicable to overcome P deficits in just one soil layer by amending the other.

Research questions

1. Does putting P, an immobile nutrient, in the soil at 15–20 cm deep increase grain yields in lower rainfall environments?
2. How does starter P interact with deep placed P?

Introduction

Soils of northern NSW, in particular the black–grey cracking clay soils (vertosols), have historically been very fertile. However, by adopting no-till farming systems and the associated intensified cropping, reserves of mineral nutrients such as P have gradually been depleted over several decades due, in part, to negative P budgets (GRDC, 2012).

This depletion has typically been in the 10–30 cm layer, beneath where the starter P is placed and residual plant matter is broken down. The result is stratified P distribution within the profile with P more readily available in surface layers (0–10 cm) and less available deeper down. Crops growing in these vertosols rely on subsoil 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 the subsoil, crop roots are unable to access the 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).

Standard industry practice has been to apply starter P in or near the seeding trench at sowing, with adequate subsoil P reserves to meet the P requirements for growth. However, with declining native subsoil P fertility, alternate fertiliser P application strategies are now becoming necessary to meet total crop P requirements and yield potential.

This experiment aimed to test the hypothesis that placing immobile nutrients such as P deeper in the soil profile could increase grain yields above the traditional approach of starter P. The experiments conducted will contribute towards the *Making Better Fertiliser Decisions for Crops* (BFDC) database, that has identified significant gaps in knowledge of plant responses to P, particularly subsoil P.

Results presented in this report are a summary of data collected over the 2017 winter from a residual P-response experiment that commenced in September 2015, where deep P treatments were initially applied as part of the *Regional Testing Guidelines for the Northern Grains Region* (UQ00063) project. This is a collaborative project between The University of Queensland (UQ), New South Wales Department of Primary Industries (NSW DPI) and the Grains Research and Development Corporation (GRDC).

Site details

Location:	'Kelvin', Gurley NSW
Co-operator	Scott Carrigan
Crop, variety	Wheat: LRPB Spitfire$^{\Phi}$
Soil type	Grey vertosol
Starting soil N	107 kg N/ha (0–120 cm)
Starting soil P	Colwell: 8 mg/kg (0–10 cm), 3 mg/kg (10–30 cm) BSES: 20.9 mg/kg (0–10 cm), 14.8 mg/kg (10–30 cm)
Starting soil water	~73 mm plant available water capacity (PAWC) to 120 cm
Sowing date	16 May 2017
In-crop rainfall	124 mm (May–October)
Harvest date	25 October 2017

Treatments

The experiment consisted of factorial combinations of six tillage/deep P treatments with or without starter fertiliser across six replicates (Table 1).

- The 'farmer reference' (FR) nil starter P treatment was the control, receiving only nitrogen (N) at sowing and was not deep ripped, as opposed to the control that was only deep ripped.
- The deep P was applied in September 2015 to ~20 cm depth, parallel to the sowing direction as triple superphosphate (TSP) on a 75 cm row spacing (Table 1).
- Starter P fertiliser in the form of MAP as Granulock® Z (N 11%, P 21.8%, S 4% and Zn 1%) was applied at sowing into the seeding trench.
- NIL treatments were balanced for N and S using urea and gypsum.
- All plots also received an additional 70 kg N/ha side banded as urea (46% N) at sowing.

Treatment means were compared by conducting two separate analyses of variance (ANOVA):

1. Six tillage/deep P treatments plus/minus deep P
2. Responses to starter P in soil that had been deep ripped and received varying rates of deep P before the first crop season.

The first analysis compared the deep-ripped treatments to see whether there was any interaction between 'tillage/deep P use' and starter P. This analysis could also compare the 'FR' treatment (no tillage) with tillage/deep P and starter P.

The second analysis explored the interaction between deep P rate and starter P in more detail and, specifically, tested the hypothesis that starter P use could overcome the need for deep P, or vice versa.

Table 1. Experimental phosphorus treatments at Gurley – 2017.

Treatment	Triple super P (kg P/ha)	Starter P (MAP)#	Cultivation*
1	0	Nil	Nil – FR
1	0	Plus#	Nil – FR
2	0	Nil	Deep ripped*
2	0	Plus#	Deep ripped*
3	10	Nil	Deep ripped*
3	10	Plus#	Deep ripped*
4	20	Nil	Deep ripped*
4	20	Plus#	Deep ripped*
5	40	Nil	Deep ripped*
5	40	Plus#	Deep ripped*
6	80	Nil	Deep ripped*
6	80	Plus#	Deep ripped*

*Deep ripped to a depth of ~20 cm
#60 kg/ha Granulock® Z (~13 kg P/ha)

Results

- There were yield responses to both starter P and deep P, however, there was no statistically significant interaction between the two factors. This suggests that starter P and deep P act independently of each other and that it is not feasible to overcome P deficits in one soil layer by amending the other.
- Starter P increased yield by 19%, equivalent to an additional 0.5 t/ha, across all treatments. The highest rate of deep P increased yield by 17% (an additional 0.5 t/ha) over the FR treatment (Nil P/no tillage); and a 36% yield increase (0.9 t/ha) relative to the deep-ripped treatment where no P was applied (Figure 1). The greater yield response to deep P in the ripped treatments reflected a yield loss in the ripped/nil P treatment relative to the FR treatment (Nil P/no tillage) at that site (Figure 2).
- The change in P uptake at maturity increased grain yield (Figure 3). An additional 232 kg grain/ha was produced for each extra kilogram of P uptake.
- Nitrogen did not limit grain yields as the grain protein concentration (GPC) of all samples exceeded 14%, well above the critical 11% GPC (data not shown).
- The relatively poor response to deep P at this site is demonstrated through no significant yield increase being observed until the highest P rate (80 kg P/ha) was applied (Figure 1). This is consistent with the generally poor responses to triple superphosphate at other sites where deep P was applied in this form. The relatively inefficient use of deep P bands, especially in contrast to the very efficient use of the small amount of P applied as MAP in the starter applications, adds weight to this observation.

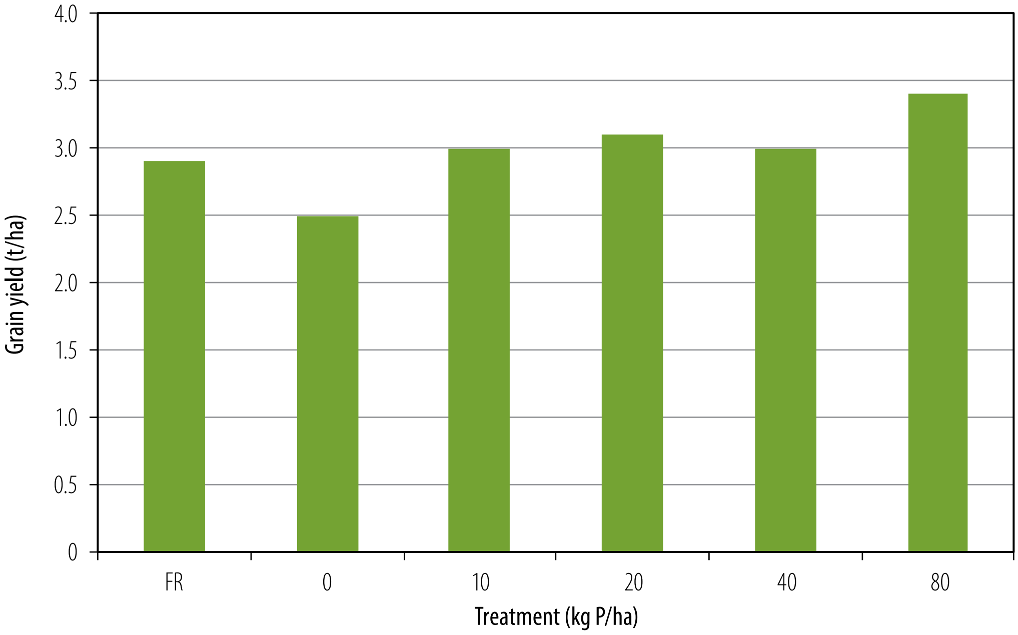


Figure 1. Grain yield response to P/tillage treatments, averaged across starter P treatments. Bars with the same letter are not significantly different ($P = 0.05$).

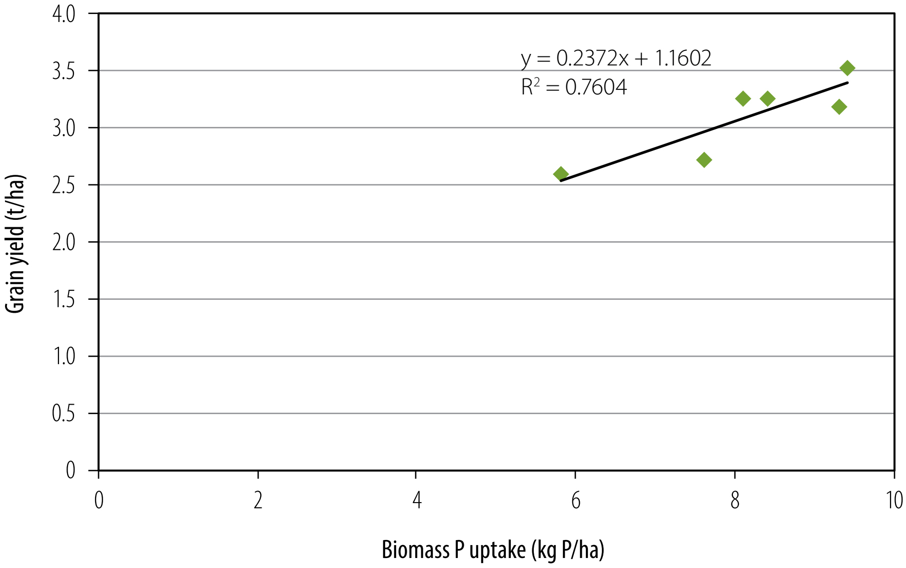


Figure 2. Crop biomass P uptake (kg P/ha) at physiological maturity vs. grain yield (t/ha).

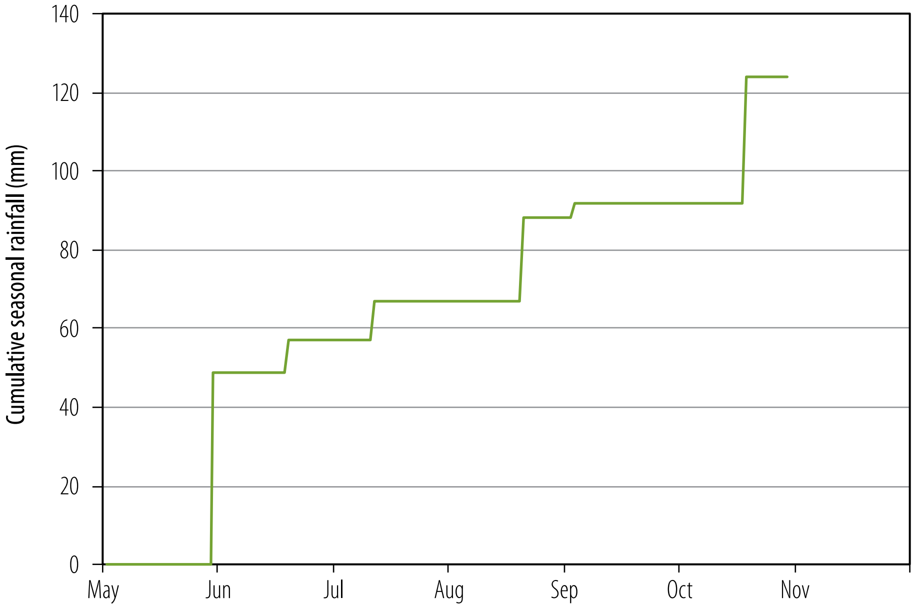


Figure 3. Cumulative rainfall at the site in 2017.

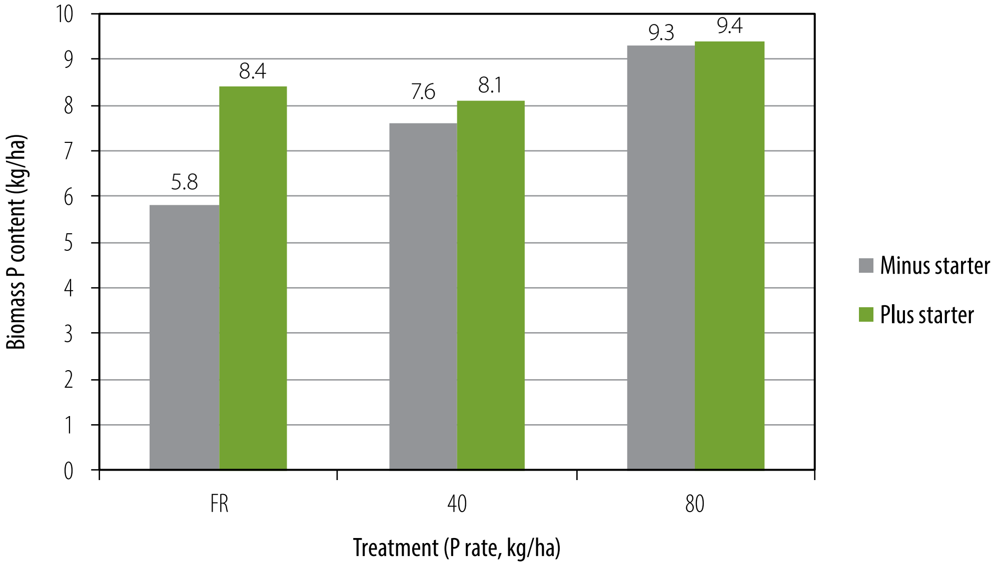


Figure 4. Crop biomass P content (kg/ha) at physiological maturity at Gurley – 2017.

Conclusions

Results from the Gurley site showed significant yield benefits from P application, with both starter P and deep P providing significant yield increases. There was no significant interaction between starter P and deep P applications, showing that neither P application strategy should be used in isolation. This is consistent with our understanding of the timing and extent of P uptake from different parts of the soil profile at different wheat growth stages.

The starter P increased yield by 19%, equivalent to an additional 0.5 t/ha grain, in a paddock with a very low starting Colwell P level of 8 mg/kg. The magnitude of the starter P response could have been accentuated by zinc (Zn) within the MAP in the starter product (Granulock® Z). However, the relatively favourable conditions for exploiting a starter fertiliser application early in crop establishment, followed by dry conditions for most of the rest of the crop's growing season (Figure 3), could also have contributed. Seasonal conditions resulted in the P uptake from the starter P treatment representing an unusually large proportion of total crop P uptake in the absence of deep P (Figure 4).Biomass P uptake data (Figure 4) shows that the FR + starter P treatment resulted in an additional 2.6 kg/ha P uptake (a 44% increase over the FR treatment with no starter P). As the rate of deep P increased, the net contribution to biomass P resulting from starter P decreased. It is interesting to note the relative inefficiency of the residual TSP as a source of P for crop uptake that was applied in 2015. In the absence of starter P, crops only obtained an additional 1.8 kg/ha P from the 40 kg/ha treatment and 3.5 kg/ha P from the 80 kg/ha treatment.

The poor response to deep-banded residual triple super phosphate (TSP) is consistent with the apparent inefficiency of those deep bands as a source of P for plant uptake. In contrast, comparatively low rates of starter P were much more efficient at supplying P to the crop in the absence of other P sources. These apparent differences in recovery of P from differently banded sources are consistent with observations in Queensland field sites in project UQ00063 and in glasshouse studies in project UQ00078 (Bell et al. 2018). To test this hypothesis, it is intended to reapply deep P as MAP in some of the Gurley treatments/plots to provide a contrasting deep P treatment to the high TSP treatment rates .

References

GRDC (2012) Phosphorus Management Northern Region Fact Sheet (https://www.grdc.com.au/GRDC-FS-PhosphorusManagement). Accessed November 2018.

Bell M, Lester D, Sands D, Graham R & 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, 2011–16, which was a collaboration between The University of Queensland, NSW DPI and GRDC.

Technical assistance provided by Stephen Morphett, Peter Perfrement and Jan Hosking (NSWDPI) is gratefully acknowledged. Thanks to Scott Carrigan, 'Kelvin', Gurley for hosting the experiment.

Contact

Rick Graham
Tamworth Agricultural Institute, Tamworth
rick.graham@dpi.nsw.gov.au
02 6763 1222

Late cereal sowing options – Gilgandra 2015

Greg Brooke
NSW DPI Trangie

Key findings

- From a late sowing date of 6 July, the two bread wheat varieties Suntop$^{(D)}$ and LRPB Dart$^{(D)}$ out-yielded the two barley varieties (Commander$^{(D)}$ and La Trobe$^{(D)}$) and two durum varieties (DBA Lillaroi and Caparoi).
- Increasing the plant population from 120 plants/m^2 (district practice) to 150 and 180 plants/m^2 had no influence on yield or grain protein levels in any variety, but did increase screening levels in all varieties at 180 plants/m^2.

Introduction

Growers are often faced with decisions around late sowing due to late autumn breaks, waterlogging or initial crop establishment failures necessitating re-sowing. Barley has traditionally been considered a better late sowing option than bread wheat because it can progress more rapidly to the vital stages of flowering and grain filling, minimising heat stress in typically hot springs. Durum has also been used as a late sowing option in preference to bread wheat because it is generally considered quicker maturing. However, growers are still faced with the questions:

1. How late is too late?
2. Should I increase the seeding rate when late sowing?
3. Which cereal species is my best option?

In recent years, a number of fast-maturing bread wheat cultivars have been released that are quicker to flower than some barley varieties and a few durum varieties. While speed to flowering is not the only determinant of successful grain fill in a short season, it is an important factor.

In this experiment, three cereal types; bread wheat, barley and durum were examined with two popular cultivars of each. Three target plant populations were chosen (120, 150 and 180 plants/m^2) to assess whether additional plant numbers increased yield in a shortened growing season. The same experiment was also conducted at Trangie Agricultural Research Centre sown on 2 July 2015.

Site details

Location	"Inglewood", Gilgandra
Co-operator	Kevin Kilby
Soil type and nutrition	Red clay loam, pH_{Ca} 5.6 (0–10 cm)
Starting nitrogen	26 kg N/ha (0–60 cm)
PREDICTA®B	Nil root lesion nematodes and 0.9 log *Fusarium* DNA/g (low) at sowing (0–30 cm)
Sowing date	6 July 2015
Rainfall	see Table 1
Fertiliser	95 kg/ha Granulock® Z Extra (flutriafol) at sowing 70 kg/ha of urea at sowing

Weed management	**Pre sowing**: Logran® 30 g/ha (triasulfuron 750g/kg) Boxer Gold® 2.5L/ha (prosulfocarb 800 g/L, s-metolachlor 120 g/L) **In crop**: Velocity® 770 ml/ha (bromoxynil 210 g/L, pyrasulfotole 375 g/L) Hasten® 0.5 L/ha (esters of canola oil 440 g/L) Axial® 150 ml/ha (cloquintocet-mexyl 25 g/L, pinoxaden 100 g/L)
Disease management	Flutriafol 2.5 L/t on starter fertiliser (Granulock® Z Extra)
Harvest date	16 November 2015

Table 1. Monthly rainfall total at the experiment site – 2015.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total rainfall (mm)	59.2	0.8	11.2	114.4	48.0	44.2	44.0	32.8	3.0	27.8	98.8	56.0

Treatments	Varieties (6)	Two wheat varieties: Suntop$^{\phi}$ and LRPB Dart$^{\phi}$ Two durum varieties: DBA Lillaroi and Caparoi Two barley varieties: Commander$^{\phi}$ and La Trobe$^{\phi}$
	Three plant populations:	120, 150, 180 plants/m^2

Results

Grain yield

The late sowing resulted in relatively low yields ranging from 0.64 t/ha La Trobe$^{\phi}$ (at 120 plants/m^2) up to 1.44 t/ha (Suntop$^{\phi}$ at 180 plants/m^2; Table 2) The crop types and varieties differed in yield with Suntop$^{\phi}$ > LRPB Dart$^{\phi}$ > DBA Lillaroi > Caparoi > Commander = La Trobe$^{\phi}$. Plant population did not significantly affect yield within individual cultivars (Table 2).

Grain protein

Plant population had no significant effect on grain protein concentration within individual varieties (Table 2).

LRPB Dart$^{\phi}$ had significantly higher grain protein levels (0.5%) for each plant population than Suntop$^{\phi}$.

The durum variety, DBA Lillaroi, had higher grain protein than Caparoi, while the protein difference between the barley varieties La Trobe$^{\phi}$ and Commander was not significant.

Screenings

Increasing plant population from 120 plants/m^2 to 180 plants/m^2 increased screenings levels in all varieties with some being more affected than others (Table 2).

Table 2. Grain yield and quality of six cereal varieties at three different plant populations – Gilgandra 2015.

Variety	Plant population (plants/m²)	Yield (t/ha)	Protein (%)	Screening (%)	Retention (% above 2.5 mm)	Screening (% below 2.2 mm)
DBA Lillaroi	120	0.86	13.4	5.4		
	150	0.89	13.2	5.0		
	180	0.92	13.3	6.5		
Caparoi	120	0.75	12.9	9.7		
	150	0.78	12.8	9.4		
	180	0.81	12.9	10.9		
Commander	120	0.66	10.4		0.38	0.19
	150	0.69	10.3		0.38	0.20
	180	0.72	10.4		0.38	0.19
LRPB Dart	120	1.11	12.4	8.2		
	150	1.14	12.2	7.8		
	180	1.17	12.3	9.3		
LaTrobe	120	0.64	10.3		0.13	0.42
	150	0.67	10.2		0.13	0.33
	180	0.70	10.3		0.13	0.40
Suntop	120	1.38	11.9	3.1		
	150	1.41	11.7	2.8		
	180	1.44	11.8	4.3		
l.s.d.		0.08	0.3	0.02	0.05	0.06

Conclusions

July is considered a relatively late sowing date for any cereal in most years at Gilgandra. In an adjacent cereal experiment sown on 12 May (seven weeks earlier), a mean yield of 4.6 t/ha was achieved in bread wheat, barley and durum varieties. This highlights the considerable drop in potential yield from such late sowing.

It is not clear why the bread wheat varieties out-yielded the barley in this experiment. The November rain would have been too late to have assisted with grain fill, however the 11 mm recorded on 22 October likely coincided with wheat grain set and floret retention. Many farmers use increasing plant population with late sowing to attempt to compensate for the lower yield potential from reduced crop growing/tillering time. In this experiment, there was a trend toward higher yield with increasing plant population in all varieties, but the effect was very small (0.02–0.03 t/ha) and not statistically significant. Increasing plant population to 180 plants/m^2 disadvantaged the bread wheat and durum varieties by increasing screenings. Increasing plant population did not affect barley retention and screenings.

Acknowledgements

This experiment was part of the project 'Variety Specific Agronomy Packages for southern, central and northern New South Wales', DAN00167, 2012–16, with joint investment by NSW DPI and GRDC.

Thanks to the Kilby family for providing the experiment site, Gavin Melville for biometric analysis and technical assistance provided by Lizzie Smith and Sally Wright.

Contact

Greg Brooke
Trangie Agricultural Research Centre, Trangie
greg.brooke@dpi.nsw.gov.au
02 6880 8000

Yield response of canola and wheat to nitrogen application – Tamworth 2017

Thomas Tendo Mukasa Mugerwa, Rick Graham and Peter Formann.
NSW DPI Tamworth

Key findings

- Results from this study highlight the yield responsiveness of canola to nitrogen (N) application.
- Canola yield increased with higher rates of N application before the yield response plateaued at 425 kg N/ha.
- Compared to canola, wheat was not as responsive to increasing rates of N, with the response plateauing at 100 kg N/ha.
- Canola protein levels increased with higher rates of N, however, there was an inverse relationship between oil concentration and increasing rates of N.
- Wheat protein levels were almost linear in response to N applications up to 225 kg N/ha, increasing from 10% to 12.6%.

Introduction

In 2016, a scoping study was undertaken to assess crop yield response data entered into the *Better Fertiliser Decisions for Cropping* (BFDC) database for various crops and nutrients in the Eastern cropping zone, in order to identify gaps in knowledge. In Northern NSW, knowledge gaps for N were identified for a winter oilseed (canola), a summer cereal (maize) and a summer oilseed (sunflower). The aim of this experiment was to generate an N-response yield curve for canola subjected to various rates of N, using wheat as a control. Data from this experiment will be used to confirm and update N-response data within the BFDC database.

Site details

Location	Tamworth Agricultural Institute
Soil type and nutrition	Grey/Brown Vertosol, pH_{Ca} 7.2 (0–10 cm)
Starting N	43 kg/ha (available soil nitrate N; 0–120 cm)
Rainfall	Growing season rainfall at the trial site was 280 mm, with stored soil moisture prior to sowing measured as 167 mm (0–120 cm)
Trial design	Nineteen N rates were established in a randomised block design. Canola (Pioneer ® 44Y90 CL) and wheat (Elmore CL PLUS$^{(\phi)}$) were grown as separate blocks, to allow for appropriate weed management. Eight replications of each treatment were established
Sowing	Experiments were direct-drilled into barley stubble on the 10 May 2017. Plots were 12 m in length on 2 m centres, with 5 rows at 33 cm spacings
Fertiliser	At sowing, phosphorus (P) fertiliser was applied as Granulock Z at 60 kg/ha, 13 kg P/ha

Plant population	Mean plant densities achieved at maturity were 50 plants/m^2 (canola) and 80 plants/m^2 (wheat).
Harvest date	27 October 2017 (canola) 15 November 2017 (wheat)

Treatment

Nitrogen rates are shown in Table 1. Nitrogen treatments were applied as granular urea (46% N) and were side-banded using a twin-disk seeder, 14 days before sowing.

Table 1. Nitrogen application treatments.

Treatment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Rate (kg N/ha)	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450

Results

Grain yield

Canola

The mean grain yield across all N treatments was 2.88 t/ha, with the nil treatment (no additional N) producing a grain yield of 1.81 t/ha (Figure 1). The highest grain yield was obtained where N was applied at a rate of 425 kg N/ha, resulting in a yield of 3.67 t/ha.

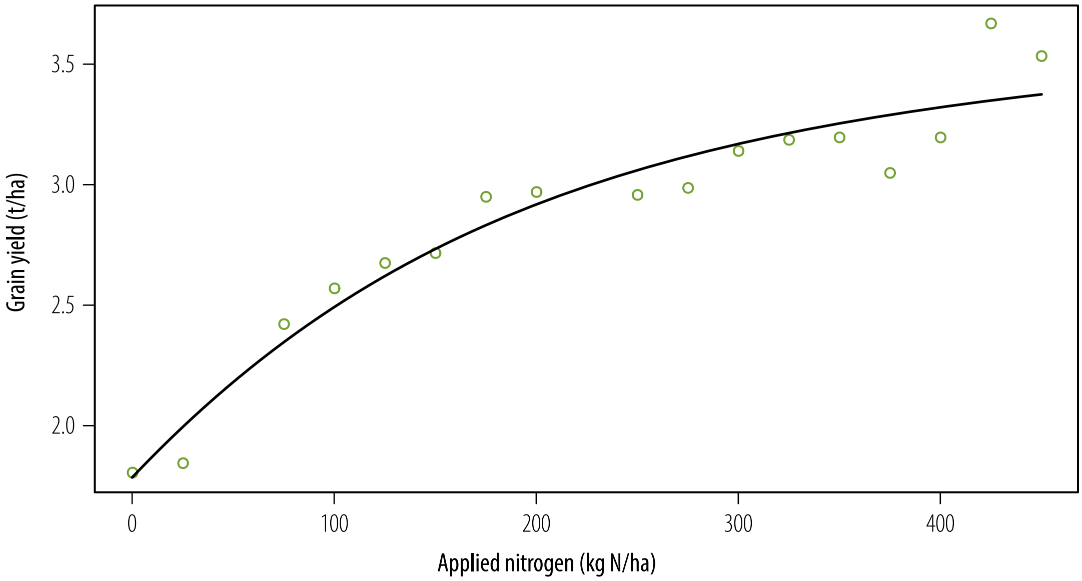


Figure 1. Relationship between canola grain yield (t/ha) and applied nitrogen (kg N/ha).

Wheat

The mean grain yield across all N treatments was 4.24 t/ha, with the nil treatment (no additional N) producing a grain yield of 3.56 t/ha (Figure 2). The highest grain yield was obtained where N was applied at 150 kg N/ha, resulting in a yield of 4.54 t/ha.

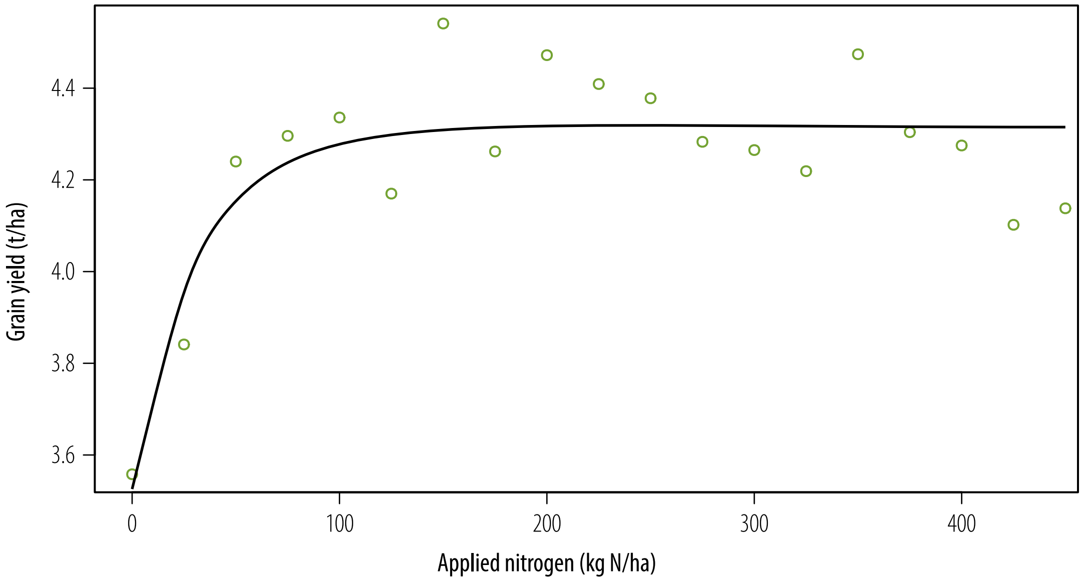


Figure 2. Relationship between wheat grain yield (t/ha) and applied nitrogen (kg N/ha).

Grain protein concentration

Canola

The mean grain protein concentration (GPC) across all N treatments was 20.59%, with the nil treatment producing a GPC of 19.51% (Figure 3). The highest GPC of 21.2% was obtained where N was applied at 325 kg/ha.

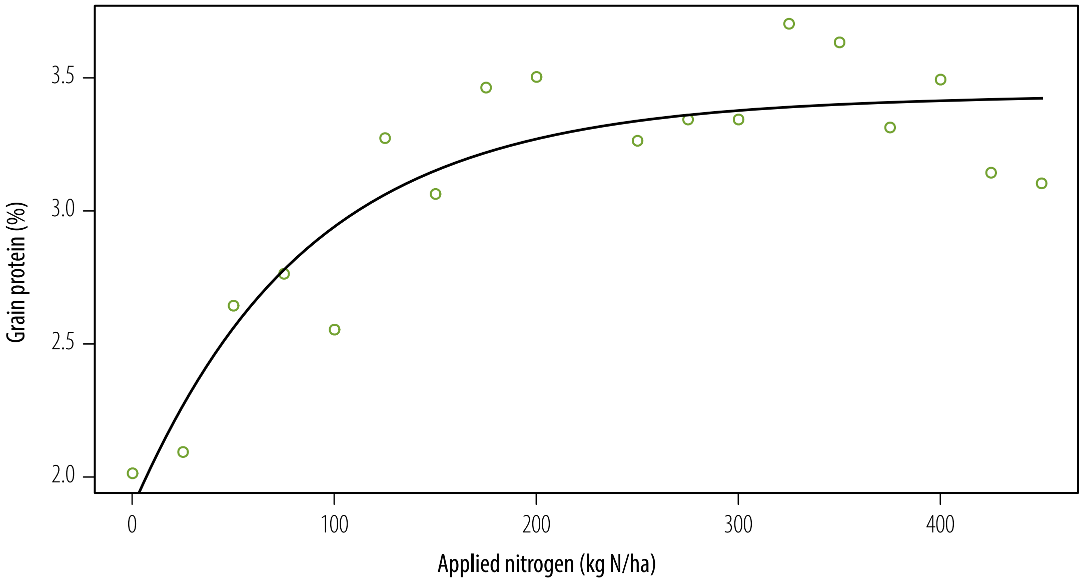


Figure 3. Relationship between canola grain protein concentration (%) and applied nitrogen (kg N/ha).

Wheat

The mean GPC across all N treatments was 11.7%, with the nil treatment producing a GPC of 10.1% (Figure 4).The highest GPC of 12.6% was obtained where N was applied at 450 kg/ha.

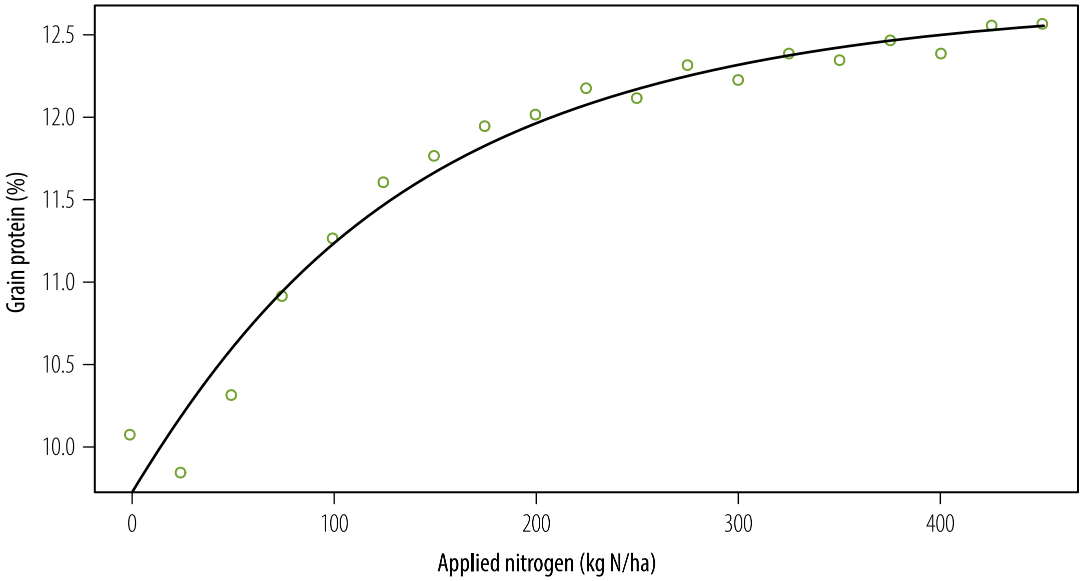


Figure 4. Relationship between wheat grain protein concentration (%) and applied nitrogen (kg N/ha).

Canola oil concentration

The mean oil concentration across all canola N treatments was 41.7%, with the highest oil concentration of 42.9% obtained where no additional N was applied (data not shown).

Discussion

Canola yields increased with greater N rates, before plateauing at 425 kg N/ha (Figure 1). At this high rate, grain yield increased by 1.86 t/ha (103%) over the nil treatment. However, at higher rates of N (>425 kg N/ha), the yield response curve was relatively flat, with yield potentials most likely affected by the 2017 growing season environmental conditions. During the growing season, Tamworth had 44 days below 0°C as well as below average annual rainfall of 631 mm, compared with the long term average of 664 mm.

Canola oil concentration declined with increased rates of N, with significant differences relative to the nil treatment recorded with rates over 50 kg N/ha (data not shown). Oil concentration was below the critical value of 42% (2017/2018 base level) where N was applied at and above 75 kg N/ha. In contrast, GPC increased with greater N rates, plateauing at 125 kg N/ha. These results highlight the inverse relationship in canola between GPC and oil in response to increasing N rates.

Wheat yield peaked at 4.54 t/ha, where N was applied at 150 kg/ha. This increase of 0.98 t/ha corresponded to a 28% increase in yield over the nil treatment. In wheat, GPC had an almost linear response up to an application rate of 225 kg N/ha, before plateauing.

Conclusions

Results from this study highlight how canola yield responds to N application. Within a grey/brown Vertosol and under relatively dry seasonal conditions that included a number of frosts, yields increased with increasing rates of N, with the N-response yield curve slightly plateauing at 425 kg N/ha. Significant increases in yield were obtained where N was applied at and above 75 kg N/ha, compared to where no additional N was applied.

In contrast, wheat was not as responsive, with the N-response grain yield curve plateauing at 100 kg N/ha. However, significant increases in yield were obtained when N was applied at ≥50 kg N/ha.

Both canola and wheat responded to N application in terms of GPC, with wheat in particular showing an almost linear GPC response to increasing N. Canola GPC increased with higher rates of N, however, there was an inverse relationship between oil concentration and increasing N. Oil concentration remained above 42% where N was applied at rates of up to 50 kgN/ha, dropping below this level when N was applied above 50 kg N/ha.

Average canola yields obtained in this study (2.88 t/ha) were well-above the state average in 2017 (1.03 t/ha). Indeed, the average yield obtained where no additional N was applied (1.81 t/ha) was still significantly higher than the state average. The yield response curve generated from this study indicated the N application rates at which optimum economic yield could be obtained.

Acknowledgements

This experiment was part of the project 'Updated nutrient response curves in the northern and southern regions', UQ00082, a joint investment by NSW DPI, GRDC and the University of Queensland.

Technical assistance provided by members of the Tamworth Agronomy Team (NSW DPI) is gratefully acknowledged. The authors would also like to acknowledge the editors for their comments during report preparation.

Contact

Thomas Tendo Mukasa Mugerwa
Tamworth Agricultural Institute, Tamworth
tendo.mukasa.mugerwa@dpi.nsw.gov.au
02 6763 1222

Improving harvest management decisions in canola – implications of seed colour change on windrow timing and yield – Tamworth 2017

Rick Graham, Rod Bambach, Jan Hosking and Stephen Morphett
NSW DPI Tamworth

Key findings

- It was observed, from the partitioning of seed from pods on the primary stem and branches, that seed colour change (SCC) occurred later on the branches compared with the stems.
- The primary stem only contributed ~16% of total seed yield.
- The whole plant (primary stem and branches) should be used when determining SCC for windrow timing.
- Relying solely on the SCC on the primary stem to determine windrow timing (WT) can underestimate overall seed development, negatively affecting seed size and ultimately yield potential.
- Windrowing at the start of SCC (10% SCC) averaged across the plant was shown to reduce yield by 16% or 0.53 t/ha compared with windrowing at ~47% SCC.
- Our results support the updated Australian Oilseeds Federation (AOF) recommendations that canola should ideally be windrowed when '40–60% of seeds collected from both the stem and branches have changed colour'. Importantly, results in this study did show that yields were optimised at 100% SCC, with no significant difference in yields achieved at 47% SCC, further underlining the significant yield penalties associated with early windrowing compared with delayed windrowing.

Introduction

Windrowing is a widely adopted harvest management practice in canola (*Brassica napus* L) in Australia. Its timing has traditionally been based on seed colour change (SCC) in seeds taken from pods (siliques) in the middle third of the primary stem (primary racemes). Over the past decade however, as hybrid varieties have been introduced, germplasm has improved and farming practices have changed, there has been increased discussion within the canola industry about how best to determine SCC and hence windrow timing.

Industry guidelines based on research conducted in the 1970s and 1980s recommend that canola (*Brassica napus* L.) is ready to windrow when 40–60% of seeds on the primary (main) stem change colour from green to red, brown or black. The main concern with this recommendation centres on the proportion of yield contained on the branches versus the primary stems, and the effect of the differential rate of seed maturity on yield and seed quality parameters.

In 2015, research began as a component of the GRDC co-funded 'Optimised Canola Profitability' project (CSP00187).The project's goal was to examine the relationship between SCC, grain yield and quality parameters, with the aim of helping growers make more informed decisions on canola harvest management in the northern grains region (NGR) of NSW, and potentially across Australia. Preliminary results found that there were large effects from where on the plant (branch *vs*. primary stem) SCC was measured. It was observed from the partitioning of seed from pods, that the seed from branches were slower to mature than that of the primary stems creating the potential for significant yield and grain quality reductions associated with incorrect windrow timing.

In 2017, a series of experiments were conducted looking at both hybrid and open pollinated varieties. Findings from an experiment conducted at Tamworth is outlined in this report. This experiment tested if there were any differences in yield components (stem *vs* branches), SCC and seed development, between a hybrid variety and an open pollinated variety.

Site details	**Location**	Tamworth Agricultural Institute
	Soil type	Grey–brown vertosol
	Previous crop	Barley
	Starting water	160 mm plant available water (PAW) to 120 cm deep
	In-crop rainfall	May to October – 203 mm
	Starting nitrogen	Soil nitrate N 51 kg N/ha (0–120 cm)
	Trial design	Replicated split plot design, with windrow timing as the main plot and variety randomised within the treatment timing plots.
	Fertiliser	60 kg/ha Granulock Z Extra treated with Intake® (500 g/L flutriafol @ 200 mL/ha) and 220 kg/ha urea (100 kg N/ha) side banded at planting
Treatments	**Varieties (2)**	Pioneer® 44Y89 (CL), ATR-Bonito$^{\phi}$
	Sowing date (SD)	5 May 2017
	Plant populations (PP)	38 plants/m^2
	Windrow timing	Windrow timings (WT) were conducted at 2–3 day intervals (i.e. Monday, Wednesday and Friday) from the start of SCC on the primary stem up until 100% SCC on branches. SCC was defined as when 'a minimum of two-thirds of the surface area of an individual seed changed colour from green to brown, red or black'. Actual SCC was determined using a representative 200-seed sub-sample, taken from pods from the middle third of the primary stem and randomly from across the branches of individual plants.

Results

The two varieties evaluated had comparable dates for 50% flowering (i.e. 50% plants with one flower open on the main stem), but differed in terms of maturity, with Pioneer® 44Y90 (CL), the hybrid, four days faster to the end of flowering (5% flowers remaining) compared with ATR-Bonito$^{\phi}$ the open pollinated variety. WT treatments started on 18 October 2017 for both varieties, but concluded on 30 October and 6 November respectively for Pioneer® 44Y90 (CL) and ATR-Bonito$^{\phi}$, reflecting differences in varietal maturity. Consequently, SCC was more advanced for Pioneer® 44Y90 (CL) compared with ATR-Bonito$^{\phi}$ at the start of the WT treatments. Pioneer® 44Y90 (CL), for example, was at 61% SCC on the primary stem, compared with 19% SCC for ATR-Bonito$^{\phi}$ at WT 1 (18 October). Pioneer® 44Y90 (CL) was considered too advanced in maturity or SCC at the start of the WT and as such the experiment progressed solely based on SCC for ATR- Bonito$^{\phi}$. Importantly, overall trends to delays in WT were comparable for both varieties, with the primary stems only contributing ~16% of seed yield for both varieties.

Consistent with previous findings, SCC occurred earlier on the primary stem compared with the branches. In the case of ATR-Bonito⁽ᶲ⁾ when the primary stems were at ~29% SCC, the branches were only at 7% SCC (WT 1) likewise, when the stems were at 90% SCC, the branches were only at 38% SCC (WT 3). The results from 2017 reinforced how rapid SCC can occur, with the branches progressing from 39% to 90% SCC over a five day period (Figure 1) underlining the potential interaction of temperature on SCC (Figure 2).

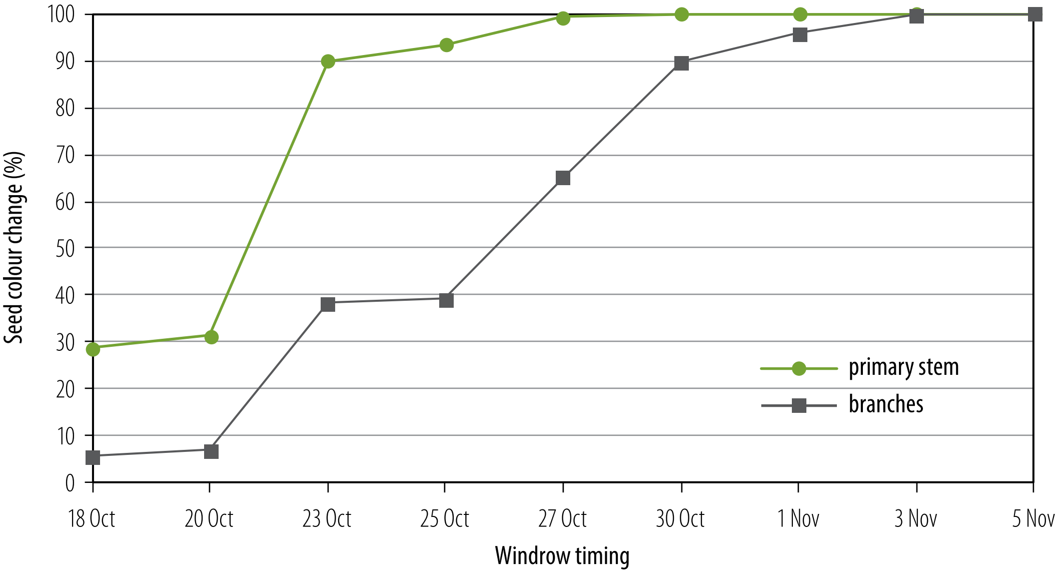


Figure 1. Seed colour change (%) of primary stem vs. branches over time as determined by windrow timing timings at Tamworth in 2017.

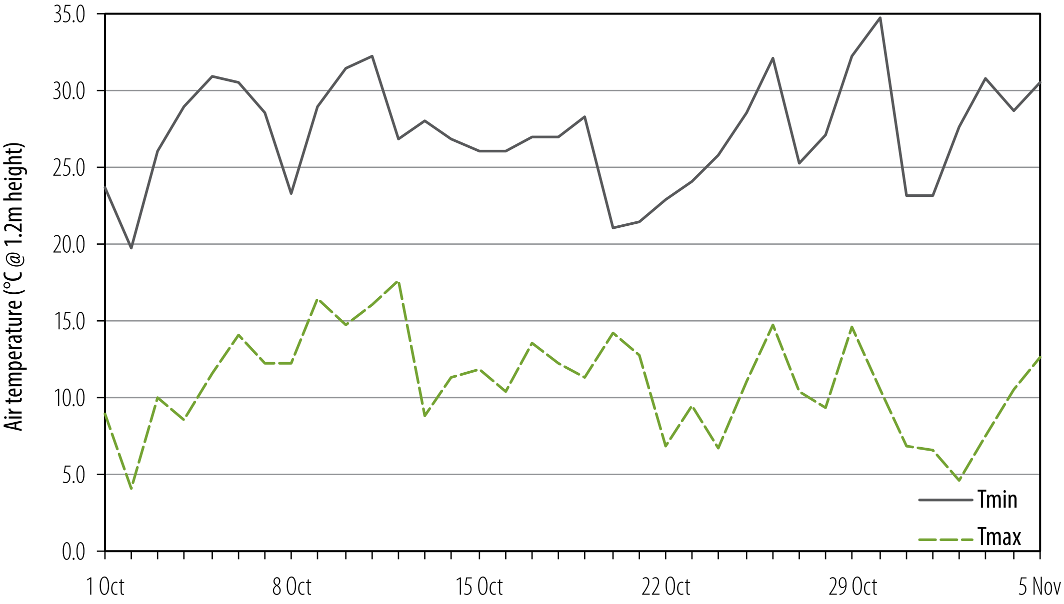


Figure 2. Maximum and minimum daily temperatures (°C) for Tamworth in 2017.

Seed size

Seed size expressed as thousand seed weight (TSW) is an indicator of both physiological maturity and yield potential. Changes in TSW over time (Figure 3) are determined by WT. It was observed that contrasts in TSW on primary stems vs. branches were largest during the earlier windrow timings reflecting differences in SCC and maturity. This would be expected given that seeds mature progressively up the primary stem and from the lower branches to the upper branches, with changes in seed colour indicating declining metabolic activity and increasing seed maturity.

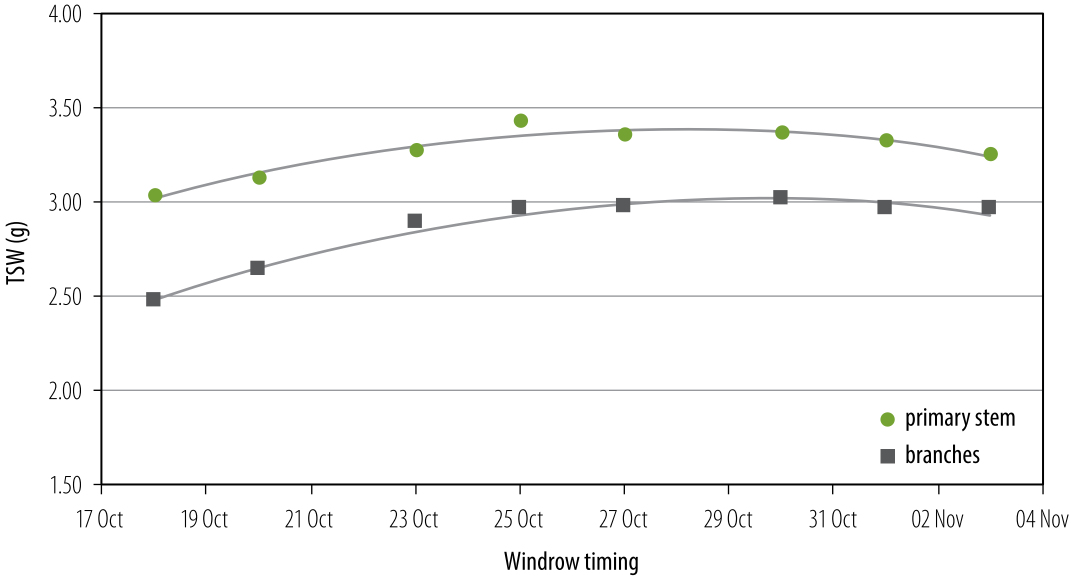


Figure 3. Changes in seed size (TSW) on primary stem vs. branches determined by windrow timing for Tamworth in 2017. l.s.d. (*P*=0.05) for primary stem = 0.15 g and l.s.d. (*P*=0.05) for branches = 0.09 g.

Grain yield

When looking at the yield component breakdown on primary stems *vs*. branches, it was observed that stems only contributed ~16% of total yield averaged across windrow timings (data not shown). As was noted with SCC, seeds sampled from the branches were less advanced than the primary stem, taking longer to reach physiological maturity.

Windrowing started at 10% SCC (average for branches and primary stems). Windrow timing one (WT1) resulted in a 0.53 t/ha decline in yield potential, compared with windrow timing two (WT2) at ~ 47% SCC equating to a 16% yield loss (Figure 4). Although yield was optimised at 100% SCC there was no significant difference compared with yields achieved at 47% SCC. TSW also plateaued at around 47% SCC (Figure 3). Potentially there would also be increased potential for harvest losses, attributed to shattering with delayed windrow timing.

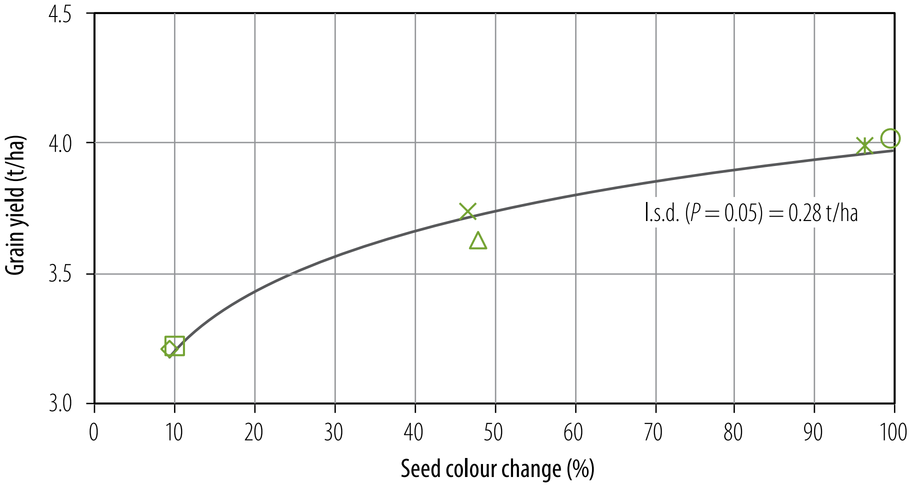


Figure 4. Effect of seed colour change on a whole plant basis (primary stem and branches) on grain yield (t/ha) at Tamworth in 2017. l.s.d. (*P*=0.05) = 0.28 t/ha.

Conclusions

Results from this experiment underline the importance of correct windrow timing and the need to accurately determine SCC. It was observed, from the partitioning of seed from pods on the primary stem and branches, that SCC was slower to develop on branches compared with stems. Importantly, in yield component breakdown, it was found that seed from the primary stem only contributed ~16% of grain yield. If SCC on the primary stem is solely relied upon for windrowing decisions, overall seed development can be underestimated and can negatively affect seed size and yield. Furthermore, windrowing earlier than 40% SCC based on a whole plant (primary stem and branches), was shown to significantly reduce yield by up to 16%.

Given the significance of the yield component that the branches contribute as opposed to stems, it appears that the method to determine SCC should be reconsidered.

This study demonstrates that SCC should ideally be based on the whole plant and not solely on the primary stem, which supports current Australian Oilseeds Federation (AOF) recommendations that canola should ideally be windrowed when '40–60% of seeds collected from both the stem and branches have undergone SCC' (Anon, 2017).

There is also a further need for a clear definition as to what constitutes actual SCC in order to develop robust industry guidelines around windrow timing.

References

Anon, (2017) [online] Available at: http://www.australianoilseeds.com/about_aof/news/media_release_check_canola_pods_on_the_branches,_not_just_the_stem [Accessed 28 September, 2018]

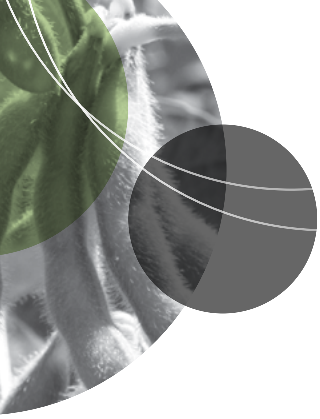
Acknowledgements

This experiment was part of the project 'Optimised canola profitability', CSP00187, 2014-19, a collaborative partnership between GRDC, NSW DPI, CSIRO and SARDI.

Rohan Brill, NSW DPI Wagga Wagga is gratefully acknowledged for experimental design and for developing the research questions, technical guidance and protocol development and Dr Neroli Graham for biometric support.

Contact

Rick Graham
Tamworth Agricultural Institute, Tamworth
rick.graham@dpi.nsw.gov.au
02 6763 1222



Crop protection

Impact of winter cereal crop choice on final soil populations of *Pratylenchus thornei* – Rowena 2017

Steven Simpfendorfer[1] and Matt Gardner[2]

[1]NSW DPI Tamworth
[2]AMPS Research

Key findings

- Winter cereal crop and variety choice can affect Pratylenchus thornei (*Pt*) population build-up within paddocks subsequently influencing the following crops' performance and/or varieties in the rotation.
- Significant differences were evident between varieties with an 8.5-fold difference in final *Pt* populations between the best (AGD043) and worst (Mitch$^{(\phi)}$) entry.
- Very susceptible varieties (e.g. Mitch$^{(\phi)}$) should be avoided in paddocks where *Pt* is known to be present as they can increase the population to high risk levels in one season.

Introduction

The root lesion nematode (RLN) *Pratylenchus thornei* (*Pt*) is widespread in cropping soils throughout northern NSW and southern Qld. Winter cereal varieties differ in their extent of yield loss from *Pt* (tolerance) and the numbers of nematodes that multiply in their root systems within a season (resistance). Resistance to *Pt* is an important consideration as it dictates a variety's effect on subsequent crops in the rotation. That is, more susceptible varieties allow greater *Pt* multiplication in their root systems over a season. The higher the resulting *Pt* population left in the soil, the greater the potential for a negative effect on a subsequent crop's yield.

The effect of four barley, four durum and 12 bread wheat varieties on final *Pt* populations was determined in a replicated field experiment near Rowena in north-western NSW in 2017.

Site details

Location	'Combos', Rowena
Co-operator	Will and Tilla Winston-Smith
Sowing date	7 June 2017
Fertiliser	220 kg/ha urea and 60 kg/ha Granulock Z Extra at sowing
Starting nitrogen (N)	115 kg N/ha to a depth of 120 cm
Plant available water content (PAWC)	~185 mm plant available soil water (0–120 cm)
Rainfall	The growing season rainfall was 103 mm

PREDICTA®B	3.7 *Pratylenchus thornei*/g soil (medium risk), nil *P. neglectus* and 0.6 log *Fusarium* DNA/g (low crown rot risk) at sowing (0–15 cm)
Post harvest soil sampling date	5 March 2018 with a bulk of 20 cores (0–15 cm) per plot

Treatments

Varieties (20)

- Four barley varieties: Commander$^{\phi}$, Compass$^{\phi}$, La Trobe$^{\phi}$ and Spartacus CL$^{\phi}$.
- Four durum varieties: Jandaroi$^{\phi}$, DBA Lillaroi$^{\phi}$, DBA Bindaroi$^{\phi}$ plus the numbered line AGD043.
- Twelve bread wheat varieties: EGA Gregory$^{\phi}$, LRPB Flanker$^{\phi}$, Coolah$^{\phi}$, Sunmate$^{\phi}$, LRPB Lancer$^{\phi}$, LRPB Reliant$^{\phi}$, LRPB Gauntlet$^{\phi}$, LRPB Spitfire$^{\phi}$, LRPB Mustang$^{\phi}$, Mitch$^{\phi}$, Suntop$^{\phi}$ and Sunguard$^{\phi}$.
- 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 did not affect final soil *Pt* densities measured after harvest. There was an 8.5 fold difference in final *Pt* densities between the lowest (AGD403) and highest (Mitch$^{\phi}$) entry (Figure 1). There were significant differences between entries in each of the three winter cereal crop types with the most susceptible barley, durum and bread wheat entries being La Trobe$^{\phi}$, Jandaroi$^{\phi}$ and Mitch$^{\phi}$, respectively. Conversely, the most resistant barley, durum and bread wheat entries appeared to be Compass$^{\phi}$, AGD043 and Suntop$^{\phi}$, respectively (Figure 1). Generally, there was less variation in final *Pt* populations with the durum entries, which were on the lower end, than with barley and bread wheat varieties, which had a larger spread between entries.

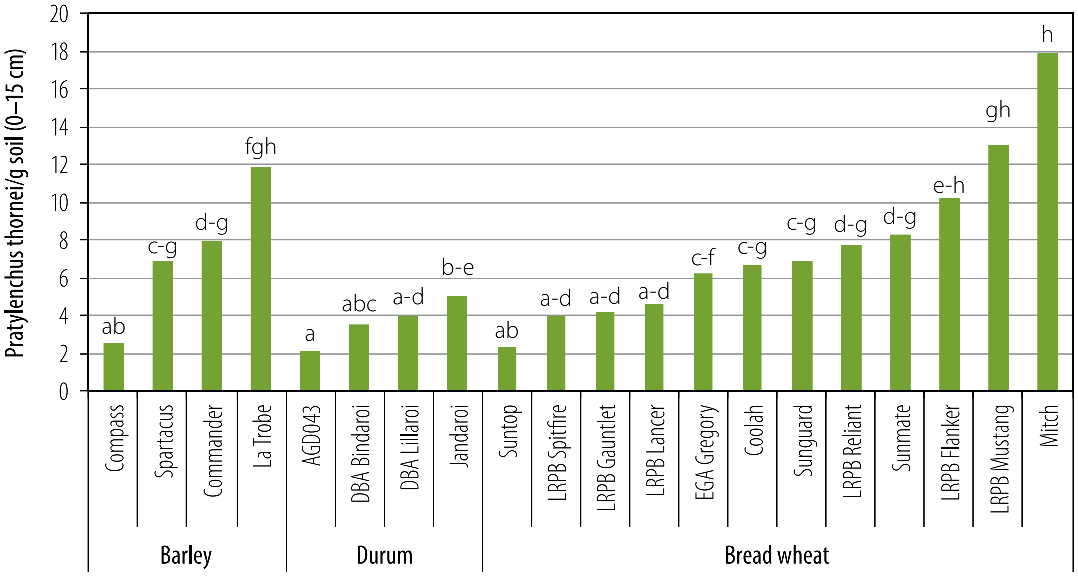


Figure 1. Final *Pratylenchus thornei* soil populations (*Pt*/g soil; 0–15 cm) produced by four barley, four durum and 12 bread wheat entries – Rowena 2017. Bars followed by the same letter are not significantly different (*P*=<0.001) based on transformed data (ln(x + 1)). Back-transformed values are presented in the figure.

Conclusions

Cereal crop and variety choice can significantly affect *Pt* build-up within paddocks. There was an 8.5-fold difference in populations between the best and worst entries at Rowena in 2017. 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. With the exception of Mitch$^{\phi}$, which elevated the *Pt* population to a high risk level, all other entries either maintained or increased *Pt* soil densities to within a medium risk level for yield loss in a subsequent crop in 2018.

Acknowledgements

This experiment was part of the 'National nematode epidemiology and management program', DAV00128, with joint investment by NSW DPI and GRDC.

Thanks to Will and Tilla Winston-Smith for providing the trial site and Robyn Shapland, Jason McCulloch, Rachael Bannister, Carla Lombardo, 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.

Contact

Steven Simpfendorfer
Tamworth Agricultural Institute, Tamworth
steven.simfendorfer@dpi.nsw.gov.au
02 6763 1222

Regional crown rot management – Gilgandra 2017

Steven Simpfendorfer[1], Greg Brooke[2], Ryan Potts[3] and Robyn Shapland[1]

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

Key findings

- The durum variety Jandaroi$^{\phi}$, plus the two bread wheat varieties LRPB Mustang$^{\phi}$ and LRPB Spitfire$^{\phi}$ were affected by frost at this site in 2017, which complicates interpretations.
- Yield loss from crown rot ranged from not significant in the four barley varieties and three of the 12 bread wheat varieties, up to 66% loss in the durum variety Jandaroi$^{\phi}$.
- The four barley varieties were 0.99–1.42 t/ha higher yielding than the susceptible bread wheat variety EGA Gregory$^{\phi}$, where high levels of crown rot infection were present.
- The bread wheat varieties LRPB Reliant$^{\phi}$, Suntop$^{\phi}$, Mitch$^{\phi}$ and Sunguard$^{\phi}$ were also higher yielding (0.40–0.46 t/ha) than EGA Gregory$^{\phi}$ in crown-rot-infected plots.

Introduction

Crown rot (CR), caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to winter cereal production in the northern grains region. Cereal varieties differ in their resistance to crown rot, which can significantly affect their relative yield when the disease is present.

This experiment was one of six NSW DPI conducted in 2017 across central/northern NSW, extending into southern Qld, to examine the effect of crown rot on the yield and quality of four barley, four durum and 12 bread wheat varieties.

Site details

Location	'Inglewood', Gilgandra
Co-operator	Kevin Kilby
Sowing date	11 May 2017
Fertiliser	80 kg/ha Granulock 12Z (treated with 2.8 L/ha of flutriafol) plus 70 kg/ha of urea spread on the soil surface at sowing
Starting nitrogen	97 kg N/ha to a depth of 120 cm
Starting soil water	~120 mm plant available soil water (0–120 cm)
Rainfall	The growing season rainfall was 63 mm
PREDICTA®B	Nil *Pratylenchus thornei*, nil *P. neglectus* and nil crown rot levels at sowing (0–15 cm of soil)
Harvest date	31 October 2017

Treatments

Varieties (20)

- Four barley varieties: Commander$^{\phi}$, Compass$^{\phi}$, La Trobe$^{\phi}$ and Spartacus$^{\phi}$.
- Four durum varieties: Jandaroi$^{\phi}$, DBA Lillaroi$^{\phi}$, DBA Bindaroi$^{\phi}$ plus the numbered line AGD043.
- Twelve bread wheat varieties: EGA Gregory$^{\phi}$, LRPB Flanker$^{\phi}$, Coolah$^{\phi}$, Sunmate$^{\phi}$, LRPB Lancer$^{\phi}$, LRPB Reliant$^{\phi}$, LRPB Gauntlet$^{\phi}$, LRPB Spitfire$^{\phi}$, LRPB Mustang$^{\phi}$, Mitch$^{\phi}$, Suntop$^{\phi}$ and Sunguard$^{\phi}$ (listed in order of increasing resistance to crown rot).

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

Yield

Frost damage was most severe in the durum variety Jandaroi$^{\phi}$ and noticeable in the bread wheat varieties LRPB Mustang$^{\phi}$ and LRPB Spitfire$^{\phi}$, which reduced their yield in both the inoculated and un-inoculated plots. In the no added CR treatment, yield ranged from 0.66 t/ha in the frost-affected durum variety Jandaroi$^{\phi}$ up to 3.22 t/ha in the barley variety La Trobe$^{\phi}$ (Table 1).

Table 1. Yield and grain quality of varieties with no added and added crown rot – Gilgandra 2017.

Crop	Variety	Yield (t/ha)		Protein (%)	Screenings (%)	
		No added CR	Added CR		No added CR	Added CR
Barley	La Trobe	3.22	2.97	13.0	1.1	2.2
	Compass	2.80	2.62	13.1	1.4	2.3
	Commander	2.89	2.56	12.7	1.7	3.7
	Spartacus	2.78	2.54	14.3	0.9	2.1
Durum	AGD043	1.60	0.93	12.8	5.3	11.2
	DBA Lillaroi	1.57	0.84	14.3	4.4	7.6
	DBA Bindaroi	1.62	0.83	13.7	3.1	8.2
	Jandaroi	0.66	0.23	15.7	1.7	4.3
Bread wheat	Sunguard	2.32	2.01	12.7	3.5	3.7
	Mitch	2.35	2.00	12.0	5.5	6.2
	Suntop	2.36	1.99	12.4	3.3	4.1
	LRPB Reliant	2.33	1.95	12.1	6.3	6.6
	Coolah	2.30	1.89	11.3	3.0	5.0
	LRPB Lancer	2.36	1.86	13.3	2.5	3.0
	LRPB Flanker	2.27	1.82	12.1	3.4	4.8
	LRPB Gauntlet	2.22	1.65	13.0	3.9	4.6
	LRPB Mustang	1.57	1.65	12.7	6.1	7.1
	EGA Gregory	2.39	1.55	12.0	4.7	5.6
	LRPB Spitfire	1.73	1.47	15.2	5.3	4.7
	Sunmate	2.00	1.34	13.0	7.2	5.7
Site mean		2.17	1.73	13.1	3.7	5.1
CV (%)		11.1		2.1	11.6	
l.s.d.		0.351		0.32	0.83	
P value		0.058		<0.001	<0.001	

The four barley varieties, the bread wheat variety Sunguard$^{\phi}$ and the two frost-affected bread wheats (LRPB Mustang$^{\phi}$ and LRPB Spitfire$^{\phi}$) did not suffer significant yield loss under high levels of crown rot infection (added CR). In the remaining entries, yield loss ranged from 15% in the bread wheat variety Mitch$^{\phi}$ (0.36 t/ha) and up to 66% in the severely frost-affected durum variety Jandaroi$^{\phi}$ (0.43 t/ha) (Table 1). In the other three durum varieties, yield loss ranged from 42–49% (0.68–0.79 t/ha). In the bread wheat varieties, yield loss associated with crown rot infection was highest in EGA Gregory$^{\phi}$ at 35% (0.84 t/ha).

All four durum varieties were lower yielding than EGA Gregory$^{\phi}$ under high crown rot infection (added CR) by between 0.63 t/ha for AGD043 and up to 1.33 t/ha for Jandaroi$^{\phi}$. Seven of the bread wheat varieties (Coolah$^{\phi}$, LRPB Lancer$^{\phi}$, LRPB Flanker$^{\phi}$, LRPB Gauntlet$^{\phi}$, LRPB Mustang$^{\phi}$, LRPB Spitfire$^{\phi}$ and Sunmate$^{\phi}$) produced a yield equivalent to EGA Gregory$^{\phi}$ in the added CR treatment (Table 1).

All four barley varieties were between 0.99 t/ha (Spartacus$^{\phi}$) to 1.42 t/ha (La Trobe$^{\phi}$), yielding higher than EGA Gregory$^{\phi}$ under high levels of crown rot infection (added CR; Table 1). Four of the bread wheat varieties (LRPB Reliant$^{\phi}$, Suntop$^{\phi}$, Mitch$^{\phi}$ and Sunguard$^{\phi}$) were also higher yielding (0.40–0.46 t/ha) than EGA Gregory$^{\phi}$ in the added CR treatment.

Grain quality

Protein levels were quite high at this site in 2017 ranging between 11.3% (Coolah$^{\phi}$) up to 15.7% (Jandaroi; Table 1). Crown rot infection (added CR) did not significantly affect grain protein levels in any of the lines at this site in 2017.

Where no CR was added, screening levels ranged from 0.9% in the barley variety Spartacus$^{\phi}$ up to 7.2% in the bread wheat variety Sunmate$^{\phi}$ (Table 1).

Screening levels were increased by between 0.9% (Compass$^{\phi}$) to 1.9% (Commander$^{\phi}$) in the added CR treatment for the four barley varieties, and by 2.6% (Jandaroi$^{\phi}$) to 5.9% (AGD043) across the four durum entries. Four of the bread wheat entries (Coolah$^{\phi}$, LRPB Flanker$^{\phi}$, LRPB Mustang$^{\phi}$ and EGA Gregory$^{\phi}$) had increased screening levels of 1–2% in the added CR treatment, while Sunmate$^{\phi}$ had 1.5% lower screenings in the inoculated plots. In the remaining bread wheats, there was no significant difference in the level of screenings between the no added CR and added CR treatments. In the added CR treatment, screening levels ranged from 2.1% in the barley variety Spartacus$^{\phi}$ up to 11.2% in the durum wheat line AGD043 (Table 1).

Conclusions

Cereal crop species and variety choice affected yield in the absence and presence of crown rot infection, which differed by 2.56 t/ha and 2.75 t/ha, respectively between the best and worst entries. Frost damage was obvious in the durum variety Jandaroi$^{\phi}$ plus bread wheat varieties LRPB Mustang and LRPB Spitfire$^{\phi}$, which carried through to reduced yields relative to the other winter cereals at this site in 2017.

The four bread wheat varieties LRPB Reliant$^{\phi}$, Suntop$^{\phi}$, Mitch$^{\phi}$ and Suntop$^{\phi}$ provided a 26–30% yield benefit over growing the susceptible bread wheat variety EGA Gregory$^{\phi}$ under high levels of crown rot infection at Gilgandra in 2017. This yield benefit was even higher (64–92%) with all four of the barley varieties at this site in 2017. 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 crown rot infection. Winter cereal crop and variety choice is therefore **not** the sole solution to crown rot, but rather just one element of an integrated management strategy to limit losses from this disease.

Acknowledgements

This experiment was part of the project 'National crown rot management and epidemiology' DAN00175, 2017–18, with joint investment from NSW DPI and GRDC.

Thanks to Kevin Kilby for providing the experiment site and Peter Matthews (NSW DPI) for helping to organise operations at the 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.

Contact

Steven Simpfendorfer
Tamworth Agricultural Institute, Tamworth
steven.simfendorfer@dpi.nsw.gov.au
02 6763 1222

Regional crown rot management – Edgeroi 2017

Steven Simpfendorfer, Rick Graham and Robyn Shapland
NSW DPI Tamworth

Key findings

- Yield loss from crown rot ranged from not significant in barley varieties Spartacus CL$^{\phi}$ and Commander to up to 39.1% in the durum variety Jandaroi$^{\phi}$.
- Bread wheat and barley variety choice affected yield in the presence of high levels of crown rot infection with three bread wheats (LRPB Mustang$^{\phi}$, LRPB Spitfire$^{\phi}$ and Suntop$^{\phi}$) and three barleys (Spartacus CL$^{\phi}$, Commander$^{\phi}$ and La Trobe$^{\phi}$) being between 0.41 t/ha and 1.00 t/ha higher yielding than EGA Gregory$^{\phi}$.
- Screening levels increased in 14 of the 20 entries by between 2.1% in the barley variety Commander$^{\phi}$ up to 7.8% in the durum entry AGD043 where there was crown rot infection.

Introduction

Crown rot (CR), caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to winter cereal production in the NSW northern grains region. Cereal varieties differ in their resistance to CR, which can significantly affect their relative yield where the disease is present.

This experiment was one of six that NSW DPI conducted in 2017 across central/northern NSW and extending into southern Qld to examine how crown rot affects the yield and quality of four barley, four durum and 12 bread wheat varieties.

Site details

Location	'Lockslea', Edgeroi
Co-operator	Cameron Williams
Sowing date	30 May 2017
Fertiliser	70 kg/ha Granulock SZn Extra (treated with 400 mL/ha of flutriafol) at sowing
Starting nitrogen	203 kg nitrogen (N)/ha to 120 cm
Starting soil water	294 mm plant available soil water (0–110 cm)
Rainfall	Growing season rainfall was 164 mm
PREDICTA®B	0.6 *Pratylenchus thornei*/g (low risk), nil *P. neglectus* and nil CR risk at sowing (0–15 cm)
Harvest date	13 November 2017

Treatments

Varieties (20)

- Four barley varieties: Commander$^{\phi}$, Compass$^{\phi}$, La Trobe$^{\phi}$ and Spartacus CL$^{\phi}$.
- Four durum varieties: Jandaroi$^{\phi}$ DBA Lillaroi$^{\phi}$ DBA Bindaroi$^{\phi}$ plus the numbered line AGD043.

- Twelve bread wheat varieties: EGA Gregory$^{\phi}$, LRPB Flanker$^{\phi}$, Coolah$^{\phi}$, Sunmate$^{\phi}$, LRPB Lancer$^{\phi}$, LRPB Reliant$^{\phi}$, LRPB Gauntlet$^{\phi}$, LRPB Spitfire$^{\phi}$, LRPB Mustang$^{\phi}$, Mitch$^{\phi}$, Suntop$^{\phi}$ and Sunguard$^{\phi}$ (listed in order of increasing resistance to CR).
- All entries sown to achieve a target plant population of 100 plants/m^2.

Pathogen treatment

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

Results

Yield

In the no added CR treatment, yield ranged from 3.17 t/ha in the bread wheat variety Sunguard$^{\phi}$ up to 3.86 t/ha in the bread wheat variety LRPB Mustang$^{\phi}$ (Table 1).

Table 1. Yield and grain quality of varieties with no added and added crown rot – Edgeroi 2017.

Crop	Variety	Yield (t/ha)		Protein (%)		Screenings (%)	
		No added CR	Added CR	No added CR	Added CR	No added CR	Added CR
Barley	Spartacus	3.34	3.54	14.9	14.6	1.6	2.5
	Commander	3.29	3.09	13.9	13.4	3.9	6.0
	La Trobe	3.81	2.95	14.1	13.7	2.7	5.4
	Compass	3.30	2.87	14.5	13.8	2.1	2.9
Durum	DBA Bindaroi	3.62	2.47	13.5	12.9	2.6	7.9
	AGD043	3.44	2.46	12.4	12.1	4.2	12.0
	DBA Lillaroi	3.36	2.40	13.6	13.7	3.2	4.9
	Jandaroi	3.44	2.10	13.9	13.9	0.9	6.1
Bread wheat	LRPB Mustang	3.86	3.33	12.2	12.3	3.0	5.3
	LRPB Spitfire	3.64	3.15	14.9	14.8	4.0	5.0
	Suntop	3.63	3.13	12.5	12.7	5.4	8.5
	Coolah	3.65	2.93	11.8	11.8	3.7	9.6
	LRPB Lancer	3.33	2.92	14.0	14.0	3.1	5.9
	Mitch	3.42	2.91	12.4	12.5	6.9	8.8
	LRPB Gauntlet	3.35	2.87	13.7	13.4	3.6	4.7
	LRPB Reliant	3.82	2.84	12.5	12.3	4.3	9.3
	Sunguard	3.17	2.76	13.2	13.0	4.5	6.8
	Sunmate	3.84	2.73	12.3	12.2	3.3	6.5
	LRPB Flanker	3.77	2.70	12.6	12.6	3.9	7.9
	EGA Gregory	3.78	2.54	12.9	12.5	4.0	7.4
Site mean		3.54	2.84	13.3	13.1	3.6	6.7
CV (%)		7.6		1.8		24.3	
l.s.d.		0.395		0.39		2.02	
P value		<0.001		0.038		<0.001	

The barley varieties Spartacus CL$^{\phi}$ and Commander$^{\phi}$ did not suffer significant yield loss under high levels of CR infection (added CR). The remaining entries suffered significant yield loss under high levels of CR infection (added CR), ranging from 12.4% in the bread wheat variety LRPB Lancer$^{\phi}$ (0.42 t/ha) up to 39.1% in the durum variety Jandaroi$^{\phi}$ (1.35 t/ha) (Table 1).

Only the durum variety Jandaroi$^{\phi}$ was lower yielding than EGA Gregory$^{\phi}$ under high CR infection (added CR). The barley varieties Spartacus CL$^{\phi}$ (1.00 t/ha higher yielding than EGA Gregory$^{\phi}$), Commander (0.55 t/ha) and La Trobe (0.41 t/ha) along with bread wheat entries LRPB Mustang$^{\phi}$ (0.79 t/ha), LRPB Spitfire$^{\phi}$ (0.61 t/ha) and Suntop$^{\phi}$ (0.59 t/ha) were all higher yielding than EGA Gregory$^{\phi}$ under high levels of CR infection (added CR; Table 1). The remaining entries produced yields equivalent to EGA Gregory$^{\phi}$ in the added CR treatment.

Grain quality

Protein levels were relatively high at this site in 2017, ranging from 11.8% (Coolah$^{\phi}$) up to 14.9% (Spartacus CL$^{\phi}$ and LRPB Spitfire$^{\phi}$) in the no added CR treatment. Crown rot infection (added CR) caused small, but significant, reductions in protein levels in the barley varieties Compass$^{\phi}$, Commander$^{\phi}$ and LaTrobe$^{\phi}$, durum variety DBA Bindaroi$^{\phi}$ and bread wheat variety EGA Gregory$^{\phi}$ (Table 1).

Screening levels in the no added CR treatment ranged from 0.9% in the durum variety Jandaori$^{\phi}$ up to 6.9% in the bread wheat variety Mitch$^{\phi}$ (Table 1). Crown rot infection (added CR) did not significantly affect screening levels in at this site in 2017 in barley varieties Spartacus CL$^{\phi}$ and Compass$^{\phi}$, durum variety DBA Lillaroi$^{\phi}$ and bread wheat varieties LRPB Spitfire$^{\phi}$, Mitch$^{\phi}$ and LRPB Gauntlet$^{\phi}$. In the remaining entries, CR infection increased screening levels by between 2.1% in Commander$^{\phi}$ barley up to 7.8% in the durum entry AGD043 (Table 1).

Conclusions

Cereal crop and variety choice affected yield in the absence and presence of CR infection, which differed by 0.69 t/ha and 1.44 t/ha, respectively between the best and worst entries. The three bread wheat varieties LRPB Mustang$^{\phi}$, LRPB Spitfire$^{\phi}$ and Suntop$^{\phi}$ provided a 31–23% yield benefit when compared with growing the susceptible bread wheat variety EGA Gregory$^{\phi}$ under high levels of CR infection at Edgeroi in 2017. Similarly, the three barley varieties SpartacusCL$^{\phi}$, Commander$^{\phi}$ and La Trobe$^{\phi}$ provided a yield benefit of between 39 and 16% when compared with EGA Gregory$^{\phi}$ under high levels of CR infection. These crop or varieties 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 and carry over the disease from season to season. 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.

Acknowledgements

This experiment was part of the project 'National crown rot management and epidemiology' DAN00175, 2017–18, with joint investment from NSW DPI and GRDC.

Thanks to Cameron Williams for providing the experiment site and Rick Graham, Jim Perfrement, Mick Dal Santo, Stephen Morphett (NSW DPI) for sowing, maintaining and harvesting the experiment. Thanks to Chrystal Fensbo (NSW DPI) for grain quality assessments and to Jason Lowien (GrainCorp) for NIR machine to determine grain protein levels.

Contact

Steven Simpfendorfer
Tamworth Agricultural Institute, Tamworth
steven.simfendorfer@dpi.nsw.gov.au
02 6763 1222

Regional crown rot management – Rowena 2017

Steven Simpfendorfer[1], Matt Gardner[2] and Robyn Shapland[1]

[1]NSW DPI Tamworth
[2]AMPS Research

Key findings

- Yield loss from crown rot ranged from 14.2% in the barley variety Compass$^{\phi}$ up to 82.7% in the durum variety Jandaroi$^{\phi}$.
- Bread wheat variety choice affected yield where there were high levels of crown rot infection, with nine bread wheats (Sunguard$^{\phi}$, Suntop$^{\phi}$, LRPB Lancer$^{\phi}$, Mitch$^{\phi}$, LRPB Reliant$^{\phi}$, LRPB Mustang$^{\phi}$, Sunmate$^{\phi}$, Coolah$^{\phi}$ and LRPB Spitfire$^{\phi}$) being between 0.28 t/ha and 0.98 t/ha higher yielding than EGA Gregory$^{\phi}$.
- Barley varieties had an even greater yield difference than the bread wheat varieties where there were high levels of crown rot infection, with Compass$^{\phi}$ being 2.37 t/ha and Commander 1.78 t/ha higher yielding than EGA Gregory$^{\phi}$.
- The four durum varieties were very susceptible to crown rot with yield losses ranging from 69.7% to 82.7% and associated significant increases screenings levels. Hence, durum should only be grown in paddocks known to have low levels of crown rot inoculum.

Introduction

Crown rot (CR), caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), 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.

This experiment was one of six that NSW DPI conducted in 2017 across central/northern NSW extending into southern Qld, to examine how CR affects the yield and quality of four barley, four durum and 12 bread wheat varieties.

Site details

Location	'Combos', Rowena
Co-operator	Will and Tilla Winston-Smith
Sowing date	7 June 2017
Fertiliser	220 kg/ha urea and 60 kg/ha Granulock Z extra at sowing
Starting nitrogen	115 kg nitrogen (N)/ha to 120 cm
Starting soil water	~185 mm plant available soil water (0–120 cm)
Rainfall	Growing season rainfall was 103 mm
PREDICTA®B	3.7 *Pratylenchus thornei*/g soil (medium risk), nil *P. neglectus* and 0.6 log *Fusarium* DNA/g (low CR risk) at sowing (0–15 cm)

Treatments

Varieties (20)

- Four barley varieties: Commanderᶲ, Compassᶲ, La Trobeᶲ and Spartacus CLᶲ. Note that La Trobeᶲ and Spartacus CLᶲ plots were selectively eaten by pigs near harvest and have been excluded from the analysis at this site in 2017.
- Four durum varieties: Jandaroiᶲ, DBA Lillaroiᶲ, DBA Bindaroiᶲ plus the numbered line AGD043.
- Twelve bread wheat varieties: EGA Gregoryᶲ, LRPB Flankerᶲ, Coolahᶲ, Sunmateᶲ, LRPB Lancerᶲ, LRPB Reliantᶲ, LRPB Gauntletᶲ, LRPB Spitfireᶲ, LRPB Mustangᶲ, Mitchᶲ, Suntopᶲ and Sunguardᶲ (listed in order of increasing resistance to CR).
- All entries sown to achieve a target plant population of 100 plants/m^2.

Pathogen treatment

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

Results

Yield

In the no added CR treatment, yields ranged from 1.52 t/ha in the durum variety DBA Lillaroiᶲ up to 3.55 t/ha in the barley variety Compassᶲ (Table 1).

All entries suffered significant yield loss under high levels of CR infection (added CR), ranging from 14.2% in the barley variety Compassᶲ (0.50 t/ha) up to 82.7% in the durum variety Jandaroiᶲ (1.90 t/ha; Table 1).

Table 1. Yield and grain quality of varieties with no added and added crown rot – Rowena 2017.

Crop	Variety	Yield (t/ha)		Protein (%)		Screenings (%)	
		No added CR	Added CR	No added CR	Added CR	No added CR	Added CR
Barley	Compass	3.55	3.04	17.6	16.5	2.4	3.6
	Commander	2.98	2.45	17.4	16.5	2.7	3.7
Durum	AGD043	2.59	0.81	16.5	14.7	5.8	43.6
	Jandaroi	2.29	0.40	16.4	16.2	4.5	32.8
	DBA Lillaroi	1.52	0.35	18.4	16.8	6.7	27.9
	DBA Bindaroi	1.77	0.34	17.2	15.5	5.4	32.0
Bread wheat	Sunguard	2.24	1.65	16.2	14.9	10.5	19.7
	Suntop	2.20	1.44	17.0	17.0	3.4	5.4
	LRPB Lancer	2.13	1.36	16.6	15.7	5.9	7.7
	Mitch	2.17	1.34	15.7	15.3	12.8	19.3
	LRPB Reliant	2.14	1.32	15.3	14.2	7.8	16.0
	LRPB Mustang	1.68	1.13	15.6	14.9	5.4	9.6
	Sunmate	2.28	1.11	16.1	15.0	6.6	13.0
	Coolah	2.35	1.10	15.6	13.6	6.8	13.2
	LRPB Spitfire	1.74	0.95	19.2	18.7	3.9	5.3
	LRPB Gauntlet	1.69	0.79	16.4	15.6	5.0	8.9
	EGA Gregory	2.06	0.67	15.6	14.3	8.1	11.7
	LRPB Flanker	1.90	0.65	15.8	14.7	4.8	15.4
Site mean		2.18	1.16	16.6	15.6	6.0	16.1
CV (%)		8.5		2.9		23.8	
l.s.d.		0.232		0.76		4.28	
P value		<0.001		0.018		<0.001	

The three durum varieties Jandaroiᶲ, DBA Lillaroiᶲ and DBA Bindaroiᶲ were between 0.27 t/ha and 0.33 t/ha lower yielding than EGA Gregoryᶲ under high CR infection (added CR).

The barley varieties Compassᶲ (2.37 t/ha) and Commanderᶲ (1.78 t/ha), along with bread wheat varieties Sunguard (0.98 t/ha), Suntopᶲ (0.77 t/ha), LRPB Lancerᶲ (0.69 t/ha), Mitchᶲ (0.67 t/ha), LRPB Reliantᶲ (0.65 t/ha), LRPB Mustangᶲ (0.46 t/ha), Sunmateᶲ (0.44 t/ha), Coolahᶲ (0.43 t/ha) and LRPB Spitfireᶲ (0.28 t/ha) were all higher yielding than EGA Gregoryᶲ under high levels of CR infection (added CR; Table 1). The bread wheat varieties LRPB Gauntletᶲ and LRPB Flankerᶲ produced yields equivalent to EGA Gregoryᶲ in the added CR treatment.

Grain quality

Protein levels were high at this site in 2017, ranging from 15.3% (LRPB Reliantᶲ) up to 19.2% (LRPB Spitfireᶲ) in the no added CR treatment. Crown rot infection (added CR) reduced grain protein levels by between 0.8% (LRPB Lancerᶲ and LRPB Gauntletᶲ) up to 2.0% (Coolahᶲ) in 15 entries, with the exception of LRPB Spitfireᶲ, Suntopᶲ, Jandaroiᶲ, Mitchᶲ and LRPB Mustangᶲ where the difference was not significant (Table 1).

Screening levels in the no added CR treatment ranged from 2.4% in the barley variety Compassᶲ up to 12.8% in the bread wheat variety Mitchᶲ (Table 1). Crown rot infection (added CR) did not significantly affect screening levels in at this site in 2017 for the barley varieties Compassᶲ and Commanderᶲ and bread wheat varieties Suntopᶲ, LRPB Spitfireᶲ, LRPB Gauntletᶲ, LRPB Mustangᶲ, LRPB Lancerᶲ and EGA Gregoryᶲ. In the remaining entries, CR infection increased screening levels by between 6.4% in the bread wheat varieties Sunmateᶲ and Coolahᶲ and up to 37.9% in the durum entry AGD043 (Table 1). The negative effect from CR on screenings was particularly noticeable in all four of the durum entries with a minimum increase in screening levels of 21.2% in DBA Lillaroiᶲ.

Conclusions

Cereal crop and variety choice affected yield in the absence and presence of CR infection, which differed by 2.03 t/ha and 2.70 t/ha, respectively between the best and worst entries. Nine of the bread wheat varieties provided a 146% (Sunguardᶲ) to 42% (LRPB Spitfireᶲ) yield benefit above growing the susceptible bread wheat variety EGA Gregoryᶲ under high levels of CR at Rowena in 2017. This benefit was even higher with the two barley varieties Compassᶲ and Commanderᶲ, which provided a yield benefit of 354% and 266%, respectively rather than growing EGA Gregoryᶲ under high levels of CR infection.

These crop or variety choices could have maximised profit in this growing season but will **not** reduce inoculum levels for subsequent crops. All winter cereal varieties are susceptible to CR infection and carry the disease over from season to season. 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.

This experiment further highlights the extreme susceptibility of durum wheat varieties to CR, with yield losses ranging from 68.7% in AGD043 and up to 82.7% in Jandaroiᶲ. Crown rot infection also dramatically increased screenings levels by 21.2% up to 37.9% in all four durum entries. Hence, very susceptible cereals such as durum, and the more susceptible bread wheat varieties, e.g. EGA Gregoryᶲ and LRPB Flankerᶲ,should only be grown in paddocks known to have low levels of CR inoculum based on PREDICTA®B testing before sowing.

Acknowledgements

This experiment was part of the project 'National crown rot management and epidemiology' DAN00175, 2017–18, with joint investment from NSW DPI and GRDC.

Thanks to Will and Tilla Winston-Smith for providing the experiment site. Thanks to Chrystal Fensbo (NSW DPI) for grain quality assessments and to Jason Lowien (GrainCorp) for NIR machine to determine grain protein levels.

Contact

Steven Simpfendorfer
Tamworth Agricultural Institute, Tamworth
steven.simfendorfer@dpi.nsw.gov.au
02 6763 1222

Insecticide resistance in *Helicoverpa armigera*: update and implications for management

Lisa Bird[1], Paul Walker[1] and Linda Drynan[2]

[1]NSW DPI Tamworth
[2]NSW DPI Narrabri

Key findings

- Indoxacarb (e.g. Steward®) resistance across northern NSW and southern Qld in 2018 was 5.6%.
- Indoxacarb resistance in central Qld in 2018 was 11%, which was significantly higher than the industry-wide average.
- Chlorantraniliprole (e.g. Altacor®) resistance across all regions in 2018 was low (<1%).
- No resistance was detected to emamectin benzoate (e.g. Affirm®) in 2018.

Introduction

Insecticide resistance is one of the greatest limitations to broadacre agricultural production in Australia. In particular, the cotton industry's long-term over-reliance on insecticides to control *Helicoverpa armigera* has resulted in wide-spread product failures due to insecticide resistance. The introduction of selective insecticides and *Bacillus thuringiensis* (Bt) cotton reduced the industries dependence on insecticides for control of *H. armigera* and resulted in a gradual decline in resistance to synthetic pyrethroids (Figure 1).

During the mid-to-late 2000s, as the pulse industry expanded, broad-spectrum pesticide use increased and resulted in rapid reselection for pyrethroid resistance (Figure 1). This highlighted the need for a strategic approach to insecticide use in grains, particularly for selective products with broad registration across different summer and winter crops. Indoxacarb and chlorantraniliprole are of particular concern because they are pivotal insecticides for Helicoverpa management across a range of farming systems and are now at increased resistance risk from over-use in the pulse industry.

Resistance surveillance is a key component of resistance management. NSW DPI provides a fully independent assessment of annual resistance frequency for selective Helicoverpa products. The results inform the ongoing process for responding to changes in resistance, including cross-industry engagement for mitigating risk of field failures and minimising economic losses across multiple commodities.

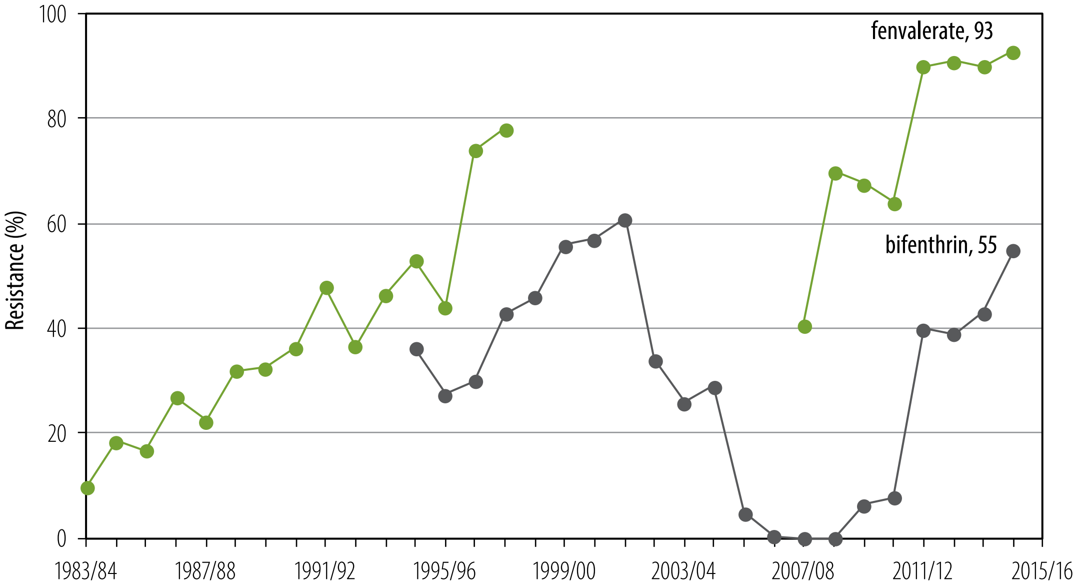


Figure 1. Historical pyrethroid resistance in eastern Australia (average of all regions). Frequency was measured by topically applying a diagnostic dose of insecticide that induces 99.9% mortality in a susceptible strain.

Surveillance methods

Sampling

Pheromone trapping systems (InSense Pty Ltd.) were used to source moths for resistance screening. Traps were located at sites in northern and central NSW: the Macquarie, Namoi and Gwydir valleys; southern Queensland (Qld): the Macintyre valley and Darling Downs region; and Emerald irrigation area (EIA) in central Qld. All traps were located close (<2 m) to known *H. armigera* crop hosts. Sampling was performed every 2–3 weeks throughout the growing season.

Establishing F_2 iso-female lines

Resistance was tested by an F_2 screening procedure based on Andow and Alstad's (1998) methods to generate iso-female lines, a proportion of which are homozygous for haplotypes present in their field-derived parents (Figure 2). This method is highly effective for detecting resistance alleles, regardless of genetic dominance (a scenario for recovering recessive alleles is shown in Figure 2) and involves the following stepwise process:

1. Collecting the parental (F_0) moths from the field;
2. Rearing F_1 offspring for each line;
3. Sib-mating F_1 adults.

We further optimized our methods by using the techniques of Stodola and Andow (2004), where field-derived male moths were individually mated to female moths from a laboratory reared susceptible strain.

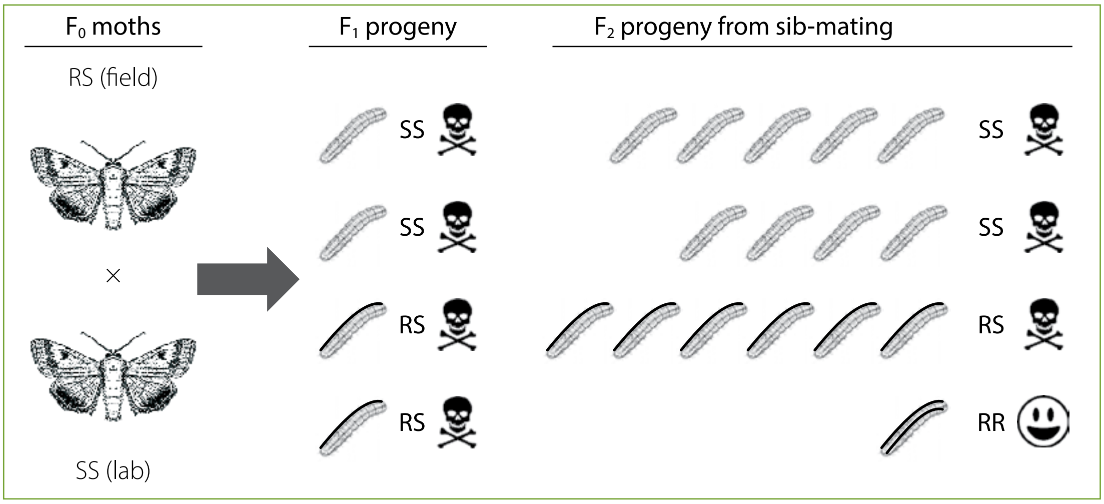


Figure 2. F_2 screen for detection of resistance alleles. Moths are collected from pheromone traps and, in this example one parent has one copy of the resistance gene (RS). Their F_1 progeny are sib-mated to produce the F_2 generation. If resistance is completely recessive then only 1 in 16 of the F_2 progeny will be homozygous (RR) for the resistance gene and will survive a diagnostic dose of insecticide. The remaining susceptible (SS) and heterozygous (RS) progeny will be killed.

Product screening

F_2 larvae were screened by bioassay using an artificial diet into which insecticide had been incorporated. Commercial formulations were used in all screening procedures: indoxacarb (Steward EC [15% active ingredient], and chlorantraniliprole (Altacor [35% active ingredient], both from DuPont Australia Ltd.,); emamectin benzoate (Affirm [1.9% active ingredient], Syngenta Crop Protection).

The ratio of diet to toxin determined the concentration and was calculated as µg insecticide/mL of diet. Insecticides were diluted in distilled water to produce a concentration expected to induce 99.9% mortality of susceptible insects. The discriminating concentration for emamectin benzoate, chlorantraniliprole, and indoxacarb was 0.2, 1 and 12 µg of insecticide/mL of diet, respectively (Bird 2015). Diluted insecticide was added to 1 L of diet and incorporated using a stick blender to produce a homogenous mixture. The insecticide-incorporated diet was then dispensed into 45-well bioassay trays. A total of 90 larvae from each iso-female line was screened against each of the three insecticides. A minimum of 500 lines was screened for each insecticide in each season.

Results

Emamectin benzoate and chlorantraniliprole

As in previous seasons, no resistance was detected to emamectin benzoate in 2017–18. Chlorantraniliprole resistance was low (0.8%, *n* = 970) and not significantly different from the previous season. Although regional frequencies were generally consistent with this industry average, elevated chlorantraniliprole resistance was found in the Darling Downs region in 2017–18 (2.6%, *n* = 56) (Figure 3A).

Indoxacarb

Industry-wide indoxacarb resistance in 2017/18 was 6.5% (*n* = 988) and was not significantly different from the previous season (6.1%, *n* = 1022). Indoxacarb resistance in 2017–18 was significantly higher in the EIA at 11% (*n* = 156), and was similar to the industry average in 2016 –17 (9.2%, *n* = 425) (Figure 3B).

Resistance increased in the lower Namoi to 8.9% (*n* = 157) compared with the previous year, with frequencies for Macintyre and Darling Downs regions similar to the industry average at 6.7% (*n* = 134) and 6.2% (*n* = 97), respectively. Resistance in the upper Namoi, Gwydir and Macquarie valleys was below the industry average in 2017–18 (Figure 3B).

Although levels of indoxacarb resistance in Emerald were over two-fold higher than those in southern Qld and NSW, it is unlikely this was a result of substantially different management practices. It is more likely associated with ecological differences unique to northern regions such as a longer growing season. A higher number of insect generations per year compared with southern regions, and the lack of an overwintering phase in the lifecycle of *H. armigera*, may be factors that contribute to elevated resistance frequencies in northern populations. The impact of winter diapause (arrested development) in indoxacarb resistance strains of *H. armigera* is currently under investigation.

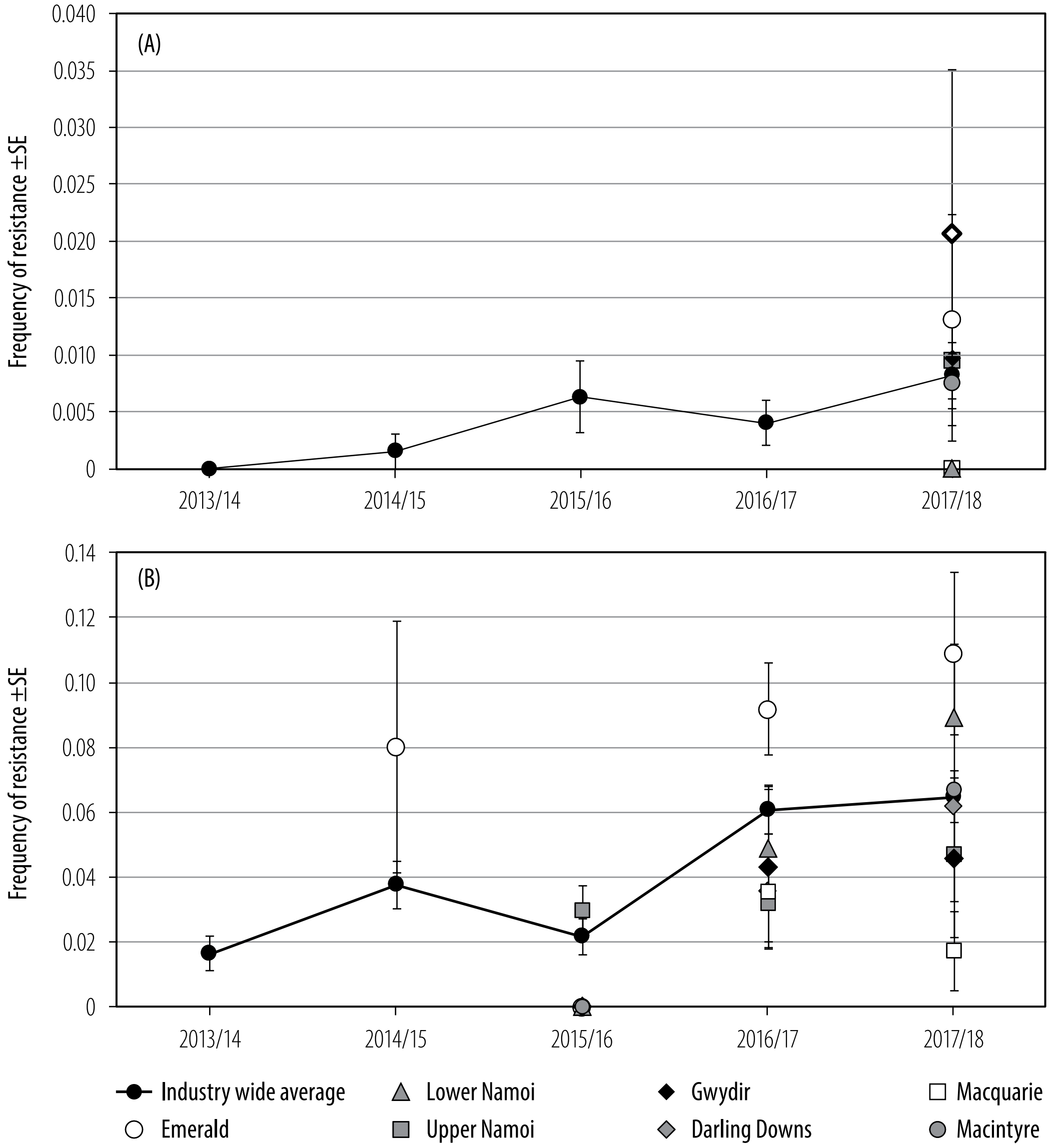


Figure 3. Annual regional frequency of chlorantraniliprole (A) and indoxacarb (B) resistance (± binomial standard error).

Conclusions and implications for management

H. armigera has a very strong track record for developing resistance in response to selection pressure from insecticides. The risk of spray failures is high for pyrethroids and carbamates due to historical resistance to these products, but still low for the selective products indoxacarb, chlorantraniliprole and emamectin benzoate, based on current resistance frequency data. However, it is highly likely that resistance will increase rapidly due to selection pressure from over-reliance on these selective products.

The grains industry is now a major user of Helicoverpa insecticides with product use especially high in pulse crops such as chickpeas. To support the grains industry in mitigating the risk of lost production due to insecticide resistance development, a resistance management strategy (RMS) has recently been produced for *H. armigera* in Australian grain crops. The National Insecticide Resistance Management

(NIRM) working group of the Grains Pest Advisory Committee (GPAC) developed the RMS which is endorsed by CropLife Australia.

The RMS is designed to minimise selection pressure for resistance to the same chemical group across consecutive generations of *H. armigera*. Rotating a broad range of selective options will reduce over-reliance on any one chemical group. Growers should use economic thresholds and avoid prophylactic sprays. Following these recommendations and complying with label instructions will minimise the risk of spray failures occurring as the result of insecticide resistance and maintain effective insecticide control of *H. armigera* into the future.

The RMS is available at: https://grdc.com.au/GRDC-FS-Helicoverpa-resistance-management

For more information on the science behind the strategy go to:
https://ipmguidelinesforgrains.com.au/ipm-information/resistance-management-strategies/

References

Andow D.A. & Alstad D.N. 1998. F_2 screen for rare resistance alleles. *Journal of Economic Entomology* 91: 572–578.

Bird L.J. 2015. Susceptibility of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) to indoxacarb, emamectin benzoate and chlorantraniliprole in Australia. *Journal of Economic Entomology* 108: 294–300.

Stodola T.J. & Andow D.A. 2004. F_2 screen variations and associated statistics. *Journal of Economic Entomology* 97: 1756–1764.

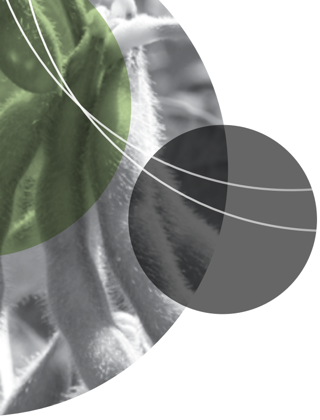
Acknowledgements

This work was part of the project 'Conventional insecticide resistance in Helicoverpa – monitoring, management and novel mitigation strategies in Bollgard III', DAN1506/00204, 2014–19 with coinvestment by NSW DPI, CRDC and GRDC.

Technical assistance provided by April Leggett, Karen Stanford, Bronwyn Scott, Stacey Cunningham and Christopher Shafto (NSW DPI) is gratefully acknowledged.

Contact

Lisa Bird
Tamworth Agricultural Institute, Tamworth
lisa.bird@dpi.nsw.gov.au
02 6763 1222



Cotton

Effects from nitrogen fertiliser timing and irrigation deficit on irrigated cotton – Narrabri 2017/18

Jon Baird[1], Graeme Schwenke[2], Guna Nachimuthu[1]

[1]NSW DPI Narrabri
[2]NSW DPI Tamworth

Key findings

- Spilt application of nitrogen (N) fertiliser increased lint yield in cotton for two differing irrigation deficits compared with the entire amount of N being applied pre-plant.
- Applying the total N fertiliser pre-plant increased N loss from the field via the tail water.
- The 70 mm irrigation deficit had a greater effect on lint yield than the 50 mm deficit.
- The 70 mm deficit with a split N application had the highest irrigation water use efficiency (IWUE).

Introduction

The experiment investigated management strategies to improve nitrogen use efficiency (NUE) within Australia's cotton industry. Yield, N uptake, plant growth response and N loss in tail water were compared under various N fertiliser application timings.

Site details

Location	Australian Cotton Research Institute, Narrabri
Soil type and nutrition	The soil type at the Narrabri research site is a self-mulching grey vertosol with low sodicity Pre-season N was applied as urea at 30 cm under the plant line. In-crop N was applied as broadcast urea followed by irrigation 1–2 days after broadcasting The plant available water content (PAWC) was 220 mm to 120 cm deep, which is representative of northern Australia's cotton growing soils. While the trial site had low sodicity, it is common for northern NSW cropping soils to be sodic at depth, which can affect PAWC
Seasonal weather	The 2017/18 growing season received 2338 day degrees (cumulative temperature >15 °C and <35 °C) and 210 mm rainfall from November 2017 to March 2018 There were six 'cold shock days' (min temp <11 °C) and 62 'hot days' (max temp >36 °C). This is approximately half the long-term site average number of cold days per season (10) and twice the long-term average of hot days (32)
Trial design	Randomised split-plot design; with irrigation deficit the main plots and N fertiliser timing as the sub-plots with three replications. Each plot was 8 m wide (8 rows) and 130 m long

Sowing date	28 October 2017
Fertiliser	Each N treatment received 244 kg/ha of urea (46% N). The N rate was chosen after pre-season soil testing to give a total available N of 200 kg N/ha (0–90 cm depth)
Cultivar	Cotton Seed Distributers (CSD) Sicot 748B3F
Plant population	Plant establishment14 plants/m^2
Insect management	15 January 2018: Transform® (240 g/L sulfoxaflor) 300 mL/ha 20 February 2018: Admiral® Advance (100 g/L pyriproxyfen) 500 mL/ha
Harvest date	14 April 2018. The central four rows were picked using a 4-row picker fitted with calibrated weigh-scales

Treatments

N fertiliser application timings

- 100% pre-plant: applied in August 2017
- 70:30% split: 70% applied August and 30% applied in December 2017
- 30:70% split: 30% applied in August and 70% applied in December 2017
- 100% in-crop: applied in December 2017

Irrigation schedule deficits

- 50 mm deficit: 9.8 ML/ha (11 irrigations applied)
- 70 mm deficit: 8.4 ML/ha (8 irritations)

Results

Lint yield

Both the irrigation deficit and the N timing treatment affected lint yield. The 50 mm irrigation deficit increased cotton lint yield by 0.81 bales/ha compared with the 70 mm irrigation deficit. Lint yield was also affected by N fertiliser application timing. Where 100% of the N was applied up front, the crop yielded was lower than the other three N treatments, which did not differ from each other (Figure 1). There was no interaction between irrigation deficit and N timing treatments.

The high day degrees accumulated in 2017/18 provided optimal long season growing conditions for the intensive irrigation deficit (50 mm) and the in-crop N application treatments. Cooler seasons that have low day degree accumulation or have earlier seasonal frosts can reduce the yield potential of the intensive deficit and the later in-crop N application treatments.

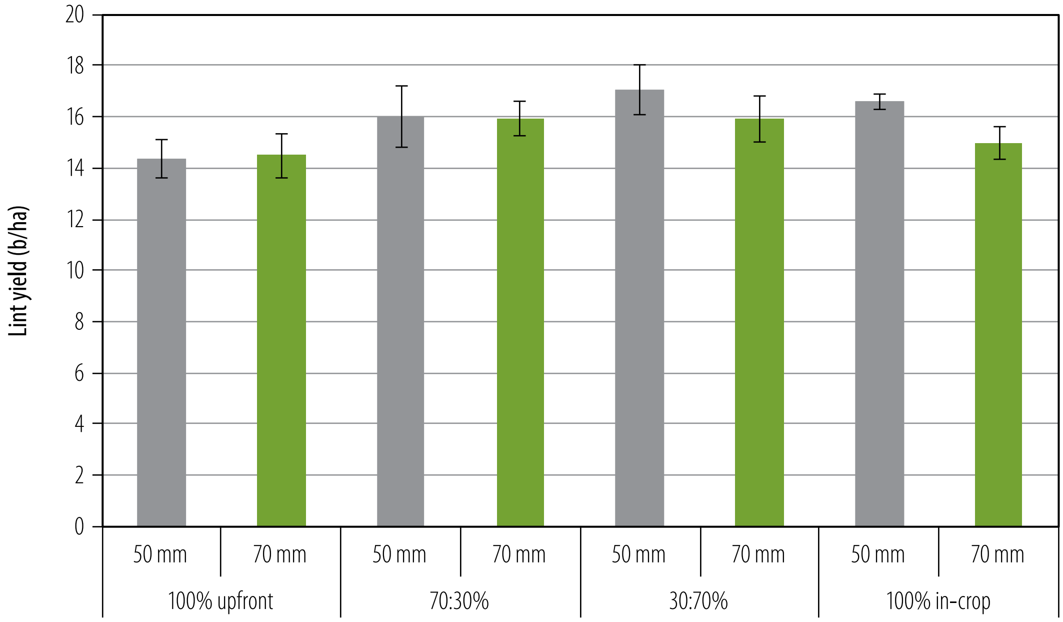


Figure 1. Lint yield for the various N applications at Narrabri. Error bars signify standard error about the means. The l.s.d. for the deficit treatment was 0.58 bale/ha, and for N timing it was 1.41 b/ha.

Water use efficiency

The crop water use (= applied water + rainfall + starting moisture – ending moisture) of the two irrigation deficits were monitored regularly throughout the growing season. Measurements were taken using an EM38 MkII, an electromagnetic device, where soil moisture is calibrated using soil core samples and neutron probe recordings.

The 50 mm deficit had a greater crop water use and a lower irrigated WUE (applied water/lint yield) However, there was no difference in production or economic WUE due to the higher lint production from the 50 mm deficit treatments (Table 1)

Table 1. Experiment water use efficiency.

Deficit treatment	Irrigations applied	Applied water (ML)	Crop water use (mm)	Irrigated water use efficiency (bales/ML)	Production water use efficiency (bales/ML)	Economic water use efficiency ($/ML)
50 mm	11	9.8	994	2.3	1.7	725
70 mm	8	8.4	868	2.9	1.9	875
Probability			<0.05	<0.05	ns	ns

Plant growth response

The two irrigation deficits had no statistically significant effect on plant height, however, applying all nitrogen pre-plant increased plant height compared with split N or 100% in-crop treatments (Table 2). Increasing cotton plant height did not necessary equate to higher yields. These results show that delaying some or the entire N application meant more plant energy was used in reproductive lint production rather than growing excessive vegetative matter.

There was no effect from the irrigation deficit or N timing treatments on fruiting nodes or the total bolls produced by the plants However, the treatment affected boll retention in the first position of a branch.

Table 2. Cotton plant response to nitrogen application treatments and irrigation deficits.

Nitrogen treatment	Irrigation deficit	Plant height (cm)	Nodes	Fruiting nodes	1st position boll number	Total boll number/plant
100% pre-plant	50 mm	103.7	23.9	16.5	8.4	10.4
	70 mm	84.6	22.2	15.5	7.6	10.4
70:30% split	50 mm	94.0	22.5	15.5	7.6	10.3
	70 mm	83.7	21.6	14.7	8.1	10.5
30:70% split	50 mm	90.5	23.8	17.0	8.1	11.1
	70 mm	79.1	21.3	14.4	7.2	10.2
100% in-crop	50 mm	92.9	23.1	16.1	8.4	10.9
	70 mm	79.0	22.3	15.3	7.3	10.2

Nitrogen application timing significantly affected plant height ($P<0.05$) and N timing × irrigation deficit affected the first position boll retention ($P<0.05$)

Tail water N loss

Nitrogen fertiliser timing had a significant effect on the amount of N lost from the field via the tail water across the season. The majority of N runoff from furrow irrigated fields occurs during the first 2–3 irrigations. The in-crop N timing treatments reduced the cumulative N losses as there was less N fertiliser in the field during the first three irrigations. Applying N fertiliser in crop results in a greater amount of available N in the field at the optimum period of plant N uptake – between flowering and the boll fill stage (90–100 days after sowing) This is opposed to having a higher amount of N available early in the season when plant N uptake is low (Table 3).

Table 3. Cumulative N losses from tail water in an irrigation field (kg N/ha).

Irrigation deficit	Cumulative N loss (kg N/ha)			
	100% upfront	70:30%	30:70%	100% in-crop
50 mm	38	26	18	13
70 mm	37	35	21	17

N timing significantly affected the amount of N lost from the irrigated field over the season ($P<0.001$).

Conclusions

The experiment found that in-crop N timing reduced N loss in irrigation water runoff and improved lint yield, compared with applying all N fertiliser pre-plant. Previous studies have found that too much in-crop N, or applying in-crop N too late in the growing season, can have no benefit on yield. Growers who do apply N in crop need to ensure it is not applied too late (post January) in the growing season as this would increase the probability of regrowth and late vegetative matter rather than reproductive growth.

The intensive irrigation strategy of 50 mm, did produce a greater yield compared with the 70 mm deficit, however, with the higher amount of applied water, the 50 mm deficit resulted in lower WUE Interestingly, the higher yield of the 50 mm deficit meant that there was no difference in $/ML. The higher yield produced by the 50 mm deficit compared with the 70 mm deficit was driven by the long growing season and high day degree accumulation. In shorter seasons with an earlier plant maturity, the yield potential could be limited by the treatments, which had late in-season N applications and lower irrigation deficits.

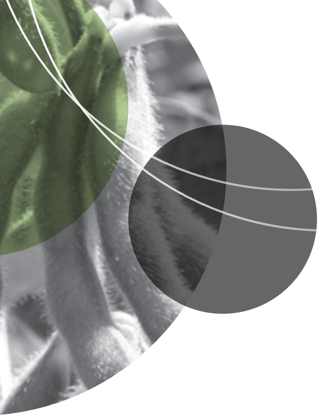
Acknowledgements

This experiment is part of the Australian Government Department of Agriculture and Water Resources 'Rural research and development for profit' program. It is a collaborative partnership with joint investment by the NSW DPI, CRDC, CSIRO and The University of Melbourne.

Technical assistance provided by Annabelle MacPherson, Clarence Mercer, Tim Grant and Stacey Cunningham (NSW DPI) is gratefully acknowledged.

Contact

Jon Baird
Australian Cotton Research Institute, Narrabri
jon.baird@dpi.nsw.gov.au
02 6799 1500



Soybean

Soybean variety evaluation – Warregah Island, Lower Clarence 2017/18

Sam Blanch and Natalie Moore
NSW DPI Grafton

Key findings

- A replicated field experiment was conducted on a grower's farm to evaluate high yielding soybean lines with known industry standards in a wide row farming system.
- The industry standard variety A6785 produced the highest yield in this experiment (4.39 t/ha) followed by recently released varieties Richmond⦶ (4.04 t/ha), Hayman⦶ (4.03 t/ha) and unreleased lines T171A-1 (3.00 t/ha) and NK94B-25 (3.66 t/ha).
- Unlike the other varieties in this experiment, the unreleased line NK94B-25 did not fill the wide inter-row spacing (90 cm). Further experiments are planned to assess the yield of this variety in different row configurations.
- Unreleased line U044-28 will not be included in further evaluations as it has not out-performed variety Hayman⦶ in yield, grain quality or maturity in North Coast NSW experiments.

Introduction

In recent decades, the 'Australian Soybean Breeding Program' (ASBP) has transformed Australian soybean varieties, responding to industry calls for varieties with superior, quality grain (high protein, large seed size, clear hilum) to supply high value human consumption markets in Australia and overseas. In 2017 the Grower Variety Selection Committee (GVSC) was formed and, in consultation with the ASBP, has focused on selecting high- yielding lines for northern NSW. Data from past experiments were assessed and several high yielding lines with adequate levels of grain quality were chosen for on-farm evaluation in the summer of 2017/18. The GVSC allows growers greater involvement in selecting new varieties from the breeding program and to participate in data review and on-farm experiments. It consists of six grower members from the North Coast of NSW (Kevin Twohill: Murwillumbah; Paul Fleming: Codrington; Kate Dowley: Tabulam; Ben Clift: Codrington; Shane Causley: Warregah Island; Alan Munro: Woodford Island) and three NSW DPI representatives (Dr Natalie Moore: Senior Research Agronomist; Nathan Ensbey: Technical Officer; Sam Blanch: Technical Assistant).

The committee meets twice a year to inspect on farm experiments and to review experiment data. The committee is responsible for:

- reviewing postharvest data and selecting varieties for progression through the system
- rating varieties pre-harvest
- conducting on farm experiments
- providing recommendations to the ASBP for new variety releases.

A replicated experiment was conducted at Shane Causley's farm near Chatsworth in the Lower Clarence district of northern NSW, to assess three soybean lines against three known industry standards.

Site details

Location	A uniform paddock with a sandy loam soil type was selected for the experiment site at Warregah Island in the Lower Clarence district (Latitude 29°23'28" S, Longitude 153°13'38" E). This is a dryland (rain fed) grain production system in rotation with sugar cane. Soil chemical properties at the site are shown in Table 1.
Co-operator	Shane Causley
Soil type	Sandy loam (see Table 1 for characteristics)
Irrigation	Nil (rain fed)
Row spacing	2 rows on a raised bed at 90 cm row spacing. Furrows at 1.8 m spacing.
Plant population	Target 360,000 plants/ha
Experiment design	6 treatments (varieties) × 6 replicates
Sowing date	9 December 2017
Harvest dates	17 April 2018 3 May 2018

Table 1. Soil chemical properties at Warregah Island, NSW.

Characteristic	Value
Soil pH (1:5 water)	5.3
Organic Carbon (%)	2.5
Sulfur (S) (mg/kg)	30.0
Phosphorus buffer index (PBI)	350.0
Phosphorus (P) (mg/kg) [BSES test]	23.0
Phosphorus (P) (mg/kg) [Colwell test]	41.0
Potassium (K) – readily available (cmol/kg)	0.3
Potassium (K) – soil reserves (cmol/kg)	3.4
Calcium (Ca) (cmol/kg)	5.4
Magnesium (Mg) (cmol/kg)	3.1
Sodium (Na) % of cations	3.9
Aluminium (Al) saturation (%)	16.0
Electrical conductivity (dS/m)	0.6
Cation exchange capacity (CEC) (cmol/kg)	11.1
Zinc (Zn) (mg/kg)	0.0
Copper (Cu) (mg/kg)	0.0
Iron (Fe) (mg/kg)	0.0
Manganese (Mn) (mg/kg)	0.0
Silicon (BSES) (mg/kg	350.0

The growers' usual farming system includes the using a minimum tillage (strip tillage) unit that incorporates stubble and forms a bed with furrows at 1.8 m spacing. Two rows of soybean were sown into each bed using a John Deere Max Emerge 1700 Vacuum planter (90 cm row spacing). A GPS guided system is used for controlled traffic on the farm.

Seasonal conditions

Total in-crop rainfall for the five months from December 2017 to April 2018 was 532.1 mm, which is 191 mm below the average of 723 mm for this location (Figure 1). Temperatures were around 0.8°C lower than the average each month. No irrigation was applied.

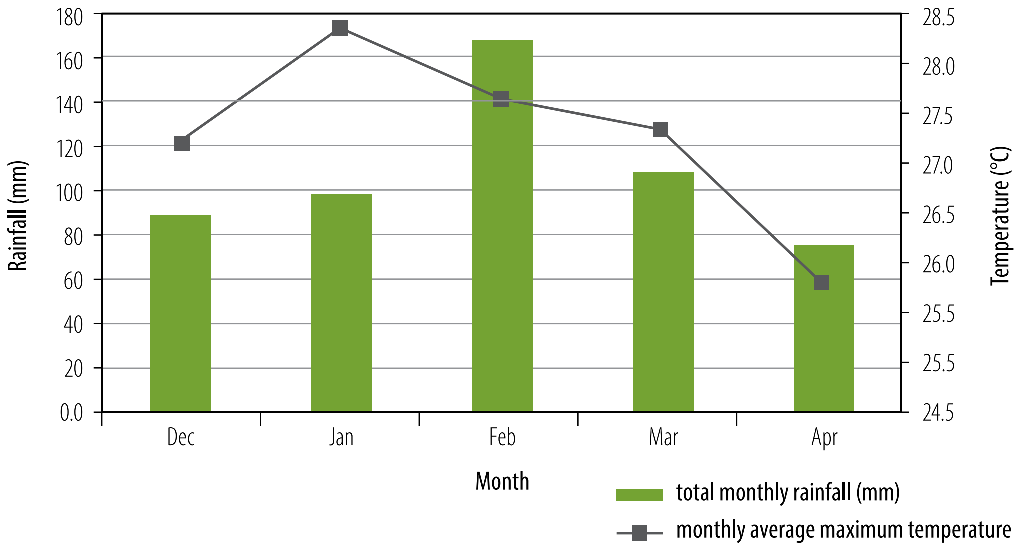


Figure 1. Rainfall and average maximum temperature at Harwood, NSW, (weather station located 5.2 km from experiment site) – 2017/18.

Fertiliser

The experiment was conducted according to the grower's usual practice. No NPK fertiliser was applied before sowing. Soybean seed was inoculated using liquid inoculant applied in furrow at 167 mL/ha. At sowing, the grower applied Stoller CoMo® (1% cobalt (Co); 6% molybdenum (Mo)) in furrow at sowing at 150 mL/ha.

A mix of Stoller CoMo® at 150 mL/ha with Stoller Bio Forge® (2.5% nitrogen, 3% potassium, 0.25% Co, 0.35% Mo) at 150 ml/ha was then applied with the first herbicide application. A second application of Stoller Bio Forge® at 150 mL/ha was applied with the second herbicide application.

Weed management

Weed management for this experiment is summarised in Table 2.

Table 2. Summary of weed management at the experiment site at Warregah Island – 2017/18.

Trade name	Active	Rate	Target weeds
Bouncer®+ Weedmaster® Argo® 540	720 g/L metolachlor + 540 g/l glyphosate	1.5 L/ha + 3 L/ha	Pre emergence broadleaf and grass weeds
Verdict™ 520	520 g/L haloxyfop	200mL/ha	Post emergent grasses
Blazer® + Basagran®	224 g/L acifluorfen + 480 g/l bentazone	1.5L/ha + 1.5L/ha	Post emergent broadleaf weeds

Insect pest management

Insect pest management for this experiment is summarised in Table 3.

Table 3. Summary of insect pest management at Warregah Island – 2017/18.

Trade name	Active	Rate	Target insect
Altacor®	350 g/kg chlorantraniliprole	75 g/ha	Soybean looper
Steward® EC	150 g/L indoxacarb	200 mL/ha	Monolepta beetle
Shield®	200 g/L clothianidin	175 mL/ha	Green vegetable bug and brown bean bug

Treatments

Experiment design

The experiment consisted of three unreleased lines and three industry standards for comparison (Table 4). Each treatment (variety) was allocated to a randomised design with six field replicates. Individual plots were 1 bed (1.8 m) wide and 30 m long. The experiment was sown with the grower's planter and measured sections of each plot were harvested with a research plot harvester to measure yield.

Table 4. Soybean varieties and unreleased lines included in the experiment and the reasons for inclusion.

Variety	Variety traits and reason for inclusion
NK94B-25	Unreleased variety with high yield potential suited to an early-mid sowing date
Richmond⟨D⟩	Industry standard with high weathering tolerance, high protein, clear hilum and high yield, suited to an early–mid sowing date
T171A-1	Unreleased variety with high yield potential suited to an early sowing date
A6785	Industry standard, small seed size, brown hilum, high yield potential, prone to lodging, suited to a mid–late sowing date
U044-28	Unreleased variety with high yield potential suited to a mid-late sowing date
Hayman⟨D⟩	Industry standard with large seed size, high protein and high tolerance to lodging suited to a mid–late sowing date

Results and conclusions

Crop growth

The experiment established well and evenly across the site (Figure 2). During the season the experiment site was visited by several grower groups including 26 growers and agribusiness representatives from the Iowa Farm Bureau, U.S.A. (Figure 3).

Figure 2. Aerial photo of experiment at flowering 51 days after planting.
Photo: S. Blanch, NSW DPI.

Figure 3. The site was visited by 26 members of the Iowa Farm Bureau, U.S.A., on the 5 March, 2018, 86 days after planting. Photo: N. Moore, NSW DPI.

Grain yield and quality

Data was collected from six field replicates and statistical analysis was performed by Stephen Morris, Biometrician, NSW DPI using the asreml package in the R environment (R Development Core Team). The analysed data for yield, seed size, oil and protein content is presented in Table 5. 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).

Some missing data for plant height prevented statistical analysis of the data for this trait only. The plant height data presented in Table 5 is an average of the available data; hence no standard error or least significant difference values are given for this trait.

Variety A6785 achieved the highest yield in the experiment with 4.39 t/ha. Note that grain yield is expressed for the farming system (including furrows) and not for the bed top only. The grower frequently achieves high yields with variety A6785 on this farm and commented that he thinks it is very well suited to his wide row system and soil type. Variety A6785 consistently produces low protein levels (<40% dry matter basis) across coastal NSW and Qld, but in this experiment it achieved grain protein of 46.9% dry matter basis, which is remarkably high compared to industry averages. Protein levels of all varieties in this experiment were high. Industry receival standards for soybean stipulate minimum protein levels of 40% dry matter basis.

Varieties Richmond$^{\Phi}$ and Hayman$^{\Phi}$ yielded 4.04 and 4.02 t/ha respectively.

Unreleased line T171A-1 produced a short plant height (54 cm). This was likely due to a slightly later than ideal sowing date for this early-maturing variety, combined with the wide row configuration. Regardless it was not significantly different in yield to Richmond$^{\Phi}$ and Hayman$^{\Phi}$. Short plant height is not ideal as it can cause difficulties at harvest and increases the potential for downgrade in quality and price due to soil in the grain.

Unreleased line NK94B-25 produced a yield that was statistically the same as Richmond$^{\Phi}$ and Hayman$^{\Phi}$, however, it was observed that this variety did not produce a lot of branches to fill in the wide inter-row space and might be better suited to narrower row spacing. To improve yield potential, the grower is adapting his planter to sow three rows on the bed instead of the current two widely spaced (90 cm) rows. Richmond$^{\Phi}$ and Hayman$^{\Phi}$ are known for their branching growth habits.

Unreleased line U044-28 yielded significantly less than the other entries and, along with variety Hayman$^{\Phi}$, took 16 days longer to mature than the other entries (harvest date 3 May compared with 17 April). The GVSC has dropped line U044-28 from experiments in 2018–19, but are continuing on-farm and processor evaluations of NK94B-25 and T171A-2 (a sister line of T171A-1) in 2018–19. Experiments to investigate row spacing with NK94B-25 are also planned.

Table 5. Grain data from 2017/18 soybean variety experiment at Warregah Island. Statistical analysis using spatial analysis in the R environment. Data was collected from six field replicates.

Soybean variety	Grain yield (t/ha)	Seed size (g/100 seed)	Grain oil content (% dry matter)	Grain protein content (% dry matter)	Plant height [a] (cm)
A6785	4.39	17.1	20.7	45.9	90.3
Richmond$^{(l)}$	4.04	23.4	20.3	43.7	65.7
Hayman$^{(l)}$	4.02	26.4	18.7	45.3	90.7
T171A-1	3.81	21.1	20.5	45.1	54.2
NK94B-25	3.66	20.7	20.6	46.1	73.0
U044-28	2.76	24.6	20.0	42.3	82.0
s.e.	0.11	0.28	0.2	0.6	-
l.s.d. ($P<0.05$)	0.33	0.81	0.57	1.76	-

[a] due to missing plant height data from some replicates, the plant height data was not statistically analysed and is presented as an average of the available data

s.e. = standard error

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

Acknowledgements

This regional evaluation was an objective of the 'Australian Soybean Breeding Program' (GRDC Project number 9175421), with joint investment by NSW DPI, CSIRO and GRDC.

The assistance of Shane and Tracey Causley in conducting this experiment is gratefully acknowledged. Technical assistance in planting and harvesting the experiment, processing grain samples and preparing data was provided by Nathan Ensbey, Jarrod Ensbey, Meg Cameron, Rodney Ellem and Kirran Ensbey, NSW DPI Grafton. Statistical analysis by Stephen Morris, NSW DPI Wollongbar is gratefully acknowledged.

Contact

Sam Blanch
Grafton Primary Industries Institute, Grafton
sam.blanch@dpi.nsw.gov.au
02 6640 1600

Evaluating new soybean varieties for Northern NSW and the Liverpool Plains – 2013/14 and 2014/15

Kathi Hertel[1], Craig Chapman[2], Joe Morphew[2] and Steven Harden[3]

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

Key findings

- Yield of Moonbi$^{\phi}$ and Richmond$^{\phi}$ were similar to Soya 791 and up to 1.3 t/ha greater than Hale on wider row spacings in dryland and irrigated production systems.
- Seed size and high protein levels of Moonbi$^{\phi}$ and Richmond$^{\phi}$ were greater than Soya 791 and Hale.
- Moonbi$^{\phi}$ flowers 3–5 days earlier than Richmond$^{\phi}$.
- Moonbi$^{\phi}$, and Richmond$^{\phi}$, show significant differences in time to flowering compared with the outclassed variety Hale. Moonbi$^{\phi}$, and Richmond$^{\phi}$ flowered 7 to 12 days later at Narrabri and 13–16 days later on the Liverpool Plains.
- Richmond$^{\phi}$ measured shorter plant heights at maturity compared with Moonbi$^{\phi}$, while Hale was consistently the shortest variety.

Introduction

The 'Northern pulse agronomy initiative – NSW' (DAN00171) was a joint project between NSW DPI and the Grains Research and Development Corporation (GRDC). While pulse crops are recognised as vital components of modern farming systems, including summer pulses – particularly soybeans, remains low in the northern grains region (NGR). Growers view the soybean crop agronomic performance as highly variable – a view based on grower experiences with older varieties suitable for lower-value crushing markets.

Recent variety releases from the 'Australian Soybean Breeding Program' (ASBP) have been developed for diverse production environments. Advances in a number of agronomic traits such as yield and disease resistance, and grain quality suitable for human consumption, has created new opportunities for varieties adapted to different cropping regions.

These experiments aimed to compare the agronomic performance of older established varieties with the performance of advanced breeding lines and newly released varieties. This information will be used to develop improved agronomic recommendations that will enable growers to realise their yield and quality potential in regional farming systems.

Site details

Locations	Pine Ridge – 'Windy Station' Breeza – Liverpool Plains Field Station Narrabri – Australian Cotton Research Institute
Site characteristics	see Table 1 for details of the three sites
Irrigation	Soybean experiments located at Breeza and Narrabri were sown into pre-watered fields with full soil moisture profiles. Each then received in-crop irrigations as required throughout the growing season.

Trial design	Randomised complete block design; three replications.
Plant population	Target 35 plants/m^2 (planting rates adjusted for seed size and germination %)

Table 1. Experiment characteristics in 2013/14 and 2014/15

Site	Pine Ridge	Breeza	Narrabri
Season	2013/14	2013/14	2014/15
Farming system	Dryland	Irrigation	Irrigation
Configuration	Continuous rows on flat	Raised bed	Raised bed
Row spacing (cm)	100	90	100
In-crop rainfall (mm)	269.6	280	329.4
Maximum temperature (°C)	45.1	46.9	40.3
Minimum temperature (°C)	-3.6	-1.5	1.9
Planting date	12 Dec 2013	6 Dec 2013	18 Dec 2014
Harvest date (days after sowing - DAS)	30 May 2014 (169 DAS)	30 May 2014 (174 DAS)	30 Apr 2015 (132 DAS)

Treatments

Genotype

Table 2. Soybean genotype evaluation experiments 2013/14 and 2014/15.

Site	Pine Ridge	Breeza	Narrabri
Genotypes	Hale	Hale	Hale
	Bunya	Bunya	Bunya
	Soya 791	Soya 791	Soya 791
	MoonbiⓅ	MoonbiⓅ	MoonbiⓅ
	RichmondⓅ	RichmondⓅ	RichmondⓅ
	PR443	PR443	N189-16

Hale (2000): A quick maturing, indeterminate public variety. This quick maturity positions it as a preferred choice for dryland situations, however seed size is small (15 g/100 seed) compared with other commercial soybean varieties. It is suitable for lower-value crushing markets.

Bunya (2006): A quick maturing, determinate variety, bred by CSIRO. Its large seed (26 g/100 seed) has a clear hilum. It is a preferred variety for tofu markets. Bunya is resistant to phytophthora (including Race 15), but is susceptible to powdery mildew.

Soy 791: A determinate, medium maturing variety with smaller seed (21 g/100 seed) and a brown hilum. It has been a standard variety in northern NSW for many years. It is not resistant to Race 15, one of the two main phytophthora root rot races in Queensland, and the Macquarie and Namoi Valleys in New South Wales. It is best suited to soyflour production.

MoonbiⓅ (2010): A quick maturing semi-determinate variety. It is a compact plant with improved weathering tolerance. It is resistant to all known races of phytophthora in Australia. The round-shaped seed has improved seed size (22 g/100 seed) with a clear hilum, making it suited to the higher value markets of tofu and soy milk.

RichmondⓅ (2013): A quick maturing variety (slightly longer than MoonbiⓅ) with high protein and the highest level of weathering tolerance of all clear hilum varieties. The clear hilum makes it suitable for human consumption, particularly flour production.

PR443 and N189-16: Advanced experimental lines from the ASBP.

Results – Pine Ridge 2013/14

The target plant population and overall site establishment was 25 plants/m^2.

- Bunya – 32 plants/m^2
- Hale – 25 plants/m^2
- Richmond$^{\Phi}$ – 25 plants/m^2
- Moonbi – 23 plants/m^2
- PR443 – 33 plants/m^2
- Soya 791 – 15 plants /m^2

Grain yield and seed size

There was no significant difference in yield between Richmond$^{\Phi}$, Moonbi$^{\Phi}$ and the experimental line PR443, 2.72 t/ha, 2.12 t/ha and 2.52 t/ha respectively (Figure 1). There was no significant difference in yield between Richmond$^{\Phi}$, Moonbi$^{\Phi}$ and Soya 791. Hale recorded the lowest yield at 1.16 t/ha. Overall site mean yield was 2.01 t/ha.

Seed size was measured as the weight of 100 seeds at 12% moisture content. Varietal differences were evident, ranging from the smallest, Hale, recording 15 g/100 seed to the largest, Bunya, at 25.3 g/100 seeds. There was no significant difference in seed size between Richmond$^{\Phi}$, Moonbi$^{\Phi}$ and Soya 791. The site mean seed size was 20.5 g /100 seeds.

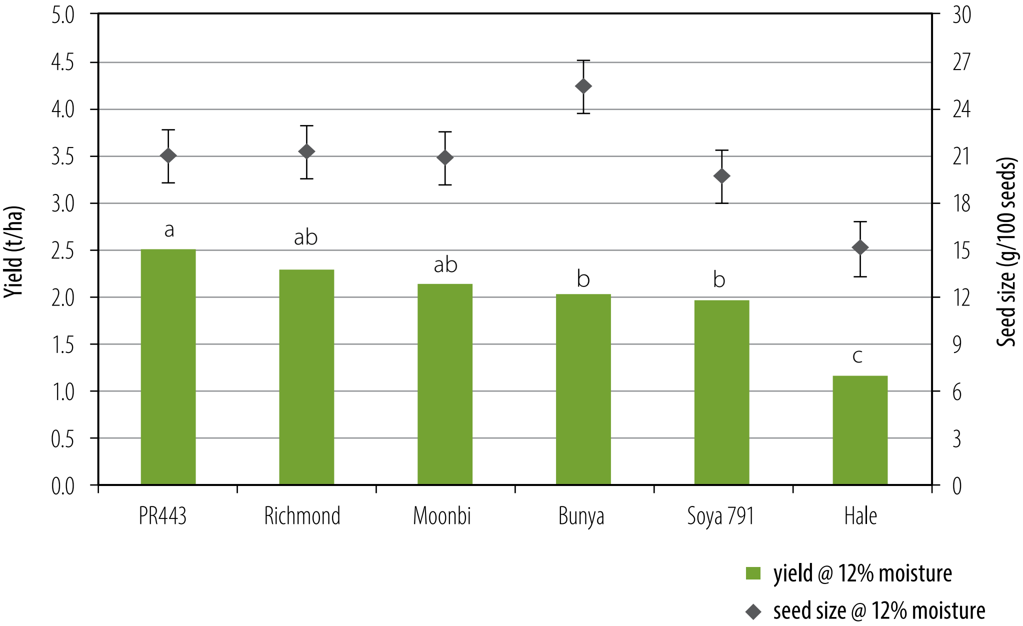


Figure 1. Grain yield and seed size of six soybean varieties sown at Pine Ridge in 2013.
Yield l.s.d. ($P<0.001$) = 0.35 t/ha; Seed size l.s.d. ($P<0.001$) = 1.7 g
Note: Bars denote least significant difference (l.s.d.).
Values with the same letter are not significantly different at 99.9% – ** ($P<0.001$) or 95% – * ($P<0.05$) confidence levels.

Plant height at maturity

Overall site mean was 62 cm, with Bunya the tallest variety at 70 cm and the shortest was Hale at 56 cm. There was no significant difference between the remaining varieties, all at 62 cm (l.s.d. 4; $P<0.05$).

Oil and protein

Oil content averaged 19.1%. There was no significant difference in oil between varieties (data not shown). The average protein measured 42.4%. Soya 791 was 41.4%, which is significantly lower than either Moonbi$^{\Phi}$ or Richmond$^{\Phi}$ (l.s.d. ($P<0.05$) = 1.4 (data not shown).

Results – Breeza 2013/14

Soybean establishment was counted 39 days after sowing, the overall site mean measuring 38 plants/m^2. The target population under irrigation was 35 plants/m^2. Soya 791 had poor seed quality resulting in the lowest population of all genotypes, 27 plants/m^2. All other genotypes achieved satisfactory populations.

Flowering

Significant differences in the time to flowering were recorded (l.s.d. ($P<0.001$) = 3 days). Hale was the quickest, where 50% of plants started flowering 41 days after sowing. This was followed by Bunya at 50 days, Moonbi$^{(\phi)}$ 54 days, Richmond$^{(\phi)}$ 57 days and both Soya 791 and PR443 at 68 days.

Grain yield and seed size

The mean yield was 2.72 t/ha with no significant differences in yield between genotypes (Figure 2).

Seed size averaged 21.7 g/100 seeds. Moonbi$^{(\phi)}$ had the largest seed of all varieties at 24.1 g/100 seeds, though not significantly greater than Richmond$^{(\phi)}$ (23.6 g/100 seeds). Hale seed size was the smallest at 15 g/100seeds.

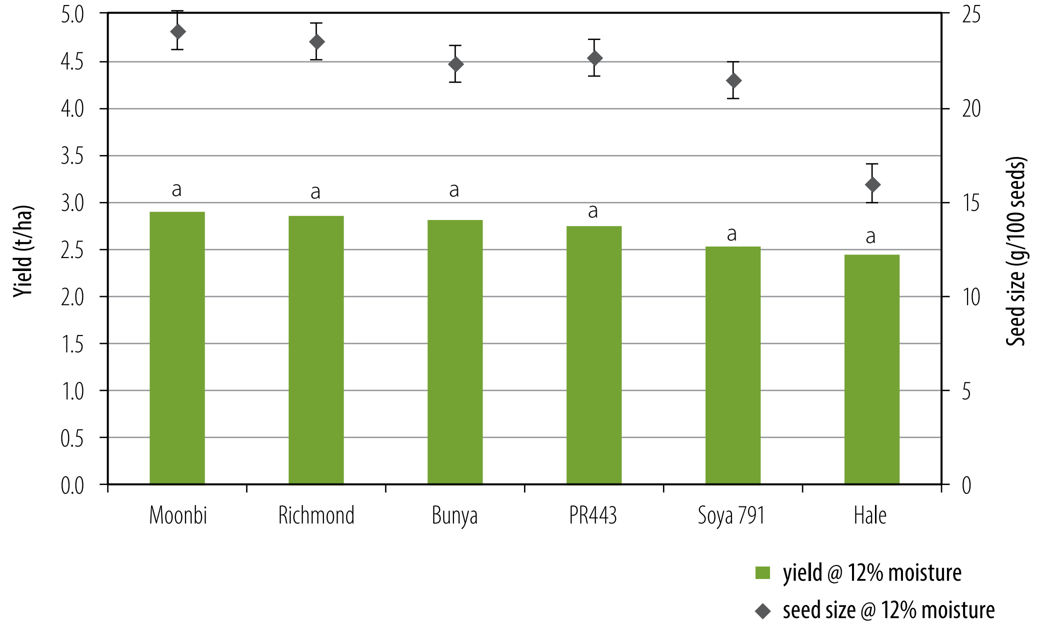


Figure 2. Grain yield and seed size of 6 soybean varieties sown at Breeza in 2013
Yield l.s.d. ($P<0.05$) = ns; Seed size l.s.d. ($P<0.001$) = 0.8 g.
Note: Bars denote least significant difference (l.s.d.).
Values with the same letter are not significantly different at 99.9% – ** ($P<0.001$) or 95% – * ($P<0.05$) confidence levels.

Plant height at maturity

Overall site mean was 81 cm, ranging between the tallest variety, Moonbi$^{(\phi)}$ at 96 cm, and shortest, Hale, at 63 cm. There was no significant difference between the remaining varieties (l.s.d. ($P<0.05$) = 19).

Oil and protein

Oil content averaged 20.6%. Bunya measured the highest oil content at 21.7% which was significantly higher than all other varieties (l.s.d. ($P<0.001$) = 0.5. The lowest oil was in Soya 791 at 20.1%.

The average protein was 40.9%. Bunya was 38%, which was significantly lower than all other varieties (l.s.d. ($P<0.001$) = 1.0). There was no significant difference between the remaining varieties where protein varied between 41% and 42%.

Results – Narrabri 2014/15

Soybean establishment was counted 21 days after sowing. Seed placement into excellent seedbed conditions resulted in all genotypes exceeding the target population of 35 plants/m^2.

Flowering

Significant differences in time to flowering were recorded (l.s.d. ($P<0.001$) = 1 day). Located approximately 200 km north of the 2013–14 Pine Ridge site, planting at the 2014/15 Narrabri was six days later than at Pine Ridge. The flowering response of genotypes was markedly quicker with some changes to the order of maturity. Hale was the first to flower, where 50% of plants started flowering 35 days after sowing. This was followed by Moonbi$^{\Phi}$ 42 days, Bunya and N189-16 at 44 days, Soya 791 45 days and Richmond$^{\Phi}$ at 47 days.

Grain yield and seed size

The site mean yield was 2.12 t/ha. Richmond$^{\Phi}$ yielded 2.65 t/ha, the highest of all genotypes, but not significantly different from Moonbi$^{\Phi}$, Soya 791 and N189-16 (Figure 3). Hale recorded the lowest yield of 1.3 t/ha, significantly lower than all other genotypes (l.s.d. ($P<0.001$) = 0.29)

Seed size averaged 15.1 g at this site. The advanced breeding line N189-16 measured the largest seed at 18.2 g/100 seeds, though not significantly greater than Richmond$^{\Phi}$ (16.9 g/100 seeds) and Bunya (16.4 g/100 seeds) (Figure 3). Hale measured the smallest seed size of 9.3 g/100 seeds. Heat stress during pod fill meant that seed size in this experiment was much smaller than normal, hence the reduced yields.

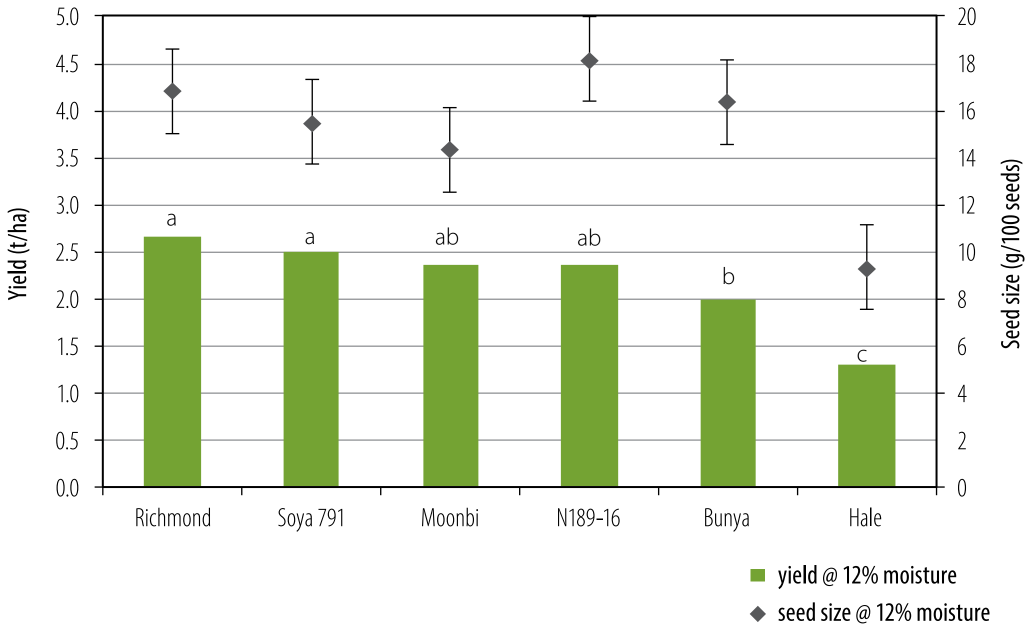


Figure 3. Grain yield and seed size of 6 soybean varieties sown at Narrabri in 2014.
Yield l.s.d. ($P<0.001$) = 0.29 t; Seed size l.s.d. ($P<0.001$) = 1.8 g.
Note: Bars denote least significant difference (l.s.d.)
Values with the same letter are not significantly different at 99.9% – ** ($P<0.001$) or 95% – * ($P<0.05$) confidence levels.

Plant height at maturity

The overall site mean was 68 cm. In order of declining height, Moonbi$^{\Phi}$ at 78 cm was the tallest, but was not significantly different from Hale and Soya 791. These three genotypes were significantly taller than all remaining genotypes. Bunya was the shortest of all genotypes at 53 cm (l.s.d. ($P<0.001$) = 3.2).

Oil and protein

Oil content averaged 19.1%. Moonbi$^{(\phi)}$ had the highest oil at 20.2%, but was not significantly higher than Richmond$^{(\phi)}$ or Bunya (l.s.d. ($P<0.05$) = 0.9). The lowest oil was in Soya 791 at 18.4% and Hale at 18.3%.

The average protein for the site was 43.4%. The highest protein was in N189-16 (45%), but was not significantly different from Soya 791 or Hale. However these were significantly greater than all other genotypes. There was no significant difference between Richmond$^{(\phi)}$ (42.8%), Bunya (42.2%) and Moonbi$^{(\phi)}$ (42%) (l.s.d. ($P<0.001$) = 1.2).

Conclusions

Moonbi$^{(\phi)}$ and Richmond$^{(\phi)}$ were released by the Australian Soybean Breeding Program (ASBP) in 2010 and 2013 respectively. They are noted for their improved yield performance and, seed quality characteristics, which includes a larger seed size and a clear hilum. They have high protein levels that are suited to the more lucrative human consumption markets, with added disease tolerance, especially to powdery mildew, which is common at the Liverpool Plains and Narrabri production areas.

Results indicate significant differences between older and new soybean varieties in their potential yields, seed quality characteristics and general plant structure. The marked phenotypical responses of genotypes to regional locations highlights the need for regionally-specific agronomic recommendations to realise the potential and improve the reliability of the newer genotypes.

Interactions between plant populations and wide row spacing affected yield performance, seed quality and plant height in these experiments. The significance and magnitude of these interactions has been a major focus of the NSW-GRDC project DAN00171in subsequent seasons, which investigated the responses of individual varieties to agronomic management practices.

These experiments were the first of the co-ordinated research program of project DAN00171 evaluating new soybean varieties and their response to agronomic management practices for suitability and adaptation to different environments and regions in NSW.

Acknowledgements

These experiments were part of the project 'Northern pulse agronomy initiative – NSW', DAN00171, 2012–17, a joint investment by NSW DPI and GRDC.

Technical assistance from Pete Formann, Rosie Holcombe, Jim Murphy, Joel Hargreaves and Dave Eglington (all NSW DPI) is gratefully acknowledged. Field preparation, irrigation and management were provided by Scott Goodworth and staff at Liverpool Plains Field station (Breeza) and Des Magann and staff at the Australian Cotton Research Institute (Narrabri). Hale seed kindly supplied by Brian Fletcher 'Marydale' Caroona and John Webster, (Quirindi Grain & Produce, Quirindi, NSW); Bunya seed kindly supplied by Ian Morgan (PB Agrifood, Toowoomba, Queensland). Thanks to Romani Pastoral Company 'Windy Station' for hosting the experiment and Crop Manager Peter Winton for his assistance. Quality testing was conducted by Futari Grain Technology Services, Narrabri.

Contact

Kathi Hertel
Trangie Agricultural Research Centre, Trangie
kathi.hertel@dpi.nsw.gov.au
02 6880 8000

Soybean row configuration × population × variety – Narrabri and the Liverpool Plains 2013/14 and 2014/15

Kathi Hertel[1], Craig Chapman[2], Joe Morphew[2] and Steven Harden[3]

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

Key findings

- Row configuration on raised beds under full irrigation had no significant effect on yield and seed quality of either Moonbi$^{\phi}$ or Richmond$^{\phi}$ in the 2013/14 and 2014/15 seasons.
- Medium (60 cm) and wide (90 and 100 cm) rows significantly decreased established plant population compared with 30 cm and 40 cm rows.
- Yields were significantly lower when population was less than 35 plants/m^2, increasing as population increased. Yield levels plateaued at populations between 39 and 49 plants/m^2.
- Yields from Richmond$^{\phi}$ were significantly higher than Moonbi$^{\phi}$ on the Liverpool Plains; however, there was no significant difference between the two varieties at Narrabri.
- Seed size of Richmond$^{\phi}$ was significantly greater than that of Moonbi$^{\phi}$. Plant population had no significant effect on seed size at harvest.
- Genotype effects on protein and oil content, while generally small, were statistically significant. Responses were dominated by seasonal climatic conditions.

Introduction

The Northern pulse agronomy initiative – NSW (DAN00171) is a joint project between NSW DPI and the Grains Research and Development Corporation (GRDC). Recent variety releases from the 'Australian Soybean Breeding Program' (ASBP) have been developed for diverse production environments. Agronomically different to older varieties, there is the need to (re)define optimum plant populations across differing row configurations.

These experiments were designed to provide data to develop regional agronomic recommendations that use advances in soybean yield potential, disease resistance and grain quality traits. The higher value of this grain, due to its suitability for human consumption, will provide new opportunities for summer cropping.

This report includes two seasons of experiments – 2013/14 and 2014/15. The 2015/16 experiments were not harvested because of severe charcoal rot (*Macrophomina phaseolina*) infection.

Site details

Locations	Narrabri – Australian Cotton Research Institute Breeza – Liverpool Plains Field Station
Irrigation	All experiments were sown into pre-watered fields with full soil moisture profiles. Each then received in-crop irrigations as required throughout the growing season.
Trial design	Split plot design with row spacing as main block; three replications.

Table 1. Row configuration experiment characteristics – 2013/14 and 2014/15.

Season	**2013/14**		**2014/15**	
Site	**Breeza**	**Narrabri**	**Breeza**	**Narrabri**
Farming system	Irrigation	Irrigation	Irrigation	Irrigation
Configuration	Raised bed	Raised bed	Raised bed	Raised bed
In-crop rainfall (mm)	168	268	305	329
Maximum temperature (°C)	45.0	47.1	39.8	40.3
Minimum temperature (°C)	8.6	0.5	−2.5	1.9

Treatments

Table 2. Soybean row configuration evaluation experiments – 2013/14 and 2014/15.

Season	**2013/14**		**2014/15**	
Site	**Breeza**	**Narrabri**	**Breeza**	**narrabri**
Genotypes	Moonbi Richmond PR443	Moonbi Richmond PR443	Moonbi Richmond	Moonbi Richmond
Target population (plants/m^2)	10, 20, 30, 40	10, 20, 30, 40	10, 20, 30, 40	10, 20, 30, 40
Row spacing (cm)	30, 60, 90	30, 60, 90	40, 60, 100	40, 60, 100
Sowing date	6 Dec 2013	20 Nov 2013	2 Dec 2014	18 Dec 2014
Harvest date (days after sowing – DAS)	23 May 2014 (167DAS)	23 May 2014 (183DAS)	19 May 2015 (167DAS)	30 April 2015 (132DAS)

Moonbi$^{\phi}$ (2010): A quick maturing semi-determinate variety. It is a compact plant with improved weathering tolerance. It is resistant to all known races of phytophthora in Australia. The round-shaped seed has improved seed size (22 g/100 seed) with a clear hilum, making it suited to the higher value markets of tofu and soy milk.

Richmond$^{\phi}$ (2013): A quick maturing variety (slightly longer than Moonbi$^{(\phi)}$) with high protein and the highest level of weathering tolerance of all clear hilum varieties. The clear hilum makes it suitable for human consumption, particularly flour production.

PR443: Advanced experimental lines from the ASBP.

Results

Row configuration

Row configuration consistently demonstrated no effect on soybean yield and seed quality characteristics (Table 3). However, row configuration had a significant effect on crop establishment in all experiments. As row spacing widened, plant population was reduced by between 28% and 42%. For example at Narrabri in 2014/15 actual crop establishment averaged 42 plants/m^2 when sown at a row spacing of 40 cm, declining to 32 plants/m^2 at 60 cm and 25 plants/m^2 at 100 cm, an overall reduction of 40%.

Table 3. Impact of row configuration on establishment, yield and seed quality – 2013/14 and 2014/15.

	Row spacing (cm)	2013/14		2014/15	
		Breeza	**Narrabri**	**Breeza**	**Narrabri**
Achieved population (plants/m^2)	30 or 40	46 ^{a}	40 ^{a}	47 ^{a}	42 ^{a}
	60	30 ^{b}	27 ^{b}	40 ^{ab}	32 ^{b}
	90 or 100	30 ^{b}	23 c	34 ^{b}	25 ^{c}
Site mean		35	29	40	33
l.s.d.		5 (*P*<0.01)	2 (*P*<0.01)	8 (*P*<0.05)	2 (*P*<0.05)
Yield – at 12% moisture (t/ha)	30 or 40	1.87	1.76	1.22	2.07
	60	1.90	1.67	1.15	2.26
	90 or 100	1.74	1.62	1.03	2.01
Site mean		1.84	1.68	1.13	2.11
l.s.d. (*P*<0.001)		ns	ns	ns	ns
Seed size – 100 seed weight (g)	30 or 40	20.8	19.2	13.6	16.9
	60	21.0	19.2	15.6	17.3
	90 or 100	21.2	20.0	14.8	16.6
Site mean		21.1	19.5	14.6	16.9
l.s.d. (*P*<0.001)		ns	ns	ns	ns
Oil – dry matter basis (%)	30 or 40	21.3	20.8	16.2	19.6
	60	21.2	20.9	16.4	19.7
	90 or 100	21.1	20.7	16.0	19.8
Site mean		21.3	20.8	16.2	19.7
l.s.d. (*P*<0.001)		ns	ns	ns	ns
Protein – dry matter basis (%)	30 or 40	40.0	43.9	40.0	42.5
	60	40.3	44.0	40.0	42.8
	90 or 100	40.0	44.1	40.3	42.3
Site mean		40.1	44.0	40.1	42.5
l.s.d. (*P*<0.001)		ns	ns	ns	ns

Note: Values with the same letter are not significantly different; ns = not significant

There was a significant interaction between row configuration and target population in three of the four experiments. Figure 1 shows the decline in crop establishment as target population increases and the row spacing widens.

This decline is attributed to the greater competition at high populations between plants for space, water and nutrients within the plant row. Competition increases as row spacing widens and causes greater variability in an individual plant's growth rate. Plant mortality is higher in plants with reduced biomass and vigour leading to significant reductions in establishment.

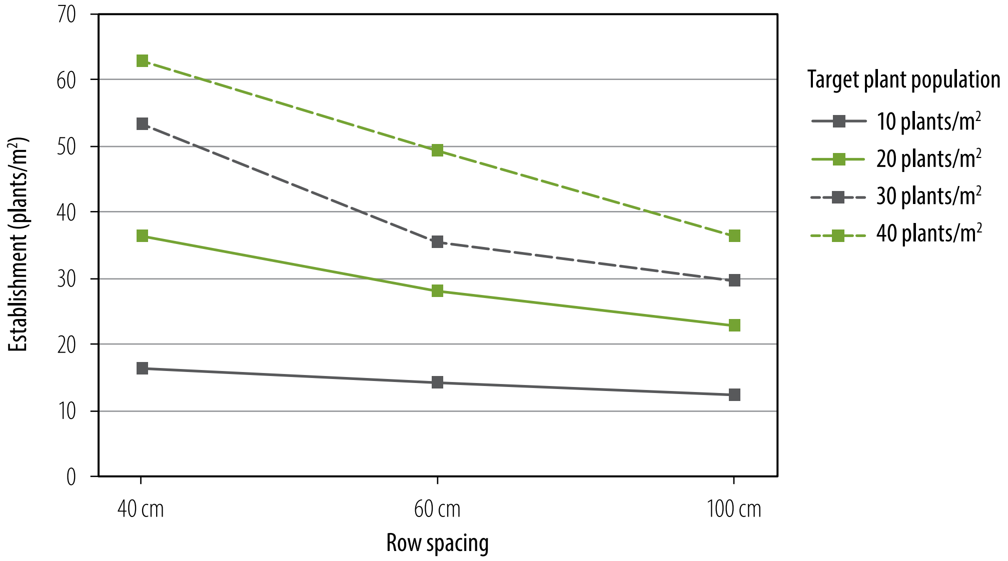


Figure 1. Interaction between row configuration and population in soybean row configuration experiment at Narrabri – 2013/14.
l.s.d. ($P<0.001$) = 5 plants/m^2.

Genotype

There was no significant difference in yields between Moonbi⟨PBR⟩ and Richmond⟨PBR⟩ at Narrabri in both seasons (Table 4). In contrast, Richmond⟨PBR⟩ yields were 5–27% greater than Moonbi⟨PBR⟩ at Breeza. Richmond⟨PBR⟩ exhibited significant differences with a larger seed size compared with Moonbi⟨PBR⟩ in all experiments.

Small but significant levels of difference in oil content and protein were measured, however, genotype ranking varied with individual sites and seasons.

In 2013/14, the protein percentage of Richmond⟨PBR⟩ was significantly higher (41.3%) than Moonbi⟨PBR⟩ (38.2%) at Breeza, but not significantly different at Narrabri (44% and 44.2% respectively). In contrast, in 2014/15, superior genotypes for oil were Moonbi⟨PBR⟩ on the Liverpool Plains (42.1%) and Richmond⟨PBR⟩ at Narrabri (43%).

The yield and seed quality traits of the experimental line PR443 was equal to or better than Moonbi⟨PBR⟩ and Richmond⟨PBR⟩. This genotype was withdrawn from testing after 2013.

Table 4. Effect of soybean genotype on establishment, yield and seed quality – 2013/14 and 2014/15.

	Genotype	**2013/14**		**2014/15**	
		Breeza	**Narrabri**	**Breeza**	**Narrabri**
Achieved population (plants/m^{2})	Moonbi	38^{a}	34^{a}	44^{a}	38^{a}
	Richmond	32^{b}	29^{a}	37^{b}	29^{b}
	PR443	35^{ab}	27^{a}	NA	NA
Site mean		35	29	40	33
l.s.d.		3**	ns*	3**	3**
Yield – at 12% moisture (t/ha)	Moonbi	1.46^{b}	1.66^{a}	1.02^{b}	2.14^{a}
	Richmond	2.00^{a}	1.74^{a}	1.25^{a}	2.09^{a}
	PR443	2.05^{a}	1.65^{a}	NA	NA
Site mean		1.84	1.68	1.12	2.11
l.s.d.		0.17**	ns*	0.12**	ns*
Seed size – 100 seed weight (g)	Moonbi	18.7^{c}	19.1^{b}	14.0^{b}	15.2^{b}
	Richmond	22.9^{a}	20.5^{a}	15.2^{a}	18.7^{a}
	PR443	21.6^{b}	18.8^{b}	NA	NA
Site mean		21.1	19.5	14.6	16.9
l.s.d.		0.4**	0.7**	1.1**	0.7**
Oil – dry matter basis (%)	Moonbi	22.7^{a}	20.8^{ab}	15.9^{b}	19.8^{a}
	Richmond	21.0^{b}	21.1^{a}	16.3^{a}	19.7^{a}
	PR443	21.1^{b}	20.6^{b}	NA	NA
Site mean		21.3	20.8	16.2	19.7
l.s.d.		0.2**	0.3*	0.4*	ns*
Protein – dry matter basis (%)	Moonbi	38.2^{c}	44.2^{a}	40.7^{a}	42.1^{b}
	Richmond	41.3^{a}	44.0^{a}	39.4^{b}	43.0^{a}
	PR443	40.8^{b}	43.8^{a}	NA	NA
Site mean		40.1	44.0	40.1	42.5
l.s.d.		0.4**	ns*	0.4**	0.4**

Note: Values with the same letter are not significantly different at 99.9% - ** ($P<0.001$) or 95% - * ($P<0.05$) confidence levels.

Population

In all experiments, the achieved plant population exceeded the targeted population (Table 5). A significant and positive relationship was shown between achieved population and grain yield. Yield increased as plant population increased before reaching a plateau at populations between 39 plants/m^{2} and 49 plants/m^{2} (Figure 2).

Table 5. Impact of population on establishment, yield and seed quality – 2013/14 and 2014/15

	Target population (plants/m^2)	2013/14		2014/15	
		Breeza	Narrabri	Breeza	Narrabri
Achieved population (plants/m^2)	10	17 ^{d}	20 ^{d}	20 ^{d}	14 ^{d}
	20	29 ^{c}	26 ^{c}	35 ^{c}	29 ^{c}
	30	42 ^{b}	35 ^{b}	48 ^{b}	39 ^{b}
	40	53 ^{a}	40 ^{a}	59 ^{a}	49 ^{a}
Site mean		35	29	40	33
l.s.d.		4**	1**	4**	4**
Yield – at 12% moisture (t/ha)	10	1.61 ^{b}	1.52 ^{b}	1.02 ^{b}	1.81 ^{c}
	20	1.76 ^{b}	1.64 ^{b}	1.02 ^{b}	2.12 ^{b}
	30	2.00 ^{a}	1.82 ^{a}	1.20 ^{a}	2.27 ^{a}
	40	2.03 ^{a}	1.76 ^{a}	1.29 ^{a}	2.26 ^{a}
Site mean		1.84	1.68	1.12	2.11
l.s.d.		0.19**	0.15**	0.17**	0.11**
Seed size – 100 seed weight (g)	10	20.8	19.1	14.9	17.1
	20	21.0	19.5	14.4	16.9
	30	21.2	19.4	14.4	17.0
	40	21.6	19.7	14.6	16.8
Site mean		21.1	19.5	14.6	16.9
l.s.d.		ns*	ns*	ns*	ns*
Oil – dry matter basis (%)	10	21.4 ^{a}	20.8 ^{a}	16.4 ^{a}	20.3 ^{a}
	20	21.4 ^{a}	20.9 ^{a}	16.2 ^{a}	19.9 ^{a}
	30	21.1 ^{b}	20.9 ^{a}	15.9 ^{a}	19.4 ^{b}
	40	21.1 ^{b}	20.7 ^{a}	16.2 ^{a}	19.4 ^{b}
Site mean		21.3	20.8	16.2	19.7
l.s.d.		0.2*	ns*	ns*	0.4*
Protein – dry matter basis (%)	10	39.8 ^{b}	44.1 ^{a}	40.0 ^{a}	41.4 ^{c}
	20	39.9 ^{ab}	43.8 ^{a}	40.0 ^{a}	42.4 ^{b}
	30	40.2 ^{a}	44.0 ^{a}	40.4 ^{a}	43.0 ^{a}
	40	40.3 ^{a}	44.1 ^{a}	40.0 ^{a}	43.4 ^{a}
Site mean		40.1	44	40.1	42.5
l.s.d.		0.4*	ns*	ns*	0.5*

Note: Values with the same letter are not significantly different at 99.9% - ** ($P<0.001$) or 95% - * ($P<0.05$) confidence levels.

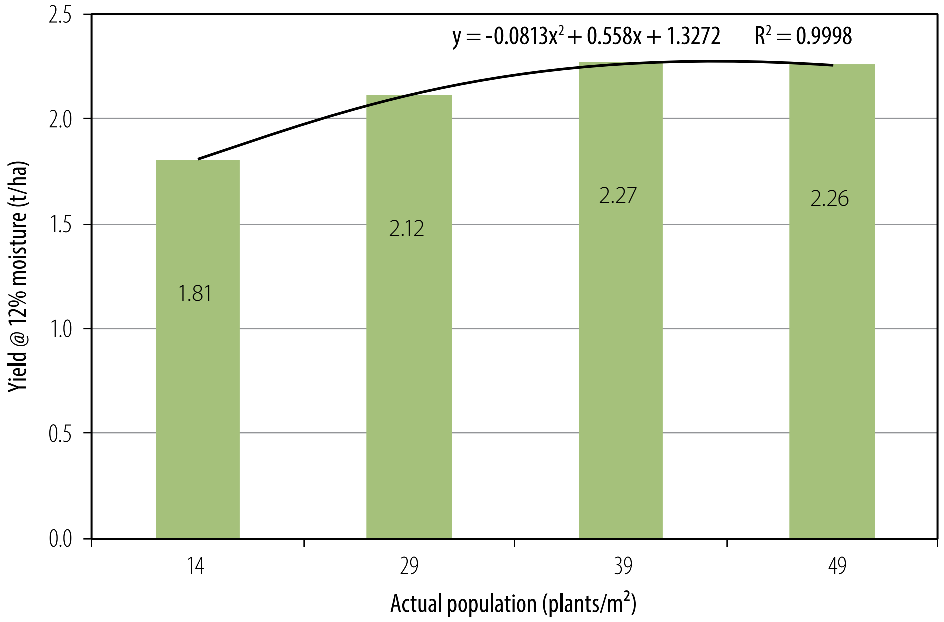


Figure 2. Effect of population on grain yield at Narrabri – 2013/14.
Yield l.s.d. ($P<0.001$) = 0.11 t/ha.

In three of the four experiments, none of the genotypes demonstrated any significant population interaction with yield with one exception. At Narrabri in 2014/15 the Moonbi$^{\Phi}$ yield (2.17 t/ha) was significantly lower than Richmond$^{\Phi}$ (2.34 t/ha) (l.s.d. ($P<0.05$) = 0.15 t/ha) at a population of 49 plants/m^2.

Population had no significant effect on seed size (Table 5).

Population effects on grain protein were variable. In two of four experiments, protein was significantly higher where target populations were 30 plants/m^2 or greater (Table 5).

Population effects on oil content were also mixed, with two experiments recording no significant difference and two experiments measuring a small but significant decline in oil content as population increased (Table 5).

Conclusions

The Australian Soybean Breeding Program (ASBP) released Moonbi$^{\Phi}$ in 2010 and Richmond$^{\Phi}$ in 2013. Both genotypes represent advances in yield potential across a number of growing regions as well as disease tolerance. Key improvements in seed quality characteristics will enable growers to have access to higher value human consumption markets.

The advanced experimental line PR433 was withdrawn after 2013 because of unspecified agronomic and seed quality attributes.

Row spacing was found to have no effect on yield and seed size in either growing region over two seasons. To maintain target populations, soybeans should be sown on narrow row spacing (30 cm to 40 cm). Row spacing of 60 cm or wider will result in significantly lower crop establishment.

Significant yield losses occurred when crop establishment is less than 35 plants/m^2.

Seed quality traits such as seed size, oil and protein are closely linked to variety. Agronomic management practices such as row spacing and population had no significant effect in these experiments; however, seasonal conditions had the largest influence on the variability measured in these experiments.

The experiments have demonstrated the performance of key agronomic indicators in genotypes across a range of agronomic management practices including row configuration and population. These results demonstrate the adaptability of both genotypes and highlight the response of key seed quality traits.

These experiments were a component of the 'Northern pulse agronomy initiative – NSW (DAN00171), evaluating new soybean varieties and their response to agronomic management practices for suitability and adaptation to different environments and regions in NSW.

Acknowledgements

These experiments were part of the project 'Northern pulse agronomy initiative – NSW', DAN00171, 2012–17, a joint investment by NSW DPI and GRDC.

Technical assistance from Stephen Beale, Pete Formann, Rosie Holcombe, Jim Murphy, Joel Hargreaves and Dave Eglington (all NSW DPI) is gratefully acknowledged. Field preparation, irrigation and management were provided by Scott Goodworth and staff at Liverpool Plains Field station, Breeza and Des Magann and staff at the Australian Cotton Research Institute, Narrabri. Moonbi$^{\phi}$ seed kindly supplied by PB Agrifood. Richmond$^{\phi}$ seed kindly supplied by Seednet. Quality testing was conducted by Futari Grain Technology Services, Narrabri.

Contact

Kathi Hertel
Trangie Agricultural Research Centre, Trangie
kathi.hertel@dpi.nsw.gov.au
02 6880 8000

Soybean sowing date × genotype × plant population – Narrabri and the Liverpool Plains 2013/14 and 2014/15

Kathi Hertel[1], Craig Chapman[2], Joe Morphew[2] and Steven Harden[3]

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

Key findings

- Sowing date had mixed effects on yields.
- Seasonal conditions had the biggest effect on crop responses.
- Richmond$^{\phi}$ yields were consistently higher than Moonbi$^{\phi}$ on the Liverpool Plains for all sowing dates. Moonbi$^{\phi}$ yields were equal to or higher than Richmond$^{\phi}$ at Narrabri when sown after early December.
- Richmond$^{\phi}$ demonstrated significant improvements in the key seed traits of seed size and protein content compared with Moonbi$^{\phi}$, Soya 791 and the advanced breeding line PR443.
- Sowing date had no effect on the protein content or seed size of Richmond$^{\phi}$ and Moonbi$^{\phi}$ in three of the four experiments.
- Soybeans were able to compensate for low plant populations across a wide range of sowing dates, growing region and seasonal conditions. Yield losses were incurred when populations fell below 20 plants/m^2 with an upper threshold of 40–50 plants/m^2.

Introduction

The 'Northern pulse agronomy initiative – NSW' (DAN00171) is a joint project between NSW DPI and Grains Research and Development Corporation (GRDC). Recent variety releases from the Australian Soybean Breeding Program (ASBP) have been developed for diverse production environments, but there is no agronomic information for newer varieties and their response to sowing date (SD), plant population and farming systems in the soybean growing regions of northern NSW.

These experiments were designed to provide data to develop regionally-specific agronomic recommendations that use the advances in yield, disease resistance and grain quality of the newer soybean varieties. Suitable for human consumption, these varieties will create new opportunities and increased profitability in different cropping regions.

This report includes two seasons of experiments: 2013/14 and 2014/15. A third season of experiments, planted in 2015 at the Australian Cotton Research Institute near Narrabri and Liverpool Plains Field Station at Breeza was abandoned due to severe charcoal rot (*Macrophomina phaseolina*) infection.

Site details

Locations	Breeza	Liverpool Plains Field Station
	Narrabri	Australian Cotton Research Institute
Irrigation	All experiments were sown into pre-watered fields with full soil moisture profiles. Each then received in-crop irrigations as required throughout the growing season (Table 1).	
Farming system	irrigated raised beds	

Trial design	Split plot design with sowing date (SD) as main block; three replications.
Plant population	Sowing rates adjusted for seed size and germination percentage to achieve target plant populations.

Table 1. Experiment characteristics at Breeza and Narrabri – 2013/14 and 2014/15

Site	2013/14		2014/15	
Season	**Breeza**	**Narrabri**	**Breeza**	**Narrabri**
Row spacing (cm)	90	100	60	100
In-crop rainfall (mm)	SD1: 268.2[◊] SD2: 255.4[◊] SD3: 251.6[◊]	SD1: 276.4 SD2: 219.6 SD3: 210.2	SD1: 356.0 SD2: 246.0 SD3: 208.0	SD1: 196.4 SD2: 195.8 SD3: 193.0
Maximum temperature (°C)	45.0 45.0 39.1	40.3 40.3 40.3	47.2 39.8 39.8	47.0 47.0 47.0
Minimum temperature (°C)	–0.3 –0.3 –0.3	1.9 1.9 6.5	–2.1 –2.1 –2.5	0.5 0.5 0.5

[◊] Gunnedah BOM data

Treatments

Table 2. Sowing date × genotype × population soybean treatments – 2013/14 and 2014/15

Season	2013/14		2014/15	
Site	**Breeza**	**Narrabri**	**Breeza**	**Narrabri**
Sowing date	SD1: 6 December SD2: 18 December SD3: 6 January	SD1: 19 November SD2: 3 December SD3: 19 December	SD1: 28 November SD2: 15 December SD3: 21 January	SD1: 18 December SD2: 6 January SD3: 21 January
Genotype[#]	Moonbi Richmond Soya 791 PR443	Moonbi Richmond Soya 791 PR443	Moonbi Richmond	Moonbi Richmond
Target population (plants/m^2)	10 20 30 40	10 20 30 40	10 20 30 40	10 20 30 40
Harvest date	SD1: 31 May SD2: 31 May SD3: 31 May	SD1: 21 May SD2: 21 May SD3: 21 May	SD1: 19 May SD2: 19 May SD3: 11 Jun	SD1: 30 April SD2: 30 April SD3: 26 May

[#] Genotype descriptions can be found in 'Evaluating new soybean varieties for Northern NSW and the Liverpool Plains – 2013/14 and 2014/15', page 76 in this publication

Results – effects from sowing date

Crop establishment

All experiments were sown into full soil moisture following pre-watering 10 days before.

Sowing date significantly affected crop establishment in three of the four experiments (Table 3). Most notable were the low populations established in both 2013 experiments at the latest sowing date (SD3). SD3 populations were 38% (Breeza) and 33% (Narrabri) below the site mean.

In the 2013/14 season for SD3, soil temperatures measured at 10 cm deep at 9:00 am (AEST) were 25°C at Breeza and 29 °C at Narrabri. Daily temperature during the week after planting reached 40 °C at Narrabri and 42 °C at Breeza. Temperatures at these levels could have been detrimental to the embryo within the seed during the germination process and contributed to reduced crop establishment. Field notes commented on the slow crop appearance at Breeza, noting emergence was not completed until around 20 days after planting.

An additional contributing factor to reduced establishment was the wide row spacing of 90 cm on which both 2013 experiments were planted. The effect of increasing row spacing from narrow (30 cm) to wide (90 cm or 100 cm) in the adjacent row configuration experiments at each location was a 43% (Breeza) and 48% (Narrabri) reduction in establishment. (Refer to 'Soybean row configuration × population × variety – Narrabri and the Liverpool Plains 2013/14 and 2014/15,' page 82 in this publication).

Table 3. Effect of sowing time on establishment, yield and seed quality, 2013/14 and 2014/15.

	Sowing date	Breeza 2013/14	Narrabri 2013/14	Breeza 2014/15	Narrabri 2014/15
Achieved population (plants/m^2)	SD1	25 ^{a}	27 ^{a}	48 ^{a}	30 ^{a}
	SD2	25 ^{a}	30 ^{a}	N^{A}	30 ^{a}
	SD3	13 ^{b}	16 ^{b}	42 ^{b}	36 ^{a}
Site mean		21	24	45	32
l.s.d.		5**	5**	5*	4*
Yield @ 12% moisture (t/ha)	SD1	2.38 ^{a}	2.27 ^{b}	2.49 ^{a}	2.13 ^{a}
	SD2	2.42 ^{a}	2.7 ^{a}	3.86 ^{a}	2.13 ^{a}
	SD3	1.39 ^{b}	2.06 ^{c}	3.02 ^{a}	2.08 ^{a}
Site mean		2.06	2.35	3.12	2.12
l.s.d.		0.21*	0.26**	ns*	ns*
Seed size @ 12% moisture (g/100 seeds)	SD1	21.6 ^{a}	18.2 ^{b}	14.8 ^{a}	19.8 ^{b}
	SD2	21.1 ^{ab}	19.1 ^{a}	16.7 ^{a}	21.6 ^{a}
	SD3	19.2 ^{b}	18.4 ^{b}	13.8 ^{a}	22.5 ^{a}
Site mean		20.6	18.6	15.1	21.3
l.s.d.		2*	0.6*	ns*	1.1*
Oil (%)	SD1	20.5 ^{a}	20.6 ^{a}	16.6 ^{a}	21.3 ^{a}
	SD2	20.2 ^{a}	20.4 ^{ab}	17.3 ^{a}	20.7 ^{a}
	SD3	20.4 ^{a}	20.2 ^{b}	15.1 ^{b}	19.2 ^{b}
Site mean		20.4	20.4	16.3	20.4
l.s.d.		ns*	0.3*	1.4*	1.6*
Protein (%)	SD1	41 ^{a}	42.8 ^{a}	40.3 ^{a}	41 ^{b}
	SD2	41.1 ^{a}	42.7 ^{a}	38.9 ^{a}	41.3 ^{b}
	SD3	39.6 ^{b}	42.5 ^{a}	39.8 ^{a}	45.5 ^{a}
Site mean		40.5	42.7	39.7	42.5
l.s.d.		0.7*	ns*	ns*	1.3**

** Values with the same letter are not significantly different at 99.9% ($P<0.001$)
* 95% ($P<0.05$) confidence levels

Grain yield and seed characteristics

Yield

Sowing date had a significant effect on yield in both experiments in 2013 (Table 3). At Breeza, the early January sowing date (SD3) yielded 1.39 t/ha. This was approximately 1 t/ha (or 42%) less than yields from the two December sowing dates. In the same season at Narrabri, there were significant differences between all three SDs, in ranked order 3 December (SD2) 2.7 t/ha, 19 November (SD1) 2.27 t/ha and 19 December (SD3) 2.06 t/ha (l.s.d. = 0.21; *P*<0.05).

In the following season (2014/15), SDs were extended to 21 January. In both experiments there was no significant difference in soybean yields for any planting date (Table 3).

Moonbi$^{\phi}$ and Richmond$^{\phi}$ responded similarly to SD in 2014/15, but yield differences were only significant in the 2013/14 season (Figure 1).

At Breeza in 2013/14, all genotypes yielded significantly less when sown in early January compared with early to mid December SDs (Figure 1A). Comparing yields from early to mid December SDs to yields from early January, Richmond$^{\phi}$ and Moonbi$^{\phi}$ were 38% and 39% higher respectively when sown in December. Richmond$^{\phi}$ out-yielded Moonbi$^{\phi}$ on all sowing dates.

At Narrabri in 2013/14, Moonbi$^{\phi}$ yields were significantly greater than Richmond$^{\phi}$ yields when sown in early and late December – 11% and 20% respectively (Figure 1B). In contrast, the Richmond$^{\phi}$ yield was 14% higher than Moonbi$^{\phi}$ when sown on 19 November.

In 2014/15, there was no significant interaction between SD and yield for Moonbi$^{\phi}$ and Richmond$^{\phi}$ (Figures 1C and D). Trends show that Richmond$^{\phi}$ yields tend to be higher than Moonbi $^{\phi}$ at Breeza, whilst Moonbi$^{\phi}$ planted after mid December was higher than Richmond$^{\phi}$ at Narrabri.

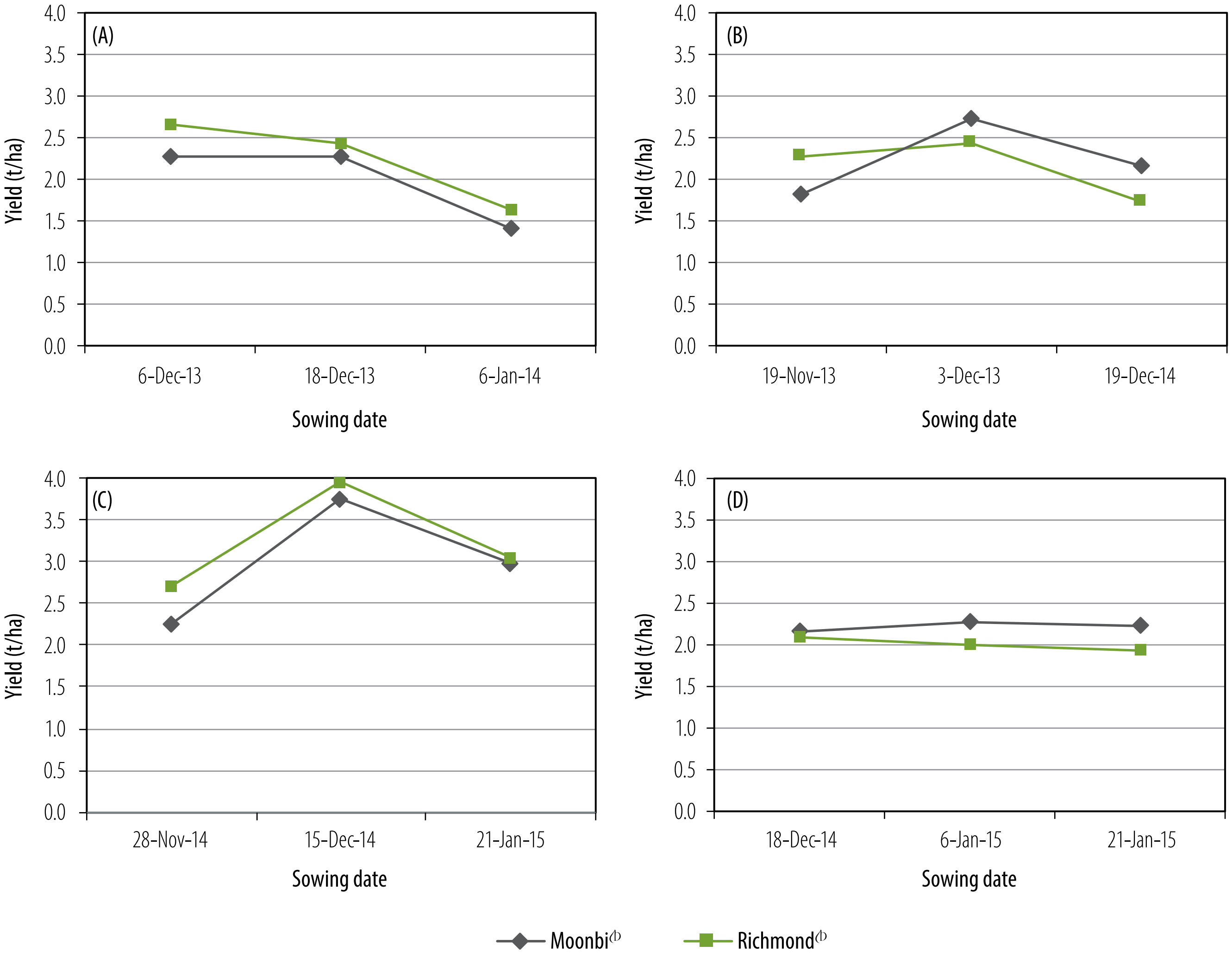


Figure 1. Relationship between sowing date and yield (@ 12% moisture) of two soybean genotypes at (A) Breeza2013/14 (l.s.d. [*P*<0.001] = 0.26 t/ha); (B) Narrabri 2013/14 (l.s.d. [*P*<0.001] = 0.32 t/ha); Breeza 2014/15 (ns, *P*<0.05); and Narrabri 2014/15 (ns, *P*<0.05).

Seed size

Sowing date significantly affected seed size in three of the four experiments (Table 3). No single SD consistently produced the smallest or largest seed. Large differences were revealed between seasons and experiment location.

Oil

Oil content varied significantly across SD in three of the four experiments. Seasonal influences were more evident with a broader range of oil levels of 15.1–21.3% in 2014/15 compared with 2013/14, which had a range of 20.2% to 20.6% (Table 3).

Protein

The interaction between SD and protein content were significant in two experiments, but not in two others (Table 3). No consistent trend across SDs, site locations, or seasons was evident. Protein varied between 38.9% and 45.5%.

Results – effects from genotype

Crop establishment

Each season, newly sourced seed tested for germination and vigour was used. The seed size of individual varieties and seeding rate was calculated to target specified populations. Despite this, seed quality differences between genotypes are apparent in the established plant population at the sites of each planting season (Table 4).

For example, populations of Soya 791 were significantly less (*P*<0.001) than the other genotypes in both 2013 experiments. Richmond$^{\phi}$ populations were significantly less (*P*<0.001) than that of Moonbi$^{\phi}$ in 2014.

Seedbed conditions were favourable for germination with seed placement into full soil moisture, approximately 10 days after pre-watering at all sites in both seasons.

Grain yield and seed characteristics

Yield

Significant differences in the genotypes yields were recorded in all experiments, with distinct differences in the rankings at the two locations (Table 4). In 2013 At Breeza, Richmond$^{\phi}$ yielded 2.24 t/ha, 11% higher than Moonbi$^{\phi}$. In 2014, Richmond$^{\phi}$ yielded 8% more than Moonbi$^{\phi}$.

Conversely, Moonbi$^{\phi}$ significantly out-yielded Richmond$^{\phi}$ at Narrabri in both seasons, 6% higher in 2013 and 9% higher in 2014.

Soya 791 was tested in 2013 only. At Breeza, Soya 791 yielded 18% less than Richmond$^{\phi}$. In contrast at Narrabri, Soya 791 significantly out-yielded Moonbi$^{\phi}$ and Richmond$^{\phi}$. The experimental line PR443 was withdrawn from testing after 2013 because of unspecified agronomic and seed quality attributes.

Seed size

Richmond$^{\phi}$ recorded significantly larger seed size than Moonbi$^{\phi}$ in both Breeza experiments (Table 4). Even though larger at Narrabri, these differences were not significant. However, differences were not significant in either season at Narrabri. Seed size of both of these varieties was significantly greater than Soya 791 and PR443 in 2013.

Oil

There was a significant difference (although small) in oil content for three of the four experiments (Table 4), ranging from 0.2% (Narrabri 2014/15) to 0.6% (Breeza 2013/14).

In 2013, the oil content of Moonbi$^{\phi}$ was significantly higher than Richmond$^{\phi}$ at both locations. In 2014, Richmond$^{\phi}$ oil content at Breeza was 16.5%, significantly higher than Moonbi$^{\phi}$ at 16.1% (l.s.d 0.3; *P*<0.05), but no significant difference was recorded at Narrabri.

Protein

A key trait of Richmond$^{(\Phi)}$ is its improved protein content. In 2013, Richmond$^{(\Phi)}$ recorded significantly higher protein than other genotypes (Table 4): Richmond$^{(\Phi)}$ protein was between 0.8% and 1.2% higher than Moonbi$^{(\Phi)}$. But in 2014, the Moonbi$^{(\Phi)}$ protein content of 40%, was significantly greater than that of Richmond$^{(\Phi)}$ at 39.4% (l.s.d. 0.3; $P<0.001$) at Breeza. There was no significant difference measured at Narrabri.

Protein content across all experiments in both seasons exhibited a narrow range, with site averages of between 39.7% and 42.7%.

Table 4. Effects of genotype on establishment, yield and seed quality – 2013/14 and 2014/15.

	Genotype	Breeza 2013/14	Narrabri 2013/14	Breeza 2014/15	Narrabri 2014/15
Achieved population (plants/m^{2})	Moonbi	20^{b}	25^{a}	51^{a}	37^{a}
	Richmond	21^{b}	25^{a}	39^{b}	28^{b}
	Soya 791	18^{c}	20^{b}	NA	NA
	PR443	24^{a}	27^{a}	NA	NA
Site mean		21	24	45	32
l.s.d.		2**	2**	3**	2**
Yield @ 12% moisture (t/ha)	Moonbi	1.99^{b}	2.23^{b}	3^{b}	2.22^{a}
	Richmond	2.24^{a}	2.1^{c}	3.25^{a}	2.01^{b}
	Soya 791	1.83^{c}	2.52^{a}	NA	NA
	PR443	2.19^{a}	2.53^{a}	NA	NA
Site mean		2.06	2.35	3.12	2.12
l.s.d.		0.14**	0.12**	0.17**	*0.13
Seed size @ 12% moisture (g/100 seeds)	Moonbi	20^{c}	19.2^{a}	13.4^{b}	21.1^{a}
	Richmond	22.4^{a}	19.4^{a}	16.9^{a}	21.5^{a}
	Soya 791	19.4^{d}	17.6^{b}	NA	NA
	PR443	20.7^{b}	18.1^{b}	NA	NA
Site mean		20.6	18.6	15.1	21.1
l.s.d.		0.4**	0.6**	0.68**	ns*
Oil (%)	Moonbi	20.8^{a}	20.7^{a}	16.1^{b}	20.3^{a}
	Richmond	20.2^{c}	20.3^{b}	16.5^{a}	20.5^{a}
	Soya 791	20.5^{b}	20.2^{b}	NA	NA
	PR443	20^{c}	20.3^{b}	NA	NA
Site mean		20.4	20.4	16.3	20.4
l.s.d.		0.2**	0.2**	0.3*	ns*
Protein (%)	Moonbi	40.3^{b}	42.7^{b}	40^{a}	42.7^{a}
	Richmond	41.5^{a}	43.5^{a}	39.4^{b}	42.4^{a}
	Soya 791	40.1^{b}	42.6^{b}	NA	NA
	PR443	40.3^{b}	41.9^{c}	NA	NA
Site mean		40.5	42.7	39.7	42.5
l.s.d.		0.4**	0.3**	0.3**	ns*

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

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

Results – effects from plant population

Crop establishment

Significant differences in plants/m^2 were measured between all target populations (Table 5). Calculations of individual seed lots were conducted to determine appropriate seeding rates for seedbed conditions, row spacing and seed characteristics. Even so, wide row spacing reduced the final plant population at the higher target populations for the experiments planted at 90 cm and 100 cm row spacing in 2013. For example, at Breeza, actual establishment was 31 plants/m^2, 78% of the 40 plants/m^2 target.

At Breeza in 2014, where row spacing were inadvertently planted at 60 cm instead of 100 cm, actual establishment exceeded all target populations (Table 5).

These results reflect the findings reported in the paper 'Soybean row configuration × population × variety, Narrabri and the Liverpool Plains, 2013/14 and 2014/15', page 82 in this publication . In particular, the experiments reported reductions in crop establishment under wide row treatments of 14% (Breeza) and 21% (Narrabri) in 2013 and 15% (Breeza) and 24% (Narrabri) in 2014, compared with the site averages.

Grain yield and seed characteristics

Yield

Plant population had significant impacts on yield in all experiments (Table 5). Figure 2 shows the relationship between yield and population in three experiments encompassing all planting dates. Results demonstrate the ability of soybeans to compensate to a range of plant populations. They indicate an upper threshold between 40 and 50 plants/m^2 and a substantial reduction in yield as crop establishment falls below 20 plants/m^2.

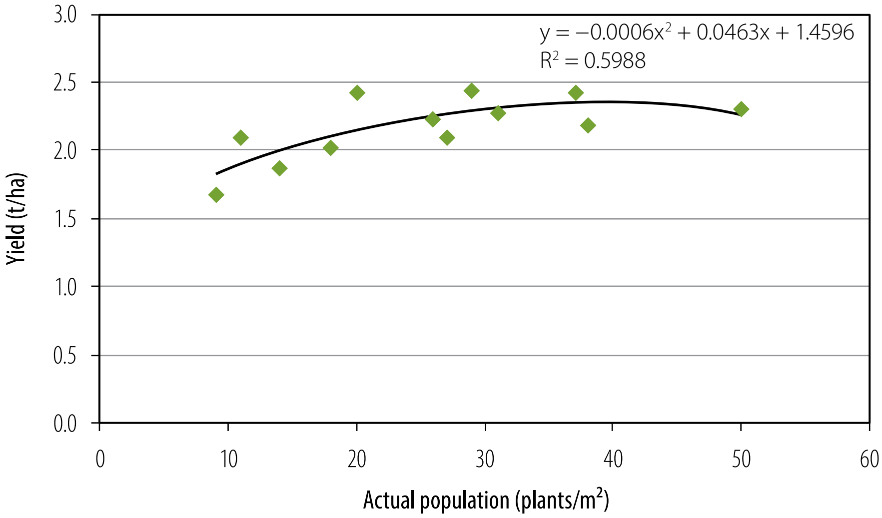


Figure 2. Relationship between actual plant population and grain yield in soybean at Narrabri and Breeza – 2013/14 and 2014/15.

Seed size

Plant population did not affect seed size in three of the four experiments (Table 5). At Breeza in 2013, the trend was for seed size to increase as population increased. Maximum seed size at the 40 plants/m^2 target population was 21.3g/100 seed (l.s.d. 0.4; $P<0.001$).

Oil

Experiments at both sites in 2013 recorded significant differences in oil content (Table 5). There was an inverse relationship of declining oil content with increasing plant population. Both experiments averaged 20.4%. In contrast, 2014 experiments measured no significant difference in oil.

Protein

The effect of plant population on protein was significant in 2013 at both locations (Table 5). In contrast to oil, there was a linear relationship between protein and population. For example, at Narrabri at a 40 plants/m^2 target population, protein was 42.7%. At the other extreme at a 10 plants/m^2 target population, protein was 42.5% (l.s.d. 0.3; $P<0.05$).

Table 5. Effect of population on establishment, yield and seed quality – 2013/14 and 2014/15.

	Target population (plants/m^2)	**Breeza 2013/14**	**Narrabri 2013/14**	**Breeza 2014/15**	**Narrabri 2014/15**
Achieved population (plants/m^2)	10	9 ^{d}	11 ^{d}	21 ^{d}	14 ^{d}
	20	18 ^{c}	20 ^{c}	38 ^{c}	27 ^{c}
	30	26 ^{b}	29 ^{b}	51 ^{b}	38 ^{b}
	40	31 ^{a}	37 ^{a}	72 ^{a}	50 ^{a}
Site mean		21	24	45	32
l.s.d.		2**	2**	4**	3**
Yield @ 12% moisture (t/ha)	10	1.68 ^{c}	2.09 ^{b}	2.68 ^{b}	1.87 ^{c}
	20	2.02 ^{b}	2.42 ^{a}	3.24 ^{a}	2.10 ^{b}
	30	2.23 ^{a}	2.44 ^{a}	3.27 ^{a}	2.19 ^{ab}
	40	2.28 ^{a}	2.42 ^{a}	3.3 ^{a}	2.31 ^{a}
Site mean		2.06	2.35	3.12	2.12
l.s.d.		0.14**	0.12**	0.24*	0.18**
Seed size @ 12% moisture (g/100 seeds)	10	20.2 ^{c}	18.5 ^{a}	14.8 ^{a}	21 ^{a}
	20	20.2 ^{c}	18.4 ^{a}	15.2 ^{a}	21.3 ^{a}
	30	20.7 ^{b}	18.7 ^{a}	15.3.2 ^{a}	21.3 ^{a}
	40	21.3 ^{a}	18.6 ^{a}	15.1.6 ^{a}	21.6 ^{a}
Site mean		20.6	18.6	15.1	21.1
l.s.d.		0.4**	ns*	ns*	ns*
Oil (%)	10	20.5 ^{a}	20.5 ^{a}	16.3 ^{a}	20.6 ^{a}
	20	20.5 ^{a}	20.5 ^{a}	16.3 ^{a}	20.3 ^{a}
	30	20.3 ^{b}	20.3 ^{ab}	16.4 ^{a}	20.5 ^{a}
	40	20.1 ^{b}	20.2 ^{b}	16.4 ^{a}	20.1 ^{a}
Site mean		20.4	20.4	16.3	20.4
l.s.d.		0.2*	0.2**	ns*	ns*
Protein (%)	10	40.2 ^{b}	42.5 ^{b}	39.6 ^{a}	42.2 ^{a}
	20	40.2 ^{b}	42.5 ^{b}	39.6 ^{a}	42.3 ^{a}
	30	40.9 ^{a}	42.8 ^{ab}	39.8 ^{a}	42.6 ^{a}
	40	40.9 ^{a}	42.9 ^{a}	39.7 ^{a}	43.1 ^{a}
Site mean		40.5	42.7	39.7	42.5
l.s.d.		0.4**	0.3*	ns*	ns*

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

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

Conclusions

Moonbi$^{\phi}$ and Richmond$^{\phi}$ are the latest releases from the ASBP in 2010 and 2013 respectively. They are noted for their improved yield performance and seed quality characteristics, which includes larger seed size and a clear hilum. They have high protein levels, which are suited to the more lucrative human consumption markets along with added disease tolerance – especially to powdery mildew, which is common on the Liverpool Plains and in the Narrabri production areas.

Yields of Richmond$^{\phi}$ were significantly higher than Moonbi$^{\phi}$ at all SD's tested in the Liverpool Plains growing region. Moonbi$^{\phi}$ offers a yield advantage in the Narrabri growing region, particularly if SD is delayed.

Richmond$^{\phi}$ has shown its superior key seed traits of size and protein compared with other genotypes across a wide range of SDs, plant populations and seasonal conditions.

The severe disease that caused the third season experiments to be abandoned, and the variability in some data has highlighted the lack of understanding about some of the fluctuations. These findings are part of a comprehensive investigation that aims to develop regionally specific regional agronomic management recommendations for recent variety releases from the ANSB.

Acknowledgements

These experiments were part of the project 'Northern pulse agronomy initiative – NSW', DAN00171, 2012–17, a joint investment by NSW DPI and GRDC.

Technical assistance from Craig Chapman, Joe Morphew, Stephen Beale, Pete Formann, Rosie Holcombe, Jim Murphy, Joel Hargreaves and Dave Eglington (all NSW DPI) is gratefully acknowledged. Thank you to Steven Harden (NSW DPI Tamworth) for experiment design and analysis. Field preparation, irrigation and management were provided by Scott Goodworth and staff at Liverpool Plains Field Station ('Breeza') and Des Magann and staff at the Australian Cotton Research Institute (Narrabri). Moonbi$^{\phi}$ seed supplied by PBAgrifoods, Toowoomba, Queensland. Richmond$^{\phi}$ seed supplied by Seednet. Quality testing was conducted by Futari Grain Technology Services – Narrabri.

Contact

Kathi Hertel
Trangie Agricultural Research Centre, Trangie
kathi.hertel@dpi.nsw.gov.au
02 6880 8000

Evaluating fipronil as a seed dressing for lucerne crown borer (*Zygrita diva*) management in soybeans – 2015/16 and 2016/17

Kathi Hertel[1], Hugh Brier[3], Mitch Whitten[2], Joe Morphew[2] and Steven Harden[4]

[1]NSW DPI Trangie
[2]NSW DPI Narrabri
[3]QDAF Kingaroy, Queensland
[4]NSW DPI Tamworth

Key findings

- Soybean yields were reduced by 50% and seed size by 16% on untreated seed compared with seed treated with fipronil (e.g. Legion®), in 2015.
- Where lucerne crown borer (LCB) infestation was heavy, fipronil seed treatment at 100 mL/100 kg of seed reduced infestation levels from 86% to 38%, girdling (stem ring barking) from 70% to 21% and plant lodging from 31% to 5%.
- Fipronil seed dressing had no negative effect on nodulation.
- Crop senescence was hastened where seed was untreated or low concentrations of fipronil were used.
- Crop maturity was delayed by up to eight days in healthier crop protected from LCB by high concentrations of fipronil seed dressing.
- Where LCB pressure was low, the fipronil concentration had no significant effect on yield or quality.

Introduction

The 'Northern pulse agronomy initiative – NSW' (DAN00171) is a joint project between NSW DPI, Queensland Department of Agriculture and Fisheries (QDAF) and Grains Research and Development Corporation (GRDC). The project's broad objectives include identifying management strategies to optimise yields and to develop agronomic recommendations to improve crop reliability.

LCB (Figure 1) is a sporadic soybeans pest capable of causing major yield losses. Infestation levels can be greater than 80% of plants infested.

Figure 1. Adult lucerne crown borer (*Zygrita diva*).
Source: K. Hertel, NSW DPI.

Managing LCB in soybeans focuses on cultivation to break up and bury stubble to kill larvae in the lower stem and roots. However, the increased adoption of zero-till has also increased LCB as they survive over winter. Monitoring for emerging larvae and adults is generally undertaken in late spring/

early summer. Chemical control is generally not effective and not conducive to fostering beneficial insect populations. It also does not comply with Helicoverpa resistance management strategies.

At Breeza, LCB caused significant damage in soybeans in the 2014/15 season. This presented the opportunity for collaboration between NSW DPI and QDAF to evaluate the efficacy of Legion® seed dressing (50 g/L fipronil) to control LCB. At this time, no insecticides were registered or under permit to control LCB in soybean .

Figure 2. Lucerne crown borer (*Zygrita diva*) larva in soybean stem.
Source: K. Hertel, NSW DPI.

Legion® is registered as a seed treatment for redlegged earth mite (*Halotydeus destructor*) in canola, and false wireworm (*Pterohelaeus darlingensis* and *Gononcephalum macleayi*) in sorghum and sunflowers.

A total of six experiments to evaluate Legion® seed dressing in soybeans were conducted in the 2015/16 and 2016/17 summer seasons at four locations: Breeza, Narrabri and Grafton in NSW, and Kingaroy in Queensland. This report shows the results of the experiments conducted at Breeza and Narrabri in 2015/16 and 2016/17, respectively.

Site details

Locations	Breeza 2015/16 – Liverpool Plains Field Station Narrabri 2016/17 – Australian Cotton Research Institute	
Farming system	Irrigated raised beds	
In-crop rainfall	Breeza 2015/16	Sowing date (SD) 1: 295.4 mm SD2: 409.4 mm
	Narrabri 2016/17	207 mm
Mean maximum temperature		
	Breeza 2015/16	SD1: 32.2°C SD2: 31.8°C
	Narrabri 2016/17	33.6°C
Mean minimum temperature		
	Breeza 2015/16	SD1: 16.1°C SD2: 16.1°C
	Narrabri 2016/17	18.1°C
Harvest date (days after sowing – DAS)		
	Breeza 2015/16	SD1: 25 May 2016 (197 DAS) SD2: 25 May 2016 (163 DAS)
	Narrabri 2016/17	2 May 2017 (158 DAS)

Irrigation	Experiments were sown into pre-watered fields with a full soil moisture profile. Each then received in-crop irrigations as required throughout the growing season.
Experiment designs	2015/16: Split plot randomised design with sowing date as the main block and fipronil rates as the sub-plots; three replications. 2016/17: Complete randomised block design; three replications.
Plant population	Target: 30 plants/m^2 (sowing rates adjusted for seed size and germination percentage).

Treatments

Table 1. Fipronil evaluation experiment treatments – 2015/16 and 2016/17.

Experiment	Breeza 2015/16	Narrabri 2016/17
Sowing date/s	SD1: 10 Nov 2015 SD2: 14 Dec 2015	24 Nov 2016
Variety	Moonbi	Moonbi, Richmond, Soya 791
Rate of fipronil (g/kg seed)	Nil 50 100	Nil 100

Assessments

Lucerne crown borer abundance

Plants from SD1 and SD2 were assessed for LCB presence/damage on two and three occasions respectively throughout the season. The most definitive data was obtained when plants were assessed at harvest on 25 May 2016. Immediately before harvest in each plot, plants from a five metre length from two rows (10 m total) were assessed for girdling and lodging, the latter being girdled (ringbarked) plants that had fallen over. Plots were then harvested, which cut the stalks just above ground level. This allowed all stems to be assessed for the presence or absence of LCB.

Infested plants were characterised by the presence of discoloured pith (dark purple or orange) in the severed stalks. In contrast, pith in uninfested plants was pale cream. The external stem colour of infested and uninfested plants was also recorded.

Nodulation

Nodulation was assessed when each SD reached early flowering. Twenty plants were selected at random, dug up and the roots washed. The root system was assessed in two sections: above and below 5 cm soil depth.

Nodulation was scored on a 0–5 scale.

Score 0 = zero nodules present in upper and lower lateral root sections

Score 5 = >10 nodules in upper lateral root system with >10 nodules in the lower root section

Results – Breeza 2015/16

Crop establishment

Crop emergence was rapid and uniform after each SD. Time of sowing and the fipronil application rate had no significant effect on crop establishment (Tables 2 and 3).

Nodulation

Seed was inoculated with peat-based Group H rhizobia prior to sowing. Nodulation scores were assessed 69 DAS and 59 DAS for SD1 and SD2 respectively. Sowing date and the fipronil concentration had no significant effect on root nodulation (Tables 2 and 3). Nodules were all coloured pink inside, indicating nitrogen fixation activity. There was no significant interaction between SD and fipronil application rate (data not shown).

Physiological maturity

Physiological maturity was recorded when 95% of plants had reached their mature pod colour (P95). Time of sowing had a significant effect on the time to physiological maturity (Table 2). The early November planting date, SD1, reached physiological maturity in May, equivalent to 190 days after planting; SD2 reached physiological maturity 155 days after planting.

The fipronil application rate significantly affected crop development by slowing the time to physiological maturity. The physiological maturity of the crop sown with seed treated with 100 g fipronil/kg seed was eight days later than the untreated seed (Table 3). The poor health of untreated plants was the likely cause of early senescence.

There was no significant interaction between sowing date and rate of fipronil on the time to crop maturity (data not shown).

Yield and seed quality

There was no significant interaction between sowing date and fipronil rate on yield or seed size (data not shown).

Time of sowing did not significantly affect the yield or seed size of Moonbi$^{\Phi}$ (Table 2); however, treatments with fipronil did have a significant effect on both yield and seed size (Figure 1). The yield from soybean treated with fipronil at 100 g/kg seed was double that of untreated seed.

Fipronil-treated (100 g /kg) seed size was 16% larger compared with the untreated seed (Figure 1).

There were marked visual differences in plants with those in plots with the highest fipronil concentration appearing much healthier compared with other treatments, and had noticeably more pods.

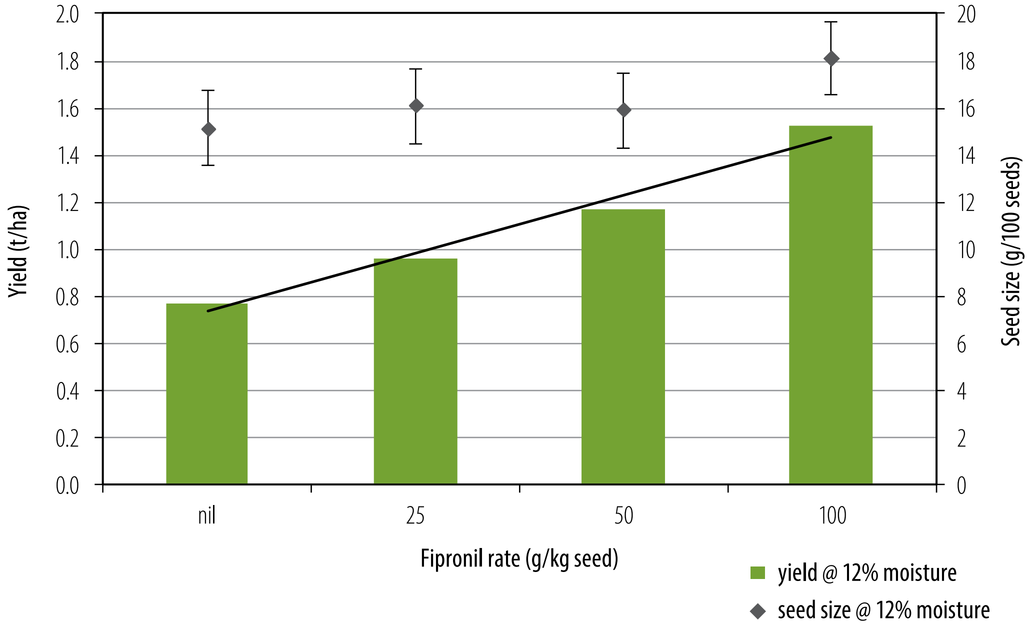


Figure 3. Effect from fipronil rate on yield and seed size at Breeza – 2015/16.
Error bars denote least significant difference (l.s.d.).
Yield l.s.d. ($P<0.001$) = 0.41 t/ha; seed size l.s.d. ($P<0.001$) = 1.58

Table 2. Sowing date effect on establishment, yield, seed size, root nodulation and time to maturity at Breeza – 2015/16.

Sowing date	Establishment (plants/m^2)	Root nodulation score (/5)	Yield (t/ha)	Seed size (g/100 seeds)	Days to physiological maturity
SD1: 10 November	23 ^{a}	1.3 ^{a}	1.02 ^{a}	15.8 ^{a}	190 ^{a}
SD2: 14 December	21 ^{a}	0.2 ^{a}	1.18 ^{a}	16.8 ^{a}	155 ^{b}
Site mean	22	0.8	1.10	16.3	173
l.s.d.	ns*	ns*	ns*	ns*	10*

Values with the same letter are not significantly (ns) different at 95% – * ($P<0.05$) confidence levels

Table 3. Effects of fipronil rate on establishment, yield, seed size, root nodulation and time to maturity at Breeza – 2015/16.

Rate of fipronil (g/kg seed)	Establishment (plants/m^2)	Root nodulation score (/5)	Yield (t/ha)	Seed size (g/100 seeds)	Days to physiological maturity
nil	23 ^{a}	0.6 ^{a}	0.76 ^{c}	15.1 ^{b}	176 ^{a}
25 g	22 ^{a}	0.7 ^{a}	0.96 ^{bc}	16.0 ^{b}	175 ^{ab}
50 g	21 ^{a}	0.9 ^{a}	1.16 ^{b}	15.9 ^{b}	171 ^{bc}
100 g	23 ^{a}	0.8 ^{a}	1.52 ^{a}	18.1 ^{a}	168 ^{c}
Site mean	22	0.8	1.10	16.3	173
l.s.d.	ns*	ns*	0.21**	1.6*	4*

Values with the same letter are not significantly different at 99.9% – ** ($P<0.001$) or 95% – * ($P<0.05$) confidence levels

Pest abundance and damage

Plant assessments during the experiment revealed a marked decrease in the number of live LCB larvae in stems in 50 g/kg and 100 g/kg fipronil-treated plants. There was a clear decrease in larval size, indicating delayed successful larvae establishment, and increased larval mortality (data not shown), with dead larvae being shrunken and black (Figure 4).

Figure 4. Dead lucerne crown borer (*Zygrita diva*) larva (5 mm).
Source: H. Brier, QDAF.

The percentage of LCB-infested plants averaged 62% across all plots in both experiments, with no significant difference between the two sowing dates (Table 4). However, a significantly higher percentage of plants were girdled (ringbarked) and lodged in SD2 compared with SD1 due to LCB infestation.

Table 4. Effect from sowing date on percentage of infestation, girdled plants and crop lodging at Breeza – 2015/16.

Sowing date	Infested plants (%)	Girdled plants (%)	Lodging (%)
SD1: 10 November	59.3 ^{a}	31.1 ^{b}	6.5 ^{b}
SD2: 14 December	64.0 ^{a}	45.1 ^{a}	16.1 ^{a}
Site mean	61.7	38.1	11.3
l.s.d.	ns*	5.7**	3.6**

Values with the same letter are not significantly different (ns) at 99.9%; ** (*P*<0.001) or 95%; * (*P*<0.05) confidence levels

In both experiments, the effects from fipronil on the percentage of infested plants, girdled plants and crop lodging was rate dependant (Table 5 shows the averages for both experiments). The high concentration of fipronil delayed girdling with just 17.6% of plants affected compared with 57.3% in the untreated treatment. Comparing the same treatments, there was a six-fold difference in subsequent lodging.

Table 5. Impact of fipronil rate on percentage of infested and girdled plants and lodging at Breeza – 2015/16.

Rate of fipronil (g/kg seed)	Infested plants (%)	Girdled plants (%)	Lodging (%)
nil	82.1 ^{a}	57.3 ^{a}	20.9 ^{a}
25 g	75.4 ^{a}	47.4 ^{b}	13.2 ^{b}
50 g	53.8 ^{b}	30.0 ^{c}	7.4 ^{c}
100 g	35.4 ^{c}	17.6 ^{d}	3.6 ^{d}
Site mean	61.7	38.1	11.3
l.s.d.	9**	8.1**	5.1**

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

These results for SD1 and SD2 clearly demonstrate the effectiveness of fipronil for protection against LCB incursions in soybeans with yield doubling at the highest rate versus the untreated control, and a commensurate reduction in LCB infestation and damage (Table 6).

Table 6. Interaction between sowing date (SD) and fipronil rate on infestation, girdled plants and crop lodging at Breeza – 2015/16.

Rate of fipronil (g/kg seed)	Infested plants (%)		Girdled plants (%)		Lodging (%)	
	SD1	SD2	SD1	SD2	SD1	SD2
nil	78.2 ^{a}	85.9 ^{a}	44.3 ^{a}	70.4 ^{a}	10.5 ^{bc}	31.2 ^{a}
25 g	71.1 ^{a}	79.6 ^{a}	41.3 ^{a}	53.6 ^{a}	9.0 ^{c}	17.5 ^{b}
50 g	54.8 ^{a}	52.8 ^{a}	24.1 ^{a}	35.9 ^{a}	4.3 ^{c}	10.6 ^{bc}
100 g	33.0 ^{a}	37.8 ^{a}	14.6 ^{a}	20.5 ^{a}	2.1 ^{c}	5.1 ^{c}
Site mean	59.3	64	31.1	45.1	6.5	16.1
l.s.d.	*ns	*ns	*7.24			

Values with the same letter are not significantly different (ns) at 95%; * (*P*<0.05) confidence levels

Results – Narrabri 2016/17

Crop establishment

The Narrabri site was sown on 24 November. Seed bed moisture was ideal after pre-watering on 17 November with a soil temperature of 24.1 °C at 9:00 am (AEST). Crop establishment was measured 18 days after sowing at the two trifoliate leaf stage (V2). All varieties exceeded the target population of 35 plants/m^2 (Table 7).

Yield and seed quality

The Narrabri site was harvested on 2 May 2017 (158DAS); the average yield was 2.86 t/ha. There was no significant difference in yield between Richmond$^{\Phi}$ and Soya 791, but both were significantly greater than Moonbi$^{\Phi}$ (Table 7). The fipronil rate did not significantly affect yield (Table 7).

There was no significant difference in seed size between Richmond$^{\Phi}$ and Moonbi$^{\Phi}$; Soya 791 was significantly smaller (Table 7). The fipronil rates had no significant effect on seed size (Table 8).

Pest abundance and damage

Pest damage was measured on 6 February 2017 (73DAS). At this time, the differences in maturity between the varieties were evident. Moonbi$^{\Phi}$ was at growth stage (GS) R4.3 (full pod development, just before visible seed development), Richmond$^{\Phi}$ – GS R2.5 (flowering, just before pod development) and Soya 791 GS – R2.4 (flowering).

Overall, there were low levels of LCB in the experiment, averaging 1.3%. Soya 791 had the highest number of insects (3.9% of plants affected), which was significantly higher than Moonbi$^{\Phi}$ (no plants affected) and Richmond$^{\Phi}$ (0.1% of plants affected) (l.s.d. = 1.3%; $P<0.001$) (Table 7).

In a separate experiment in 2014/15, levels of infested plants showed distinct differences between varieties. Infestation levels appeared to relate to the stage of plant growth at the time of egg laying.

Similarly, in this experiment there were significant differences between infestation levels of the varieties tested; Moonbi$^{\Phi}$ and Richmond$^{\Phi}$ have similar maturity, much quicker than Soya 791. These differences might influence how attractive the plants are to adult LCB at egg laying early in the season, and explain the apparent preference and subsequent infestation in Soya 791.

The rate of fipronil had no significant effect on the level of infestation (Table 8).

Table 7. Effect of variety on establishment, yield, seed size and level of LCB infestation at Narrabri – 2016/17

Variety	Establishment (plants/m^2)	Yield (t/ha)	Seed size (g/100 seeds)	No. infested plants (%)
Moonbi$^{\Phi}$	54^{a}	2.45^{b}	21.5^{a}	0.0^{b}
Richmond$^{\Phi}$	50^{a}	3.24^{a}	22.2^{a}	0.1^{b}
Soya 791	35^{b}	2.89^{a}	18.0^{b}	3.9^{a}
Site mean	47	2.86	20.6	1.3
l.s.d.	9*	0.4*	0.9**	1.1**

Values with the same letter are not significantly different at 99.9% – ** ($P<0.001$) or 95% – * ($P<0.05$) confidence levels

Table 8. Impact of fipronil rate on establishment, yield, seed size and level of LCB infestation at Narrabri – 2016/17.

Rate of fipronil (g/kg seed)	Establishment (plants/m^2)	Yield (t/ha)	Seed size (g/100 seeds)	No. infested plants (%)
nil	47 ^{a}	2.89 ^{a}	20.5 ^{a}	1.3 ^{a}
100 g	46 ^{a}	2.83 ^{a}	20.6 ^{a}	1.4 ^{a}
Site mean	47	2.86	20.6	1.3
l.s.d.	ns*	ns*	ns*	ns*

Values with the same letter are not significantly (ns) different at 95% – * ($P<0.05$) confidence levels

Conclusions

Fipronil seed dressing has the potential to reduce LCB levels and the consequent severity of damage, including stem girdling and crop lodging.

It was most effective at the highest rate – 100 g/kg seed. The marked rate response in these experiments show that rates lower than 100 g/kg seed would give inferior performance, particularly at the 50 g/kg seed rate.

The information contained in this report and from experiments conducted at Grafton (NSW) and Kingaroy (Queensland) was subject to a Minor Use Permit from the Australian Pesticide and Veterinary Medicines Authority (PER83319 expiry 31 January 2018).

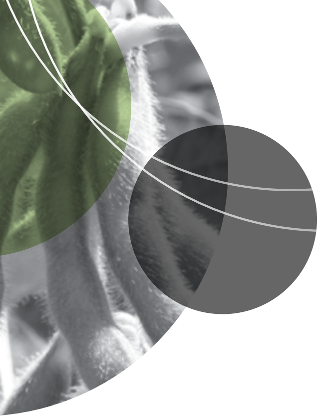
Acknowledgements

These experiments were part of the project 'Northern pulse agronomy initiative – NSW', DAN00171, 2012–17, a joint investment by NSW DPI and GRDC.

Technical assistance from Stephen Beale, Rosie Holcombe and Stacey Cunningham (all NSW DPI) and Hugh Brier and his team including Liz Williams, Joezef Wessels and Trevor Volp (all QDAF) is gratefully acknowledged. Note that the QDAF personnel were operating under GRDC *Northern Grains IPM* project DAQ00196, for which LCB was identified as a key pest of interest. Field preparation, irrigation and management were provided by Scott Goodworth and staff at Liverpool Plains Field Station, Breeza and Des Magann and staff at Australian Cotton Research Institute, Narrabri. Moonbi$^{\phi}$ and Soya791 seed was supplied by PB Agrifood. Richmond$^{\phi}$ seed supplied Auswest Seeds. Quality testing was conducted by Futari Grain Technology Services – Narrabri.

Contact

Kathi Hertel
Trangie Agricultural Research Centre, Trangie
kathi.hertel@dpi.nsw.gov.au
02 6880 8000



Mungbean

Evaluating mungbean varieties for northern NSW and the Liverpool Plains – 2013/14 and 2014/15

Kathi Hertel[1], Craig Chapman[2], Joe Morphew[2] and Steven Harden[3]

[1]NSW DPI Trangie
[2]NSW DPI, Narrabri
[3]NSW DPI, Tamworth

Key findings

- There were no significant differences between Jade-AU$^{(\phi)}$ and Crystal$^{(\phi)}$ in yield, seed size, protein content, plant height and height above ground of the lowest pod in 2013/14 and 2014/15.
- There were no significant differences between Celera II-AU$^{(\phi)}$ and Green Diamond$^{(\phi)}$ yield, seed size, protein content, and height above ground of the lowest pod in 2013/14.
- Variations in protein content were relatively small across genotypes. Environmental conditions at individual experiment sites and across seasons appear to have the main influence on seed protein content.
- Potential harvest difficulties posed by the short height of the lowest pod in Regur were evident, regardless of the production system.

Introduction

The 'Northern pulse agronomy initiative – NSW' (DAN00171) is a joint project between NSW DPI and the Grains Research and Development Corporation (GRDC). While pulse crops are recognised as vital components of modern farming systems, mungbean is still regarded largely as an opportunistic crop rather than an important integral component of farming systems in the northern grains region.

The focus of this project is to develop crop agronomy guidelines that enable growers to improve crop reliability, productivity and profitability across growing regions. This includes experiments designed to identify the constraints and effects of different agronomic management practices. The project aimed to evaluated the agronomic performance of older, established varieties, advanced breeding lines and newly released varieties from the 'National mungbean improvement program' (NMIP) (DAQ00172).

Findings from this project will be used to develop improved agronomic management recommendations to increase the reliability and profitability of mungbean production in regional farming systems.

Site details

Locations	'Windy Station', Pine Ridge (2013/14) Australian Cotton Research Institute, Narrabri (2014/15) Liverpool Plains Field Station, Breeza (2013/14 and 2014/15)
Site characteristics	see Table 1

Dryland	The experiment was located at 'Windy Station' near Pine Ridge on the southern Liverpool Plains.
Irrigation	Experiments located at Breeza and Narrabri were planted into pre-watered fields with full soil moisture profiles. Each site received a single irrigation at early flowering.
Trial design	Randomised complete block design; three replications.
Note	For these experiments, seed size is expressed as the weight (grams) of 100 seeds.

Table 1. Experiment site characteristics – 2013/14 and 2014/15.

Site	Pine Ridge	Breeza	Breeza	Narrabri
Season	2013/14	2013/14	2014/15	2014/15
Farming system	Dryland	Irrigation	Irrigation	Irrigation
Configuration	Continuous rows on flat	Raised bed	Raised bed	Raised bed
Row spacing (cm)	100	90	60	100
In-crop rainfall (mm)	359	137	181	270.2
Mean maximum temperature (°C)	35.1	30	28.6	34.5
Mean minimum temperature (°C)	15.2	14.4	12.9	18.8
Planting date	12 December 2013	6 December 2013	20 January 2015	23 January 2015
Harvest date (days after sowing – DAS)	6 May 2014 (144 DAS)	16 April 2014 (130 DAS)	13 May 2015 (112 DAS)	26 May 2015 (122 DAS)

Treatments

Table 2. Mungbean genotypes evaluated – 2013/14 and 2014/15.

Site Season	Pine Ridge 2013/14	Breeza 2013/14	Breeza 2014/15	Narrabri 2014/15
Genotypes	Berken	Berken	Berken	Berken
	Crystal$^{\phi}$	Crystal$^{\phi}$	Crystal$^{\phi}$	Crystal$^{\phi}$
	Celera II-AU$^{\phi}$	Celera II-AU$^{\phi}$	Jade AU$^{\phi}$	Jade AU$^{\phi}$
	Green Diamond$^{\phi}$	Green Diamond$^{\phi}$	Satin II$^{\phi}$	Satin II$^{\phi}$
	Jade AU$^{\phi}$	Jade AU$^{\phi}$	M010047	M010047
	Regur	Regur	M01157	M01157
	Satin II$^{\phi}$	Satin II$^{\phi}$	Regur	–

Genotypes

Berken (1975) is popular for the sprouting market. Its bright green, medium–large seeds produces large sprouts that buyers prefer. Seed size is 5.0–6.7 g/100 seeds Berken is susceptible to powdery mildew, tan spot and halo blight, and can also be prone to lodging and weather damage.

Celera II-AU$^{\phi}$ (2014) is a small-seeded, shiny mungbean released to replace Green Diamond$^{\phi}$ and Celera$^{\phi}$. Seed size is 3.2–3.5 g/100 seeds. It has the best available halo blight resistance of any current variety, with an MR (moderately resistant) rating. It is MS (moderately susceptible) to tan spot and powdery mildew.

Crystal$^{\phi}$ (2008) has widespread regional adaptation. It is a relatively tall, erect genotype, suitable for both spring and summer plantings. Seed size is usually within between 5.9–7.1 g/100 seeds. Crystal$^{\phi}$ has low levels of hard seed, increasing its attractiveness to the cooking and processing markets.

Green Diamond$^{\phi}$ (1997) is a quick maturing, small-seeded variety, with hard seed levels as high as 70%. Seed size is 3.3–3.7 g/100 seeds. At the time of release, Green Diamond$^{\phi}$ had similar grain quality to the now outclassed Celera$^{\phi}$, but demonstrated superior agronomic traits including tall erect growth habit with higher pods and improved lodging tolerance. It is MS to powdery mildew, tan spot and halo blight.

Jade-AU$^{\phi}$ (2013) is a large-seeded, bright green mungbean. Seed size is 6.0–7.3 g/100 seeds. Broadly adapted to the northern grains region, it is suitable for both spring and summer plantings. It has an equivalent grain quality to Crystal$^{\phi}$ but NMIP experiments have demonstrated consistent yield increases of 12% across northern New South Wales. Jade-AU$^{\phi}$ has the best available combined suite of disease resistance of all current commercial varieties. It is MS to powdery mildew, which is a better rating than Crystal$^{\phi}$, and for tan spot and halo blight it is MS, which is equivalent to Crystal$^{\phi}$.

Satin II$^{\phi}$ (2008) is a dull-seeded mungbean grown for a small niche sprouting market. Released as a replacement for Satin$^{\phi}$, it has improved seed quality including increased seed size (5.9–7.1 g/100 seeds), improved lodging resistance and offers both significant yield increases (20%) and disease advantages (powdery mildew and tan spot) over Satin$^{\phi}$.

Regur (1975) is a black gram pea that is a closely related species to mungbean, but with dull grey–black seeds. Seed size is 4.5–5.6 g/100 seeds. The seed has good resistance to cracking and weather damage at maturity. The indeterminate growth habit produces an extended flowering period and uneven maturation pattern in some seasons. Its characteristic low set bottom pods on the plant can cause harvest difficulties.

Results

Crop establishment

The target population at Pine Ridge was 25 plants/m^2. Crop establishment was measured 26 days after planting with an average of 24 plants/m^2 (Table 3). There was no significant difference between any genotype.

The target population under irrigation at Breeza and Narrabri was 35 plants/m^2. Establishment in these experiments varied from 39 plants/m^2 to 55 plants/m^2. Target populations were exceeded in all experiments, but with no significant difference between genotypes, except at Breeza in 2013/14, where Green Diamond$^{\phi}$ averaged 72 plants/m^2. This is believed to be due to an error in packaging during trial preparation.

Table 3. Mungbean crop establishment – 2013/14 and 2014/15.

Genotype	**Plant population achieved (plants/m^{2})**			
	Pine Ridge 2013/14	**Breeza 2013/14**	**Breeza 2014/15**	**Narrabri 2014/15**
Berken	19 ^{a}	47 ^{b}	55 ^{a}	46 ^{a}
Celera II-AU	21 ^{a}	50 ^{b}	-	-
Green Diamond	29 ^{a}	72 ^{a}	-	-
Crystal	29 ^{a}	49 ^{b}	-	43 ^{a}
Jade AU	25 ^{a}	47 ^{b}	53 ^{a}	43 ^{a}
Regur	20 ^{a}	48 ^{b}	54 ^{a}	-
Satin II	22 ^{a}	49 ^{b}	49 ^{a}	50 ^{a}
M010047	–	–	49 ^{a}	41 ^{a}
M01157	–	–	54 ^{a}	39 ^{a}
Site mean	24	51	52	44
l.s.d.	ns*	10**	ns*	ns*

Values with the same letter are not significantly (ns) different at 99.9%
** (*P*<0.001) or 95%
* (*P*<0.05) confidence levels

Yield and grain quality

At Pine Ridge, the average yield was 1.16 t/ha (Table 4). Jade-AU$^{\Phi}$ was the highest yielding genotype at 1.45 t/ha. There was no significant yield difference between Jade-AU$^{\Phi}$, Crystal$^{\Phi}$ and Berken.

Seed size was not significantly different between Jade-AU$^{\Phi}$, Crystal$^{\Phi}$, Satin II$^{\Phi}$ and Berken. In comparison, the Regur seed size was significantly smaller (5.54 g/100 seeds). There was no significant difference between the small-seeded genotypes Celera II-AU$^{\Phi}$ and Green Diamond$^{\Phi}$ at 3.27 g/100 seeds and 3.94 g/100 seeds respectively.

The yields of the three experiments at Breeza and Narrabri averaged between 0.82 and 0.93 t/ha; the order of genotype ranking varied.

There was no significant difference in yield, seed size or seed protein content between Jade-AU$^{\Phi}$ and Crystal$^{\Phi}$ in all experiments.

Table 4. Yield (@12% moisture) and seed quality of mungbean genotypes - 2013/14 and 2014/15.

	Genotype	**Pine Ridge 2013/14**	**Breeza 2013/14**	**Breeza 2014/15**	**Narrabri 2014/15**
Yield (t/ha)	Berken	1.12 ^{ab}	0.81 ^{a}	0.76 ^{cd}	0.83 ^{a}
	Celera II-AU	0.78 ^{bc}	0.45 ^{b}	–	–
	Green Diamond	0.99 ^{ab}	0.73 ^{ab}	–	–
	Crystal	1.42 ^{ab}	0.98 ^{a}	–	1.01 ^{a}
	Jade AU	1.45 ^{a}	0.94 ^{a}	0.69 ^{d}	0.99 ^{a}
	Regur	0.77 ^{bc}	0.84 ^{a}	1.41 ^{a}	-
	Satin II	1.31 ^{a}	0.94 ^{a}	0.62 ^{d}	0.95 ^{a}
	MO10047	–	–	0.98 ^{b}	0.95 ^{a}
	MO1157	–	–	0.86 ^{bc}	0.86 ^{a}
Site mean		1.16	0.82	0.89	0.93
l.s.d.		0.43*	0.25*	0.15**	ns*
Seed size (g/100 seeds)	Berken	6.73 ^{a}	5.83 ^{b}	5.35 ^{c}	6.53 ^{b}
	Celera II-AU	3.27 ^{c}	3.72 ^{d}	–	–
	Green Diamond	3.94 ^{c}	3.94 ^{d}	–	–
	Crystal	6.73 ^{a}	6.11 ^{a}	–	6.61 ^{b}
	Jade AU	6.97 ^{a}	6.15 ^{a}	5.67 ^{c}	6.61 ^{b}
	Regur	5.54 ^{b}	4.92 ^{c}	4.25 ^{d}	-
	Satin II	6.52 ^{a}	6.04 ^{a}	5.48 ^{c}	6.36 ^{b}
	MO10047	–	–	7.08 ^{a}	6.85 ^{a}
	MO1157	–	–	6.38 ^{b}	7.19 ^{a}
Site mean		5.83	5.38	5.70	6.69
l.s.d.		0.65**	0.23**	0.57**	0.51*
Protein (%, dry matter basis)	Berken	26.3 ^{b}	–	18 ^{c}	14.8 ^{a}
	Celera II-AU	27.6 ^{a}	–	–	–
	Green Diamond	27.7 ^{a}	–	–	–
	Crystal	27.7 ^{a}	–	-	15.1 ^{a}
	Jade AU	27.6 ^{a}	–	19.3 ^{b}	15.0 ^{a}
	Regur	25.1 ^{c}	–	25.0 ^{a}	–
	Satin II	27.4 ^{a}	–	19.3 ^{b}	14.6 ^{a}
	MO10047	–	–	19.5 ^{b}	14.5 ^{a}
	MO1157	–	–	19.3 ^{b}	14.7 ^{a}
Site mean		27.1	–	20.1	14.8
l.s.d.		0.28**	–	0.57**	ns*

Values with the same letter are not significantly (ns) different at 99.9%
** ($P<0.001$) or 95%
* ($P<0.05$) confidence levels

Plant architecture

Overall plant height was measured in three of four experiments (Table 5). Average plant height in experiments receiving supplementary irrigation was up to 28% taller than heights in the dryland experiment. Similarly, the average height of the lowest pod above ground in the irrigated plots was up to 33% higher compared with the dryland site average.

In the dryland experiment at Pine Ridge there was no significant difference between the tallest genotypes, i.e. Jade-AU$^{\Phi}$ 44.4 cm, Satin II$^{\Phi}$ 43.3 cm, Crystal$^{\Phi}$ 40.6 cm and Regur 40.6 cm.

The height of the lowest pod in Regur was significantly lower than all other genotypes in 2013/14, with the exception of Berken at Pine Ridge. This characteristic can contribute to issues with harvest efficiency, particularly where the ground is uneven.

Table 5. Comparing plant architecture in mungbean genotypes – 2013/14 and 2014/15.

	Genotype	Pine Ridge 2013/14	Breeza 2013/14	Breeza 2014/15	Narrabri 2014/15
Plant height (cm)	Berken	32.8 ^{b}	45.6 ^{c}	–	54.4 ^{a}
	Celera II-AU	35.6 ^{b}	45.0 ^{c}	–	–
	Green Diamond	34.4 ^{b}	51.7 ^{b}	–	–
	Crystal	40.6 ^{ab}	55.0 ^{ab}	–	52.8 ^{a}
	Jade AU	44.4 ^{a}	57.8 ^{a}	–	54.9 ^{a}
	Regur	40.6 ^{ab}	48.9 ^{b}	–	-
	Satin II	43.3 ^{ab}	55.6 ^{ab}	–	58.4 ^{a}
	MO10047	–	–	–	54.3 ^{a}
	MO1157	–	–	–	55.8 ^{a}
Site mean		39.5	51.7	–	55.1
l.s.d.		8.9*	4.5**	–	ns*
Height above ground of lowest pod (cm)	Berken	20.6 ^{bc}	21.1 ^{b}	–	33.9 ^{a}
	Celera II-AU	21.1 ^{b}	26.1 ^{b}	–	-
	Green Diamond	22.8 ^{b}	25.0 ^{b}	–	-
	Crystal	28.3 ^{a}	36.1 ^{a}	–	30.7 ^{a}
	Jade AU	29.2 ^{a}	35.0 ^{a}	–	33.8 ^{a}
	Regur	17.2 ^{c}	18.9 ^{c}	–	–
	Satin II	30.0 ^{a}	34.4 ^{a}	–	38.0 ^{a}
	MO10047	–	–	–	34.4 ^{a}
	MO1157	–	–	–	22.7 ^{b}
Site mean		24.8	28.5	–	32.3
l.s.d.		4.1*	7.1**	–	9.1*

Values with the same letter are not significantly (ns) different at 99.9%
** ($P<0.001$) or 95%
* ($P<0.05$) confidence levels

Conclusions

Jade-AU$^{\phi}$ and Crystal$^{\phi}$ yields were not significantly different, achieving the number one ranking in three of the four experiments. Their seed size was largest in 2013/14, compared with other commercial varieties tested. Traits, such as plant height and lowest pod position were equivalent to, or greater than, those in other varieties. Jade-AU$^{\phi}$ remains the preferred large-seeded shiny variety for production in northern NSW and the Liverpool Plains. Crystal$^{\phi}$ remains a suitable second choice option, although its disease package is not as robust.

There was no significant difference in yield, seed size, seed protein content and height to lowest pod between Celera II-AU$^{\phi}$ and Green Diamond$^{\phi}$ in all experiments. Celera II-AU$^{\phi}$ is the preferred small-seeded shiny variety for production in northern NSW and the Liverpool Plains. It is a direct replacement for Green Diamond$^{\phi}$ and Celera$^{\phi}$.

Satin II$^{\phi}$ attained yields in the top three rankings of genotypes tested at all sites with the exception of Breeza in 2014/15. For height and position of lowest pods, it was ranked equal first with other genotypes.

Regur's characteristic low setting pods means management should include ground preparation that ensures clod-free level conditions to minimise harvest difficulties.

These experiments were planted on medium (60 cm) to wide (100 cm) row spacings. Rows at these spacings have been shown to reduce mungbean establishment by up to 30% compared with narrow (40 cm) rows. Crop establishment generally met or exceeded targeted populations in these experiments, an important factor in achieving potential yields in mungbean. (For further information see 'Mungbean row configuration x population × variety – Narrabri and the Liverpool Plains 2014/15', page 114 in this publication.)

These experiments were the first of the co-ordinated research program in project DAN00171, 'Northern pulse agronomy initiative – NSW', evaluating new mungbean varieties and their response to agronomic management practices for suitability and adaptation to different environments and regions in northern NSW'.

Acknowledgements

These experiments were part of the project 'Northern pulse agronomy initiative – NSW', DAN00171, 2012–17, with joint investment by NSW DPI and GRDC.

Technical assistance from Pete Formann, Rosie Holcombe, Jim Murphy, Joel Hargreaves and Dave Eglington (all NSW DPI) is gratefully acknowledged. Field preparation, irrigation and management were provided by Scott Goodworth and staff at the Liverpool Plains Field Station, Breeza and Des Magann and staff at the Australian Cotton Research Institute, Narrabri. Thanks to Romani Pastoral Company 'Windy Station', Pine Ridge for hosting the experiment in 2013/14 and crop manager Peter Winton for his assistance. Mungbean seed was kindly supplied by the Australian Mungbean Association. Experiment lines were provided by the National Mungbean Improvement Program. Quality testing was conducted by Futari Grain Technology Services at Narrabri.

Contact

Kathi Hertel
Trangie Agricultural Research Centre, Trangie
kathi.hertel@dpi.nsw.gov.au
02 6880 8000

Mungbean row configuration × population × variety – Narrabri and the Liverpool Plains 2014/15

Kathi Hertel[1], Craig Chapman[2], Joe Morphew[2] and Steven Harden[3]

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

Key findings

- Under a raised bed, supplementary flood irrigation system, row spacing had no significant effect on yield or seed size.
- Medium (60 cm) and wide (100 cm) row spacing significantly decreased established plant populations by up to 30% compared with narrower (40 cm) rows.
- Seed size at harvest of Satin II$^{\phi}$ was significantly larger than that of Jade-AU$^{\phi}$ at Breeza, but there was no significant difference at Narrabri.
- Established plant population affected mungbean yield in both experiments. The yield benefit of high populations (59 plants/m^2) compared with low populations (17 plants/m^2) was 0.57 t/ha at Breeza and 0.21 t/ha at Narrabri.
- Increasing mungbean plant population generally increased seed size, plant height and the height of the lowest pod.

Introduction

The 'Northern pulse agronomy initiative – NSW' (DAN00171) is a joint project between NSW DPI and the Grains Research and Development Corporation (GRDC). Less than 2% of the total crop area in northern NSW currently comprises summer pulse production. Mungbean make up the larger proportion of the summer pulse area compared with soybean and cowpea, however, agronomic performance is variable across regions, seasons and by water management.

Recent variety releases from the 'National Mungbean Improvement Program' (NMIP) have been developed for specific markets and diverse production environments. Jade-AU$^{\phi}$, released in 2013, is the current leading variety for bold, shiny mungbean and Satin II$^{\phi}$, released in 2008, is the leading variety for sprouting markets.

These experiments were designed to identify variety-specific management strategies to optimise yield, seed quality and plant architecture to aid harvest ability. The data will be used to develop sound regional agronomic management recommendations to improve mungbean yield, quality and reliability.

Site details

Locations	Breeza – Liverpool Plains Field Station Narrabri – Australian Cotton Research Institute	
Farming system	irrigated raised beds	
In-crop rainfall	Breeza Narrabri	251.0 mm 156.6 mm

	Mean maximum temperature		
		Breeza	31.4°C
		Narrabri	33.8°C
	Mean minimum temperature		
		Breeza	15.3°C
		Narrabri	18.1°C
	Irrigation	Both experiments were sown into pre-watered fields on raised beds with full soil moisture profiles. Each then received a supplementary irrigation at the late bud growth stage.	
	Sowing date	Breeza Narrabri	3 December 2014 17 December 2014
	Harvest date	Breeza Narrabri	15 April 2015 (132 days after sowing) 23 March 2015 (95 days after sowing)
	Trial design	Split plot design with row spacing as main block; three replications.	
Treatments	**Genotype**	Jade-AU$^{\phi}$ Satin II$^{\phi}$	
	Target population	10, 20, 30, 40 plants/m^2	
	Row spacing	40, 60, 100 cm	

Results

Row spacing

Establishment declined as row spacing increased above 40 cm at both sites (Table 1). Crop establishment was reduced by 30% at Breeza and 27% at Narrabri when the mungbean were sown in 100 cm rows compared with the 40 cm rows.

Row spacing did not significantly affect yield or seed size.

Overall plant height was significantly taller with 100 cm row spacing at Breeza compared with the two narrower spacings, whilst row spacing had no effect on crop height at Narrabri (Table 1).

Crop lodging was not observed at maturity. The height of the lowest pod varied with the different row spacings. The lowest pod height, (47 cm) was measured in the 60 cm row spacing at Breeza. In contrast, row configuration had no significant effect on plant architecture at Narrabri. This might be due to the shorter growing season at Narrabri (95 days) compared with Breeza (132 days).

Table 1. Effect of row configuration on establishment, yield, seed size and plant architecture – 2014/15.

	Row spacing (cm)	Breeza	Narrabri
Achieved population (plants/m^2)	40	43.8 ^{a}	48.0 ^{a}
	60	36.5 ^{b}	37.0 ^{b}
	100	31.1 ^{c}	35.0 ^{b}
Site mean		37.2	39.7
l.s.d.		4.5*	7*
Yield @ 12% moisture (t/ha)	40	1.81 ^{a}	1.12 ^{a}
	60	1.84 ^{a}	1.02 ^{a}
	100	1.73 ^{a}	1.02 ^{a}
Site mean		1.79	1.05
l.s.d.		ns*	ns*
Seed size (g/100 seeds)	40	9.0 ^{a}	8.3 ^{a}
	60	8.9 ^{a}	8.6 ^{a}
	100	8.9 ^{a}	8.5 ^{a}
Site mean		8.9	8.5
l.s.d.		ns*	ns*
Plant height (cm)	40	67 ^{b}	70 ^{a}
	60	66 ^{b}	73 ^{a}
	100	73 ^{a}	75 ^{a}
Site mean		69	73
l.s.d.		4*	ns*
Height above ground of lowest pod (cm)	40	50.2 ^{a}	50.6 ^{a}
	60	47.4 ^{b}	52.2 ^{a}
	100	53.7 ^{a}	48.7 ^{a}
Site mean		50.4	50.5
l.s.d.		4.6*	ns*

Note: Values with the same letter are not significantly (ns) different 95% - * ($P<0.05$) confidence levels

Genotype

The yield from Jade-AU$^{\phi}$ and Satin II$^{\phi}$ were not significantly different at either location in 2014/15 (Table 2). The Satin II$^{\phi}$ seed size was significantly larger than that of Jade-AU$^{\phi}$ at Breeza, but there was no significant difference at Narrabri. The two varieties did not differ in plant height or lowest pod height between experiments (Table 2).

Table 2. Effect of mungbean genotype on establishment, yield, seed size and plant architecture – 2014/15.

	Genotype	Breeza	Narrabri
Achieved population (plants/m^2)	Jade-AU	37^{a}	35^{b}
	Satin II	37^{a}	44^{a}
Site mean		37	40
l.s.d.		ns*	2**
Yield @12% moisture (t/ha)	Jade-AU	1.84^{a}	1.02^{a}
	Satin II	1.74^{a}	1.08^{a}
Site mean		1.79	1.05
l.s.d.		ns*	ns*
Seed size (g/100 seeds)	Jade-AU	8.2^{b}	8.5^{a}
	Satin II	9.6^{a}	8.4^{a}
Site mean		8.9	8.5
l.s.d.		0.12**	ns*
Plant height (cm)	Jade-AU	68^{a}	73^{a}
	Satin II	70^{a}	72^{a}
Site mean		68.5	73
l.s.d.		ns*	ns*
Height above ground of lowest pod (cm)	Jade-AU	50^{a}	50^{a}
	Satin II	51^{a}	51^{a}
Site mean		50.4	50.5
l.s.d.		ns*	ns*

Note: Values with the same letter are not significantly (ns) different at 99.9% – ** ($P<0.001$) or 95% – * ($P<0.05$) confidence levels

At Narrabri, the interaction between variety and population had a positive response on the height of the lowest pod. The plant's structure is represented in Figure 1. Each bar shows the overall plant height, with pods located in the upper canopy. The 'stem' indicates the position of the lowest pod on the plant. Total plant height was not affected by the target plant population but the position of the lowest pod increased as population increased above 10 plants/m^2 in both Jade-AU$^{\Phi}$ and Satin II$^{\Phi}$. A similar trend was observed at Breeza, but the differences were not significant (data not shown).

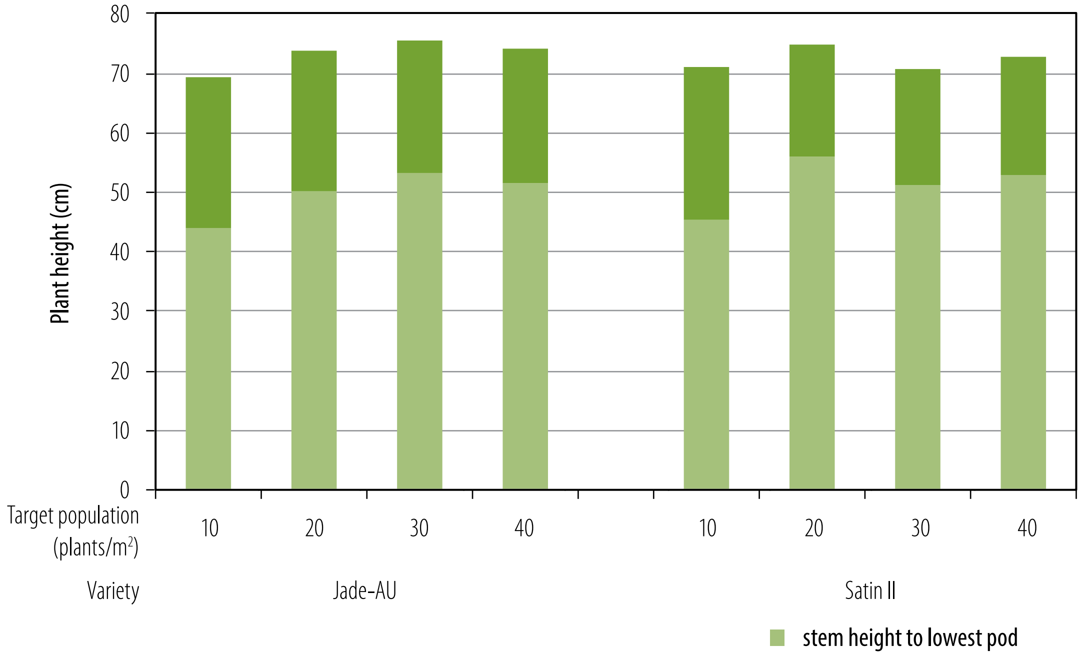


Figure 1. Interaction between genotype and plant population on plant height and height to lowest pod at Narrabri – 2014/15.
Total plant height ($P<0.05$) ns
Stem height to lowest pod l.s.d. ($P<0.05$) = 3.5 cm.

Plant population

Crop establishment exceeded the targeted population in both experiments with significant differences between each treatment (Table 3).

Yield generally increased as established plant population increased at both locations, but was only significant when going from a 30 plants/m^2 to 46 plants/m^2 or more at Breeza and at Narrabri from 20 plants/m^2 to 33 plants/m^2 or more (Table 3).

Achieved plant populations were similar in both locations; however, the yield reduction between the lowest and highest populations was 28% at Breeza and 18% at Narrabri (Table 3).

The flatter yield response and overall lower average yields at Narrabri are probably related to the shorter growing season (95 days) imposed by environmental factors compared with Breeza (132 days).

Plant populations above 30 plants/m^2 at Breeza and above 20 plants/m^2 at Narrabri resulted in increased seed size (Table 3).

Similarly, significant differences in increased plant height and the height of the lowest pod were associated with higher plant populations (Table 3). At Breeza, comparing the lowest population treatment with the highest, the difference in plant height was 7 cm and height to lowest pod was 9.2 cm (Table 3). These differences were smaller at Narrabri with 3.1 cm for plant height and 7 cm for height to lowest pod. These elevated mungbean pod heights would help to capture all seeds at harvest to maximise yield.

Table 3. Effect of population on establishment, yield, seed quality and plant architecture – 2014/15.

	Target population (plants/m²)	**Breeza**	**Narrabri**
Achieved population (plants/m²)	10	17^{d}	20^{d}
	20	30^{c}	33^{c}
	30	46^{b}	48^{b}
	40	56^{a}	59^{a}
Site mean		37	40
l.s.d.		3**	3**
Yield @ 12% moisture (t/ha)	10	1.49^{b}	0.94^{b}
	20	1.64^{b}	1.05^{a}
	30	1.98^{a}	1.07^{a}
	40	2.06^{a}	1.15^{a}
Site mean		1.79	1.05
l.s.d.		0.18**	0.1*
Seed size (g/100 seeds)	10	8.81^{b}	8.20^{b}
	20	8.86^{b}	8.46^{a}
	30	9.00^{a}	8.56^{a}
	40	9.05^{a}	8.62^{a}
Site mean		8.9	8.5
l.s.d.		0.17*	0.23*
Height (cm)	10	64.4^{c}	70.2^{b}
	20	67.9^{b}	74.4^{a}
	30	70.5^{ab}	73.2^{a}
	40	71.3^{a}	73.4^{a}
Site mean		68.5	72.8
l.s.d.		3**	2.7*
Height above ground of lowest pod (cm)	10	45.5^{c}	44.6^{b}
	20	50.1^{b}	53.0^{a}
	30	51.2^{b}	52.3^{a}
	40	54.7^{a}	52.1^{a}
Site mean		50.4	50.5
l.s.d.		2.82**	2.5**

Note: Values with the same letter are not significantly (ns) different at 99.9% - ** ($P<0.001$) or 95% - * ($P<0.05$) confidence levels

Conclusions

These experiments demonstrated the response of key mungbean varieties to management practices, including row spacing and plant population under supplementary irrigation.

Row spacing did not significantly affect yield or seed size. Low plant populations (20 plants/m² or less), yielded up to 28% less than those with higher populations (56–59 plants/m²).

Mungbeans characteristically short growing season and inherent plant structure limits the crop's grain production capacity. It is expected that a supplementary irrigation production system would improve the plant's ability to compensate for low populations. However, yield potential still appeared to be strongly related to the established plant population.

The height of the lowest pod is a key desirable attribute in Jade-AU⟨PBR⟩ and Satin II⟨PBR⟩. Maintaining adequate height above ground of low pods improves harvest efficiency and reduces the risk of quality downgrades due to soil contamination. The agronomic management practices evaluated in these experiments have shown no detrimental effects on this trait.

The two locations at which these experiments were conducted highlight the dominating influence of prevailing environmental factors on mungbean production. Differences in the length of crop season, 132 days at Breeza versus 95 days at Narrabri affected the duration of growth and development phases, thereby constraining the varieties' genetic potential. Further investigations into the interaction between environmental conditions and crop growth and development will be reported in the future.

Acknowledgements

These experiments were part of the project 'Northern pulse agronomy initiative – NSW', DAN00171, 2012–17, with joint investment by NSW DPI and GRDC.

Technical assistance from Pete Formann, Rosie Holcombe and Stephen Beale (all NSW DPI) is gratefully acknowledged. Field preparation, irrigation and management were provided by Scott Goodworth and staff at Liverpool Plains Field Station (Breeza) and Des Magann and staff at the Australian Cotton Research Institute (Narrabri). Jade-AU⟨PBR⟩ and Satin II⟨PBR⟩ seed was kindly supplied by the Australian Mungbean Association (AMA). Quality testing was conducted by Futari Grain Technology Services at Narrabri.

Contact

Kathi Hertel
Trangie Agricultural Research Centre, Trangie
kathi.hertel@dpi.nsw.gov.au
02 6880 8000

Mungbean planting date × row configuration × population – Narrabri 2015/16

Kathi Hertel[1], Mitch Whitten[2], Joe Morphew[2] and Steven Harden[3]

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

Key findings

- Sowing date (SD) had a significant effect on crop duration with the early spring planting, SD1, harvested 118 days after sowing (DAS), compared with 70 days for the early summer planting, SD2.
- Sowing date significantly affected yield, with SD1 yielding almost double that of SD2. Plant population and row spacing had significant impacts on yield in SD1 but no impact on yield with SD2.
- Yield was maximised with populations between 25 plants/m^2 and 44 plants/m^2 planted on 40 cm wide rows.
- Population had no significant effect on seed size or harvest index. The main response to increasing populations was reduced in crop establishment and increased crop height.
- Sowing date had a small, but significant, influence on seed size.
- The effect from widening row spacing from narrow (40 cm) to wide (100 cm) significantly decreased crop establishment and yield, yet increased crop height. A small but significant reduction in seed size was also observed: a result not previously found.

Introduction

The 'Northern pulse agronomy initiative – NSW' (DAN00171) is a joint project between NSW DPI and the Grains Research and Development Corporation (GRDC). The project aims to identify management strategies to optimise the yield and overall reliability of new mungbean varieties across different growing regions.

This experiment is the third season investigating the effects from key management practices, including sowing date, row spacing and plant population on mungbean production in northern NSW. Preceding experiments encompassed a range of sowing dates at Narrabri and on the Liverpool Plains.

Planned experiments for the 2015/16 summer season were restricted with delays in field preparation due to inclement weather in spring. As a result, a single experiment was sown at Narrabri with the leading variety Jade-AU$^{(\phi)}$.

Sowing dates were within recommended optimal windows for Narrabri. SD1 was in the spring (early) window; SD2 was at the beginning of the optimal sowing time for the summer (late) window.

Site details

Location	Narrabri – Australian Cotton Research Institute
Farming system	Irrigated raised beds
Genotype	Jade-AU$^{(\phi)}$

In-crop rainfall	Sowing date (SD)1: 345 mm SD2: 207 mm
Mean maximum temperature (°C)	SD1: 33.7 °C SD2: 34.1 °C
Mean minimum temperature (°C)	SD1: 17.9 °C SD1: 18.4 °C
Irrigation	In the experiment, SD1 and SD2 were sown into pre-watered fields with full soil moisture profiles. As no further irrigation was applied; each planting date was then reliant on in-crop rainfall (see above).
Experiment design	This was a split-split block design with SD as the main plot, and row spacing as sub-plots with plant population randomised within sub-plots; three replications.
Plant population	Sowing rates adjusted for seed size and germination percentage to achieve target plant populations (see Treatments below).

Table 1. Soil chemical characteristics – 2015/16.

Characteristic	Depth (cm)				
	0–10	10–30	30–60	60–90	90–120
pH_{Ca}	6.9	7.1	7.8	7.8	7.8
Nitrate nitrogen (mg/kg)	2	7	5	1	<1
Sulfur (mg/kg)	194.0	66.1	17.5	13.5	17.7
Phosphorus (Colwell) (mg/kg)	54	38.0	42	55	56
Phosphorus buffering index	132.1	148.5	–	–	–
Organic carbon (%)	1.12	0.64	0.57	0.53	0.44
Conductivity (dS/m)	0.320	0.160	0.066	0.105	0.136

Treatments

Sowing date (SD)	SD1: 29 Oct 15 SD2: 16 Dec 15
Row spacing (cm)	40, 60, 100
Target population	10, 20, 30, 40 plants/m^2
Harvest date	SD1: 25 Feb 16 (118 days after sowing) SD2: 25 Feb 16 (70 days after sowing)

Measurements

In this experiment, seed size is expressed as the weight of 100 seeds at 12% moisture and yield as tonnes per hectare at 12% moisture.

Results – effects from sowing date

Crop establishment

The experiment was sown into ideal soil moisture following pre-watering 10 days earlier. Seedbed temperature at 9:00 am (ADST) was 25.3 °C on SD1 and 29.6 °C on SD2.

Crop establishment was satisfactory for each SD, exceeding all target populations (Table 2).

Table 2. Effect from sowing date and population on crop establishment at Narrabri – 2015/16.

	Achieved crop establishment (plants/m^2)			
Target population (plants/m^2)	**10**	**20**	**30**	**40**
Sowing date				
29 Oct 2015 (SD1)	14 ^{e}	26 ^{d}	37 ^{c}	44 ^{b}
16 Dec 2015 (SD2)	16 ^{e}	25 ^{d}	37 ^{c}	50 ^{a}
Site mean	15	26	37	47
l.s.d. ($P<0.05$)	3.4			

Values followed by the same letter are not significantly different at the 95% confidence level ($P<0.05$)

These results support findings in other experiments where SD did not significantly affect crop establishment or targeted populations ($P<0.05$). Mungbean has demonstrated the capacity to germinate, emerge and establish seedlings over a broad range of soil temperatures where seedbed moisture levels are satisfactory.

Grain yield and seed characteristics

Yield. Sowing date significantly affected yield. The late October planting date (SD1) yield averaged 1.54 t/ha compared with 0.83 t/ha in mid-December (SD2) (l.s.d. = 0.05 t/ha; $P<0.001$). This is equivalent to a 46% yield advantage.

There was no significant interaction between SD and row spacing ($P<0.05$) on grain yield (data not shown).

The interaction of sowing date and population on yield varied for the different sowing dates (Figure 1). At SD1, yield increased as population increased, a finding measured in other related experiments in this project. In contrast, SD2 yields were effectively identical, regardless of population.

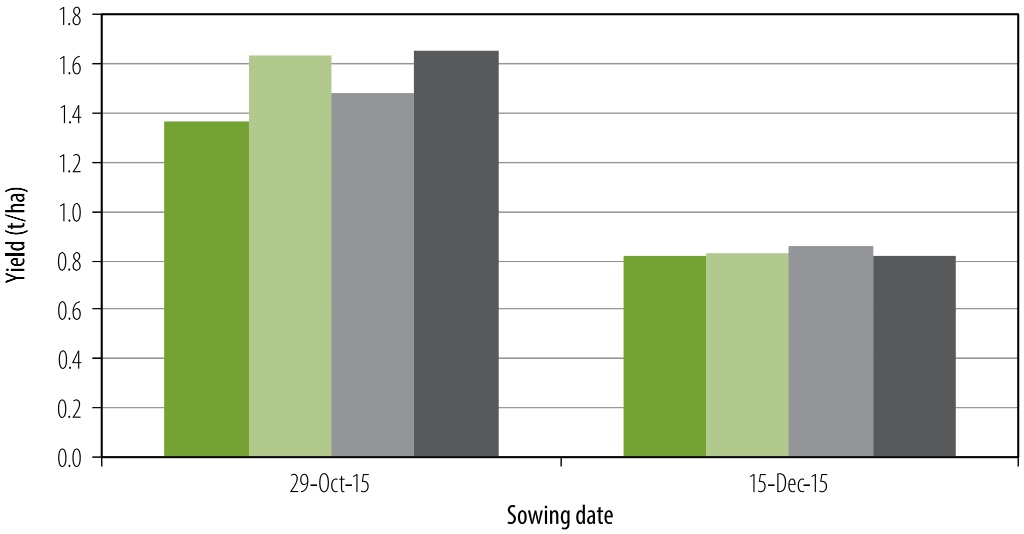


Figure 1. Interaction of sowing date and population on mungbean yield (@ 12% moisture) at Narrabri – 2015/16. l.s.d. ($P<0.05$) = 0.11 t/ha.

Seed size. Sowing date had a small but significant effect on seed size. The average seed size of SD1 was 6.9 g/100 seeds, significantly larger than SD2 at 6.61 g/100 seeds (l.s.d. = 0.09 g; $P<0.05$).

The interaction of sowing date with population showed no significant impact on seed size despite a trend for smaller seed size as sowing was delayed (data not shown). This result is consistent with other similar experiments conducted at different locations within this project.

Harvest index. Harvest index (HI) refers to the ratio of the weight of grain yield to the total above ground biomass. It is a measure of a crop's reproductive efficiency where the higher the number, the greater the efficiency of the production of grain.

Significant differences in HI were measured in response to planting date with SD1 having a higher HI of 0.32 compared with SD2 at 0.26 (l.s.d. = 0.4; $P<0.05$).

Plant architecture

Plant height. Plant height was measured at physiological maturity. SD2 was significantly taller at 64 cm compared with SD1 at 42 cm (l.s.d. = 5; $P<0.05$).

The interaction between sowing date and population was significant only at 90% confidence level ($P<0.1$), showing an increase in plant height as plant population increased. At each sowing date, differences between populations were small. Plant height at target populations of 10, 20, 30 and 40 plants/m^2 in SD1 were 42.7, 42.1, 41.3 and 42.4 cm and 60.8, 64.6, 64.6 and 64.2 cm at SD2, respectively.

Results – row configuration impacts

Crop establishment

Row spacing significantly affected crop establishment, with wide rows having reduced crop establishment. Crop establishment under 40, 60 and 100 cm row spacing was 35.1, 32.6 and 25.5 plants/m^2, respectively when averaged across the four target plant population treatments and two sowing dates (l.s.d. = 1.7; $P<0.05$).

The interaction between row spacing and population on establishment is shown in Figure 2. At all target populations, achieved crop establishment generally declined as row spacing increased (Figure 2).

The reduction in crop establishment under wide rows and the interaction with population is consistent with findings in earlier row spacing experiments.

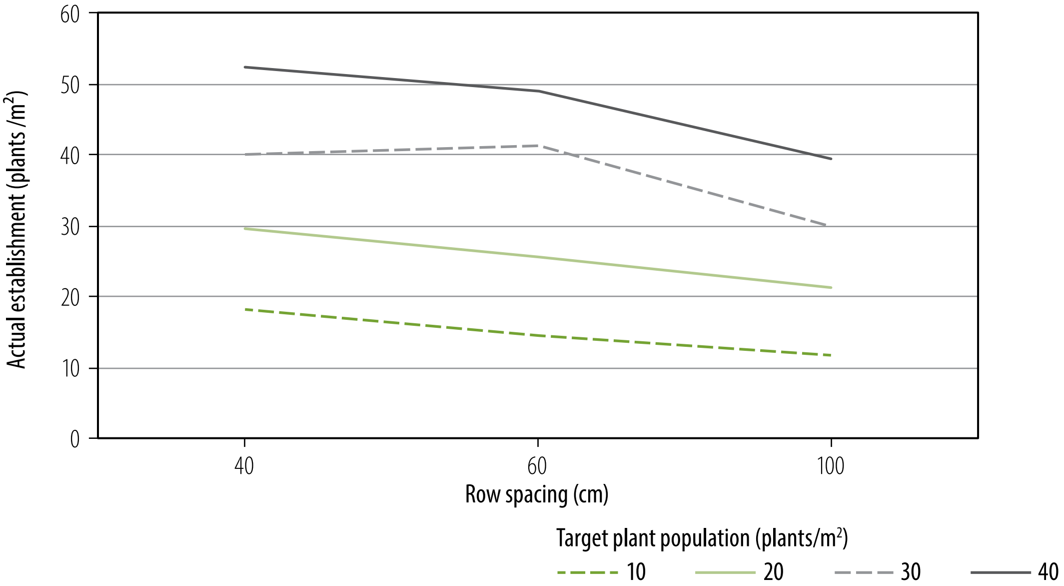


Figure 2. Interaction of row spacing date and population on mungbean establishment – Narrabri 2015/16 l.s.d. ($P<0.11$) = 4.9 plants/m^2.

Grain yield and seed characteristics

Yield. As row spacing increased, yield declined (Figure 3B). The average experiment yield was 1.18 t/ha. Compared to site average, the yield at 40 cm row spacing of 1.28 t/ha was equivalent to 8% higher than the site average. The yield at row spacing of 60 and 100 cm were 1% or 7% less.

Seed size. Small but significant decreases in seed size were found as row spacing widened from 40 cm to either 60 cm or 100 cm (Figure 3B). This is the first significant impact of row spacing on seed size in mungbean grown under supplementary irrigation to be recorded in the cohort of mungbean experiments conducted since 2013.

There were no other significant interactions of row spacing with sowing date or populations, a finding consistent with all other corresponding mungbean experiments.

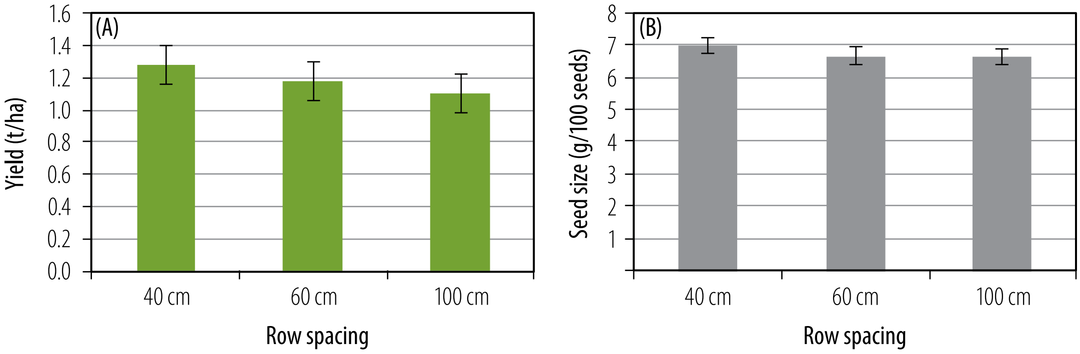


Figure 3. Impact of row spacing on mungbean yield (A) and seed size (B) at Narrabri – 2015/16. Yield l.s.d. ($P<0.05$) = 0.12 t/ha; seed size l.s.d. ($P<0.05$) = 0.25 g/100 seeds.

Harvest index (HI). Row spacing had no significant impact on HI. All interactions with population and sowing date were not significant.

Plant architecture

Plant height. There were small but significant increases in plant height as row spacing widened. Plant height at 40, 60 and 100 cm row spacing was 50.5, 52.9 and 54.6 cm respectively (l.s.d. = 2.1 cm; $P<0.05$).

Results – population impacts

Crop establishment

There were significant differences in crop establishment where all target populations were exceeded (Figure 4A).

Grain yield and seed characteristics

Yield. Crop population had a significant impact on yield (Figure 4B). Figure 4B shows the relationship between yield and achieved population. This chart reflects the dominant influence of adverse environmental conditions, specifically high temperatures during flowering and pod fill in SD2 causing a flat yield response across all treatments in the experiment.

In experiments where seasonal conditions were not limiting, mungbean yield has been shown to be strongly related to population (see other mungbean experiments in this publication).

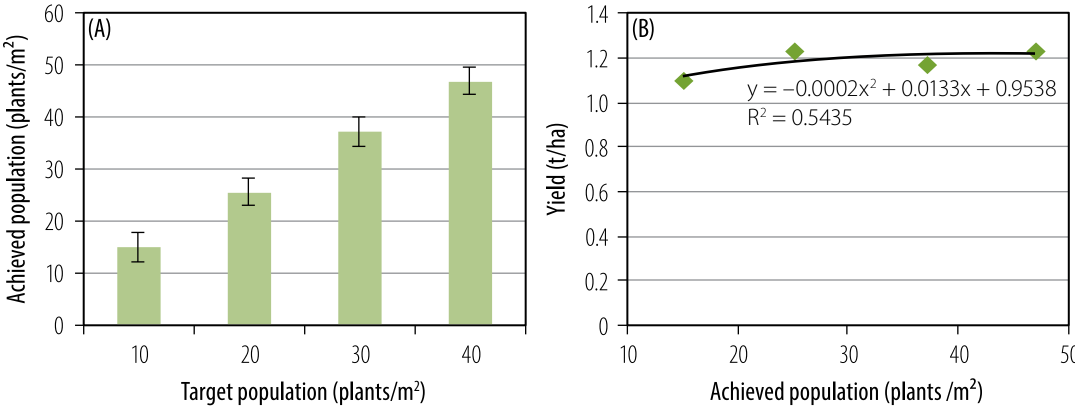


Figure 4. Impact of target population on mungbean crop establishment (A) and achieved population and mungbean yield (@ 12% moisture) (B) – Narrabri 2015/16.
Crop establishment l.s.d. ($P<0.001$) = 2.7 plants/m²; yield l.s.d. ($P<0.05$) = 0.08 t/ha.

Seed size

There was no significant impact of population on seed size (data not shown), a result that is consistent in the findings in other mungbean experiments.

Harvest index

Population had no significant impact on harvest index (data not shown).

Plant architecture

Plant height

There was a small but significant response to target plant populations of 10, 20, 30 and 40 plants/m² where plant height was 51.2, 53.4, 52.9 and 53.3 cm, respectively (l.s.d. = 1.7 cm; $P<0.05$).

Conclusions

This experiment was part of the research program of project 'Northern pulse agronomy initiative – NSW' (DAN00171), which is evaluating new mungbean varieties and their response to agronomic management practices for suitability and adaptation to different environments and regions in NSW.

This experiment investigated the response of Jade-AU$^{\text{⏀}}$ to sowing date, row spacing and population at Narrabri. Results have reflected those of experiments conducted in 2013/14 and 2014/15.

Sowing date has a major impact on the duration of a crop's growth and development phases. Mungbean are a short season crop type with crop growth driven by temperature. Therefore sowing date has the largest influence on the length of the growing season and therefore the potential yield of any mungbean crop. This was evident in this experiment where the SD1 was harvested 118 DAS and SD2 was harvested 70 DAS. The duration of the SD1 crop was 41% longer than that of SD2 with a resulting 46% higher grain yield.

Hence, differences between the two sowing dates resulted in the greatest impacts on yield, seed quality and plant architecture.

Findings in this experiment of the impacts of row spacing and population mirrored those of previous experiments. Where seasonal conditions are not limiting, the yield of mungbean is strongly correlated with plant population. Planting in wide rows will significantly reduce crop establishment and crop yield.

Seed size is a strongly heritable trait and a key characteristic of mungbean varieties that is an important quality used to define marketing standards. Under production systems where mungbeans are grown with supplementary irrigation, population had no significant impact on seed size. Row spacing in this experiment had a small but significant influence on seed size, a finding not found in previous experiments.

The tall plant architecture of Jade-AU⦶ has been shown to be consistently at heights that enable maximum grain capture at harvest.

Acknowledgements

These experiments were part of the project 'Northern pulse agronomy initiative – NSW', DAN00171, 2012–17, with joint investment by NSW DPI and GRDC.

Technical assistance from Brooke McAlister, Rosie Holcombe and David Cain (all NSW DPI) is gratefully acknowledged. Field preparation, irrigation and management were provided by Des Magann and staff at the Australian Cotton Research Institute (Narrabri). Jade-AU⦶ seed was supplied by the Australian Mungbean Association (AMA). Quality testing was conducted by Futari Grain Technology Services – Narrabri.

Contact

Kathi Hertel
Trangie Agricultural Research Centre, Trangie
kathi.hertel@dpi.nsw.gov.au
02 6880 8000

Australian Government
Cotton Research and
Development Corporation

GRDC
GRAINS RESEARCH
& DEVELOPMENT
CORPORATION

CSIRO

Australian Government
Department of Agriculture
and Water Resources

THE UNIVERSITY OF
MELBOURNE

Queensland
Government

THE UNIVERSITY
OF QUEENSLAND
AUSTRALIA

Government
of South Australia
Primary Industries
and Regions SA

SARDI
SOUTH AUSTRALIAN
RESEARCH AND
DEVELOPMENT
INSTITUTE

Northerm NSW research results 2018

RESEARCH & DEVELOPMENT – INDEPENDENT RESEARCH FOR INDUSTRY

NSW
GOVERNMENT
Department of
Primary Industries

www.dpi.nsw.gov.au