Department of Primary Industries

Southern NSW research results 2015

RESEARCH & DEVELOPMENT – INDEPENDENT RESEARCH FOR INDUSTRY

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RESEARCH & DEVELOPMENT – INDEPENDENT RESEARCH FOR INDUSTRY

an initiative of Southern Cropping Systems

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Foreword

NSW Department of Primary Industries (NSW DPI) welcomes you to the second edition of *Southern NSW Research Results 2015*. This book has been produced to increase awareness of research and development (R&D) activities undertaken by NSW DPI in the southern cropping region of NSW. It delivers the outcomes of these activities to our stakeholders including agribusiness, consultants and growers.

This document is a comprehensive, annual report of NSW DPI's R&D activities in southern NSW. This year the book has been expanded to include the soils, climate, weeds, farming systems, water and irrigation research in southern NSW.

NSW DPI, in collaboration with our major funding partner GRDC, is at the forefront of agricultural research in the southern cropping region of NSW. Our R&D teams conduct applied, scientifically sound, independent research to advance the profitability and sustainability of our farming systems.

The Department's major research centres in the southern region of NSW are Wagga Wagga, Yanco, Condobolin and Cowra where our team of highly reputable research and development officers and support staff are based. The regional geographic spread of the research centres allows for experiments to be replicated across high, medium and low rainfall zones with Yanco providing the opportunity to conduct irrigated experiments.

NSW DPI's research program includes the areas of germplasm improvement; farming systems management e.g. nutrient management, agronomy, water use efficiency and crop sequencing; plant protection e.g. entomology, pathology and integrated weed management; water productivity; and supply chains and market access. The following papers provide an insight into selected R&D activities taking place in the southern region. We hope you will find them interesting and valuable to your farming system or the farming clients you work with.

We acknowledge the many collaborators (growers, agribusiness and consultants) that make this research possible. We also encourage feedback to help us produce improved editions in future years.

The Research and Development Teams
NSW Department of Primary Industries

Contents

nutrition & soil

crop protection

irrigation & climate

Seasonal conditions 2015

The 2015 season was characterised by below average minimum temperatures in June and mid-September, followed by above-average temperatures at the end of the season (Figure 1). The lower temperatures early in the season reduced biomass production and were followed by a rapid shift in temperature extremes in September, which caused crops to mature quickly.

There were 16 frosts at the Wagga Wagga Agricultural Institute (WWAI) in 2015 with the most severe on 3 July (–3.5 °C) and the latest on 23 and 24 September (–1.0 °C and –0.5 °C respectively) (Figure 2).

Growing season rainfall (April–October) in 2015 was 333 mm, which is almost average for the site, but this fell predominantly in early to mid-season with September and October rainfall below average (Figure 3).

Across the district, growers and agronomists reported average to above average yields in the majority of locations including WWAI. Above average rainfall throughout winter provided a full soil profile leading into spring, helping the crops cope with higher than average temperatures in late September and early October. Despite quicker crop development in spring (flowering dates had a very tight range for the later sowings of 3–5 days compared with 14 days for early sown crops), crop yields were not adversely affected around Wagga Wagga.

Generally speaking, disease was slow to develop in crops early in the growing season due to drier conditions in autumn (May). However, very wet conditions in June, July and August were ideal for root and foliar pathogens to establish in many crops in the region. Multiple wet days meant long periods of leaf wetness and high soil moisture, causing multiple infections and high disease pressure heading into spring. In spring, below average rainfall and warm temperatures significantly reduced disease progression across the region. However, in many crops the damage from disease had already been done in winter and these crops struggled with the dry finish to the season.

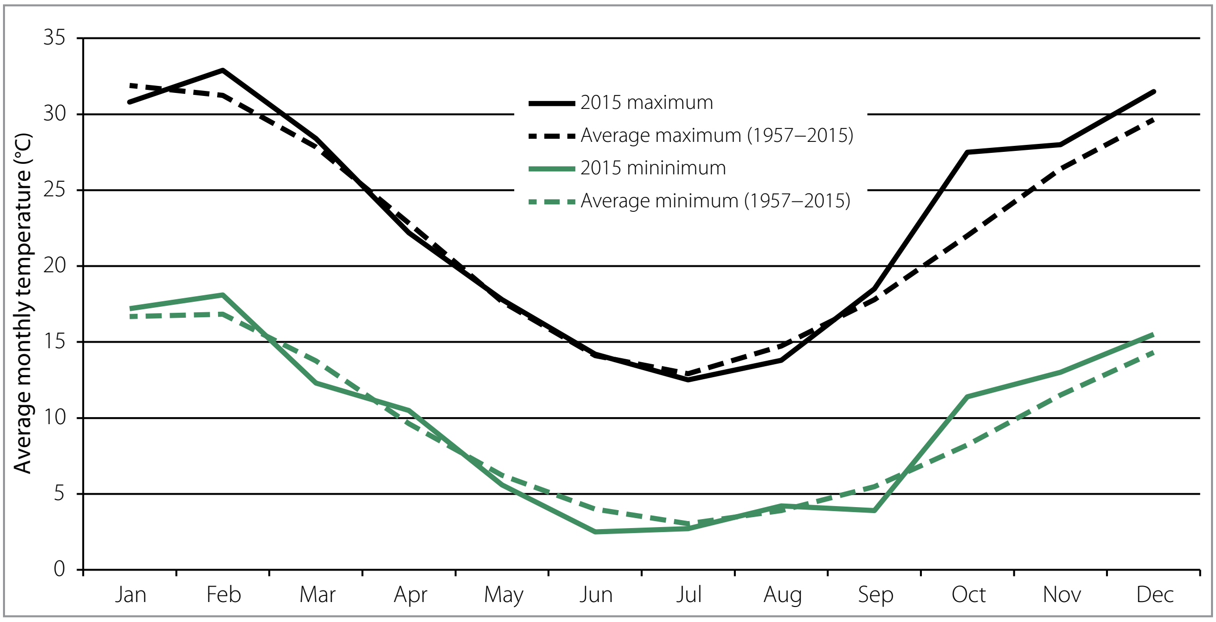

Figure 1. Monthly temperatures at WWAI in 2015.

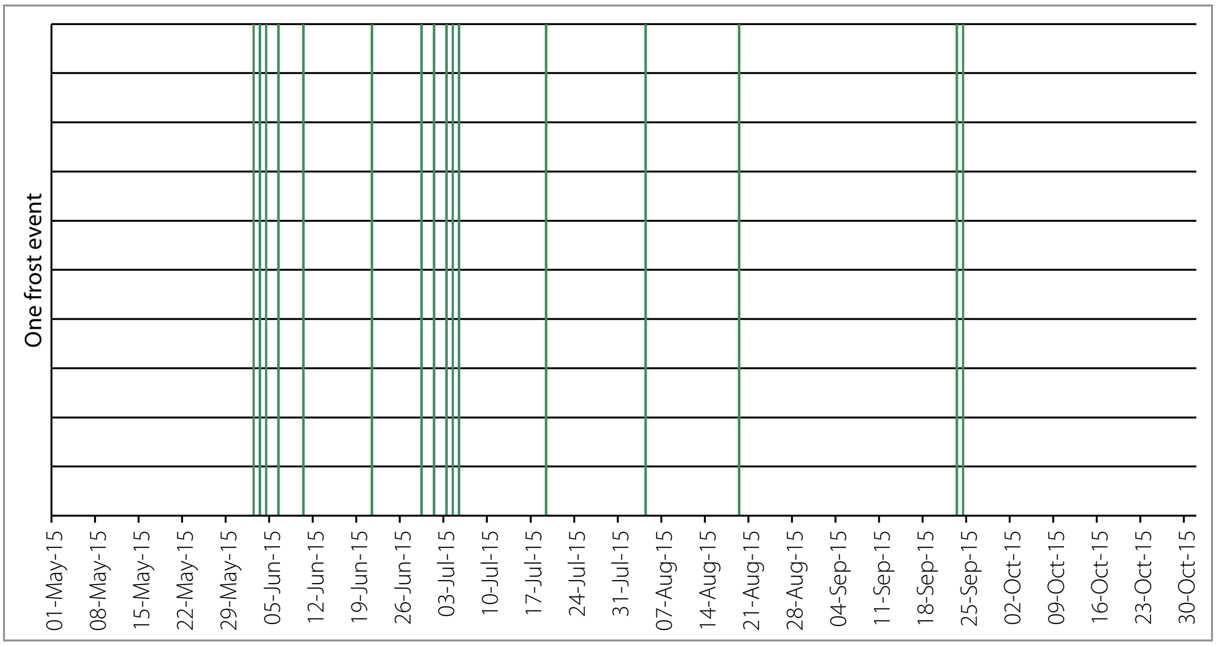

Figure 2. Timing of frost events (<–2 °C) at WWAI in 2015.

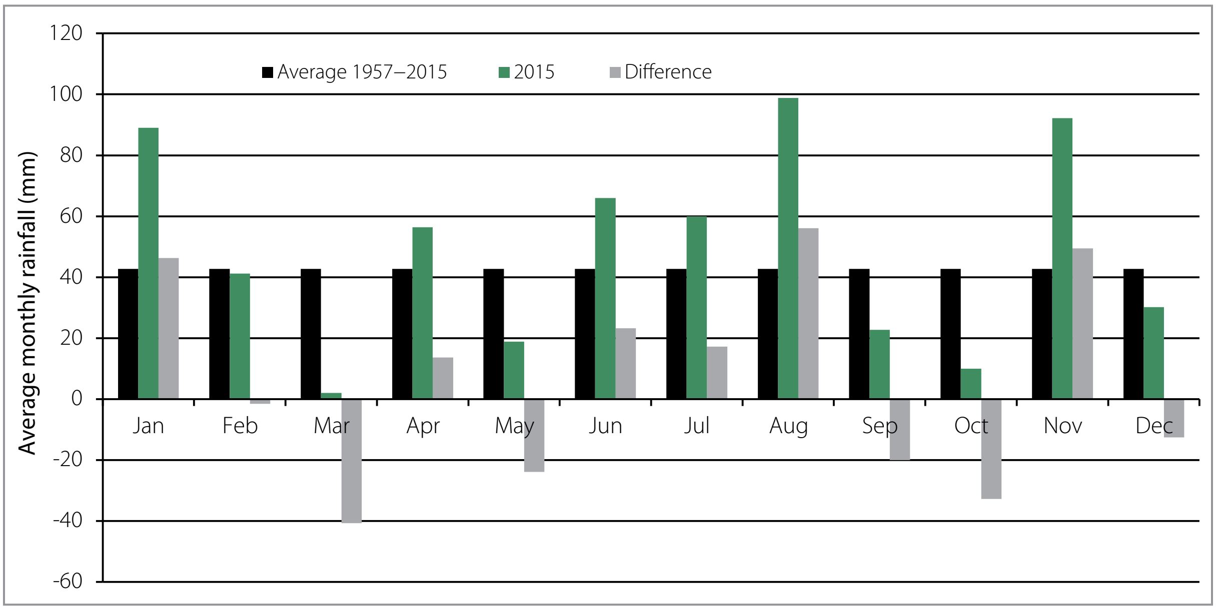

Figure 3. Monthly rainfall at WWAI in 2015.

Understanding wheat phenology: flowering response to sowing time

Dr Felicity Harris NSW DPI, Wagga Wagga; **Dr Peter Martin** Howqua Consulting; **Dr Howard Eagles** University of Adelaide

Key messages

» Flowering time is determined by responses to vernalisation, photoperiod and earliness per se.

» Match variety and sowing time to ensure flowering occurs during the optimal period for your growing environment.

Flowering time is critical!

It is critical to match variety and sowing time to ensure flowering occurs during the optimal flowering window to maximise grain yield potential. The optimum flowering window is determined by a balance in the water used during canopy development and water used during the grain formation and grain-filling phases (Fischer 1979), as well as the declining frequency and severity of frosts (Richards et al. 2014). Crops that flower too early have increased risk of frost damage, whilst crops that flower too late have an increased risk of high temperature impact and water deficit, which can restrict grain formation and grain-filling.

How is flowering time regulated?

Accumulated thermal time has a major influence on the developmental rate in wheat, with development occurring more rapidly as the temperature increases. The relative maturity of varieties is largely controlled by responses to vernalisation and photoperiod (Figure 1).

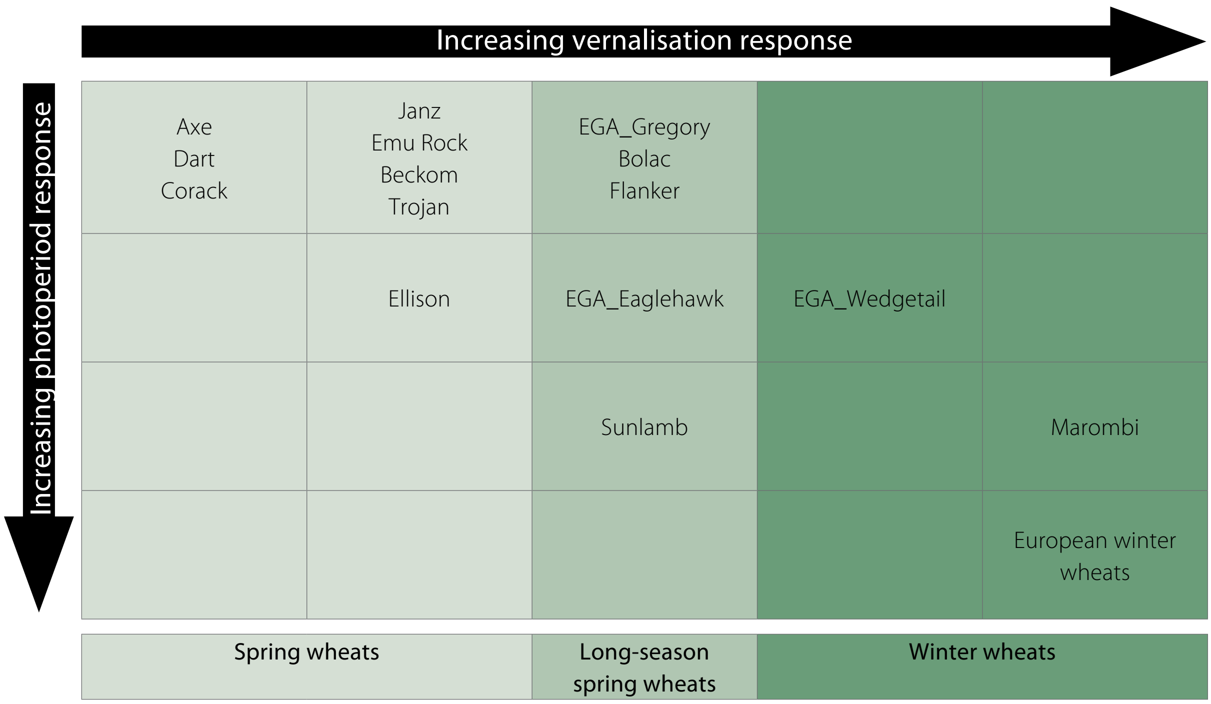

Figure 1. Estimated response of some wheat varieties to vernalisation and photoperiod.

Vernalisation

Varieties responsive to vernalisation require a period of cold temperatures to make the transition from vegetative to reproductive development. Following saturation of the vernalisation response, floral initiation occurs, marking the completion of the initiation of further leaves and the start of the floral organ initiation at the shoot apex. In wheat, vernalisation accumulates most rapidly between 3–10 °C, but can accumulate at a slower rate up to 17 °C. Vernalisation can occur at different stages of the individual plant's lifecycle: during germination, during vegetative plant growth, and for subsequent generations, during seed formation in the mother plant (Flood & Halloran 1986).

Photoperiod

Wheat is a long-day plant, in which the rate of development is increased with longer day-lengths. However, individual genotypes of current commercial varieties have varying levels of responsiveness to photoperiod, including insensitivity. A large number of Australian varieties are insensitive to photoperiod (Cane et al. 2013). In photoperiod sensitive genotypes, short-day (SD) conditions (10 hours or less light) prolong the vegetative phase and delay the transition to reproductive development, whilst long-day (LD) conditions (14 hours or more light) decrease time to floral initiation (Beales et al. 2007).

In vernalisation responsive varieties, following saturation of the vernalisation response, long days hasten progressive inflorescence development and stem elongation. Vernalisation is essentially the prerequisite for long days to reduce the time to flowering (Trevaskis 2010).

Table 1. The vernalisation and photoperiod genes present in some commercial varieties grown in New South Wales, their relative maturities and habit classification (Cane et al. 2013).

Cultivar	Gene*					Maturity**	Type
	Ppd-B1	*Ppd-D1*	*Vrn-A1*	*Vrn-B1*	*Vrn-D1*		
Axe[ɸ]	*a*	*a*	*a*	*a*	*v*	Fast	Spring
Bolac[ɸ]	*b*	*a*	*a*	*v*	*v*	Mid–slow	Spring
Corack[ɸ]	*b*	*a*	*v*	*a*	*a*	Mid–fast	Spring
Dart[ɸ]	*b*	*a*	*a*	*a*	*v*	Fast	Spring
EGA_Eaglehawk[ɸ]	*b*	*b*	*b*	*v*	*a*	Mid–slow	Spring
EGA_Gregory[ɸ]	*b*	*a*	*v*	*v*	*a*	Mid	Spring
EGA_Wedgetail[ɸ]	*b*	*a*	*v*	*v*	*v*	Slow	Winter
Ellison[ɸ]	*a*	*b*	*v*	*a*	*a*	Mid–fast	Spring
Emu Rock[ɸ]	*b*	*a*	*a*	*a*	*v*	Mid–fast	Spring
Gauntlet[ɸ]	*a*	*a*	*a*	*v*	*v*	Mid–fast	Spring
H45[ɸ]	*d*	*a*	*a*	*v*	*a*	Fast	Spring
Harper[ɸ]	*b*	*d*	*a*	*a*	*v*	Mid	Spring
Janz[ɸ]	*c*	*a*	*a*	*v*	*v*	Mid	Spring
Lancer[ɸ]	*a*	*a*	*a*	*v*	*v*	Mid–slow	Spring
Livingston[ɸ]	*b*	*a*	*a*	*a*	*v*	Mid	Spring
Mace[ɸ]	*a*	*a*	*v*	*a*	*v*	Mid–fast	Spring
Marombi[ɸ]	*a*	*b*	*w*	*v*	*v*	Slow	Winter
Merlin[ɸ]	*b*	*a*	*v*	*a*	*a*	Mid–fast	Spring
Mitch[ɸ]	*b*	*a*	*w*	*a*	*a*	Mid–slow	Spring
Spitfire[ɸ]	*a*	*a*	*v*	*a*	*a_v*	Mid–fast	Spring
Sunguard[ɸ]	*a*	*a*	*a*	*v*	*v*	Mid	Spring
Suntop[ɸ]	*d*	*a*	*v*	*a_v*	*a*	Mid	Spring
Sunvale[ɸ]	*a*	*a*	*a*	*v*	*v*	Mid	Spring
Trojan[ɸ]	*a*	*c*	*v*	*a*	*a*	Mid	Spring

*Ppd-B1b is responsive to photoperiod, while Ppd-B1a, Ppd-B1c and PpdB1d are less responsive; Ppd-D1b is a functional gene that is responsive to photoperiod, Ppd-D1a is generally non-responsive to photoperiod and promotes early flowering, while Ppd-D1c and Ppd-D1d are corrupted genes that are largely non-responsive to photoperiod and associated with later flowering; Vrn-A1a and Vrn-A1b are the spring alleles and generally unresponsive to vernalisation, Vrn-A1v is a winter allele and responsive to vernalisation, Vrn-A1w is a winter allele and has a strong vernalisation response; Vrn-B1a and Vrn-D1a are the spring alleles and generally unresponsive to vernalisation, Vrn-B1v and Vrn-D1v are the winter alleles and respond to vernalisation.

**adapted from Cane et al. (2013) and Matthews, McCaffery and Jenkins (2015). Varieties suited for sowing in NSW range in maturity from slow winter (suited to early sowing) to fast spring types (suited to later sowing).

Genetic controls of flowering time

The genetic control of flowering time is complex. There are three primary gene sets with each set controlling vernalisation response, photoperiod response and earliness per se. The genes interact to determine the time of flowering in a specific environment (Slafer & Whitechurch 2001; Trevaskis et al. 2007).

Diagnostic markers for the vernalisation (*Vrn-A1*, *Vrn-B1* and *Vrn-D1*) and photoperiod (*Ppd-B1* and *Ppd-D1*) genes have enabled characterisation of current commercial varieties (Cane et al. 2013) (Table 1). The traditional classification of winter versus spring wheat has been oversimplified. Identifying the form of gene (allele) present enabled genotypes to be grouped as either a spring or winter type, or as being photoperiod-sensitive or insensitive. A spring genotype is characterised by the presence of at least one dominant *VRN1* allele (*a*). A winter genotype required recessive *VRN1* alleles (*v*) at the three *VRN1* loci in wheat, for example *Vrn-A1v* + *Vrn-B1v* + *Vrn-D1v* (Eagles et al. 2009). Photoperiod response is determined by the presence of either the insensitive allele (*a*), or the sensitive allele (*b*) at the *Ppd-D1* locus (Eagles et al. 2009). A more complex analysis of the effect of these genes on development is made possible by identifying the effect of key alleles and allelic combinations of the known major vernalisation and photoperiod genes. Cane et al. (2013) studied the influence of allelic variation and the interactions between the *VRN1* and *PPD1* genes, and reported significant differences in heading date attributed to the allelic combinations of *Vrn-A1*, *Vrn-B1*, *Vrn-D1*, *Ppd-B1* and *Ppd-D1*. The identified alleles accounted for 53% of the genetic variance for heading date.

It is likely that other major *VRN1* and *PPD1* genes affect phasic development in wheat (e.g. *Vrn-D4*) and that there are other unknown major genes and alleles affecting phasic development. Whilst the general adaptation in flowering time is affected by the major *VRN1* and *PPD1* genes, flowering time in both winter and spring wheat genotypes is also controlled by a third level of genes, the earliness *per se* (*Eps*) genes. The effects of *Eps* genes are not as defined as vernalisation and photoperiod, and only a few *Eps* loci have been properly identified in wheat. These have been identified as having more of a fine-tuning effect on flowering time relative to regional adaptations. The interactive nature of the vernalisation and photoperiod genes means the effect of certain genes on flowering time is much greater in specific combinations of alleles.

Flowering response to sowing time

To achieve maximum grain yield potential, it is important to ensure wheat varieties are sown according to their relative maturities (dictated by their response to vernalisation and photoperiod) so flowering occurs in the optimal window.

Wheat varieties responsive to vernalisation (winter types) can be sown early, and will remain vegetative until their vernalisation requirement has been satisfied. This acts to delay reproductive development so that flowering coincides with favourable seasonal conditions. Should a spring variety be sown early (when temperatures are warmer and days longer), development will progress quickly and flowering will occur earlier than optimum, reducing grain yield potential. For example, cv. Dart sown 16 April 2015 at Wagga Wagga flowered on 16 September, while EGA_Wedgetail sown on the same day flowered on 11 October and within the optimum flowering window for Wagga Wagga. However, when sown 6 weeks later (25 May), they flowered more closely together: Dart flowered 14 October and EGA_Wedgetail flowered 17 October.

In sowing time trials at Wagga Wagga and Canowindra in 2015 the highest grain yields were achieved when flowering occurred at the optimum time. Wheat varieties with varied responses to vernalisation and photoperiod can provide greater flexibility to the sowing schedule. Winter wheats can be sown from late February through to April, long-season spring wheats from mid-April to early May and mid-short season spring wheats from late April onwards. Getting wheat phenology right by matching sowing time and variety is critical to optimising yield potential, and is low-cost in comparison with other agronomic management tactics.

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Wheat varieties differ in response to natural heat events during the early reproductive stage

Dr Livinus Emebiri, **Kerry Taylor**, **Shane Hildebrand** and **Denise Pleming** NSW DPI, Wagga Wagga; **Nicholas Collins** Australian Centre for Plant Functional Genomics, Adelaide

Key findings

» The most intense of three heat events averaged 35.5 °C and reduced grain numbers per spikelet by 21%.

» Significant genetic variation was observed for floret sterility induced by natural heat events. The variety Halberd was identified as most heat tolerant and Westonia as most sensitive.

» The results indicate a genetic variation that could be exploited to improve wheat crop resilience under heat stress.

Introduction

Substantial genetic variation has been demonstrated for wheat response to heat stress at post-flowering stages (Emebiri et al. 2015). However, relatively few studies have compared varieties exposed to stress at an early reproductive stage when the potential grain number is determined (Fischer 2011). Genetic variation for tolerance at this early reproductive stage is desirable, because it is the loss in grain number, rather than a reduction in grain size, that largely accounts for crop yield reduction when abiotic stress occurs (Dolferus et al. 2011). In studies under controlled-environment conditions, tolerance differences were observed between wheat varieties, but no field study has been reported.

This study determined whether genetic differences in tolerance can be identified in field-grown wheat exposed to natural heat events at the early reproductive stage of development.

Treatments

The experiment was conducted at the Wagga Wagga Agricultural Institute in the 2015 winter cropping season.

Eight wheat varieties ranging in maturity were grown under a birdcage (Figure 1) in single-row plots. Planting was repeated every two weeks from 20 June to 29 September using a randomised complete block design. The consecutive planting was to ensure tillers at the sensitive stage of gametogenesis were available to be tagged from each genotype at the time of a heat event. Each planting was independently watered using a dripper system to limit drought stress. A heat event was defined as a block of ≥2 days of maximum temperature >30 °C.

Immediately after each heat event, a minimum of 30 tillers per genotype with a 0–3 cm auricle interval length (the distance between the bases of the flag leaf and next leaf down) were tagged to represent tillers exposed to heat stress at the sensitive stage. For controls, a minimum of 15 tillers per genotype from the same plots with an average auricle interval length of >9 cm were also tagged to represent those that were past the sensitive stage.

There were three heat events during the experiment period during which tillers were tagged. The first occurred on 4–6 October with an average maximum temperature of 32.7 °C, the second on 15–16 October with an average maximum temperature of 31.6 °C and the third on 18–20 November with an average maximum temperature of 35.5 °C. At maturity, the tagged heads were harvested for floret fertility scoring (grains per spikelet in the basal two florets of each spikelet).

Figure 1. Floret fertility heat tolerance experiment under the birdcage.

Results

Data was obtained from scoring five spikes per genotype per heat event. Scoring the remaining tagged tillers is not yet complete.

The first two heat events had little or no impact on grain number per spikelet, but the damage from the third event, with a maximum temperature averaging 35.5 °C (Figure 2), was significant ($P = 0.001$) and reduced grain number per spikelet by 21%. Genotypes also differed significantly ($P = 0.05$) in their responses to this heat event for grain number per spikelet.

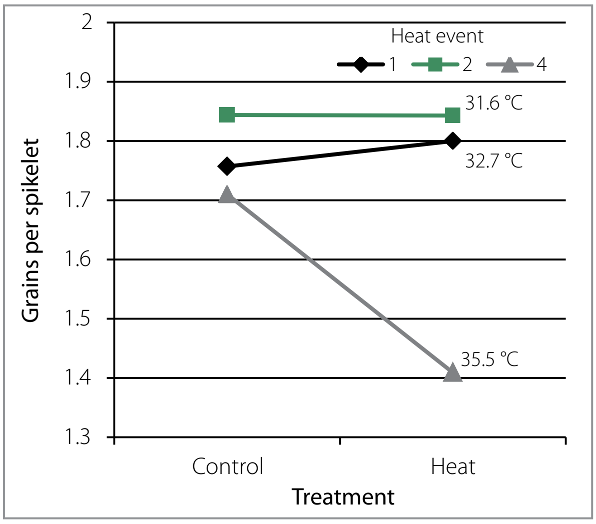

Figure 2. Changes in grain number per spikelet in wheat following exposure at the sensitive tiller stage (heat), or past the sensitive stage (control), to three natural heat events in a field experiment at Wagga Wagga, NSW during the 2015 season.

The wheat variety Halberd was most tolerant (Figure 3), showing virtually no reduction in grains per spikelet. By contrast, Westonia showed a 35.4% reduction in grains per spikelet, indicating it was sensitive to the natural heat event.

Summary

Confirmation of differences in tolerance between the varieties will require analysis of the complete tagged tiller set from the 2015 experiment and repeat experiments. If confirmed, this will be the first description of differences in wheat varietal responses to natural heat events at the early reproductive stage. This would indicate genetic variation that could be exploited to improve wheat crop resilience under heat stress.

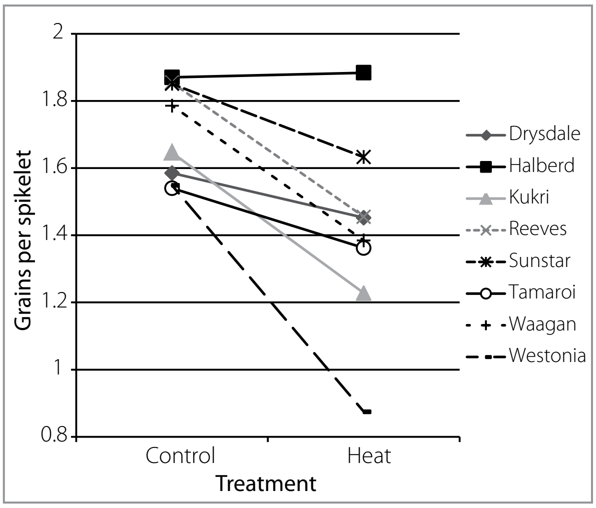

Figure 3. Floret fertility of wheat varieties exposed to a natural heat event at the sensitive tiller stage (heat), or past the sensitive stage (control), in field experiments at Wagga Wagga Agricultural Institute, NSW during the 2015 season.

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Acknowledgements

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Effect of sowing date on grain yield of 36 wheat varieties – Wagga Wagga 2015

Eric Koetz, **Hugh Kanaley** and **Greg McMahon** NSW DPI, Wagga Wagga

Key findings

» Grain yield was maximised by matching variety phenology with the correct sowing time to target the optimal flowering period.

» Early maturing spring types sown on 16 April suffered frost damage and reduced grain yield.

» Long season varieties sown on 28 May had reduced grain yield as a result of higher moisture and heat stress conditions at flowering.

» The highest yielding variety was Sunvale$^{\phi}$ (6.3 t/ha) sown on 16 April.

» Beckom$^{\phi}$ sown on 7 May yielded 6.2 t/ha and Condo$^{\phi}$ sown on 28 May yielded 4.9 t/ha.

Introduction

This experiment was designed to assess the effect of early, mid and late sowing times on the phenology, grain yield and grain protein of several newer wheat varieties grown in southern NSW. Wheat varieties respond differently to sowing time. There are different responses in flowering time and relative grain yield with changes in time of sowing. The results presented here from the Wagga Wagga experiment is one in a series of experiments aimed at establishing variety responses to sowing time and phenological development.

Site details

Location	Wagga Wagga NSW
Trial period	2015
Soil type	Red chromosol
Previous crop	Canola
Stubble management	Full cut cultivation
Planter	Plot air seeder, DBS tynes
Harvest date	1 December 2015
Fertiliser	100 kg/ha diammonium phosphate (DAP) + 100 kg urea 10 July
Soil tests	pH 4.8_{Ca}
Nitrogen	121 kg N/ha tested 0–30 cm
Phosphorus	57 mg/kg
Herbicides	Knockdown: Roundup CT 1.5 L/ha, Pre-emergent: Logran 35 g/ha + Sakura 118 g/ha Post-emergent: Precept 500 mL/ha + Lontrel 150 mL/ha. Axial 150 mL/ha.
Fungicide	Flutriafol 400 mL/ha on fertiliser at sowing
In-crop rainfall (Apr–Oct)	332 mm

Treatments

Thirty-six varieties and crossbreds likely to be released (Table 1) sown at three dates.

Sowing dates	16 April 7 May 28 May

Table 1. Wheat varieties and phenology group.

Phenology group	Variety or breeding line	
Winter	EGA_Wedgetail$^{\phi}$	LPB11-0140
Very slow	EGA_Eaglehawk$^{\phi}$, Sunlamb$^{\phi}$	VO7176-69
Slow	Bolac$^{\phi}$ Kiora$^{\phi}$	Lancer$^{\phi}$ Suntime$^{\phi}$
Mid	Flanker$^{\phi}$ EGA_Gregory$^{\phi}$ Gauntlet$^{\phi}$ HRZ08-0062 Janz	Mitch$^{\phi}$ Sunvale$^{\phi}$ Trojan$^{\phi}$ Viking$^{\phi}$
Mid–fast	Beckom$^{\phi}$ Cosmick$^{\phi}$ Elmore CL PLUS$^{\phi}$ Harper$^{\phi}$	Merlin$^{\phi}$ Sunguard$^{\phi}$ Suntop$^{\phi}$
Fast	ADV03-0056 Corack$^{\phi}$ Emu Rock$^{\phi}$ Livingston$^{\phi}$	LPB09-0358 Mace$^{\phi}$ Spitfire$^{\phi}$ Sunmate$^{\phi}$
Very fast	Condo$^{\phi}$ Dart$^{\phi}$	LPB10-0018

Results

Flowering

Thirty-six commercial and unreleased wheat lines with a range of maturities were sown at Wagga Wagga in 2015 (Table 1). The highest grain yields were achieved from the earliest sowing date when varieties flowered between late September and early October (Figure 1). The optimum flowering window (2015) was bound by early frost events and later heat and soil moisture stress. This emphasises the importance of matching phenology, variety type and sowing time to optimise yield where the trade-offs are frost (early stress) and high temperatures and low soil water availability (late stress). When these constraints are considered, an optimal flowering period can be determined for maximising the probability of achieving high grain yields (Figure 1).

Variety, sowing time and the interaction between variety and sowing time were significant for grain yield ($P < 0.001$) (Figure 1). Fast maturing spring varieties sown on 16 April flowered in mid-September and were exposed to frost during the vulnerable boot and growth stages. There was a significant decrease in grain yield from the 28 May sowing date.

Grain yield

Variety and sowing date had significant effects on grain yield ($P < 0.001$). The interaction between variety and sowing date was also significant ($P < 0.001$). The hotter temperatures in the first week of October reduced the grain yield of the late (28 May) sowing time by 1.07 t/ha compared with the mid-season (7 May) sowing time (Table 2). Early sowing (16 April) consistently produced higher grain yields for varieties with a maturity classification of either 'winter', 'very slow', 'slow' and 'mid' (Figure 2). For varieties classified as 'mid–fast', 'fast' and 'very fast', the best sowing time to maximise grain yield was early May (7 May). Late sowing (28 May) consistently produced lower grain yields. Variety choice was only partly able to compensate for the late sowing time (Figure 2).

Table 2. Average grain yield of 36 wheat varieties sown on three dates at Wagga Wagga in 2015.

Sowing date	Grain yield (t/ha)
16 April	5.14
7 May	5.20
28 May	4.13
l.s.d. ($P < 0.05$) = 0.2 t/ha	

Grain protein

Variety ($P < 0.001$) and sowing date ($P < 0.05$) were significant for grain protein (Table 3). Screenings were significant for variety and sowing date, however, there was no interaction between sowing date and variety (Table 3). There was a strong decrease in grain protein associated with grain yield increases for the first time of sowing ($y = -0.5164x + 14.048$, $R^2 = 0.56$), which could be due to protein dilution. Conversely, the highest grain proteins were generally achieved by the late sowing time, probably because the lower grain yields would have concentrated more protein in the grain. This is probably a reflection of the hot dry spring in Wagga Wagga in 2015.

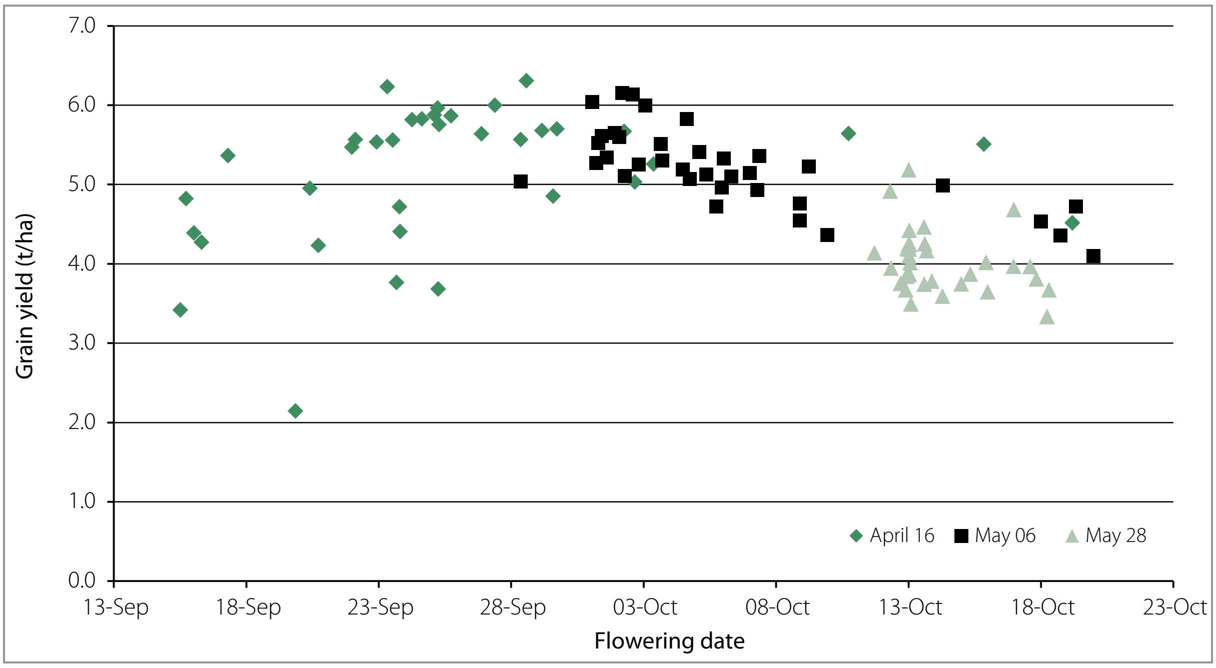

Figure 1. Anthesis date and grain yield of 36 wheat varieties sown at three dates near Wagga Wagga in 2015.

The first week of October had six days above 33 °C. Screenings were generally low across all sowing dates; there was a slight trend towards increased screenings from the longer maturity varieties sown on 28 May. Bolac and Cosmick had high screenings at all sowing dates and Beckom, sown on 28 May, had high screenings.

When assessing the pros and cons of new varieties, the rankings for grain yield at each sowing date is a good indicator of the performance of varieties in any one season (Table 3). A single year's result does not provide an adequate insight into the optimum flowering period. However, to estimate the optimal flowering period, SOWMAN (a part of the CropMate software) is used to simulate frost, heat and soil moisture stress over a 40-year period. This provides an estimate of the optimal flowering period. The ideal variety and sowing time combination is shown in Table 3. These estimates suggest that in the longer-term, growers need to not only consider grain yield, protein and screenings, but also the likely flowering period.

Table 3. Grain yield, protein and screenings of 36 wheat varieties sown on three dates near Wagga Wagga in 2015.

Genotype	Sowing date 16 April				Sowing date 7 May				Sowing date 28 May			
	Yield (t/ha)	Protein (%)	Screenings (%)	Yield rank	Yield (t/ha)	Protein (%)	Screenings (%)	Yield rank	Yield (t/ha)	Protein (%)	Screenings (%)	Yield rank
ADV03-0056	4.9	10.9	5.4	24	5.6	10.4	0.9	8	4.0	11.6	2.2	17
Beckom	5.8	10.8	4.4	8	6.2	10.3	6.5	1	4.2	11.6	11.5	8
Bolac	5.7	11.8	11.3	12	4.8	11.3	10.6	29	3.7	12.5	8.3	30
Condo	4.8	11.1	7.3	26	6.0	10.6	2.0	3	4.9	11.9	1.8	2
Corack	4.3	11.4	4.0	31	6.1	10.9	0.7	2	4.7	12.1	1.3	3
Cosmick	5.4	10.8	5.9	21	5.7	10.3	7.5	6	4.2	11.6	10.4	6
Dart	3.4	12.9	4.4	35	5.0	12.4	2.1	25	3.7	13.6	6.3	31
EGA_Eaglehawk	5.7	11.1	9.5	11	4.5	10.6	9.4	33	3.8	11.8	9.2	26
EGA_Gregory	6.0	11.1	6.4	3	5.1	10.6	4.2	21	4.2	11.8	4.3	13
EGA_Wedgetail	5.6	11.6	7.1	13	4.7	11.1	5.1	31	3.6	12.3	3.0	33
Elmore CL PLUS	5.8	11.3	5.4	7	5.1	10.8	4.1	23	3.9	12.0	7.3	22
Emu_Rock	3.7	12.7	5.3	34	5.6	12.2	2.6	7	4.5	13.4	2.6	4
Gauntlet	5.8	11.2	5.6	9	5.3	10.7	2.5	14	4.2	11.9	4.1	12
Harper	5.5	11.1	7.7	18	5.3	10.6	3.7	17	3.9	11.8	6.4	20
HRZ08-0062	5.9	11.4	6.2	5	4.5	10.9	6.4	32	3.5	12.2	8.9	35
Janz	5.9	10.8	3.5	6	5.1	10.3	4.4	24	3.8	11.6	7.2	25
Kiora	5.7	11.2	5.7	10	5.1	10.7	6.0	20	3.6	12.0	9.4	34
Lancer	4.8	11.9	4.0	25	5.2	11.4	1.6	18	4.0	12.7	3.5	18
Livingston	2.1	13.1	3.4	36	5.1	12.5	5.4	22	4.1	13.8	5.6	15
LPB09-0358	5.5	10.7	5.3	20	6.0	10.2	1.2	4	4.2	11.4	3.5	11
LPB10-0018	4.4	11.6	3.7	30	5.3	11.1	3.2	16	5.2	12.4	5.7	1
LPB11-0140	5.5	10.9	8.1	19	5.0	10.4	4.8	26	4.0	11.7	8.6	19
LRPB Flanker	6.0	10.7	3.1	4	5.4	10.2	3.2	12	4.2	11.5	5.0	10
Mace	4.7	11.2	2.5	27	5.5	10.7	5.3	9	4.1	11.9	4.5	14
Merlin	4.4	12.3	2.9	29	5.3	11.8	2.5	13	4.0	13.1	4.5	16
Mitch	5.6	10.8	7.2	16	4.7	10.3	6.5	30	3.8	11.6	7.8	28
Spitfire	4.2	12.1	3.5	32	5.2	11.6	3.2	19	3.9	12.9	3.2	23
Sunguard	5.6	11.0	6.5	14	5.3	10.5	1.6	15	4.2	11.7	4.9	9
Sunlamb	4.5	11.8	9.4	28	4.1	11.3	5.3	36	3.3	12.6	5.1	36
Sunmate	3.8	11.4	5.9	33	5.5	10.9	2.0	10	3.9	12.2	9.8	21
Suntime	5.0	11.2	8.9	23	4.4	10.7	7.2	34	3.7	11.9	9.2	29
Suntop	5.6	10.9	6.8	15	5.4	10.4	5.6	11	4.4	11.6	4.9	5
Sunvale	6.3	11.9	4.4	1	4.9	11.4	4.1	28	3.8	12.7	8.6	27
Trojan	6.2	10.6	5.3	2	5.8	10.1	1.6	5	4.2	11.3	7.9	7
V07176-69	5.3	11.7	7.8	22	4.4	11.2	5.5	35	3.7	12.5	8.1	32
Viking	5.6	11.2	1.8	17	5.0	10.7	6.7	27	3.9	11.9	5.6	24
l.s.d. ($P < 0.001$)	0.57	0.94	0.62									

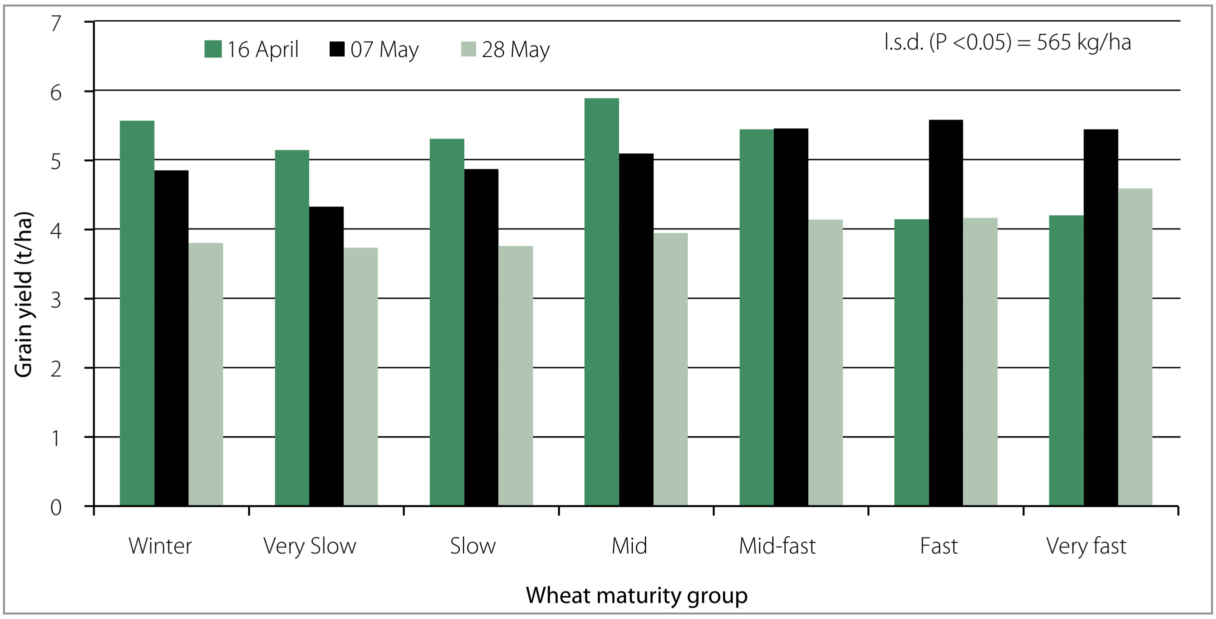

Figure 2. Average grain yield of wheat varieties grouped into seven different maturity classifications and sowing on three different dates near Wagga Wagga in 2015.

Summary

The high average grain yields from the first two sowing dates (16 April and 7 May) coincided with flowering times falling within the optimal flowering period of late September to early October. The later sowing date of 28 May resulted in varieties flowering later in October, which reduced grain yields, particularly in the longer-season varieties. The variation in flowering dates ranged from 37 days for the first sowing date to only seven days for the late sowing on 28 May. Delaying sowing in 2015 past the middle of May resulted in a decrease in grain yield of 1.2 t/ha averaged across all varieties. Beckom, Corack, Trojan and Condo were the highest yielding varieties averaged across all the sowing dates. Varieties such as Beckom, Trojan, Flanker and Corack appear to be less sensitive to the sowing date and yielded higher than other varieties across a range of sowing dates. Sowing times that target the optimal flowering period resulted in the highest grain yield in this experiment.

Acknowledgements

This experiment is part of 'Variety Specific Agronomy Packages for southern, central and northern New South Wales', DAN00167, 2013–17, jointly funded by GRDC and NSW DPI.

Effect of sowing date and nitrogen rate on grain yield of six wheat varieties – Lockhart 2015

Eric Koetz, **Hugh Kanaley** and **Greg McMahon** NSW DPI, Wagga Wagga

Key findings

» Increased nitrogen application rates equated to increased grain yield.
» Early sowing had a grain yield advantage of 0.74 t/ha averaged across all varieties and nitrogen application rates.
» Corack was the highest yielding variety in this trial.
» Splitting nitrogen application in the second time of sowing increased grain yield.
» Grain protein concentration increased as nitrogen application rates increased.
» The highest proteins occurred at the maximum nitrogen rate of 160 kg/ha in Lancer$^{\phi}$, EGA_Gregory$^{\phi}$ and Spitfire$^{\phi}$ from the 12 May sowing.

Introduction

Varieties can differ in their ability to yield at various sowing dates. Varieties also differ in their response to different rates of nitrogen (N) and how they convert it into yield and protein. This experiment was designed to measure the influence of sowing date and N rate on six common wheat varieties.

This experiment is one in a series of N experiments aimed at establishing variety responses to sowing dates and different N rates and timings.

Site details

Location	Lockhart NSW
Soil type	Grey vertosol
Previous crop	Canola
Stubble management	Direct drill
Planter	Plot air seeder, DBS tynes
Fertiliser	100 kg/ha Superfect
Soil tests:	pH 4.8_{Ca} phosphorus 41 mg/kg nitrogen 70 kg N/ha (0–30 cm)
Herbicides	Knockdown: Roundup CT 1.5 L/ha Pre-emergent: Logran 35 g/ha + Sakura 118 g/ha Post-emergent: Precept 500 mL/ha + Lontrel 150 mL/ha. Axial 150 mL/ha
Fungicide	Flutriafol 400 mL/ha on fertiliser at sowing Prosaro 150 mL/ha + Hasten 1% v/v
Harvest date	21 November 2015

Treatments

Varieties	Corack$^{\phi}$ EGA_Gregory$^{\phi}$, Lancer$^{\phi}$	Spitfire$^{\phi}$ Suntop$^{\phi}$ Trojan$^{\phi}$
Sowing dates	TOS 1: 23 April TOS 2: 12 May	
Nitrogen fertiliser	0, 20, 40, 80, 160 kg N/ha at sowing 40 kg N/ha top-dress TOS 1: 14 July, TOS 2: 28 August	

Seasonal review

The 2015 season had a good autumn break and a cold, wet winter. Total rainfall at the site was 386 mm of which 256.5 mm was in-crop rainfall

Table 1. Rainfall for 2015 at Lockhart. Growing season (April–October) rainfall 257 mm

Lockhart rainfall for 2015 (mm)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
38	25	0	59	19	70	25	62	19	3.5	45	22

(Table 1). The long-term average in-crop rainfall is 302.5 mm. The winter provided ideal conditions for growth; however, the spring period was dry and hot with only 18.5 mm falling in September during the critical grain filling period.

Results

Flowering

Delayed flowering dates correlated with a decreased grain yield (Figure 1). The 12 May sowing date flowered later than the optimal window and flowered under heat stress conditions (7 days >33 °C in early October). At both sowing dates there was a trend toward lower grain yields as the flowering date was delayed.

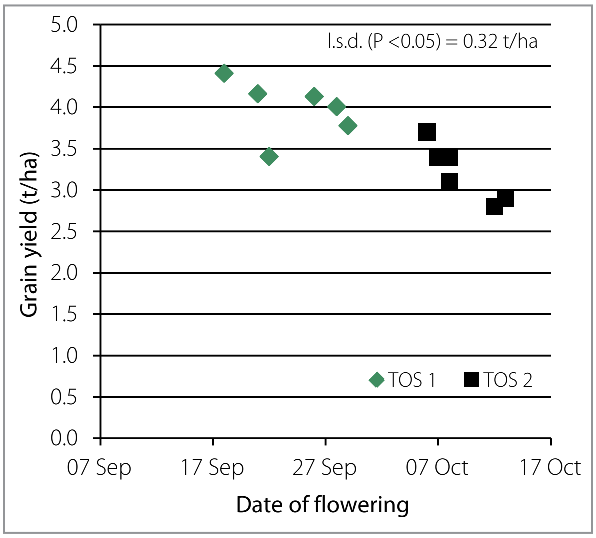

Figure 1. Anthesis date and grain yield of six varieties averaged across nitrogen rates at Lockhart, 2015.

Grain yield

Variety and N rate had significant effects (P <0.05) on grain yield (Figure 2). The interaction between variety and sowing date was also significant (P <0.05). Averaged across variety and N rate, delaying sowing from 23 April until 12 May decreased yield by an average of 0.74 t/ha (Table 2).

Table 2. Average grain yield of six wheat varieties sown at two dates at Lockhart in 2015.

Sowing date	Grain yield (t/ha)
23 April	3.98
12 May	3.24
l.s.d. (P <0.05)	0.32

Figure 2 shows that there was a consistent increase in grain yield as the N rate increased across all varieties sown on 23 April (TOS 1). Grain yield plateaued as the N rate exceeded 80 kg/ha in the 12 May sowing (TOS 2). The split application (28 August) on the second sowing date produced more dry matter per hectare, which correlated with increased grain yield. This could be linked to some waterlogging events during winter when N applied at sowing might not have been available for plant growth for periods during the growing season.

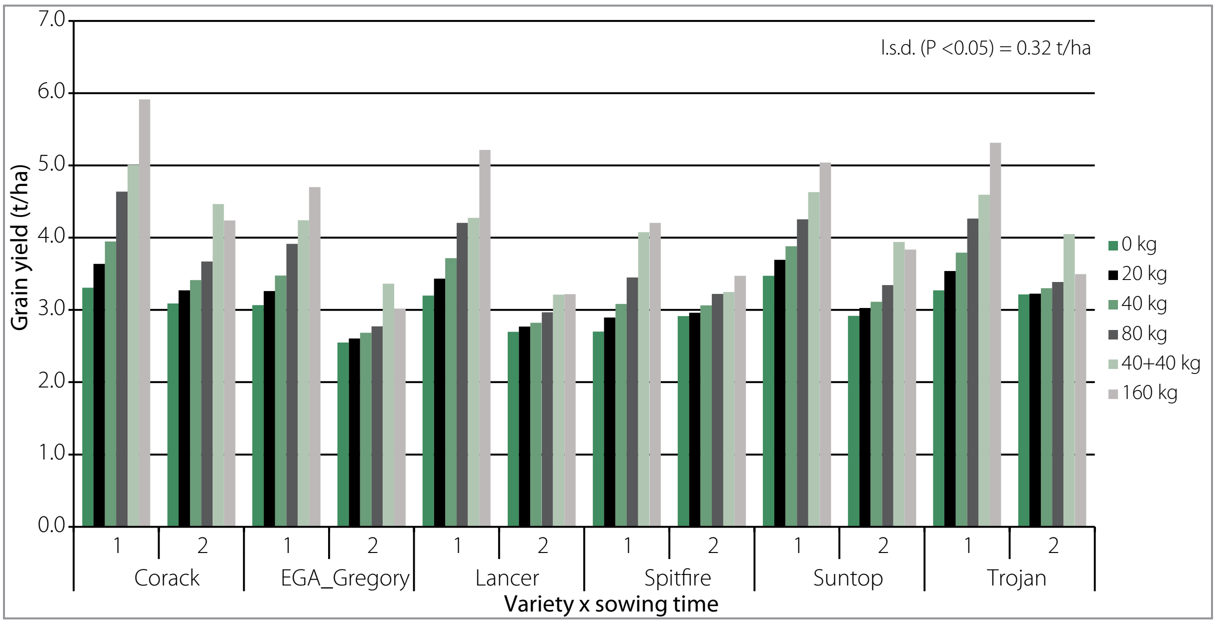

Figure 2. Grain yield of six wheat varieties at five nitrogen rates at Lockhart in 2015.

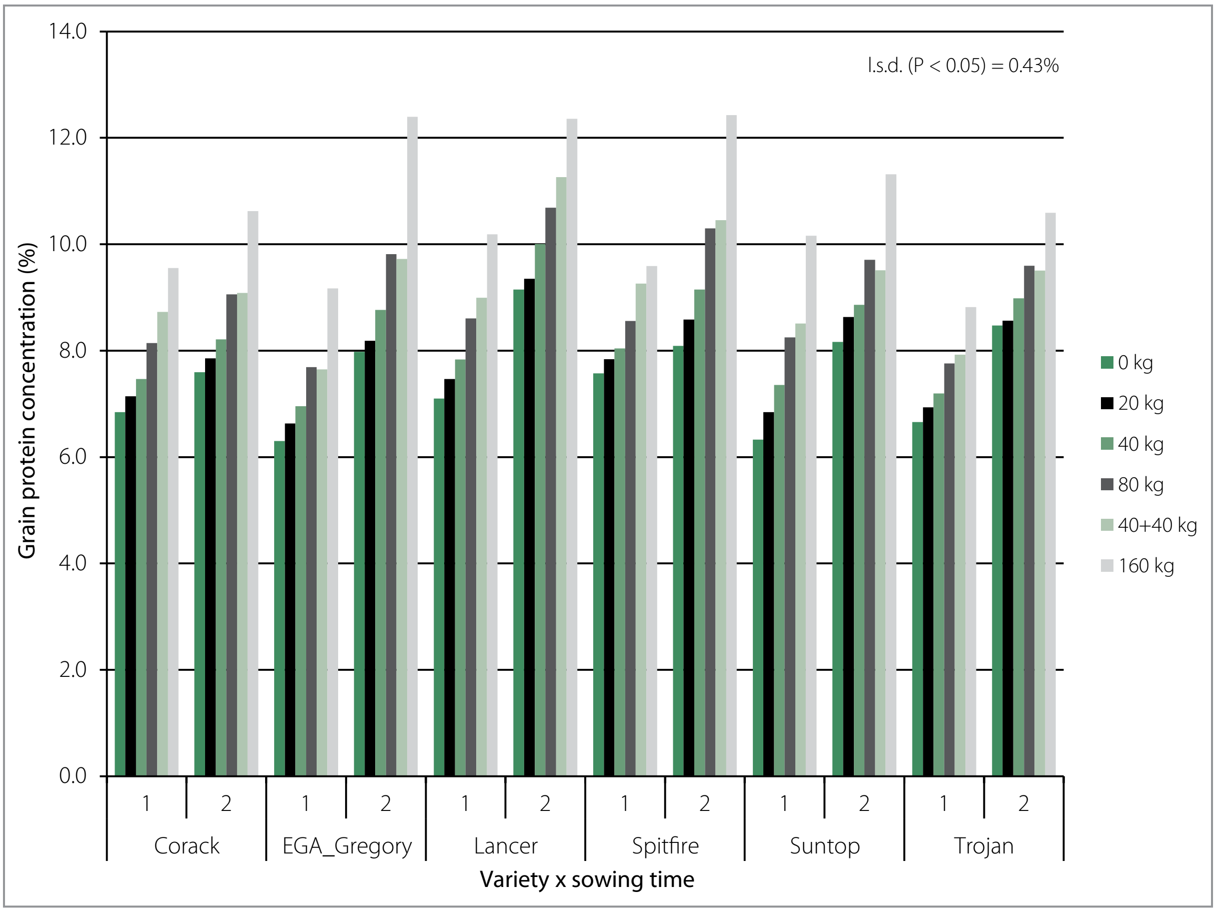

Figure 3. Grain protein concentration of six wheat varieties at five nitrogen rates at Lockhart in 2015.

Grain protein

There was a significant interaction for variety by N application and sowing time by N application (P <0.05). Lancer and Spitfire had the highest grain protein averaged across sowing time and application rates. For the first sowing, grain protein increased as the N rate increased. For the second sowing, there was no significant difference between the 80 kg/ha N rate at sowing and the split application of 40 kg/ha N at sowing and 40 kg/ha N at GS31. The highest grain protein was measured from the 160 kg/ha N rate from the 12 May sowing date in EGA_Gregory, Lancer and Spitfire (Figure 3).

Summary

Matching the variety phenology with the optimal flowering period was critical to maximising grain yield. As the flowering date was delayed, grain filling was occurring under heat stress conditions decreasing the grain yield potential. As N rates increased, grain yield and grain protein increased. This site was very responsive to applied N. Averaged across varieties and nitrogen rates there was a 0.74 t/ha penalty for delaying sowing by 19 days (23 April to 12 May) in 2015. There was a significant (P <0.05) increase in grain protein across all varieties as N rates increased. Grain protein increased by 2.9%from the 0–160 kg/ha applied N. The highest grain protein recorded was 12.4% from the second sowing, most likely a reflection of the hot, dry finish.

Acknowledgements

This experiment is part of 'Variety Specific Agronomy Packages for southern, central and northern New South Wales', DAN00167, 2013–17, jointly funded by GRDC and NSW DPI.

The cooperation of the Warakirri Cropping group, especially John Stevenson at Orange Park is greatly appreciated.

Effect of nitrogen rate and sowing time on grain yield and grain protein of six wheat varieties – Condobolin 2015

Ian Menz, **Nick Moody** and **Daryl Reardon** NSW DPI, Condobolin

Key findings

» Yield was reduced by dry and hot conditions during flowering for both times of sowing.

» Spitfire yielded highest in time of sowing 1 (1.55 t/ha) and Condo$^{\Phi}$ yielded highest in time of sowing 2 (1.15 t/ha).

» The nil nitrogen treatment yielded highest (1.01 t/ha); increasing nitrogen rate decreased grain yield for both times of sowing.

Introduction

This experiment evaluated the effect of time of sowing (TOS) and nitrogen rate on grain yield and grain quality for six current wheat varieties in the low rainfall zone of central western NSW.

Site details

Location	Condobolin Agricultural Research and Advisory Station (Condobolin ARAS)
Soil type	Red-brown earth
Previous crops	Pasture 2012, wheat 2013 and 2014
Fertiliser	70 kg/ha MAP + Jubilee at 400 mL/ha (fungicide on fertiliser)
Available nitrogen (N)	68 kg/ha (0–60 cm)
In-crop rainfall (1 April–30 September)	198.2 mm
Harvest date	TOS1: 9 November TOS2: 10 November

Treatments

Wheat varieties	Condo$^{\Phi}$ EGA_Gregory$^{\Phi}$ Lancer$^{\Phi}$	Spitfire$^{\Phi}$ Suntop$^{\Phi}$ Viking$^{\Phi}$
Nitrogen rates	0, 20, 40, 80, 40 + 40 split* and 160 kg N/ha * Split application 40 kg N/ha at sowing + 40 kg N/ha at first node stage (GS 31)	
Sowing times	TOS 1: 5 May TOS 2: 26 May	

Seasonal conditions

Growing season rainfall at the experiment site was just below average with the Condobolin ARAS recording 198.2 mm. The long-term average (LTA) in-crop rainfall is 209 mm. The rain was spread across the first five months of the growing season. Rainfall in May was 11.6 mm (LTA 34.4 mm) and in September 6.2 mm (LTA 29.1 mm), which fell in the first week of September. The next substantial rainfall of 16 mm was not until 22 October (Table 1).

High daytime temperatures at Condobolin (33–38 °C) and hot winds during the first week of October coincided with flowering and contributed to the lower yields in TOS 2.

The experiments were sown into adequate moisture and established quickly and evenly. The experiment was weed-free and very even throughout the season.

Table 1. Monthly rainfall at the Condobolin ARAS 2015.

Condobolin ARAS rainfall for 2015 (mm)														
Dec 2014	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	In-crop
88.8	59.2	35.9	0.2	64.7	11.6	31.8	41.6	42.3	6.2	65.2	67.3	28.5	454.5	198.2

Results

Grain yield

The experiments were sown into retained stubble with 68 kg N/ha (0–60 cm) of available N. There was a significant difference (P <0.05) between the grain yields of six varieties (Table 2) and the response of grain yield to applied nitrogen (Table 3). At the first time of sowing (5 May), Spitfire (1.55 t/ha), Condo (1.46 t/ha) and Suntop (1.43 t/ha) were the highest yielding varieties. At the second time of sowing (26 May) Condo (1.15 t/ha), Dart (1.06 t/ha) and Spitfire (0.93 t/ha) were the highest yielding varieties. Lancer (1.09 t/ha at TOS 1 and 0.38 t/ha at TOS 2) yielded the least.

Table 2. Grain yield (t/ha) of six wheat varieties sown on 5 May and 26 May at Condobolin 2015. (Note: the l.s.d. represents the difference within each TOS only).

Variety	Grain yield (t/ha)	
	TOS 1: 5 May	TOS 2: 26 May
Condo	1.46	1.15
Dart	1.36	1.06
EGA_Gregory	1.19	0.55
Lancer	1.09	0.37
Spitfire	1.55	0.93
Suntop	1.43	0.89
l.s.d. (P <0.05)	0.07	0.07

There was a significant difference (P <0.05) between N rates (Table 3) averaged across all varieties at both sowing times. Grain yield decreased with increasing N rate. The nil N treatment yielded the highest across both sowing times (Table 3).

Table 3. Grain yield (t/ha) averaged across all varieties at six N rates, sown on 5 May and 26 May at Condobolin 2015 (Note the l.s.d. represents the difference within each TOS only).

Nitrogen rate (kg N/ha)	Grain yield (t/ha)	
	TOS 1: 5 May	TOS 2: 26 May
0	1.43	1.01
20	1.40	0.89
40	1.37	0.84
80	1.34	0.77
40 + 40 split	1.31	0.70
160	1.23	0.71
l.s.d. (P <0.05)	0.07	0.08

Grain quality

There was a significant interaction (P <0.05) in grain quality between variety, sowing time and nitrogen treatments. There was a significant difference in grain protein, screening and test weights for the six varieties (Table 4) and the six N treatments (Table 5).

The dry conditions in spring would have contributed to the low yields, high grain protein and high screenings in TOS 2.

There was an increase in grain protein between TOS 1 and TOS 2 across all varieties (Table 4). Grain protein increased across all nitrogen treatments between the two sowing times (Table 5).

Spitfire achieved the highest grain nitrogen yield (41.4 kg N/ha) and test weight (70.0 kg/hL) in TOS 1. Lancer had the lowest screenings (6.9%) and the highest test weight (78.9 kg/hL) for TOS 2. Lancer grain N yield was low (11.5 kg N/ha) for the TOS 2 due to the low grain yield achieved from the 26 May sowing time (Table 4).

Table 4. Grain quality of six wheat varieties at two times of sowing at Condobolin 2015.

Variety	TOS 1: 5 May				TOS 2: 26 May			
	Grain protein (%)	Grain nitrogen yield (kg N/ha)	Screenings (%)	Test weight (kg/hL)	Grain protein (%)	Grain nitrogen yield (kg N/ha)	Screenings (%)	Test weight (kg/hL)
Condo	14.1	36.0	22.2	66.7	16.0	32.2	34.6	66.7
Dart	15.0	35.6	41.2	66.1	17.1	31.8	45.3	64.8
EGA_Gregory	14.3	29.8	23.2	67.8	16.5	15.8	18.5	76.8
Lancer	15.7	29.9	26.1	68.5	17.9	11.5	6.9	78.9
Spitfire	15.3	41.4	22.9	70.0	17.8	28.8	33.2	70.9
Suntop	13.7	34.1	32.3	69.6	15.8	24.5	36.9	74.6
l.s.d. (P <0.05)	0.001	NA	2.1	0.8	0.3	NA	2.8	2.1

Table 5. Grain quality of wheat at six N rates and two times of sowing at Condobolin 2015.

Nitrogen rate (kg N/ha)	TOS 1: 5 May				TOS 2: 26 May			
	Grain protein (%)	Grain nitrogen yield (kg N/ha)	Screenings (%)	Test weight (kg/hL)	Grain protein (%)	Grain nitrogen yield (kg N/ha)	Screenings (%)	Test weight (kg/hL)
0	12.3	30.6	18.5	71.1	15.0	26.5	22.6	73.7
20	13.2	32.3	22.2	70.2	16.0	25.0	24.5	73.1
40	14.3	34.1	26.2	68.7	16.5	24.4	30.4	72.1
80	15.4	36.0	30.3	67.8	17.2	23.3	31.2	71.5
40 + 40 split	16.2	37.2	34.1	66.0	18.2	22.3	34.0	71.2
160	16.9	36.3	36.8	65.4	18.2	22.7	32.6	71.1
l.s.d. (P <0.05)	0.001	NA	2.1	0.8	0.3	NA	2.7	0.9

Summary

Growing season rainfall was slightly lower than average with the majority falling in April, July and August. The dry weather during September (6.2 mm) coupled with high temperatures in September and October contributed to the low grain yields for the 26 May sowing time as the plants 'hayed off'. The above-average October rainfall did not benefit the plants as they could not recover from the earlier dry conditions.

The shorter season varieties such as Condo, Dart and Spitfire had the highest grain yields for both sowing times. These varieties were able to fill grain before the drier conditions during spring affected the plants. The longer season varieties (EGA_Gregory and Lancer) yielded lowest for both times of sowing as the dry spring affected grain filling.

The low yield achieved for both times of sowing is attributed to the varieties flowering during late September (16–22 September) when moisture was limited and temperatures were increasing.

The grain quality results showed that the dry spring conditions affected both sowing times.

Acknowledgements

This experiment is part of 'Variety Specific Agronomy Packages for southern, central and northern New South Wales', DAN00167, 2013–17, jointly funded by GRDC and NSW DPI.

Thanks to the operational and technical officers at Condobolin ARAS and Dr Neroli Graham for statistical analyses.

Effect of sowing date on grain yield, water-use efficiency and grain quality of wheat – Canowindra 2015

Colin McMaster NSW DPI, Cowra; **Adam Coleman** NSW DPI, Orange

Key findings

» The variety Beckom sown on 5 May yielded highest (5.67 t/ha).

» Grain yield reductions up to 4 t/ha occurred when varieties were not sown at the correct time (due to flowering throughout August–September frost events).

» Greatest yield losses occurred when quick maturing varieties were sown early rather than longer season varieties sown late.

» Winter wheats and very long spring wheats performed better in 2015 than 2014, presumably due to less early aphid pressure (BYDV) in 2015.

» Grain yield was maximised when winter wheats were sown early (mid-April) or mid to mid–fast varieties were sown in the first week of May. If spring conditions had been favourable, the winter wheats may have outperformed the mid to mid–fast varieties when sown in late May.

» Screenings increased as sowing was delayed.

agronomy – cereals

Introduction

Recent research and crop modelling (Hunt et al. 2013) identified potential grain yield advantages from sowing slower maturing wheat varieties with either strong vernalisation (winter wheats) or strong photoperiod requirement in early- to mid-April when seasonal conditions allow.

This experiment evaluated the performance of recently released wheat varieties in response to various times of sowing. The wheat varieties evaluated ranged from long season winter wheats to very fast spring wheats.

Site details

Location	"The Pines" Canowindra NSW
Soil type	Red chromosol
Previous crop	Canola
Stubble management	Stubble incorporated with Kelly chain prior to sowing
Harvest date	24 November 2015
Fertiliser	20 kg P/ha banded at sowing 80 kg N/ha applied at 2–3 leaf stage
Soil pH_{Ca}	6.4
Colwell P (mg/kg)	29
Mineral N at sowing (1.2 m depth)	176 kg N/ha
Fungicide	Flutriafol-treated fertiliser (400 mL/ha) Prosaro® applied at flag leaf emergence (GS39)
Starting soil moisture[a]	157 mm (plant available water)
In-crop rainfall (April–October)	316 mm (only 6 mm in September)
Frost events (late August–October) 20 events	21/8, 30/8, 31/8, 1/9, 2/9, 6/9, 8/9, 9/9, 16/9, 17/9, 18/9, 19/9, 23/9, 24/9, 25/9, 26/9, 27/9, 28/9, 29/9, 2/10

[a] Gravimetric moisture measured via five soil cores

Treatments

Thirty-six wheat varieties were sown at three sowing dates: 17 April, 5 May and 25 May 2015 (Table 1).

Table 1. Wheat varieties, maturity type and recommended sowing window for central-eastern NSW.

Maturity type	Suggested sowing window	Varieties
Winter wheat	Late Feb to late April	Naparooɸ, EGA_Wedgetailɸ, LPB11-0140
Very slow	Early to mid-late April	Eaglehawkɸ, Sunlambɸ
Slow	Mid-April to early May	Bolacɸ, Lancerɸ, Suntimeɸ, Kioraɸ
Mid	Late April to mid-May	EGA_Gregoryɸ, Flankerɸ, Gauntletɸ, Sunvaleɸ, Vikingɸ, Mitchɸ, Trojanɸ, HRZ08-0062
Mid–fast	Early May to mid-May	Elmore CL PLUSɸ, Sunguardɸ, Suntopɸ, HRZ03-0056, Beckomɸ, Janz, Harperɸ, LPB09-0358, Cosmickɸ
Fast	Mid-May onwards	Corackɸ, Emu Rockɸ, Livingstonɸ, Maceɸ, Merlinɸ, Spitfireɸ, Sunmate, Dartɸ, Condoɸ, LPB10-0018

Table 2. Grain yield and rank of 36 wheat varieties sown at three sowing dates at Canowindra, 2015.

Variety	Grade (South)	Maturity group	Grain yield (t/ha) and rank					
			17 April		5 May		25 May	
EGA_Wedgetail	APH	Winter wheat	5.52	2	4.82	19	3.31	35
LPB11-0140		Winter wheat	5.54	1	4.66	26	3.85	24
Naparoo	FEED	Winter wheat	5.19	4	4.41	30	3.53	32
EGA_Eaglehawk	APH	Very slow	5.41	3	4.65	27	3.49	33
Sunlamb	ASW	Very slow	5.06	5	4.70	24	2.85	36
Bolac	APH	Slow	4.78	6	4.55	28	4.02	18
HRZ08-0062		Slow	3.72	11	5.24	5	3.34	34
Kiora	AH	Slow	4.51	7	5.00	11	3.74	28
Lancer	APH	Slow	4.14	10	5.12	7	3.61	29
Suntime		Slow	4.36	8	4.72	22	3.61	30
Cosmick		Mid	1.93	23	4.68	25	4.21	15
EGA_Gregory	AH	Mid	3.05	13	5.09	8	4.26	13
Gauntlet	AH	Mid	1.41	29	5.05	9	3.89	23
Flanker	APH	Mid	2.19	21	5.29	4	4.45	7
Mitch	APW	Mid	2.81	16	4.77	21	3.79	26
Sunvale	APH	Mid	4.22	9	4.91	16	3.54	31
Trojan	APW	Mid	3.06	12	5.61	2	4.39	8
Viking	APH	Mid	2.40	19	5.22	6	4.30	11
Elmore CL PLUS	AH	Mid–fast	2.14	22	4.95	13	4.45	6
Harper		Mid–fast	2.87	14	4.95	14	4.24	14
HRZ03-0056		Mid–fast	1.33	30	5.31	3	4.32	10
Janz	APH	Mid–fast	2.22	20	4.77	20	3.94	20
LPB09-0358		Mid–fast	2.67	18	5.03	10	4.27	12
Sunguard	AH	Mid–fast	2.79	17	4.86	18	3.95	19
Suntop	APH	Mid–fast	2.83	15	4.98	12	4.36	9
Beckom	AH	Mid–fast	1.52	27	5.67	1	4.54	4
Condo	AH	Fast	1.55	26	4.94	15	3.56	3
Corack	APW	Fast	0.75	35	4.71	23	4.81	1
Dart	AH	Fast	1.68	24	3.76	35	3.80	25
Emu Rock	AH	Fast	1.64	25	3.88	34	3.94	21
Livingston	AH	Fast	0.58	36	4.05	32	4.20	16
LPB10-0018		Fast	0.90	31	4.35	31	4.51	5
Mace	AH	Fast	0.81	33	4.45	29	4.68	2
Merlin	AH	Fast	0.77	34	3.58	36	3.93	22
Spitfire	APH	Fast	0.87	32	3.89	33	3.77	27
Sunmate	AH	Fast	1.42	28	4.86	17	4.14	17
		Min	0.58		3.58		2.85	
		Mean	2.74		4.76		4.02	
		Max	5.54		5.67		4.81	
l.s.d.(P=0.05)	Sowing date = 0.14; variety = 0.25; sowing date × variety = 0.44							

Results

The 2015 season had ideal soil moisture levels in autumn to germinate and establish all wheat varieties across all three sowing dates. The winter had above average rainfall during July and August providing good conditions for crop growth but spring was dry and hot with only 6 mm of rainfall during the critical period leading up to anthesis/grain fill (September). This resulted in grain yield reductions across the entire trial site. Late rainfall events occurred in mid-October which would have benefited the longer season varieties sown in late May.

Table 3. Grain quality results including protein (%), test weight (kg/hL) and screenings (%) of 36 wheat varieties sown at three sowing dates at Canowindra, 2015.

Variety	TOS 1 – 17 April			TOS 2 – 5 May			TOS 3 – 25 May		
	Protein (%)	Test weight (kg/hL)	Screenings (%)	Protein (%)	Test weight (kg/hL)	Screenings (%)	Protein (%)	Test weight (kg/hL)	Screenings (%)
Bolac	13.1	74.6	8.2	13.0	74.6	12.0	13.7	77.8	10.7
Condo	15.3	77.8	7.2	12.6	77.2	8.1	12.9	76.9	7.4
Corack	16.0	77.6	2.0	13.4	77.8	3.2	12.2	76.0	5.9
Cosmick	13.2	74.8	5.4	12.4	73.7	9.1	13.2	73.2	14.0
Dart	16.0	79.4	4.8	13.9	77.9	4.3	13.3	77.1	8.6
EGA_Eaglehawk	11.7	76.5	9.7	13.3	77.9	6.8	13.9	79.8	5.6
EGA_Gregory	13.1	77.9	3.7	12.5	76.8	7.3	12.9	77.4	9.0
EGA_Wedgetail	12.6	71.2	4.8	13.5	72.5	7.2	13.8	74.5	4.1
Elmore CL PLUS	14.7	79.6	3.5	12.7	77.0	6.1	13.6	77.1	12.5
Emu Rock	16.1	77.3	3.5	14.1	77.3	5.2	13.1	75.4	5.8
Gauntlet	14.7	78.5	4.1	12.9	77.9	9.0	12.7	80.7	4.1
Harper	13.9	77.1	4.6	13.6	76.5	8.1	13.2	76.0	8.5
HRZ03-0056	14.9	76.3	4.0	12.5	75.5	4.7	12.6	76.9	6.1
HRZ08-0062	13.3	77.3	4.3	12.6	74.6	6.2	13.5	78.6	6.9
Janz	14.0	78.9	2.6	13.0	75.5	7.1	13.3	78.3	8.1
Kiora	13.1	78.3	4.7	13.1	75.0	11.1	13.4	78.3	11.2
Lancer	13.5	76.2	3.3	13.0	77.1	4.7	14.3	79.2	5.3
Livingston	16.4	76.1	4.5	13.7	77.0	6.5	13.6	75.4	10.7
LPB09-0358	14.7	77.3	4.2	12.8	75.8	4.5	12.8	75.7	7.5
LPB10-0018	15.4	77.6	3.6	12.9	77.5	5.6	12.6	77.0	10.4
LPB10-2555	14.1	78.2	3.7	12.2	76.8	7.9	12.7	77.8	10.8
LPB11-0140	11.9	77.4	7.7	12.9	76.9	6.0	13.1	78.4	7.2
Mace	15.8	76.6	2.6	12.8	77.2	4.1	11.9	76.3	7.2
Merlin	17.0	77.2	2.4	14.7	79.7	3.6	13.9	78.4	7.2
Mitch	13.0	75.7	4.1	11.9	73.7	6.6	12.7	75.8	9.4
Naparoo	12.2	74.2	12.0	12.7	75.5	11.1	13.3	77.2	8.7
Spitfire	17.2	77.6	4.0	14.8	80.2	3.9	13.6	79.0	5.3
Sun512C	12.6	75.4	9.7	13.4	77.7	10.6	15.1	78.5	7.1
Sunguard	13.7	76.8	5.9	12.4	76.2	6.7	13.1	76.5	8.1
Sunmate	14.6	76.8	4.2	12.1	74.7	6.6	13.1	76.5	6.2
Suntime	13.2	75.8	7.4	12.6	76.4	9.5	13.2	79.5	7.2
Suntop	13.9	76.6	5.4	12.3	75.7	7.1	12.2	78.2	10.4
Sunvale	13.2	79.3	3.5	13.6	76.9	7.3	14.0	78.4	8.5
Trojan	13.5	78.1	3.7	12.3	76.9	4.7	13.0	78.8	7.3
V06008-14	14.3	77.9	3.7	11.9	74.8	6.4	12.7	75.3	12.8
Viking	14.1	79.0	3.7	12.5	76.3	9.4	12.8	79.8	11.5
Min	11.7	71.2	2.0	11.9	72.5	3.2	11.9	73.2	4.1
Mean	14.2	77.0	4.9	13.0	76.4	6.9	13.2	77.4	8.3
Max	17.2	79.6	12.0	14.8	80.2	12.0	15.1	80.7	14.0
l.s.d. (P=0.05)									
TOS	0.4	0.7	1.4						
Variety	0.4	1.1	2.0						
Variety × TOS	0.7	2.0	3.5						

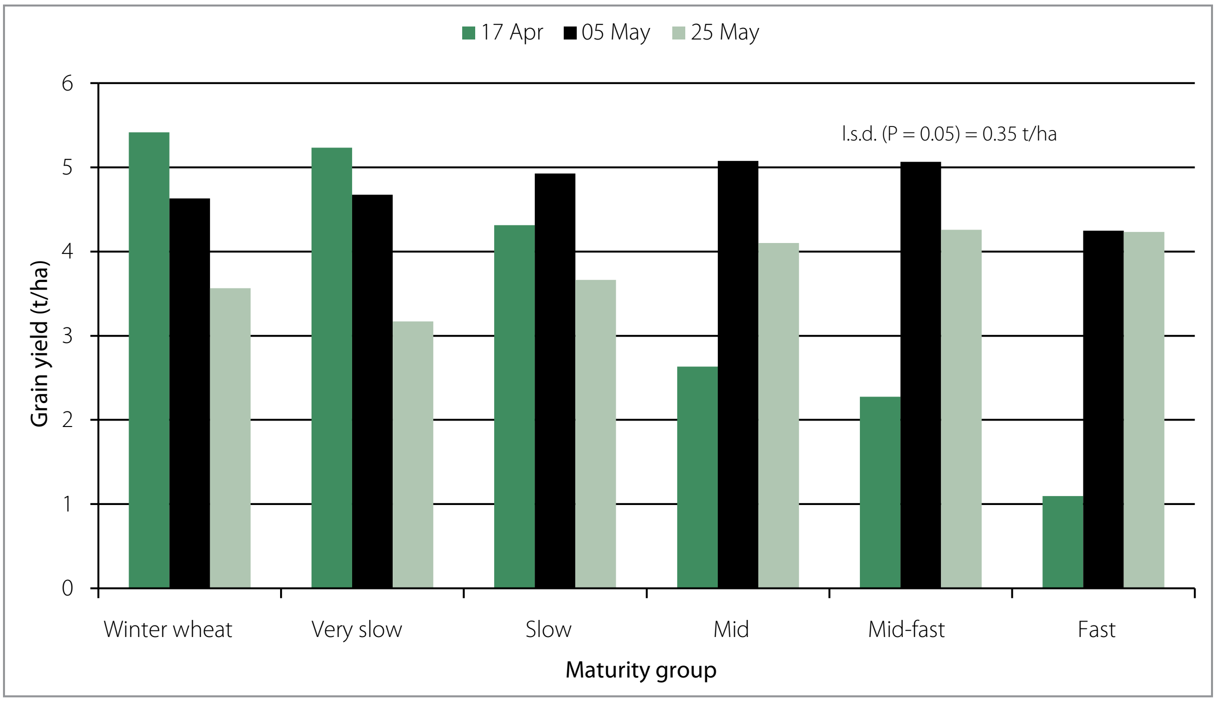

Figure 1. Average grain yield of various maturity groups sown at three sowing dates at Canowindra, 2015.

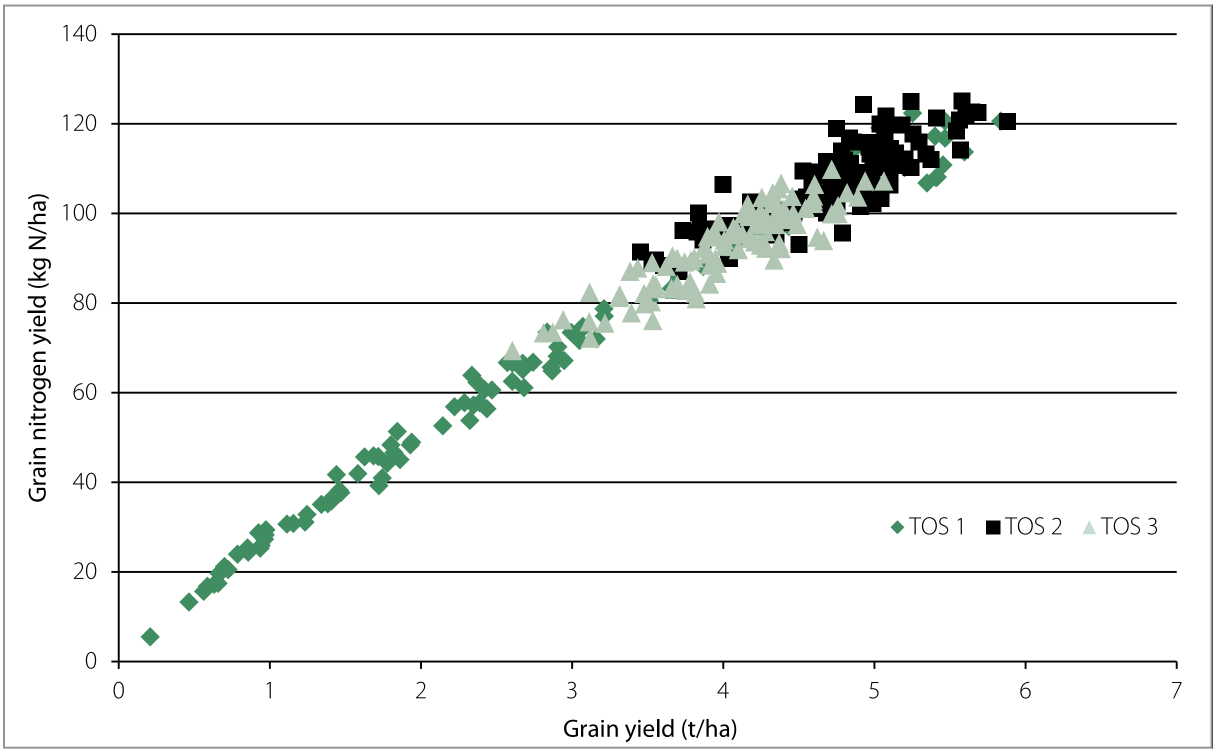

Figure 2. Relationship between grain yield and grain nitrogen yield across three sowing dates at Canowindra, 2015.

Grain yield

Wheat grain yield was significantly affected by time of sowing (P<0.001), variety (P<0.001) and the interaction between sowing time and variety (P<0.001). The interaction between sowing time and phenology type was also significant (P<0.001).

When averaged over all 36 varieties, grain yield was significantly higher when sown on 5 May (4.76 t/ha) compared to either 17 April (2.74 t/ha) or 25 May (4.02 t/ha). The highest yielding variety was Beckom (5.67 t/ha) sown on 5 May and the lowest was Livingston sown on 17 April (0.58 t/ha) (Table 2).

Varieties that performed well across all sowing dates (achieved above average yields in each time of sowing) were EGA_Gregory, Suntop and Trojan. These varieties ranged from mid- to mid–fast phenology types.

Winter wheats and the longer season spring varieties such as LPB11-0140, EGA_Wedgetail, EGA_Eaglehawk, Naparoo and Sunlamb performed well when sown early but poorly when sown late.

Conversely, fast to very fast maturing varieties performed poorly with early sowing but well with later sowing e.g. Corack, Mace, Condo, Beckom and LPB10-0140. These quicker maturing varieties, when sown in mid-April suffered major yield penalties due to reproductive frost damage caused by August/ September frosts. Corack had a 4 t/ha grain yield reduction when sowing occured 18 days earlier (5 May compared to 17 April). Interestingly, this same trend occurred in 2014 (McMaster et al. 2015).

Grain yield was maximised by sowing a winter wheat early (mid-April) or a mid- to mid–fast maturing variety in the first week of May (Figure 1).

Grain quality (protein, test weight and screenings)

Grain protein was significantly affected by time of sowing ($P<0.002$), variety ($P<0.001$) and the interaction between sowing time and variety ($P<0.001$). Total nitrogen removal (yield × protein × 1.75) was correlated with grain yield (Figure 2).

Grain protein, test weight and screenings are found in Table 3. Due to the dry finish, screenings increased as sowing was delayed.

Summary

These results highlight that specialist varieties exist for specific sowing dates enabling grain yield to be maximised for a given sowing window. However, a specialist variety sown outside its window could result in large yield penalties as observed in this experiment and in the 2014 experiment.

The central-eastern region of NSW is characterised by high yield potential but grain yield reductions of up to 4.0 and 4.9 t/ha occurred in 2014 and 2015 experiments respectively when variety phenology and sowing time were not carefully matched. Highest grain yield losses occurred when quicker maturing varieties were sown early as they flowered during the frost prone period of late August and early September, resulting in severe reproductive frost damage.

Grain yield was maximised by sowing a winter wheat early (mid-April) or a mid to mid–fast variety in the first week of May. If the spring had been more favourable, the winter wheats may have out yielded the mid to mid–fast varieties.

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Effect of sowing time on 32 wheat varieties – Condobolin 2015

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Key findings

- » LPB10-0018 was the highest yielding variety sown on 30 April (2.09 t/ha).
- » Emu Rock$^{\phi}$ was the highest yielding variety sown on 22 May (1.72 t/ha) and 11 June (0.89 t/ha).
- » Emu Rock$^{\phi}$ was the highest yielding variety (1.49 t/ha) when averaged across all sowing times.
- » Dry conditions during September and October contributed to the lower average yields in the 22 May and 11 June sowing times.

Introduction

This experiment investigated the effect of time of sowing (TOS) on grain yield of 32 new and current wheat varieties in the low rainfall region of central western NSW. The three sowing dates represented the full span of the sowing window.

Site details

Location	Condobolin Agricultural Research and Advisory Station
Soil type	Red-brown earth
Previous crops	Lucerne pasture (2012–14). Fallowed August 2014.
Fertiliser	70 kg/ha MAP + Jubilee @ 400 mL/ha (fungicide on fertiliser)
Available N	174 kg/ha (0–60 cm)
In-crop rainfall (April–Oct)	198.2 mm
Harvest date	24 November 2015

Treatments

Varieties	Bolac$^{\phi}$	Gauntlet$^{\phi}$	Mitch$^{\phi}$
	Condo$^{\phi}$	Impala$^{\phi}$	Phantom$^{\phi}$
	Corack$^{\phi}$	Janz	Spitfire$^{\phi}$
	Dart$^{\phi}$	Lancer$^{\phi}$	Strzelecki$^{\phi}$
	EGA_Eaglehawk$^{\phi}$	Lincoln$^{\phi}$	Sunguard$^{\phi}$
	EGA_Gregory$^{\phi}$	Livingston$^{\phi}$	Sunmate$^{\phi}$
	EGA_Wedgetail$^{\phi}$	LPB09-0358	Suntop$^{\phi}$
	Elmore CL PLUS$^{\phi}$	LPB10-0018	Sunzell$^{\phi}$
	Emu Rock$^{\phi}$	Mace$^{\phi}$	Viking$^{\phi}$
	Espada$^{\phi}$	Merinda$^{\phi}$	Wallup$^{\phi}$
	Forrest$^{\phi}$	Merlin$^{\phi}$	
Sowing dates	TOS 1: 30 April TOS 2: 22 May TOS 3: 11 June		

Seasonal conditions

Growing season rainfall at the experiment site was slightly below average; the Condobolin Agricultural Research and Advisory Station recording 198.2 mm. The long-term average (LTA) growing season rainfall is 209 mm. The rain was spread across the first five months of the growing season. Rainfall in May was 11.6 mm (LTA 34.4 mm) and in September 6.2 mm (LTA 29.1 mm), which fell in the first week. The next substantial rainfall of 16 mm was not until 22 October (Table 1).

Condobolin experienced high day time temperatures (34–38 °C) and hot winds in the first week of October. These high temperatures and dry conditions coincided with flowering and could have contributed to the lower yields in TOS 2 and TOS 3.

The experiments were sown into adequate moisture, had even establishment and were weed-free.

Results

Time of sowing significantly affected wheat grain yield ($P < 0.001$). When averaged across all varieties, there was a grain yield reduction of 0.51 t/ha from TOS 1 (30 April) to TOS 2 (22 May) and a further reduction of 0.65 t/ha from TOS 2 to TOS 3 (11 June) (Figure 1).

The lower grain yields in TOS 2 (22 May) and TOS 3 (11 June) may have been attributed to the dry spring conditions coupled with high day time temperatures experienced in Condobolin during October. There was below average rainfall during September (6.2 mm recorded, LTA 29.1 mm). These dry conditions and high temperatures coincided with the optimal flowering window for Condobolin.

Table 1. Condobolin rainfall 2015.

Condobolin Agricultural Research and Advisory Station rainfall for 2015 (mm)														
Dec 2014	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	In-crop
88.8	59.2	35.9	0.2	64.7	11.6	31.8	41.6	42.3	6.2	65.2	67.3	28.5	454.5	198.2

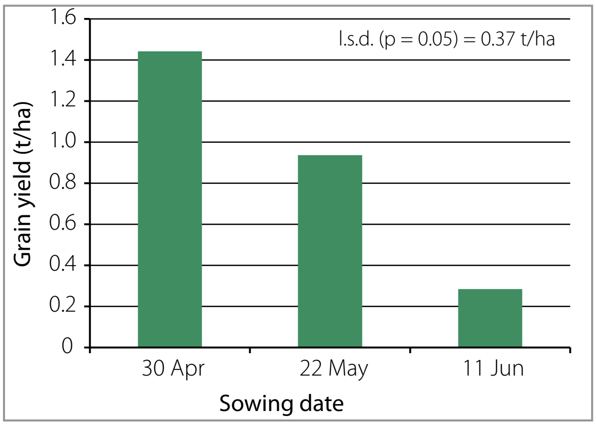

Figure 1. Average grain yield (t/ha) of 32 wheat varieties for three times of sowing at Condobolin, 2015.

The interaction between sowing time and variety also significantly affected wheat grain yield. LBP10-0018 (2.09 t/ha) was the highest yielding variety sown on 30 April, and Emu Rock was the highest yielding variety sown on 22 May and 11 June (1.72 t/ha and 0.89 t/ha respectively). These two varieties were ranked within the top six varieties across all three sowing times (Table 2).

Table 2. Grain yield and rank of 32 wheat varieties at three sowing times at Condobolin, 2015.

TOS 1: 30 April			TOS 2: 22 May			TOS 3: 11 June		
Rank	Variety	Yield (t/ha)	Rank	Variety	Yield (t/ha)	Rank	Variety	Yield (t/ha)
1	LPB10-0018	2.09	1	Emu Rock	1.72	1	Emu Rock	0.89
2	Dart	1.99	2	Corack	1.72	2	Mace	0.78
3	Wallup	1.86	3	Mace	1.63	3	Corack	0.69
4	Emu Rock	1.84	4	LPB10-0018	1.46	4	LPB10-0018	0.56
5	Suntop	1.84	5	Wallup	1.43	5	Dart	0.54
6	Janz	1.81	6	LPB09-0358	1.37	6	LPB09-0358	0.50
7	Sunmate	1.71	7	Livingston	1.37	7	Condo	0.47
8	Merinda	1.70	8	Condo	1.33	8	Espada	0.40
9	Condo	1.66	9	Impala	1.26	9	Impala	0.39
10	Elmore CL PLUS	1.65	10	Sunguard	1.23	10	Spitfire	0.35
11	Gauntlet	1.59	11	Spitfire	1.15	11	Elmore CL PLUS	0.33
12	Espada	1.58	12	Dart	1.08	12	Livingston	0.31
13	Impala	1.55	13	Sunmate	1.04	13	Merlin	0.31
14	Merlin	1.52	14	Lincoln	1.01	14	Lincoln	0.31
15	Sunguard	1.51	15	Merinda	0.98	15	Sunmate	0.28
16	EGA_Gregory	1.50	16	Viking	0.97	16	Sunguard	0.25
17	Spitfire	1.48	17	Espada	0.96	17	Phantom	0.24
18	Corack	1.46	18	Suntop	0.93	18	Merinda	0.20
19	LPB09-0358	1.46	19	EGA_Gregory	0.90	19	Janz	0.19
20	Mace	1.45	20	Mitch	0.84	20	Suntop	0.18
21	Phantom	1.44	21	Elmore CL PLUS	0.82	21	Wallup	0.15
22	Viking	1.42	22	Merlin	0.73	22	Mitch	0.12
23	Livingston	1.41	23	Gauntlet	0.72	23	Lancer	0.11
24	Lancer	1.40	24	Phantom	0.71	24	EGA_Gregory	0.10
25	Mitch	1.29	25	Janz	0.52	25	Bolac	0.09
26	Lincoln	1.29	26	Lancer	0.49	26	Strzelecki	0.09
27	Strzelecki	1.15	27	Strzelecki	0.40	27	Sunzell	0.08
28	Bolac	1.02	28	Bolac	0.31	28	Viking	0.08
29	Sunzell	0.94	29	Sunzell	0.29	29	Forrest	0.06
30	Forrest	0.73	30	EGA_Wedgetail	0.27	30	Gauntlet	0.06
31	EGA_Eaglehawk	0.57	31	EGA_Eaglehawk	0.18	31	EGA_Wedgetail	0.05
32	EGA_Wedgetail	0.26	32	Forrest	0.14	32	EGA_Eaglehawk	0.01
	l.s.d. (P <0.05)	0.48						

Summary

The highest yielding varieties across all sowing times were the very fast or fast maturing varieties (e.g. LPB10-0018 and Emu Rock). The dry conditions in September and higher than average temperatures in October favoured the quicker maturing varieties as they had the ability to flower before the dry spring conditions.

The slower and longer season varieties (e.g. EGA_Eaglehawk and EGA_Wedgetail) yielded lowest across all sowing times. The shorter 2015 growing season, characterised by hot temperatures during grain filling, resulted in the longer season varieties being moisture stressed and heat stressed during flowering. The earlier sowing times had less exposure to the hot dry finish and grain yields were significantly higher than the latest time of sowing.

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Response of twelve barley and four wheat varieties to three sowing dates – Matong 2015

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Key findings

» The 12 barley varieties were, on average, 26% higher yielding than the four wheat varieties in this experiment.

» The fast developing wheat varieties Emu Rock and Condo generally reached anthesis around the same date as the slow developing barley varieties Navigator, Oxford and Urambie.

» Long season barley varieties such as Oxford and Urambie performed well from early sowing (24 April), but most barley lines had their highest yield from main season sowing (12 May).

» The four early season wheat varieties generally had better yield from main season sowing than from early sowing.

Introduction

Barley cultivation has increased markedly in southern NSW in recent seasons, largely due to higher grain yield than wheat in dry springs and greater frost tolerance at flowering than wheat. Despite these findings in commercial paddocks, few experimental comparisons have been made between the two cereal types. This experiment was designed to examine the response of 12 commercially relevant barley cultivars and four fast-developing wheat varieties at three sowing dates in southern NSW.

Site details

Soil type	Brown chromosol (Table 1)
Previous crop	Wheat
Rainfall April–October	300 mm + 120 mm December 2014–March 2015
Fertiliser (sowing)	100 kg/ha MAP + 200 mL/ha flutriafol (500 g/L formulation)
Fertiliser (in-crop)	100 L/ha UAN (42% N) 14 June
Fungicide	300 mL/ha Prosaro applied 7 July and 2 September

Table 1. Soil test results for the experimental site at Matong, 15 April 2015.

	0–10 cm	10–30 cm	0–30 cm
pH (Ca)	4.8	5.9	–
Phosphorus (Colwell mg/kg)	92.0	10.0	–
Exc. Aluminium (%)	1.2	0.4	–
Available nitrogen (N) (kg/ha)	–	–	49.0

Treatments

Sowing dates	24 April 12 May 28 May	
Barley varieties	Commanderⓓ Compassⓓ Fathomⓓ Flindersⓓ GrangeRⓓ La Trobeⓓ	Navigatorⓓ Oxfordⓓ Rosalindⓓ Scope CLⓓ Urambieⓓ WI4897
Wheat varieties	Condoⓓ Corackⓓ	Emu Rockⓓ Spitfireⓓ

Results

La Trobe was the first barley variety to reach anthesis from the 24 April and 12 May sowing times (Table 2). Fathom was slightly quicker to anthesis than La Trobe from the 28 May sowing time. Condo and Emu Rock were the fastest wheat varieties to anthesis from the 24 April sowing time, but were 13 days slower than La Trobe. Anthesis occurred in Condo and Emu Rock at similar dates to the slowest barley varieties, Urambie and Navigator.

Table 2. Anthesis date and grain yield of 12 barley varieties and four wheat varieties sown at three sowing times, Matong 2015.

Variety	Anthesis date			Grain yield (t/ha)		
	24 Apr	12 May	28 May	24 Apr	12 May	28 May
Commander	8 Sep	21 Sep	1 Oct	3.6	4.3	3.5
Compass	3 Sep	17 Sep	29 Sep	3.8	4.3	3.6
Condo*	14 Sep	29 Sep	4 Oct	2.9	3.6	2.9
Corack*	15 Sep	2 Oct	11 Oct	3.2	3.2	3.0
Emu Rock*	14 Sep	30 Sep	6 Oct	2.9	3.4	3.3
Fathom	5 Sep	19 Sep	24 Sep	4.1	4.4	3.0
Flinders	11 Sep	25 Sep	3 Oct	4.1	4.2	2.8
GrangeR	9 Sep	23 Sep	3 Oct	4.0	4.7	3.8
La Trobe	1 Sep	15 Sep	25 Sep	4.1	4.1	3.6
Navigator	14 Sep	1 Oct	4 Oct	3.9	3.7	2.9
Oxford	13 Sep	3 Oct	5 Oct	4.4	4.0	3.3
Rosalind	3 Sep	16 Sep	2 Oct	3.8	4.9	4.2
Scope	6 Sep	19 Sep	1 Oct	3.6	3.8	2.7
Spitfire*	16 Sep	1 Oct	12 Oct	2.6	3.3	2.3
Urambie	15 Sep	1 Oct	4 Oct	4.5	4.1	2.4
WI4897	5 Sep	17 Sep	30 Sep	4.1	4.6	3.8
				l.s.d. (P = 0.05) = 0.4 t/ha		
*denotes wheat variety. Cells shaded grey indicate the highest yielding variety within a sowing time.						

There was an interaction (P <0.001) between variety and sowing date for grain yield. Longer-season barley varieties Urambie, Navigator and Oxford recorded their highest yield from the 24 April sowing time. The remainder of the barley varieties and the four wheat varieties had higher (or equal) grain yield from the 12 May sowing time than the 24 April and 28 May sowing times. The average grain yield of the 12 barley varieties was 3.9 t/ha compared with 3.1 t/ha for the four wheat varieties.

Relationship between anthesis date and grain yield (barley only)

The highest grain yield was achieved when anthesis date occurred around mid-September (Figure 1). There was a slight yield penalty when anthesis occurred in early September (from fast varieties such as La Trobe sown on 24 April). There was a stronger grain yield penalty when anthesis occurred in early October.

Summary

The experiment site was waterlogged at several points during July and August, which reduced the grain yield potential.

Averaged across sowing dates, the 12 barley varieties in this experiment were 26% higher yielding than the four wheat varieties. Sowing barley early gave good results, provided a relatively long season variety was selected, such as Oxford or Urambie. The four wheat varieties generally had their highest yield from sowing on 11 May. Spikelets from selected wheat and barley treatments were scored for frost-induced sterility to determine the reason for lower grain yield from early sowing.

The optimum anthesis date of mid-September in this experiment was similar to the optimum timing of anthesis in 2014 (results reported in Southern Cropping Region Trial Results 2014). In 2014, the yield penalty from early anthesis was due to frost events in August. Frost assessments are still being compiled from the 2015 experiment.

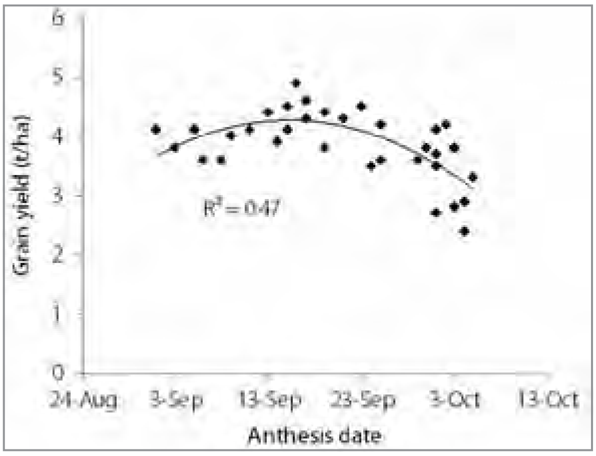

Figure 1. The effect of anthesis date on grain yield of 12 barley varieties, Matong 2015.

Acknowledgements

This experiment was part of the project 'Management of barley and barley cultivars for the southern region,' DAN00173, 2013–18, jointly funded by GRDC and NSW DPI. Thanks to Stephen, Michelle and Rod Hatty at Matong for experiment site cooperation.

Optimising barley phenology: flowering response to sowing time in Central West NSW

David Burch and **Nick Moody** NSW DPI, Condobolin; **Dr Felicity Harris** and **Graeme Sandral** NSW DPI, Wagga Wagga

Key findings

» Flowering time is determined by plant genetics and interacts with time of sowing and the environment.

» Matching variety and time of sowing to ensure flowering occurs at an optimal time in spring is critical to maximising yield.

» Sow longer-season varieties mid-April to May and shorter-season varieties May to June.

Introduction

This experiment was designed to determine the phenological response (flowering time) to sowing time for a range of barley varieties. Identifying an optimum flowering time for a given location is critical, as grain yield is bound by the risk of early frost damage and later by heat and moisture stress. In the Condobolin region, growers have a selection of commercial barley cultivars available ranging in maturity (days from sowing to anthesis). Matching varietal maturity with appropriate sowing times allows flowering and grain fill during a period that optimises the probability of maximum grain yield and minimises the likelihood of significant stress events.

Site details

The experiment was conducted at Condobolin Agricultural Research and Advisory Station, NSW under rain-fed conditions (Table 1). Seventeen barley varieties, varying in maturity (Table 2) were sown at five sowing times. The experiment was conducted in a bird exclusion cage and varieties sown in individual rows 30 cm apart. Plants were spaced 5 cm apart in order to simulate a typical cropping environment. Time of flowering was recorded for each variety by sowing time combination.

Table 1. Experimental site details.

Average annual rainfall	454.7 mm
Growing season rainfall (Apr–Oct)	267.4 mm
Soil type	Red-brown earth
Previous crop	Barley
Soil pH_{Ca}	4.7 (0–10 cm), 5.7 (10–60 cm)
Nitrogen (0–100 cm)	27 mg/kg
Phosphorus (0–100 cm)	15 mg/kg

Treatments

Varieties	Bass⟨PBR⟩	Flinders⟨PBR⟩	Oxford⟨PBR⟩
	Buloke⟨PBR⟩	Gairdner⟨PBR⟩	Schooner
	Commander⟨PBR⟩	GrangeR⟨PBR⟩	Scope⟨PBR⟩
	Compass⟨PBR⟩	Hindmarsh⟨PBR⟩	Westminster⟨PBR⟩
	Fathom⟨PBR⟩	La Trobe⟨PBR⟩	IGB1334T
	Fleet⟨PBR⟩	Navigator⟨PBR⟩	
Times of sowing	TOS 1: 17 April	TOS 4: 23 June	
	TOS 2: 8 May	TOS 5: 14 July	
	TOS 3: 1 June		

Results

Faster maturing varieties such as Hindmarsh⟨PBR⟩, LaTrobe⟨PBR⟩, IGB1334T and Fathom⟨PBR⟩ flowered earlier across all sowing times, whilst slower maturing varieties such as Westminster⟨PBR⟩, Oxford and Navigator⟨PBR⟩ flowered later (Table 2). Faster maturing varieties have a shorter growing season and are more suited to later sowings, whilst slower maturing varieties have a longer growing season and are more suited to earlier sowings.

The optimal estimated flowering window for Condobolin, simulated using SOWMAN (part of GRDC's CropMate package), is 20 August to 19 September (Figure 1). SOWMAN allows users to consider wheat phenology, climate variability and risks of frost and heat at a specific location. The phenology model integrates temperature, photoperiod and vernalisation for predicting flowering. An update of varietal information in SOWMAN is currently under consideration. When complete, the software will allow growers to set parameters such as location, variety and a risk profile for yield potential to determine the optimal flowering window, and calculate an appropriate sowing time to achieve this.

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Table 2. Flowering dates for 17 barley varieties at five times of sowing (TOS) at Condobolin 2015*.

	TOS 1: 17/4/15		TOS 2: 8/5/15		TOS 3: 1/6/15		TOS 4: 23/6/15		TOS 5: 14/7/15	
1	Hindmarsh (F)	18 Aug	IGB1334T (F)	7 Sep	Hindmarsh (F)	19 Sep	Fathom (F)	2 Oct	Scope (M)	11 Oct
2	La Trobe (F)	18 Aug	Hindmarsh (F)	8 Sep	La Trobe (F)	19 Sep	Hindmarsh (F)	2 Oct	Hindmarsh (F)	14 Oct
3	Buloke (F)	21 Aug	La Trobe (F)	10 Sep	Fathom (F)	20 Sep	IGB1334T (F)	3 Oct	La Trobe (F)	14 Oct
4	Bass (M)	22 Aug	Buloke (F)	11 Sep	IGB1334T (F)	20 Sep	La Trobe (F)	3 Oct	IGB1334T (F)	15 Oct
5	Scope (M)	22 Aug	Fathom (F)	13 Sep	Compass (M)	22 Sep	Commander	6 Oct	GrangeR (M)	16 Oct
6	Compass (M)	25 Aug	Compass (M)	15 Sep	Buloke (F)	23 Sep	Buloke (F)	7 Oct	Buloke (F)	18 Oct
7	Fleet (M)	25 Aug	Scope (M)	15 Sep	Commander (M)	25 Sep	GrangeR (M)	7 Oct	Commander (M)	18 Oct
8	Gairdner (M)	25 Aug	Commander (M)	16 Sep	GrangeR (M)	25 Sep	Schooner (M)	8 Oct	Compass (M)	18 Oct
9	Fathom (F)	26 Aug	Fleet (M)	16 Sep	Schooner (M)	25 Sep	Westminster (L)	8 Oct	Fathom (F)	18 Oct
10	Schooner (M)	27 Aug	Schooner (M)	16 Sep	Scope (M)	25 Sep	Fleet (M)	9 Oct	Schooner (M)	18 Oct
11	Flinders (L)	29 Aug	Bass (M)	17 Sep	Gairdner (M)	26 Sep	Gairdner (M)	9 Oct	Navigator (L)	19 Oct
12	GrangeR (M)	30 Aug	Gairdner (M)	17 Sep	Bass (M)	27 Sep	Bass (M)	10 Oct	Bass (M)	20 Oct
13	Oxford (L)	30 Aug	Westminster (L)	17 Sep	Flinders (L)	27 Sep	Compass (M)	10 Oct	Westminster (L)	20 Oct
14	Commander (M)	31 Aug	Flinders (L)	19 Sep	Westminster (L)	29 Sep	Scope (M)	11 Oct	Gairdner (M)	22 Oct
15	Westminster (L)	31 Aug	GrangeR (M)	19 Sep	Fleet (M)	4 Oct	Flinders (L)	12 Oct	Fleet (M)	23 Oct
16	Navigator (L)	3 Sep	Oxford (L)	20 Sep	Navigator (L)	4 Oct	Oxford (L)	14 Oct	Oxford (L)	23 Oct
17	IGB1334T (F)	*	Navigator (L)	22 Sep	Oxford (L)	7 Oct	Navigator (L)	19 Oct	Flinders (L)	29 Oct

Varieties are ranked (1–17) for each sowing time, from earliest to latest flowering date. Letters in brackets indicate relative maturity of variety (F = fast, M = mid, L = late). Italicised flowering dates fall within the optimum flowering window based on SOWMAN model simulation.

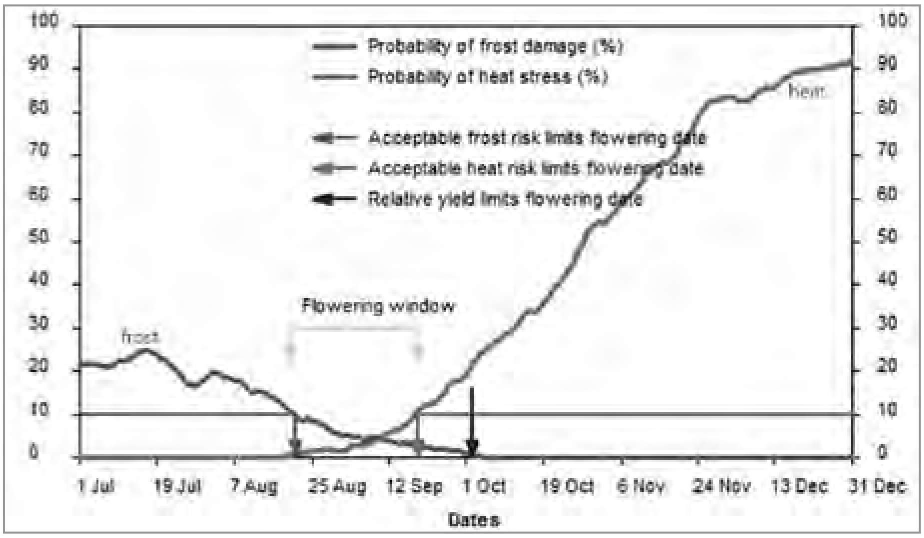

Figure 1. Output of the SOWMAN simulation model predicting the optimum flowering window at Condobolin. The optimum flowering window is determined by the probability of frost damage and heat stress (%).

Acknowledgements

This experiment was part of the project 'Management of barley and barley cultivars for the southern region', DAN00173, 2013–18, jointly funded by GRDC and NSW DPI.

Thanks to Technical Assistants Linda Brangwin and Fraser Campbell, and Technical Officer Nick Hill.

Grain yield of eighteen barley varieties sown at three different dates – Condobolin 2015

David Burch, Nick Moody and **Ian Menz** NSW DPI, Condobolin

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Key findings

» Late sowings could have a negative effect on barley yield due to heat and water stress during grain fill. In 2015 this was the key determining factor for grain yield.

» While mid-season varieties yielded well in the first sowing time, mid and late sowings favoured early-flowering varieties.

» Early sown, early flowering crops are at risk of flowering during frost events, and sowing decisions should be based on the phenology of the particular variety and understanding the region's climate.

Introduction

This experiment assessed the performance of 18 commercial barley varieties sown at three dates during 2015 at the Condobolin Agricultural Research and Advisory Station (CARAS). The impact of sowing time on flowering time, phenology and yield for each variety and sowing time is reported.

Site details

Location	Condobolin Agricultural Research and Advisory Station
Experiment period	April–November 2015
Soil type	Red-brown chromosol
Previous crop/s	Lucerne
Soil pH_{Ca}	4.4 (0–10 cm), 6.3 (10–60 cm)
Nitrogen	173 kg/ha
Fertiliser	70 kg/ha mono-ammonium phosphate (MAP) applied at sowing

Treatments

Sowing dates	TOS 1: 30 April TOS 2: 22 May TOS 3: 11 June	
Varieties	IGB1334T Bass⊕ Buloke⊕ Commander⊕ Compass⊕ Fathom⊕ Flinders⊕ Gairdner⊕ GrangeR⊕	Hindmarsh⊕ La Trobe⊕ Navigator⊕ Oxford⊕ Schooner Scope⊕ Urambie⊕ Westminster⊕ Wimmera⊕

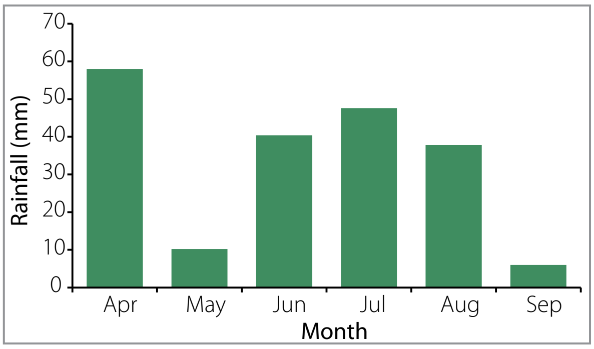

Figure 1. Growing season rainfall for Condobolin 2015. Growing seasons rainfall (GSR), 198 mm, total annual rainfall 421.8 mm. Mean annual rainfall 442.9 mm, mean GSR, 234 mm.

Results

There was very little rainfall throughout spring at Condobolin (Figure 1), which, when combined with unseasonally high temperatures in spring, resulted in a premature end to the growing season. There was a significant difference between yields from the three sowing dates (P <0.001), showing a negative correlation with sowing time (Figure 2).

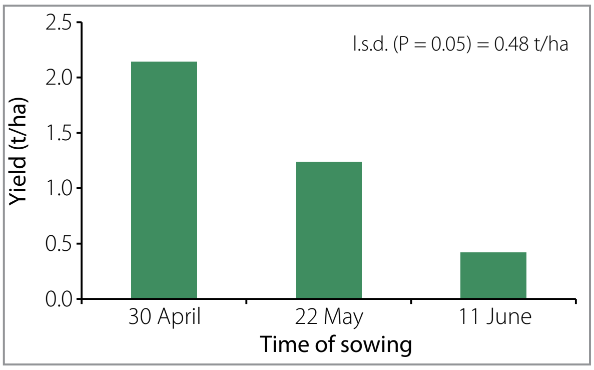

Figure 2. Yield (t/ha) of 18 barley varieties sown at three dates grouped by sowing time at Condobolin 2015.

Table 1. Yield (t/ha) of 18 barley varieties sown at three sowing dates at Condobolin.

	Yield (t/ha)		
Variety	30 Apr	22 May	11 Jun
Spartacus CL	2.93	1.91	0.90
Flinders	2.93	1.64	0.42
Wimmera	2.92	1.09	0.20
Fathom	2.89	1.77	1.19
Compass	2.68	1.61	0.49
La Trobe	2.67	1.74	0.69
Bass	2.40	1.71	0.56
Buloke	2.30	1.36	0.47
Gairdner	2.21	0.92	0.19
Hindmarsh	2.21	1.85	0.95
Scope	2.18	1.47	0.53
Schooner	1.99	1.33	0.69
GrangeR	1.88	0.71	0.42
Westminster	1.85	0.67	0.06
Commander	1.71	1.22	0.17
Navigator	1.70	0.75	0.17
Oxford	1.47	0.84	0.03
Urambie	1.29	0.64	0.12
Mean	2.23	1.29	0.46
l.s.d. (P = 0.05) variety 0.26 t/ha, date 0.15 t/ha			

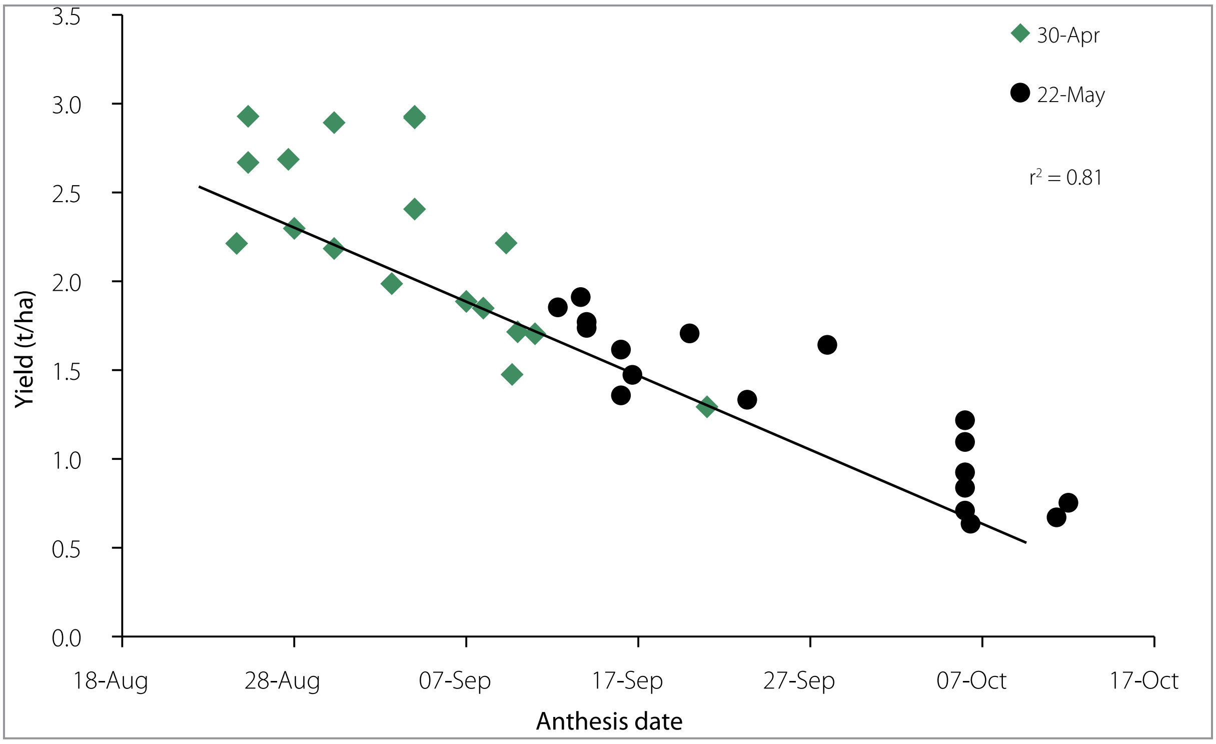

Figure 3. Anthesis dates vs yield for 18 barley varieties. June 11 sowing data not presented due to early senescence disrupting flowering.

A strong ($r^2 = 0.81$) correlation was observed between anthesis dates and yield, with varieties that yielded over 2.5 t/ha flowering before the first week of September (Figure 3). Yields declined sharply with delayed flowering. In years with cooler, wetter spring conditions, late sown varieties might not receive such a severe yield penalty.

The highest yielding varieties from the first time of sowing were Spartacus CL, Flinders and Wimmera (Table 1). Spartacus CL flowered on 25 August, while mid to late maturing varieties Flinders and Wimmera flowered 10 days later, indicating that at earlier sowings, mid-flowering varieties can be competitive. However, this competitiveness decreases rapidly when sowing is delayed.

The May and June sowings heavily favoured early-flowering varieties, while long season types such as Westminster, Oxford and Urambie failed to yield commercial quantities. From the late sowing time, the highest yielding variety was feed variety Fathom, with yields of 1.19 t/ha that was significantly higher than the site average for that sowing time.

Summary

Barley varieties have widely different flowering phenology, with early flowering types suited to low rainfall short seasons where grain fill is achieved before moisture and heat stress sets in. Growers sowing early flowering varieties should be aware of when frost risk is greatest, and target their sowing times to avoid flowering during this period. During 2015 there were a number of frost events recorded during the flowering period of the early sowing treatments, however, any impact on yield was overshadowed by the hot, dry grain filling conditions.

If sowing a mid-season variety under similar hot, dry conditions, earlier sowings of these types have the potential to maximise yield, ensuring the crop flowers at the optimum interval, allowing sufficient time for grain filling.

Late-flowering varieties will produce superior yield and quality in medium to high rainfall and long, mild growing seasons. They incur severe penalties in short, dry season conditions such as those experienced at Condobolin in 2015.

The six highest yielding varieties from the early sowings were all released within the past three years. Switching varieties from older types can result in yield advantages, and potentially improved disease packages. For example, early sown Hindmarsh was significantly out-yielded (0.72 t/ha) by its recently released successor Spartacus CL, which has the additional benefit of imidazolinone tolerance.

Acknowledgements

This experiment was part of the project 'Management of barley and barley cultivars for the southern region', DAN00173 2013–18, jointly funded by GRDC and NSW DPI.

Thanks to Daryl Reardon, Nick Hill and Fraser Campbell for technical assistance and to Neroli Graham for biometric analysis.

The effect of sowing date and fungicide application on grain yield of canola – Alma Park 2015

Rohan Brill, **Paula Charnock**, **Warren Bartlett** and **Sharni Hands** NSW DPI, Wagga Wagga

Key findings

- Sowing date and varietal phenology both affected the exposure of canola to rain days and potential disease infection.
- Early sowing increased the level of pod blackleg infection.
- Early sowing increased sclerotinia infection in the early flowering variety Hyola® 575CL but not in the slower variety Pioneer® 45Y88 (CL).
- Grain yield was higher from the later sowing date (22 April) than the early sowing date (7 April).
- Grain yield was closely correlated to total biomass accumulation, which was greater from the 22 April sowing time than the 7 April sowing time.

Introduction

Sowing canola early has become more common in recent seasons, but there are still concerns about the potential for early sowing to increase disease risk, especially Sclerotinia stem rot. This experiment was sown to determine agronomic management practices that increase grain yield potential while also minimising the risk of fungal diseases.

Site details

Location	Alma Park, 25 km SW of Henty
Previous crop	Barley
Fertiliser applied	100 kg/ha MAP + Flutriafol SC at 200 mL/ha 400 L/ha Sulsa (27 N:7 S w/v)
Plant available water (at sowing)	40 mm
Available nitrogen (N) (at sowing)	76 kg/ha (0–30 cm)
In-crop rainfall (April–October)	360 mm

Treatments

The experiment was sown as a full factorial combination of sowing date, variety and fungicide (Table 1). The fungicide treatment Prosaro® was applied at 450 mL/ha at the start of flowering of each individual treatment, determined as the date when 50% of plants had one open flower.

Table 1. Sowing date, variety and fungicide treatments at Alma Park, 2015.

Sowing date	7 April 22 April
Variety	Pioneer® 45Y88 (CL) Hyola® 575CL
Fungicide (Prosaro®)	Plus Minus

Results

Flowering

Hyola® 575CL was 21 days quicker to flower than Pioneer® 45Y88 (CL) from the 7 April sowing date, but was only six days quicker from the 22 April sowing date. The differences in flowering date affected not only the overall grain yield potential, but also the exposure to rain events during flowering. Sowing Hyola® 575CL early exposed the variety to 23 rain days during flowering, whereas early sowing with the slower variety Pioneer® 45Y88 (CL) exposed the variety to only 13 rain days during flowering (Table 2).

Table 2. The effect of two sowing dates on the flowering date (date when 50% of plants have one open flower) and number of rain days during flowering of two varieties at Alma Park in 2015.

Variety	Flowering date		Rain days during flowering	
	7 Apr	22 Apr	7 Apr	22 Apr
Hyola 575CL	25 Jul	24 Aug	23	10
Pioneer 45Y88 (CL)	15 Aug	30 Aug	13	5

Disease

Blackleg

The experiment was scored at maturity to assess the level of blackleg infection on the pods and branches.

Pod blackleg rating scale	
0	blackleg lesions absent
1	<5 diseased pods/plant
2	5–10 diseased pods/plant
3	10–20 diseased pods/plant
4	>20 diseased pods/plant

Branch blackleg rating scale	
0	no infection
1	small lesions (0–15 mm), few lesions
2	medium lesions (16–40 mm), few lesions
3	large lesions (larger than 40 mm, physical cankers), many lesions
4	death of whole branches (causing significant yield loss)

There was significantly more blackleg on the pods and branches of Pioneer® 45Y88 (CL) than Hyola® 575CL (Table 3). The 7 April sowing date treatments also had more pod blackleg than the 22 April sowing date, but branch blackleg was not affected by the sowing date.

Table 3. The effect of variety and sowing date on pod and branch blackleg severity, Alma Park, 2015.

Variety	Pod blackleg	Branch blackleg
Hyola 575CL	1.4	1.4
Pioneer 45Y88 (CL)	2.3	2.2
l.s.d. (P = 0.05)	0.34	0.34
Sowing date		
7 Apr	2.3	1.9
22 Apr	1.4	1.7
l.s.d. (p = 0.05)	0.34	n.s.

Sclerotinia

Sclerotinia is reported as the percentage of plants in a plot with disease symptoms. There was a significant interaction (P = 0.045) between fungicide and variety (Table 4). Fungicide application had no effect on Sclerotinia in Pioneer® 45Y88 (CL). Hyola® 575CL had more Sclerotinia than Pioneer® 45Y88 (CL) where fungicide was not applied, but had reduced Sclerotinia when fungicide was applied.

Table 4. The effect of variety and fungicide treatment on the level of Sclerotinia infection, Alma Park, 2015.

Variety	Plants infected with Sclerotinia (%)	
	Minus fungicide	Plus fungicide
Pioneer 45Y88 (CL)	0.9	0.7
Hyola 575CL	6.5	1.8
l.s.d. (P = 0.05)	1.4	

Grain yield

There were significant effects of variety (P <0.001), sowing date (P = 0.002) and fungicide (P = 0.001) on grain yield, but there were no interactions between these factors. There was a 0.4 t/ha benefit from planting Pioneer® 45Y88 (CL) compared with Hyola® 575CL; a 0.3 t/ha benefit of sowing on 22 April compared with 7 April; and a 0.4 t/ha yield increase from applying Prosaro® fungicide at flowering (Table 5).

Table 5. The main effects of variety, sowing date and fungicide treatment on grain yield of canola, Alma Park, 2015.

Treatment	Grain yield (t/ha)
Variety	
Pioneer 45Y88 (CL)	3.2
Hyola 575CL	2.8
l.s.d. (p = 0.05)	0.16
Sowing date	
7 Apr	2.9
22 Apr	3.2
l.s.d. (p = 0.05)	0.18
Fungicide treatment	
Minus	2.8
Plus	3.2
l.s.d. (p = 0.05)	0.19

Grain yield was related to biomass at maturity (Figure 1). Sowing on the 22 April increased biomass at maturity compared with sowing on 7 April; sowing Pioneer® 45Y88 (CL) compared with Hyola® 575CL, and with applying fungicide (data not shown).

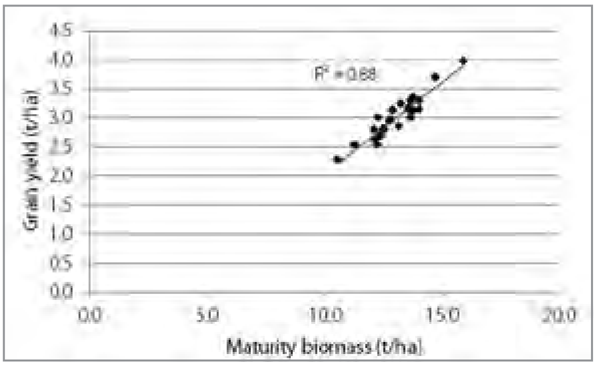

Figure 1. The relationship between biomass at maturity and grain yield of canola at Alma Park, 2015.

Discussion and conclusion

Varietal phenology had a large impact on exposing canola to rain days and hence potential disease development. The slower variety, Pioneer® 45Y88 (CL), had half the number of rain days during flowering (averaged across both sowing dates), compared with the faster variety Hyola® 575CL. Applying the fungicide Prosaro® reduced Sclerotinia infection in the fast variety Hyola® 575CL sown early, but had no effect on the slower variety Pioneer® 45Y88 (CL). There was a significant grain yield response (0.4 t/ha averaged across sowing dates and varieties) to fungicide application, despite the modest levels of Sclerotinia infection.

Early sowing and variety choice (i.e. Pioneer® 45Y88 (CL)) both increased the level of pod/branch blackleg infection, but there was no effect from fungicide applied at flowering on upper canopy blackleg. Further work is required to quantify yield loss and management strategies for blackleg on branches and pods.

Grain yield was strongly correlated to the amount of total biomass at maturity. Maturity biomass and grain yield were both affected by sowing date, variety choice and fungicide application. Along with nitrogen management and variety type, these factors will be investigated in more detail in the current 'Optimising canola profitability' project.

Acknowledgements

This experiment was jointly funded by GRDC and NSW DPI as part of the collaborative project 'Optimising canola profitability', CSP10087; 2014–19, a partnership also including CSIRO and SARDI. Thanks to Graeme Kotzur and family for experiment site cooperation.

The effect of sowing date and irrigation pre-sowing on the grain yield of canola – Ganmain 2015

Rohan Brill, **Paula Charnock**, **Warren Bartlett** and **Sharni Hands** NSW DPI, Wagga Wagga

Key findings

» Early sown (9 April) Pioneer® 45Y88 (CL) yielded similarly to later sown (20 April) Pioneer® 45Y88 (CL) and Hyola® 575CL.

» The irrigation treatment that stored 20 mm plant available water did not increase grain yield or oil concentration.

» The maturity biomass was higher from the later sowing date, but the harvest index was slightly higher from the early sowing date.

Introduction

Water stored in the fallow phase can contribute significantly to grain yield of all crops. This experiment was designed to determine if early sowing of canola will improve the efficiency of use of stored water.

Site details

Location	Ganmain
Previous crop	Barley
Fertiliser applied	100 kg/ha MAP + Flutriafol SC at 200 mL/ha 400 L/ha Sulsa (27N:7S w/v) prior to sowing 100 kg/ha Urea 15-6
Available nitrogen (N) at sowing	54 kg/ha (0–180 cm)
Plant available water (at sowing):	60 mm (non-irrigated treatment)
In-crop rainfall (April–October)	320 mm

Treatments

The experiment was sown as a full factorial combination of sowing date, variety and irrigation (Table 1).

Table 1. Sowing date, variety and irrigation treatments, Ganmain 2015.

Sowing date	9 April 20 April
Variety	Pioneer® 45Y88 (CL) Hyola® 575CL
Irrigation	Plus Minus

The irrigation was applied in March 2015 using a dripper line laid into pre-drilled furrows (Figure 1). An equivalent of 38 mm rainfall was supplied to the 'plus' irrigation treatment. Of the 38 mm applied, 20 mm was stored and available when the soil was cored two weeks later.

Figure 1. Irrigating plots in March 2015. Irrigation has just been completed on rows seven and eight in this image.

Results

Flowering

From the 9 April sowing date, Hyola® 575CL was 21 days quicker to flower than Pioneer® 45Y88 (CL), but was only eight days quicker from the 20 April sowing date (Table 2).

Table 2. The effect of two sowing dates on the flowering date (date when 50% of plants had one open flower) of two varieties, Ganmain 2015.

Variety	9 April	20 April
	Date 50% flower	
Hyola 575CL	20 July	19 August
Pioneer 45Y88 (CL)	10 August	27 August

agronomy – canola

Grain yield

There was a significant interaction between variety and sowing date (P = 0.007) for grain yield. Pioneer® 45Y88 (CL) was significantly higher yielding than Hyola® 575 CL from the 9 April sowing date, but there was no difference between the two varieties from the 20 April sowing date (Table 3). The irrigation treatment had no effect on grain yield.

Table 3. The effect of variety and sowing date on grain yield of canola, Ganmain 2015.

Variety	9 April	20 April
	Grain yield (t/ha)	
Pioneer 45Y88 (CL)	3.2	3.1
Hyola 575CL	2.9	3.2
l.s.d. (P = 0.05)	0.18	

The amount of biomass grown by the time the plant matured had a large effect on grain yield (Figure 2). Biomass at maturity was 1 t/ha higher for the 20 April sowing date compared with the 9 April sowing, but the higher biomass from the later sowing date of 20 April resulted in a marginally lower harvest index (0.23) compared with the 9 April sowing (0.25).

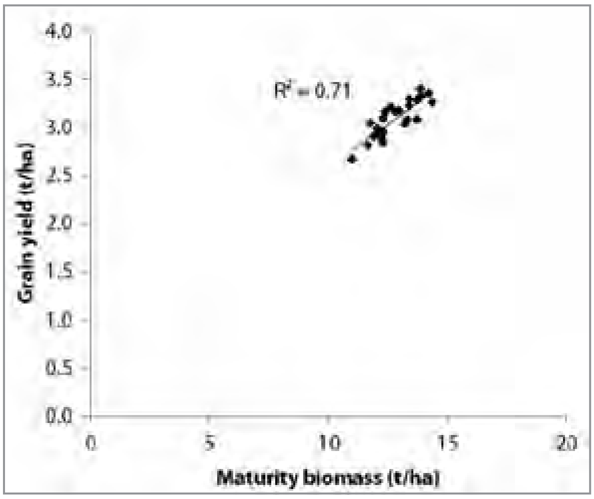

Figure 2. Relationship between biomass at maturity and grain yield of canola, Ganmain 2015.

Grain quality

Neither the sowing date nor irrigation affected oil concentration (at 6% moisture), but there was a significant effect between varieties. Hyola® 575CL had a higher oil content (42.8%) compared with Pioneer® 45Y88 (CL) (41.1%). Seed protein was unaffected by the treatments, averaging 21.6%.

Discussion and conclusion

Grain yield was strongly correlated with the amount of total biomass at maturity. The effects of the interactions between sowing date, variety choice and nitrogen management will be further investigated in subsequent experiments to determine the most effective way to optimise biomass accumulation and subsequent grain yield for different regions.

The lack of response to the extra water supplied through pre-sowing irrigation suggests that yield was limited by factors other than water. Assuming mineralisation of 40 kg/ha N through the growing season along with available N of 54 kg/ha and fertiliser N of 164 kg/ha, this experiment would have had approximately 258 kg/ha N available in the soil. The 'rule of thumb' for canola is that it requires 80 kg N/ha available in the soil to produce 1 t/ha grain. The highest yielding treatments in this experiment would have required 256 kg/ha N, which suggests that N could have limited further yield gains.

Acknowledgements

This experiment was jointly funded by GRDC and NSW DPI as part of the collaborative project 'Optimising canola profitability', CSP10087; 2014–19, a partnership also including CSIRO and SARDI. Thanks to Dennis and Dianne Brill for experiment site cooperation.

Effect of sowing date on phenology and grain yield of twelve canola varieties – Canowindra 2015

Colin McMaster NSW DPI, Cowra; **Adam Coleman** NSW DPI, Orange

Key findings

» Early sowing exacerbated phenological differences between the varieties.

» The spread of days to reach 50% flowering within each time of sowing (TOS) varied by 35, 26 and 14 days in TOS 1, TOS 2 and TOS 3 respectively.

» The highest yield was achieved by Nuseed GT-50 (3.59 t/ha) sown on 1 May.

» Hyola® 600RR was the highest yielding variety when averaged across all sowing dates.

» The sowing time had a negligible impact on grain yield.

» The biomass at 50% flowering was greatest in TOS 2 (9.92 t/ha) followed by TOS 1 (7.93 t/ha) and TOS 3 (9.23 t/ha).

» There was a strong correlation between biomass at maturity and grain yield, i.e. a higher biomass produced a higher yield.

Introduction

Sowing dates in the high rainfall zones of central and southern NSW have slowly shifted earlier in recent seasons. Crop modelling (Lilley et al. 2015) and some early field experiments from the Optimised Canola Profitability project have indicated that there are potential grain yield increases from sowing earlier than the traditional date of 25 April, provided the appropriate varietal management is used.

This experiment evaluated the effect of sowing date on phenology and grain yield of 12 canola varieties ranging from long- to short-season phenology types.

Site details

Location	Canowindra, NSW
Soil type	Red chromosol
Previous crop	Wheat
Stubble management	Burnt
Fertiliser	83 kg/ha Gran-Am predrilled, 130 kg/ha urea predrilled and 68 kg/ha MAP banded at sowing
Soil pH_{Ca}	4.6
Colwell P 0–10 cm (mg/kg)	66
Mineral nitrogen (N) (0–1.8 m)	104 kg N/ha
Plant-available water at sowing	100 mm
Frosts (July–September) 16 events	3/6, 4/6, 21/6, 29/6, 3/7, 4/7, 5/7,6/7, 8/7, 9/7,19/7, 29/7, 4/8,9/8, 19/8, 30/8

Monthly rainfall at experiment site													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2015	76	34	10	42	23	26	70	86	0	19	61	45	492
LTA	59	52	45	43	44	52	50	50	46	56	51	53	601
*LTA = long-term average													

Treatments

12 canola varieties	Pioneer® 44Y89 (CL) Pioneer® 45Y88 (CL) ATR Gem⍉ ATR Stingray⍉ AV Garnet⍉ Nuseed GT-50	Hyola® 559TT Hyola® 575CL Hyola® 577CL Hyola® 600RR Hyola® 750TT IH30 RR
Sowing dates	TOS 1: 2 April TOS 2: 15 April TOS 3: 1 May	

Results

The TOS 1 (2 April) and TOS 2 (15 April) treatments required irrigation with drip tape (equal to 12 mm rainfall) to establish. The TOS 3 (1 May) treatment did not require supplementary irrigation for establishment. Plant establishment was 32, 37 and 38 plants/m^2 for TOS 1, TOS 2 and TOS 3 respectively.

The experiment had ideal conditions for crop growth during winter with above average rainfall for April–August (247 mm). However, spring was relatively dry with no rain during September and above average temperatures during October.

Flowering date

The flowering date (50% of plants have one open flower) varied from 30 June to 30 August and was significantly affected by time of sowing (P <0.001), variety (P <0.001) and the time of sowing by variety interaction (P <0.001) (Table 1).

Flowering occurred on 19 July, 8 August and 25 August for TOS 1, TOS 2 and TOS 3 respectively when averaged across all 12 varieties.

The three fastest maturing varieties (shortest time to reach 50% flowering) were IH30 RR, ATR Stingray and Hyola® 575CL. The slowest maturing varieties were Hyola® 577CL, Hyola® 750TT and Hyola® 600RR.

The phenological difference between varieties significantly reduced as sowing was delayed. The spread of days to reach 50% flowering within each TOS was 35, 26 and 14 days for TOS 1, TOS 2 and TOS 3 respectively. In TOS 1, the quicker developing variety IH30 RR reached 50% flowering on 30 June compared with 4 August (35 days) for the slower developing variety Hyola® 577CL. However, in TOS 3 the difference in flowering date between IH30 RR and Hyola® 577CL was reduced, with 50% flowering occurring on 16 August and 30 August (14 days) respectively.

Dry matter at 50% flowering

Dry matter at 50% flowering ranged from 5.0 t/ha to 11.7 t/ha and was significantly affected by sowing time (P = 0.009), variety (P <0.001) and the interaction between sowing time and variety (P <0.001). Biomass accumulation at 50% flowering was greatest at TOS 2 (9.92 t/ha) compared with TOS 1 (7.93 t/ha) or TOS 3 (9.23 t/ha).

Biomass at 50% flowering increased as sowing was delayed in the faster developing varieties such as ATR Stingray, with an additional 1.0 t/ha and 2.1 t/ha produced from TOS 2 and TOS 3

Table 1. Grain yield, dry matter (DM) and flowering date at the experiment site near Canowindra, 2015.

Variety	Phenology	50% flowering date [a]			Dry matter at flowering (t/ha)			Grain yield (t/ha)		
		TOS 1 2 Apr	TOS 2 15 Apr	TOS 3 1 May	TOS 1 2 Apr	TOS 2 15 Apr	TOS 3 1 May	TOS 1 2 Apr	TOS 2 15 Apr	TOS 3 1 May
44Y89 (CL)	Mid	14 Jul	4 Aug	24 Aug	6.7	9.9	9.9	3.43	3.29	3.08
45Y88 (CL)	Long	26 Jul	13 Aug	29 Aug	9.4	10.8	9.0	3.35	3.08	2.90
ATR Gem	Mid	10 Jul	9 Aug	29 Aug	5.2	8.0	7.2	2.51	2.79	2.42
ATR Stingray	Short	5 Jul	23 Jul	17 Aug	5.0	6.0	7.1	2.66	2.70	2.38
AV Garnet	Mid	23 Jul	3 Aug	25 Aug	7.0	9.6	10.2	3.01	3.25	3.36
Nuseed GT-50	Mid	22 Jul	8 Aug	25 Aug	9.7	10.4	10.9	3.14	3.18	3.59
Hyola 559TT	Mid	23 Jul	11 Aug	25 Aug	7.6	10.3	9.5	2.31	3.21	2.75
Hyola 575CL	Short	6 Jul	4 Aug	25 Aug	6.4	10.4	11.1	3.02	2.98	2.99
Hyola 577CL	Long	6 Aug	15 Aug	30 Aug	10.1	11.4	9.6	2.92	3.31	3.10
Hyola 600RR	Long	31 Jul	14 Aug	28 Aug	11.2	11.8	9.6	3.40	3.23	3.52
Hyola 750TT	Long	4 Aug	18 Aug	30 Aug	10.6	11.7	7.9	2.40	3.23	2.78
IH30 RR	Short	30 Jun	31 Jul	16 Aug	6.1	9.0	9.1	3.36	2.97	3.05
	min	30 Jun	23 Jul	16 Aug	5.0	6.0	7.1	2.31	2.70	2.38
	mean	19 Jul	8 Aug	25 Aug	7.9	9.9	9.2	2.96	3.10	2.99
	max	6 Aug	18 Aug	30 Aug	11.2	11.8	11.1	3.43	3.31	3.59
P = 0.05	<0.001	<0.001	0.02							
5% l.s.d.	7 days	2.01 t/ha	0.49 t/ha							

a = flowering date was measured when 50% of plants had one open flower.

respectively, compared with TOS 1. Conversely, the longer-season varieties achieved greatest biomass accumulation from TOS 1 and TOS 2, e.g. Hyola® 750TT had a biomass of 10.6, 11.7 and 7.9 t/ha at TOS 1, TOS 2 and TOS 3 respectively.

Grain yield

Grain yield was significantly affected by the time of sowing (P = 0.040) despite the yield only varying by 0.14 t/ha. Grain yield was also affected by variety (P <0.001) and the interaction between time of sowing and variety (P = 0.018). The water use efficiency of all treatments was 6–16 kg/mm (data not shown).

The highest grain yield was achieved from Nuseed GT-50 sown on 1 May (3.59 t/ha) and the lowest from ATR Stingray sown on 1 May (2.38 t/ha). Varieties that performed above average across all sowing dates were Pioneer® 44Y89 (CL), AV Garnet, Nuseed GT-50 and Hyola® 600RR.

There was no relationship between biomass at flowering and grain yield (R^2 = 0.06). In TOS 1, IH30 RR produced a grain yield of 3.36 t/ha from a dry matter of 6.1 t/ha while Hyola® 600RR yielded 3.40 t/ha from a biomass of 11.2 t/ha. However, there was a strong relationship between biomass at maturity and grain yield (greater maturity biomass produced higher yields) (Figure 1). In this experiment there was significant biomass produced during the post-flowering period.

Summary

This experiment highlighted large differences in phenology between varieties sown at three sowing dates and demonstrated how these differences are exacerbated if sowing is brought forward to early April.

Seasonal conditions and management will ultimately influence when canola is sown on a year to year basis. However, these results give growers the information required to select the appropriate variety to capitalise on early sowing opportunities that still enable flowering to occur during the optimum period (mid-August to late-September) to minimise frost risk. More research is required to understand the relationship between critical phases of biomass accumulation and grain yield across a range of seasonal conditions.

Reference

Lilley, J, Bell, L & Kirkegaard, J 2015, 'Optimising grain yield and grazing potential of crops across Australia's high rainfall zone: a simulation analysis', *Crop and Pasture Science*, vol. 66, pp. 349–364.

Acknowledgements

This experiment was jointly funded by GRDC and NSW DPI as part of the collaborative project 'Optimising canola profitability', CSP10087; 2014–19, a partnership also including CSIRO and SARDI. Thanks to the Harrison family for hosting the trial in 2015 and to Rob Dunkley and Justin Paul for technical assistance throughout the year.

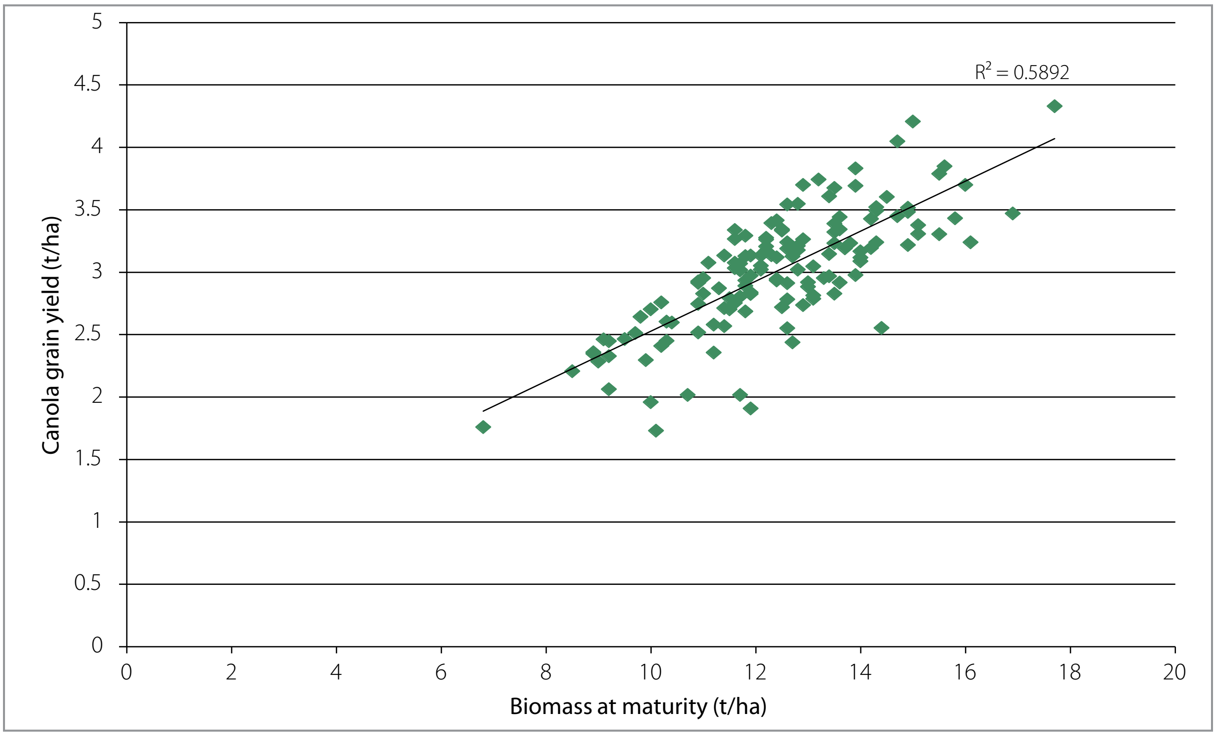

Figure 1. The relationship between grain yield and biomass of canola at maturity, Canowindra 2015.

Effect of sowing date and applied phosphorus on canola grain yield – 2014 and 2015

Colin McMaster NSW DPI, Cowra; **Mark Conyers** NSW DPI, Wagga Wagga; **Adam Coleman** NSW DPI, Orange

Key findings

» There was no significant interaction between sowing time and phosphorus (P) response in 2014 and 2015.

» Both sites and years responded positively to P fertiliser with 10 kg P/ha achieving a relative yield of 88% and 97% in 2014 and 2015 respectively.

» Further research is required to determine if winter canola requires less applied P than slow spring phenology types (due to the longer vegetative phase to accumulate biomass by flowering).

Introduction

Recent research has identified potential grain yield advantages from planting canola earlier than the traditional date of 25 April. It is assumed that this shift in sowing time could have interactions with other components of the farming system, including P management.

Previous research on wheat (Batten et al. 1999) demonstrated that less fertiliser P is required to achieve maximum grain yield when the crop is sown early. The research found that plants take up more P during both the vegetative and reproductive phases of crop growth. In wheat, much of the P uptake benefits from early sowing are related to increased P diffusion to the roots (i.e. delayed sowing reduces root growth) and a longer vegetative phase of crop development ranging from 95 to 103 days in wheat.

This experiment tested the hypothesis that less fertiliser P is required to achieve maximum grain yield if a mid-maturing variety (Hyola® 559TT) is sown earlier than the traditional date of 25 April.

This report provides only grain yield results. A more detailed paper, to be published later in 2016, will report on P uptake and use within the canola plant.

Site details

	2014	2015
Location	Cowra	Cargo
Soil type	Red chromosol	Red chromosol
Previous crop	Wheat	Oats
Colwell P (0–10 cm)	19 ppm	21 ppm
Applied nitrogen (N) fertiliser	80 kg N/ha (pre-drilled)	80 kg N/ha (pre-drilled)
Variety	Hyola® 559TT	Hyola® 559TT

Treatments

	2014	2015
Time of sowing	TOS 1: 17 Apr	TOS 1: 16 Apr
	TOS 2: 5 May	TOS 2: 2 May
	TOS 3: 20 May	TOS 3: 17 May
P fertiliser rate*	0, 10, 20 and 30 kg P/ha	

* P was applied at sowing and placed 2 cm below the seed

Results

Grain yield

In both 2014 and 2015 grain yield was significantly affected by time of sowing (P = 0.004, P <0.001) and phosphorus fertiliser rate (P <0.003, P <0.001). The interaction between sowing time and P fertiliser was not significant in either year, indicating that P fertiliser rates need to be maintained across all sowing times.

In 2014, grain yield declined by an average of 0.21 t/ha for every week sowing was delayed beyond 17 April with grain yield reducing by 0.31 t/ha and 0.96 t/ha for the 7 May and 22 May sowing times respectively (Figure 1).

In 2015 however, there was no significant grain yield difference between sowing on 16 April and 2 May, but there was a 0.79 t/ha yield penalty for sowing on 15 May (Figure 1).

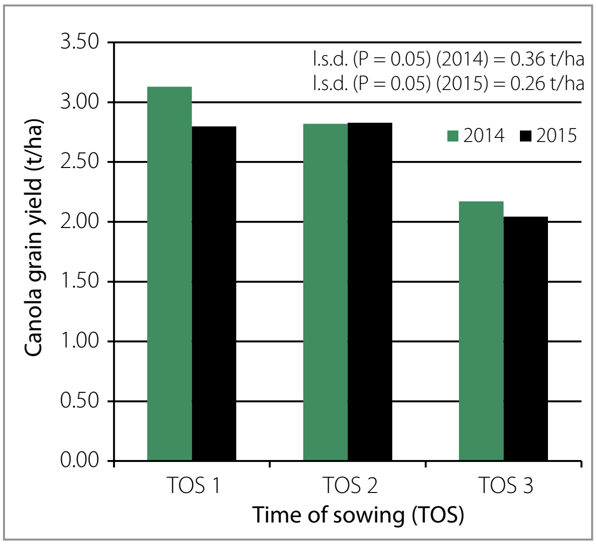

Figure 1. Average canola grain yield for three sowing dates across two years.

Grain yield responded positively to applied P in both years. In 2014 the 10, 20 and 30 kg P/ha produced a grain yield benefit of 0.19 t/ha, 0.23 t/ha and 0.54 t/ha respectively over the nil P fertiliser treatment (Figure 2). In 2015, the highest grain yield was achieved from 10 kg P/ha with a 0.59 t/ha grain yield benefit. The 10 kg P/ha achieved a relative yield of 88% and 97% of maximum yield in 2014 and 2015 respectively.

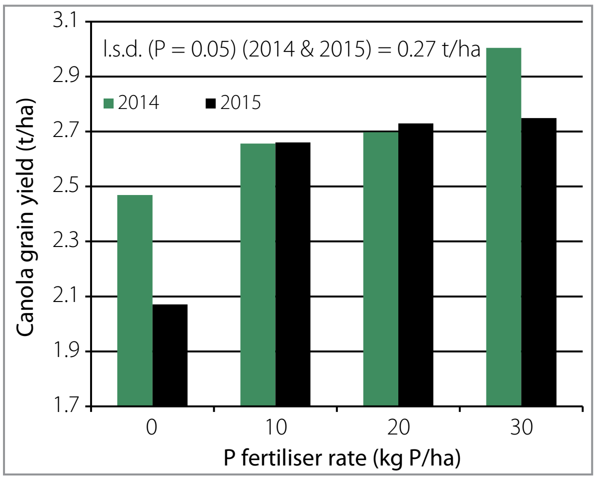

Figure 2. Average canola grain yield over four phosphorus rates, three sowing dates and two years.

Discussion

Research results from McCormick (2012) showed that approximately 5 t/ha canola dry matter is required at flowering to maximise grain yield at Wagga Wagga. Sowing a longer season canola variety (i.e. winter type) early might require less P than a quicker maturing variety sown late as the longer season canola type would have an extra 30–40 days to achieve optimum biomass at flowering. Further research is required to investigate the relationship between vegetative length before flowering and P response.

Results from this experiment suggest that P fertiliser rates should not be reduced if sowing a mid-maturing spring canola in mid-April compared with mid-May.

References

Batten, GD, Fettell, NA, Mead, JA & Khan, MA 1999, 'Effect of sowing date on the uptake and utilisation of phosphorus by wheat (cv. Osprey) grown in central New South Wales', *Australian Journal of Experimental Agriculture*, vol. 39, pp. 161–170.

McCormick, JI, Virgona, JM & Kirkegaard, JA 2012, 'Growth, recovery and yield of dual-purpose canola (*Brassica napus*) in the medium-rainfall zone of south-eastern Australia', *Crop and Pasture Science*, vol. 63, pp. 635–646.

Acknowledgements

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Thanks to Cowra Agricultural Research Station and Rob Dunkley for hosting the trial in 2014 and 2015 and Albert Oates, Graeme Poile, Rob Dunkley and Justin Paul for technical assistance.

Effect of sowing date on phenology and grain yield of six canola varieties – Condobolin 2015

Ian Menz and **Daryl Reardon** NSW DPI, Condobolin; **Rohan Brill** NSW DPI, Wagga Wagga

Key findings

- » Grain yield was highest from the early sowing date (17 April).
- » Pioneer® 44Y89 (CL) was the highest yielding variety.
- » The early sowing treatments grew more total biomass and had a higher harvest index than the two later sowing dates.
- » Pioneer® 44Y89 (CL) had a better harvest index than all other varieties in this experiment.

Introduction

The experiment was conducted to determine the grain yield and phenology response of six canola varieties sown at three different dates in a low rainfall environment.

Site details

Location	Condobolin Agricultural Research and Advisory Station
Soil type	Red chromosol
Previous crop	Lucerne pasture (2012–14), fallowed August 2014
Fertiliser	70 kg/ha monoammonium phosphate (MAP) + flutriafol (250 g/L) @ 400 mL/ha
Available nitrogen at sowing	250 kg/ha (0–180 cm)
Plant available water at sowing	30 mm
In-crop rainfall (April–October)	198 mm
Harvest date	Various according to maturity (hand harvest)

Treatments

Canola varieties	Pioneer® 43C80 (CL) Pioneer® 45Y86 (CL) Pioneer® 45Y88 (CL) Pioneerr 44Y89 (CL) Hyola® 575CL Hyola® 577CL
Sowing dates	TOS 1: 17 April TOS 2: 4 May TOS 3: 19 May

Seasonal conditions

Rainfall for the growing season was just below average, with Condobolin Agricultural Research and Advisory Station (CARAS) recording 198 mm. The long-term average growing season rainfall is 209 mm. An irrigation event of 13 mm was applied to the experiment on 29 April to optimise establishment.

The first sowing date was 17 April. There was adequate moisture but rainfall soon after sowing reduced emergence (average 20 plants/m^2) compared with the 4 May (average 45 plants/m^2) and 19 May (average 40 plants/m^2) sowing dates.

Results

Flowering

Hyola® 575CL was the fastest variety to flower from the 17 April sowing date (Table 1). The difference between Hyola® 575CL flowering and the slowest varieties (Pioneer® 45Y88 (CL), Pioneer® 45Y86 (CL) and Hyola® 577CL) was 14 days.

From the 19 May sowing date, the difference between the fastest variety Pioneer® 43C80 (CL) and the slowest variety Hyola® 577CL was only five days.

Table 1. Date of flowering (50% of plants with one open flower) of six canola varieties sown at three sowing dates, Condobolin 2015.

Variety	Date 50% flower		
	17 Apr	4 May	19 May
Pioneer 43C80 (CL)	1 Aug	17 Aug	30 Aug
Pioneer 44Y89 (CL)	26 Jul	20 Aug	1 Sep
Pioneer 45Y88 (CL)	3 Aug	26 Aug	3 Sep
Pioneer 45Y86 (CL)	3 Aug	26 Aug	2 Sep
Hyola 575CL	22 Jul	20 Aug	1 Sep
Hyola 577CL	3 Aug	26 Aug	4 Sep

Grain yield

The 17 April sowing date (average 1.2 t/ha) was significantly (P <0.001) higher yielding than the two later sowing dates (4 May average 0.3 t/ha, 19 May average 0.2 t/ha) (Figure 1). Pioneer® 44Y89 (CL) was the highest yielding variety in the experiment (average 0.8 t/ha across three sowing dates), with an overall grain yield benefit (across sowing dates) of 0.2 t/ha over the next best varieties: Pioneer® 43C80 (CL) and Pioneer® 45Y88 (CL). The interaction between variety and sowing date was not significant (P = 0.11).

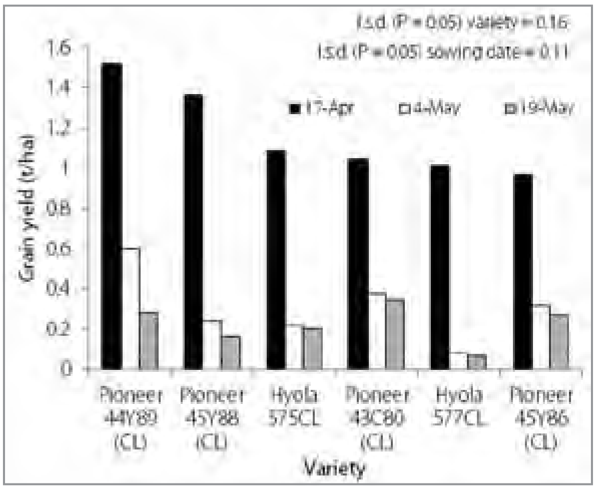


Figure 1. Grain yield (t/ha) of six canola varieties sown at three dates at Condobolin 2015.

There was a positive correlation ($R^2 = 0.79$) between biomass at maturity and grain yield (Figure 2), with higher biomass at maturity (from the 17 April sown treatments) resulting in higher grain yield.

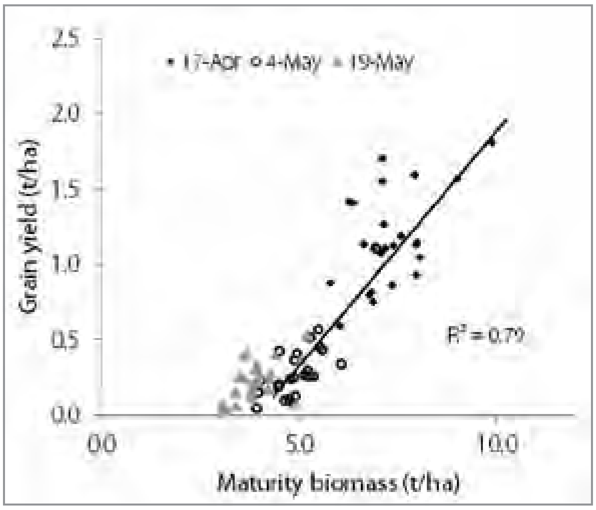


Figure 2. Relationship between maturity biomass (t/ha) and grain yield (t/ha) of six canola varieties sown on three dates at Condobolin 2015.

Sowing date and variety also affected the Harvest index (HI). Harvest index from the 17 April, 4 May and 19 May sowing dates was 0.16, 0.06 and 0.06 respectively. Averaged across the three sowing dates, Pioneer® 44Y89 (CL) had a significantly higher HI than all other varieties, being 0.13 compared with the next highest variety, Pioneer® 43C80 (CL) with 0.11.

Summary

The 17 April sowing date resulted in the highest yield across all varieties in this experiment. Pioneer® 44Y89 (CL) was the highest yielding variety when averaged across the three sowing dates.

This experiment shows that profitable canola production is possible in a low rainfall environment such as Condobolin, provided the sowing date is optimised and the most appropriate variety is selected. The water use efficiency (WUE) achieved from selecting the best variety and sowing early was 12 kg/ha/mm. The average WUE of all varieties from the 19 May sowing date was only 1.5 kg/ha/mm. Further research in this environment will quantify the benefits of stored water for canola and the interactions between stored water and agronomy decisions such as sowing date, variety choice and nitrogen application.

Acknowledgements

This experiment was jointly funded by GRDC and NSW DPI as part of the collaborative project 'Optimising canola profitability', CSP10087; 2014–19, a partnership also including CSIRO and SARDI.

Thanks to Daryl Reardon and Linda Brangwin at CARAS for technical assistance throughout this experiment.

Effect of sowing date, seeding rate and irrigation pre-sowing on grain yield of two canola varieties – Condobolin 2015

Ian Menz and **Daryl Reardon** NSW DPI, Condobolin; **Rohan Brill** NSW DPI, Wagga Wagga

Key findings

- The combination of extra stored water (20 mm) and early sowing (17 April) resulted in the highest grain yield in this experiment.
- Early sowing without extra stored water gave a higher yield than late sowing (4 May), regardless of the irrigation treatment at the later sowing date.
- The extra grain yield from early sowing and irrigation was due to increased biomass accumulation and improved harvest index.
- Oil concentration was low overall, but was higher from the early sowing (33.6%) than the later sowing (30.5%).

Introduction

Water stored in the fallow phase can contribute significantly to the grain yield of all crops. This experiment was designed to determine which management factors for canola improved the efficiency of using stored water.

Site details

Location	Condobolin Agricultural Research and Advisory Station
Soil type	Red chromosol
Previous crop	Lucerne pasture (2012–2014), fallowed August 2014
Fertiliser	70 kg/ha MAP + flutriafol 250 g/L @ 400 mL/ha
Available nitrogen (N) at sowing	278 kg/ha (0–180 cm)
Plant available water at sowing	30 mm (non-irrigated treatment)
In-crop rainfall (April–October)	198 mm
Harvest date	According to maturity (hand harvest)

Treatments

The experiments were sown as a full factorial combination of variety, sowing date, irrigation (plus and minus) and plant density.

Variety	Hyola 575CL Pioneer 45Y88 (CL)
Sowing date	17 Apr 4 May
Irrigation	Plus Minus
Plant density	15 plants/m^2 45 plants/m^2

Irrigation of 64 mm was applied with a small lateral irrigator in March. The soil was cored prior to sowing and the extra water stored by this irrigation was 20 mm, giving plant available water in the irrigated treatment of 50 mm compared with 30 mm in the non-irrigated treatment.

Results

Grain yield

The irrigation treatment and sowing date interaction significantly affected grain yield ($P = 0.006$). There was a 0.7 t/ha grain yield benefit from the irrigated treatment compared with the non-irrigated treatment when sown early (17 April), but no benefit from the irrigated treatment when sown on 4 May (Figure 1). The non-irrigated treatment sown on 17 April yielded more than the irrigated treatment sown on 4 May.

Variety had a significant effect on grain yield ($P = 0.031$). Pioneer® 45Y88 (CL) was higher yielding when averaged across all treatments than Hyola® 575CL (1.2 v 1.0 t/ha). Seeding density had no effect on grain yield.

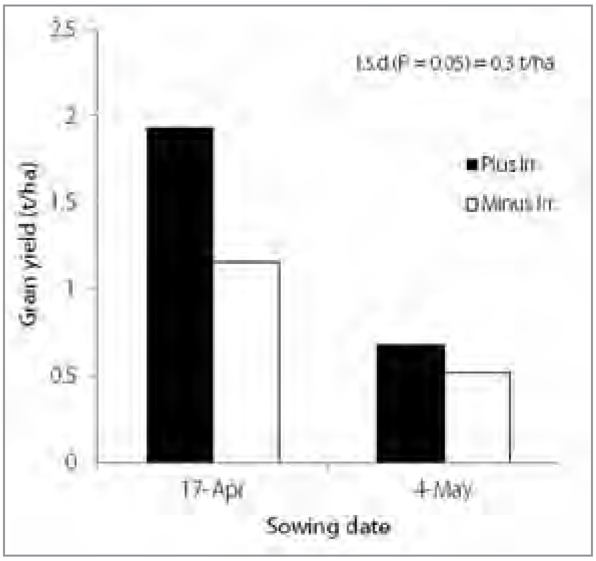


Figure 1. The effect of sowing date and irrigation treatment on grain yield of canola, averaged across two target plant densities, Condobolin 2015.

Maturity biomass and harvest index

Grain yield is a function of total crop biomass and harvest index i.e. the proportion of the biomass that is grain.

Sowing early (17 April) with irrigation resulted in the highest biomass at maturity and highest harvest index (HI) (Figure 2). Late sowing (regardless of irrigation) had low biomass and low HI.

Oil concentration

Oil concentration (reported at 6% moisture content) was significantly (P <0.001) higher for Hyola® 575CL (33.1%) than for Pioneer® 45Y88 (CL) (31.0%). Oil was also significantly (P <0.001) higher from the 17 April sowing date (33.6%) than the 4 May sowing date (30.5%).

Grain protein concentration was high for all treatments, averaging 29.6%.

Summary

The irrigation treatment in this experiment only stored an extra 20 mm of water in the soil; however this moisture resulted in a 0.7 t/ha grain yield increase when canola was sown early. This equates to marginal water use efficiency (extra grain yield generated per extra millimetre of water stored) of 35 kg/ha/mm. Assuming a grain price of $500/tonne with no change in oil concentration, the average return of each extra millimetre of water stored was $17.50/ha. This highlights the importance of timely fallow weed control to maximise water storage for the crop to use during the critical reproductive stages.

The extra grain yield from the early sowing with irrigation resulted from increased biomass as well as an improved HI. Research into the factors that affect biomass, and then the conversion of that biomass into grain, will form a major part of future research in the 'Optimising canola profitability' project. Factors to be investigated include sowing date, nitrogen management and variety.

The low oil levels observed in this experiment were consistent with past research (Brill et al. 2015) that has shown that increasing N has a negative effect on oil concentration. The starting N level of 278 kg/ha ensured that N was non-limiting and that grain yield was most likely to be limited by water.

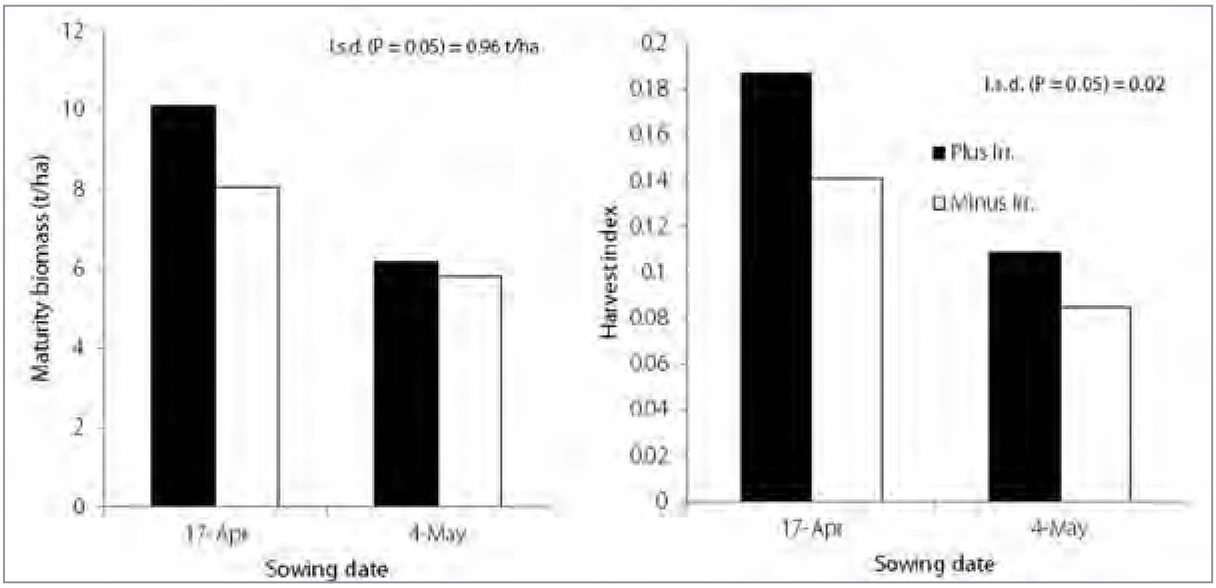


Figure 2. The effect of sowing date and irrigation treatment on biomass at maturity and harvest index of canola, averaged across two target plant densities, Condobolin 2015.

Reference

Brill, R, Street, M & Jenkins, L 2015, 'Improving WUE of canola in central NSW'. 17th Australian Agronomy Conference. Hobart 2015. Full paper at: http://www.agronomy2015.com.au/1303

Acknowledgements

This experiment was jointly funded by GRDC and NSW DPI as part of the collaborative project 'Optimising canola profitability', CSP10087; 2014–19, a partnership also including CSIRO and SARDI.

Thanks to Daryl Reardon and Linda Brangwin at CARAS for technical assistance throughout this experiment.

Faba bean time of sowing – Wagga Wagga 2014

Dr Eric Armstrong, **Gerard O'Connor** and **Luke Gaynor** NSW DPI, Wagga Wagga

Key findings

- » Sowing time has far greater consequences on growth, development, dry matter and grain yield of faba bean than variety choice.
- » The dry spring, combined with temperature constraints, imposed a common ceiling to yield despite large differences measured in dry matter (DM), height and reproductive node number across all treatments.
- » Early-sown faba bean was primarily affected by severe frosts, while later sown was limited by flower-node production and heat stress.
- » Under these conditions, early April sowings resulted in greater biomass, taller plants, more flowering nodes, additional lodging, more disease and greater frost damage. Given a more favourable spring, disease and lodging could have been further exacerbated, inflicting even greater yield penalties to the first time of sowing (TOS).
- » Findings from this and previous experiments show the optimum sowing window for faba bean on acidic, red-brown soils of southern NSW to be from 20 April to 15 May. The later sown crops within this window could still be disadvantaged under early unfavourable finishing conditions.

Introduction

This experiment compared the growth, development and yield of current commercial faba bean varieties and promising advanced breeding lines at three sowing dates on a hard-setting, acidic, red-brown soil at Wagga Wagga. This information will be used to confirm and update current agronomic recommendations for faba bean production in this region.

Site details

Site	Paddock 20A, Wagga Wagga Agricultural Institute
Soil type	Red-brown earth, pH_{Ca} 5.2 (0–10 cm) (Table 1). The site was limed in 2010
Paddock history	Sown to pasture in autumn 2013 but poor establishment led to chemical fallowing of the paddock in the spring. Therefore, stubble was absent for the 2014 season
Fertiliser	80 kg/ha SuPerfect® grain legume fertiliser (NPKS 0:13.8:0:6.1) placed 2 cm below seed.
Plant population	Targeted 35 plants/m² adjusted for seed size and germination
Sowing	Direct-drilled using a six-row cone seeder with 300 mm row spacing, press wheels and GPS auto-steer
Inoculation	Group F peat inoculant was mixed directly into an on-board 200 L water tank then pumped through micro-tubes into each sowing furrow
Weed management	Commercial practices aimed at weed-free conditions to eliminate weed competition and prevent weed seed set. Fallow weed control: 2 L/ha glyphosate (450 g/L) and 1 L/ha 2,4-D LV ester (680 g/L) Incorporated by sowing: 2 L/ha glyphosate (450 g/L), 2 L/ha Stomp® (440 g/L pendimethalin), 2 L/ha Avadex® (400 g/L tri-allate) and 1 kg/ha Terbyne® (750 g/kg terbuthylazine) Post sow pre-emergent: 250 g/ha Terbyne® (750 g/kg terbuthylazine) Post emergent: 330 mL/ha Select® (240 g/L clethodim), 100 mL/ha Verdict® (520 g/L haloxyfop) and 500 mL/100 L Uptake® spraying oil
Disease management	Penncozeb® 750 (mancozeb) – 2 kg/ha on 23 June for chocolate spot Howzat® (carbendazim) – 500 mL/ha on 8 August and 1 September for chocolate spot
Insect management	Targeting *Helicoverpa* sp.: 400 mL/ha Fastac® Duo (100 g/L alpha-cypermethrin) – 20 September and 24 October

Treatments

Varieties (8)	Farah$^{\phi}$ PBA Nasma$^{\phi}$ Nura$^{\phi}$ PBA Rana$^{\phi}$	PBA Samira$^{\phi}$ PBA Zahra$^{\phi}$ AFO7125 AFO6125
Time of sowing (3)	TOS 1: 2 April TOS 2: 24 April TOS 3 12 May	

Soil

Pulse growth and rhizobia survival can be affected when soil pH falls below five. This can lead to problems on the acidic, red-brown soils that dominate the cropping zones of southern NSW. Growers need to consider this and routinely monitor soil acidity to maintain a base pH of approximately five using strategic lime applications.

The 2014 Wagga Wagga site was limed in 2010, and its topsoil (0–10 cm) pH_{Ca} is now 5.2. Soil nitrogen levels were low and phosphorus levels medium (Table 1).

Table 1. Site soil chemical characteristics for 0–10 cm and 10–20 cm depths at Wagga Wagga, 2014.

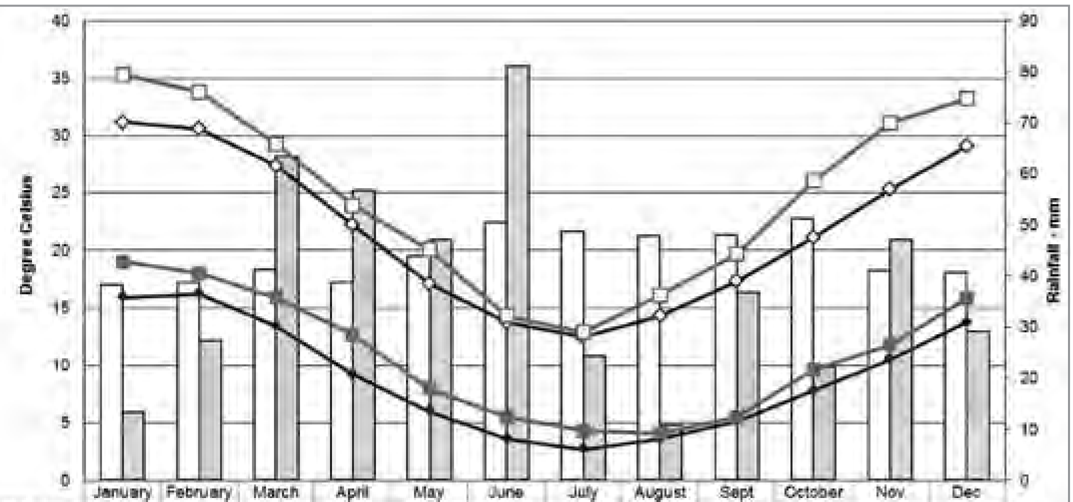
Characteristic	Depth	
	0–10 cm	10–20 cm
pH (1:5 $CaCl_2$)	5.2	5.0
Al Sat (%)	1.7	2.5
Nitrate N (NO_3) (mg/kg)	8.5	15.0
Ammonium N (mg/kg)	0.8	1.1
P (Colwell) (mg/kg)	34.0	13.0
CEC (cmol(+)kg)	7.0	6.5

Season

The 2014 season at Wagga Wagga was warmer, drier and shorter than normal (Figure 1). Early season rainfall (March–June) was 40% above the long-term average and, in combination with the mild temperatures during this period, the conditions were ideal for plant establishment and early growth. This rainfall also replenished sub-soil moisture, benefiting grain fill at the end of the season when July to October rainfall was only half (93 mm) the long-term average. Crops finished 2–3 weeks earlier under these low rainfall and warm temperatures (1–2 °C above average) conditions.

There were 43 frost events in 2014 where temperatures fell below 2 °C. More severe frosts occurred in July and August (18 events where temperatures dropped below 0 °C) causing isolated stem-splitting with some flower and pod loss. A further three significant frosts occurred in September (temperatures fell below –1°C on 4, 19 and 20 September). Further flower and pod loss resulted from these events; however, moisture and high temperature stresses ultimately became the overriding limitations to grain fill and yield.

These conditions were not conducive to disease and incidence was low.



	January	February	March	April	May	June	July	August	Sept	October	Nov	Dec
Long term rainfall	38.1	38.6	41.1	38.6	43.8	50.4	48.5	47.6	47.8	51.0	40.9	40.6
2014 rain	13.2	27.2	63.4	56.6	47.0	81.0	24.2	10.6	36.6	22.0	47.0	29.0
Long term Max temps	31.2	30.6	27.4	22.2	17.1	13.7	12.5	14.3	17.3	21.1	25.3	29.1
2014 mean max	35.3	33.8	29.3	23.8	20.1	14.3	12.9	16.1	19.7	26.0	31.1	33.2
Long term Min temps	15.9	16.2	13.4	9.2	6.0	3.6	2.7	3.6	5.1	7.8	10.5	13.7
2014 mean min temp	19.0	18.0	15.9	12.7	8.0	5.5	4.3	4.1	5.5	9.6	11.8	15.8

Figure 1. Monthly rainfall in 2014, monthly temperature in 2014, and long-term average rainfall (1898–2014) at Wagga Wagga.

Results

Seasonal effects

Chocolate spot (*Botrytis* sp.) developed, especially in TOS 1 (2 April), but was held in check with strategic preventative fungicide applications, the dry spring weather and associated lower humidity. Overall, 2014 was a very favourable year for pulses at Wagga Wagga despite the frosts and late moisture stresses. It was characterised by minimal disease, above average yields; and an early, dry harvest producing good quality, unblemished seed.

Grain yield, dry matter production and harvest index (HI%)

The unusual outcome of this experiment was that grain yield across all three sowing times and eight varieties was statistically the same, averaging 2.87 t/ha. This is well above the expected long-term average of 1.8–2.0 t/ha for faba bean in this region, despite the dry, tight finish to the season.

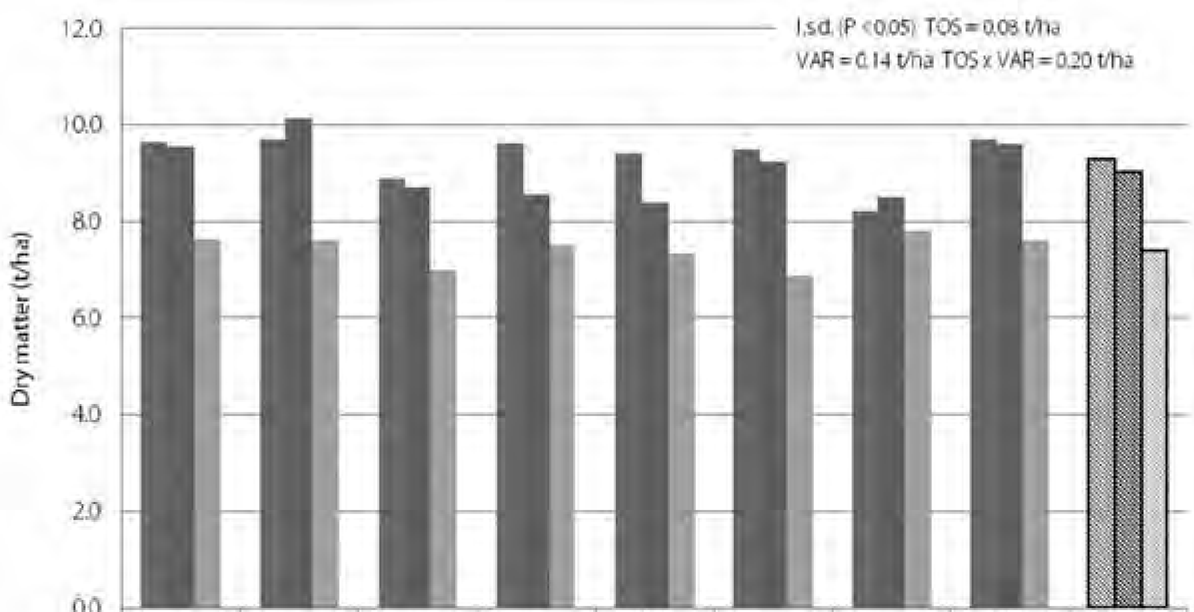
This absence of any yield differences across all treatments was unexpected given the very large variation in dry matter production, height, lodging and flowering across the three sowing times and eight varieties (figures 2, 3, 4 and 5). Despite these large variations it seems likely that the moisture and temperature constraints of spring set a ceiling on pod set, seed fill and yield. No doubt, varying sowing dates (and to a lesser degree the different varieties) reached this ceiling via different means: the early sowings produced taller stems with a greater number of flowering nodes but high abortion rates; the later sowings produced fewer flowering nodes but with better pod retention.

To put these results in perspective, the average commercial yield of faba beans across southern NSW is 1.83 t/ha compared with 1.46 t/ha, 1.35 t/ha and 1.28 t/ha for lupin, field pea and chickpea respectively (Scott, 2013). However, commercial faba bean yields have reached 4.0 t/ha, and in some instances up to 6.0 t/ha (Matthews & Marcellos 2003). To achieve these yield levels, seasonal conditions (moisture and temperature in particular) have to be ideal to reduce the high rates of flower abortion observed here along the stems.

Nevertheless, these results are consistent with maximum faba bean yield resulting from mid-April to mid-May sowing in this region. Growers still need to consider the consequences of:

- » sowing too early (before 15 April) – excessive height, lodging and disease
- » sowing too late (after the middle of May) – short plants and restricted dry matter and grain yield.

Growers also need to consider that in cool, moist and extended springs, even late April sowings can be subject to greater disease pressure and require careful monitoring and appropriate foliar fungicide responses.



	PBA Rana	PBA Zahra	AF06125	AF07125	PBA Nasma	Farah	PBA Nura	PBA Samira	MEAN
2 Apr	9.67	9.72	8.88	9.62	9.42	9.50	8.23	9.71	9.30
24 Apr	9.56	10.15	8.73	8.56	8.39	9.24	8.49	9.61	9.02
12 May	7.66	7.63	7.00	7.51	7.36	6.88	7.81	7.63	7.40

Figure 2. Dry matter production of eight varieties of faba bean sown at three times at Wagga Wagga, 2014.

Dry matter production was statistically the same at TOS 1 and TOS 2 (mean of 9.1–9.3 t/ha) but decreased significantly (by 20%) when sowing was delayed to 12 May (TOS 3 average 7.4 t/ha). The more vigorous growth of PBA Rana, PBA Zahra, PBA Samira and Farah was reflected in higher DM at TOS 1 and TOS 2 and higher normalised difference vegetation index (NDVI) readings at the early vegetative stage, especially PBA Rana (data not shown). (Note: NDVI was measured on 19 June and 25 July using a hand-held GreenSeeker®, which gives an index of plant 'greenness' or photosynthetic activity).

Harvest index (HI) averaged 33.8% across the experiment with no significant differences between sowing time and variety, although mean HI did increase to 38% for TOS 3. This reflected lower DM and plant heights in TOS 3 combined with a more efficient conversion of DM into grain. The implication here is that a higher proportion of fixed nitrogen is exported in the grain resulting in less residual nitrogen for subsequent crops.

Plant height, lodging and podding

Late varieties, such as PBA Rana, flower and pod later; and flower and set pods at nodes higher up the stem compared with early varieties such as PBA Nasma (Figure 3). As sowing was delayed from early April to mid-May, plant height and bottom-pod height reduced significantly. This places physical restrictions on reaching the lowest pods during harvest. Conversely, sowing too early extends growing periods and produces excessively tall plants leading to lodging and further problems at harvest, as seen with PBA Rana and Farah at TOS 1 (Figure 4). All varieties at TOS 2 and TOS 3 were shorter and remained erect, simplifying management and harvest.

Growth and development phases

The development phases of all faba bean varieties contracted as sowing was progressively delayed (Figure 5). As an example, a 40-day delay of sowing (TOS 1 to TOS 3) was reduced to a 12-day difference by the end flowering (17 September to 29 September), then to only a 4-day difference by maturity (27 October to 31 October).

This significant reduction in growing periods at later sowing times translates into shorter flowering periods (73 days down to 37 days), shorter grain-filling periods, shorter plants, reduced number of flowering nodes, more erect growth, less disease and reduced DM. Yet, as previously stated, yield remained unaffected but harvest index increased. This reflects greater environmental stresses imposed on earlier sowings in this experiment, particularly frost and the extra moisture and nutrient demand plants require when producing greater biomass.

Varieties differed in their growth patterns. For example, PBA Nasma was the first to flower and Nura the last at all sowing dates. PBA Nasma is a very early, northern NSW variety and was included in this trial to compare phenology and performance with southern lines. It flowered 60, 37 and 18 days earlier than PBA Rana at the TOS 1, TOS 2 and TOS 3 respectively, but finished flowering only 6–8 days earlier, most likely due to high temperatures. The longer flowering window of PBA Nasma enables it to produce a large number of flowering nodes, greater DM and yield plasticity, and provides better insurance against environmental stresses during flowering and pod-fill. While its yield was similar to other varieties this season, it was the top yielding variety in experiments at Wagga Wagga in 2013.

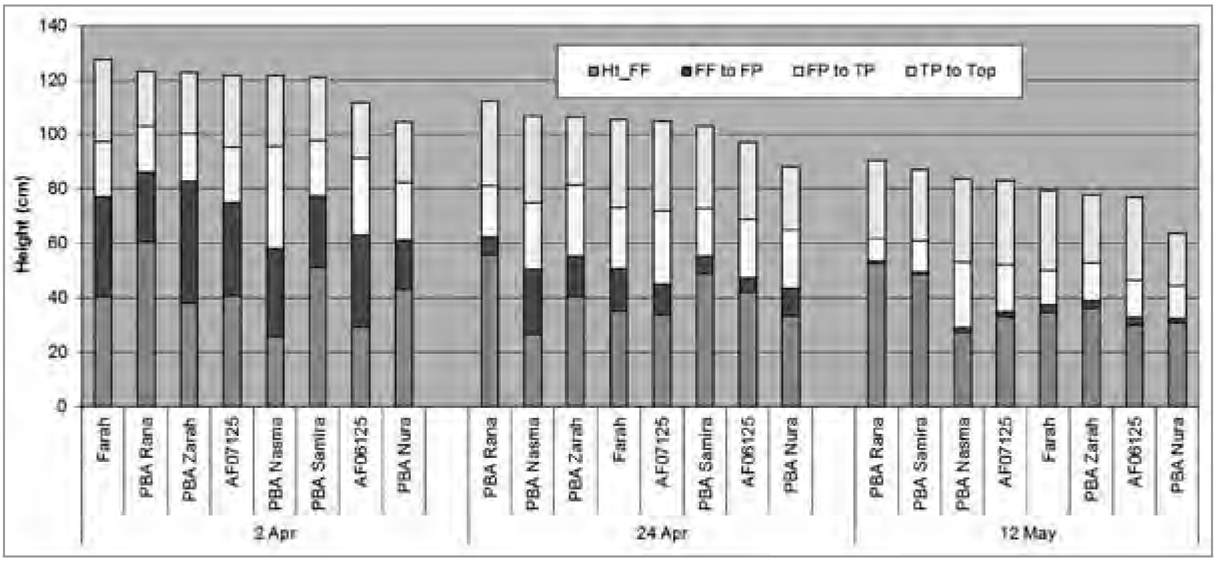


Figure 3. Stem height to first flower (Ht_FF), first pod (FF to FP), last pod (FP to TP) and to the top (TP to Top) of eight varieties of faba bean sown on three dates at Wagga Wagga, 2014.

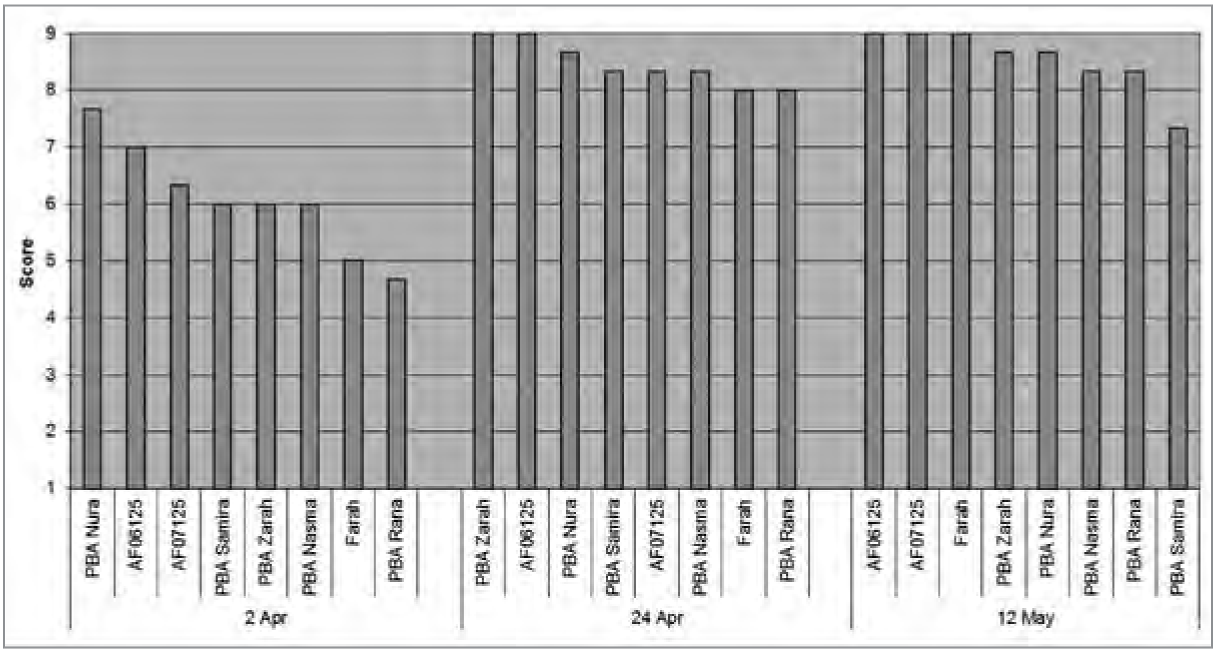


Figure 4. Erect scores at maturity of eight varieties of faba bean sown at three dates at Wagga Wagga in 2014. These scores subjectively estimate how well each variety stands at maturity on a 1 to 9 scale, where 1 is flat on the ground and 9 is completely erect.

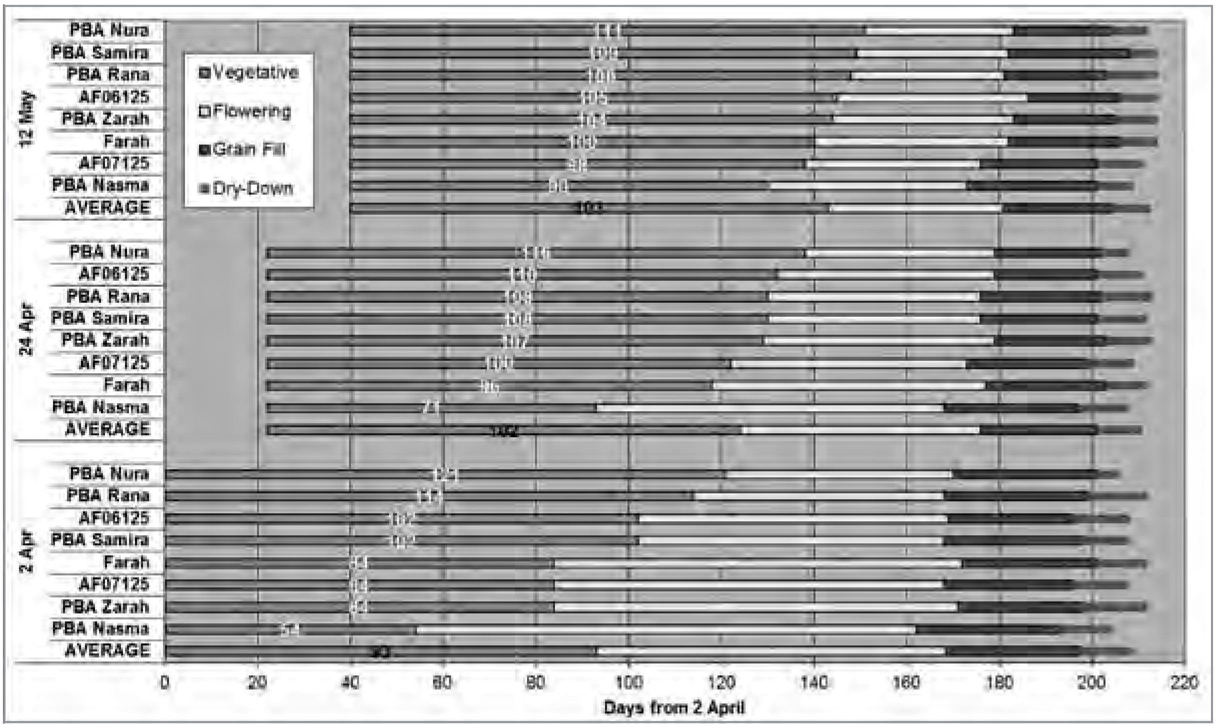


Figure 5. Phases of development of eight varieties of faba bean sown at three dates at Wagga Wagga 2014.

Summary

- Growth and development of faba bean appeared normal on these hard-setting, acidic, red-brown soils and excellent yields were achieved, indicating considerable potential for faba bean production across southern NSW.
- Faba bean yield was unaffected by sowing time and variety during the 2014 season at Wagga Wagga, yielding 2.87 t/ha.
- The dry spring combined with temperature constraints imposed a common ceiling to yield despite large differences measured in dry matter (DM), height and reproductive node number across all treatments.
- Early-sown faba bean was primarily affected by severe frosts, while later sown was limited by flower-node production and heat stress.

- Under these conditions, early April sowings resulted in greater biomass, taller plants, more flowering nodes, additional lodging, more disease and greater frost damage. Given a more favourable spring, disease and lodging could have been further exacerbated, inflicting even greater yield penalties to (time of sowing) TOS 1.
- Later sowing (mid-May onwards) is projected to produce fewer podding nodes, shorter plants, lower bottom pods and lower yield.
- Sowing time has far greater consequences on growth, development, DM and grain yield of faba bean than choice of variety.
- Findings from this and previous experiments shows the optimum sowing window for faba bean on acidic, red-brown soils of southern NSW to be from 20 April to 15 May. The later sown crops within this window might still be disadvantaged under early unfavourable finishing conditions.

References

Matthews, P & Marcellos, H 2003, Faba bean Agfact, P4.2.7, 2nd edn. NSW Agriculture.

Scott, F 2013, NSW Grains Report Summary 1993–2013, NSW Department of Primary Industries, unpublished.

Acknowledgements

This experiment was part of the project 'Expanding the use of pulses in the southern region', DAV00113 2013–16, a collaborative pulse project between state agencies in Victoria, NSW and South Australia, jointly funded by NSW DPI and GRDC.

Faba bean time of sowing – Wagga Wagga 2015

Mark Richards, **Dr Eric Armstrong**, **Luke Gaynor**, **Karl Moore**, **Russell Pumpa** and **Jon Evans** NSW DPI, Wagga Wagga

Key findings

- » The optimum time to sow faba beans at Wagga Wagga in 2015 was mid–late April.
- » PBA Nasma, PBA Samira, PBA Zahra, Farah and Fiesta VF were the highest yielding commercial varieties.
- » Time of sowing had a far greater effect on growth, development and grain yield of faba bean than variety in this experiment.
- » PBA Nasma produced a small grain size of 53 g/100 seeds, which could have negative marketing implications. Further testing is required to determine if this was a seasonal effect.

Introduction

This experiment aimed to compare growth, development and yield of current commercial faba bean varieties and advanced breeding lines at three times of sowing (TOS) at Wagga Wagga. This information will be used to confirm and update current agronomic recommendations for faba bean in this region.

Site details

Site	Paddock 18, Wagga Wagga Agricultural Institute
Soil type	Red-brown earth, pH_{Ca} 5.8 (0–10 cm) (Table 1)
Experiment design	Randomised complete block design with sowing date as the main blocks and varieties as the sub-plots; three replications
Sowing	Direct-drilled using a six-row cone seeder with 300 mm row spacings, press wheels and GPS auto-steer
Inoculation	Group F peat inoculant was mixed directly into an on-board 100 L water tank then pumped through micro-tubes into each sowing furrow
Stubble management	Burnt to remove wheat stubble (light burn only, still some stubble standing)
Fertiliser	80 kg/ha Grain legume super (N:P:K:S; 0:13.8:0:6.1) placed 50 mm below the seed
Plant population	Target 30 plants/m²

Weed management
Commercial practices used with the aim of weed-free experiments to eliminate weed competition and weed seed set.
Fallow weed control: glyphosate (450 g/L) 2.0 L/ha and 2,4-D LV ester (680 g/L) 1 L/ha
Incorporated by sowing: glyphosate (450 g/L) 2.0 L/ha, Stomp® (440 g/L pendimethalin) 2.0 L/ha, Avadex® (400 g/L tri-allate) 1.6 L/ha and Terbyne® (750 g/kg terbuthylazine) 900 g/ha
Post sowing: Terbyne® (750 g/kg terbuthylazine) 300 g/ha, Select® (240 g/L clethodim) 500 mL/ha, Verdict® (520 g/L haloxyfop) 100 mL/ha and Uptake® spraying oil 500 mL/100 L
Insect and disease management Targeting *Helicoverpa* sp, lucerne flea and chocolate spot
Lemat® 100 mL/ha (12 June 2015) Penncozeb® 750 1 kg/ha (9 July 2015) Penncozeb® 750 1 kg/ha (7 August 2015) Howzat® (500 g/L carbendazim) 500 mL/ha (2 September 2015) Howzat® (500 g/L carbendazim) 500 mL/ha (21 September 2015) Trojan® (150 g/L gamma-cyhalothrin) 30 mL/ha (24 October 2015)

Table 1. Site soil chemical characteristics for 0–10 cm and 10–30 cm depths at Wagga Wagga in 2015.

Characteristic	Depth	
	0–10 cm	10–30 cm
pH (1:5 $CaCl_2$)	5.8	5.0
Aluminium Exc. (meq/100 g)	<0.1	<0.1
Total N (%)	0.026	0.041
Sulfur (mg/kg)	5.1	6.4
Phosphorus (Colwell) (mg/kg)	21	47
CEC (cmol(+)kg)	7.4	5.5
Organic carbon (OC) (%)	0.51	0.37

The 2015 growing season at Wagga Wagga was almost ideal for pulse production except for a dry and hot September–October period. Growing season rainfall (April–October) was close to the long-term average (333 mm) with 56 mm of this falling in early April enabling timely sowing. Rainfall in June, July and August was 50% above the long-term average and contributed to valuable sub-soil moisture.

However, the flowering and grain filling period of September–October experienced eight continuous weeks of no effective rainfall and wide temperature fluctuations (5 September to 31 October). Three consecutive days in late September (23–25 September) received below zero temperatures and damaging frosts only to be followed by an exceptionally hot, dry October. Average daily maximum temperatures for the month exceeded the long-term average by 8.3 °C and the first week experienced unseasonal temperatures in the mid-30s.

Treatments

Varieties (10)	PBA Zahra$^{\Phi}$ PBA Samira$^{\Phi}$ PBA Rana$^{\Phi}$ PBA Nasma$^{\Phi}$ Nura$^{\Phi}$	Farah$^{\Phi}$ Fiesta VF AF08207 AF10089 Determinant type
Time of sowing (TOS)	TOS 1: 14 April TOS 2: 1 May TOS 3: 18 May	

Results

Establishment

Faba bean establishment was slightly above the target of 30 plants/m^2. TOS 1 had an average plant establishment of 36.7 plants/m^2 and TOS 2 had an average of 34.5 plants/m^2. TOS 3 was significantly lower ($P < 0.001$) at 28 plants/m^2.

Grain yield, dry matter production and harvest index

Time of sowing (TOS) was a critical factor for maximising faba bean yield in this experiment. Whilst there was no significant difference between TOS 1 and TOS 2 (at $P < 0.001$), a delay in sowing until 18 May resulted in a yield decline of 26% across all 10 varieties (Figure 1).

There was also a significant variety and TOS interaction ($P < 0.001$) in this experiment. The 2015-released variety PBA Nasma yielded significantly higher than all other varieties in TOS 1. PBA Nasma is a northern NSW variety susceptible to Ascochyta blight and its seed size in this trial was smaller than either PBA Zahra or PBA Samira, which could have marketing implications. Across all sowing dates, PBA Nasma, PBA Samira, PBA Zahra, Farah and Fiesta VF were the highest yielding varieties. The large-seeded PBA Rana was significantly lower yielding than the other commercially available varieties for all three TOS treatments (Figure 2).

The last significant rainfall of the growing season was on 4 September and the trial suffered severe heat and moisture stress in the first week of October. This caused all TOS treatments to abort flowers and mature prematurely. Due to the more advanced stage of development, TOS 1 and TOS 2 were less severely affected. However, these results are consistent with maximum faba bean yields resulting from mid-April to early-May sowing in this region. Growers still need to consider the consequences of:

- sowing too early (before 20 April) – excessive height, lodging and disease
- sowing too late (after 10 May) – short plants and restricted dry matter and grain yield.

Growers also need to be aware that in cool, moist extended springs, even late April sowings can be subject to greater disease pressure and require careful monitoring and foliar fungicide sprays. Whilst this site experienced a wet winter and early spring, a preventative fungicide program, combined with dry spring conditions, reduced disease levels to an insignificant level.

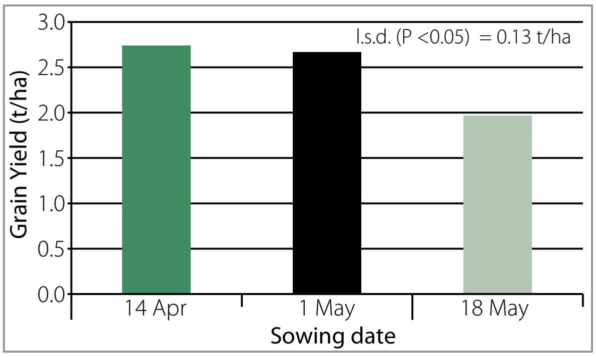
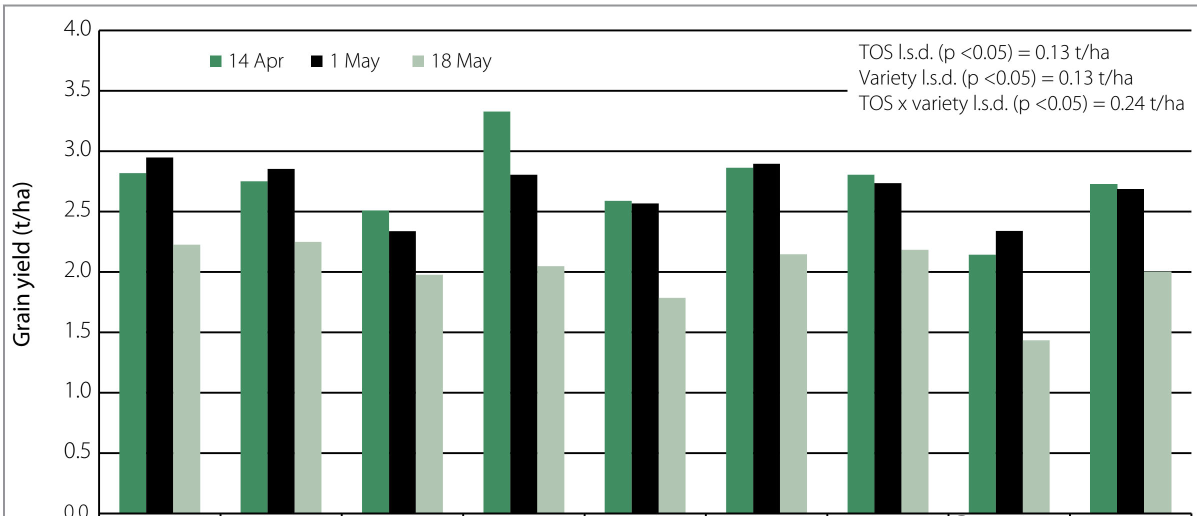
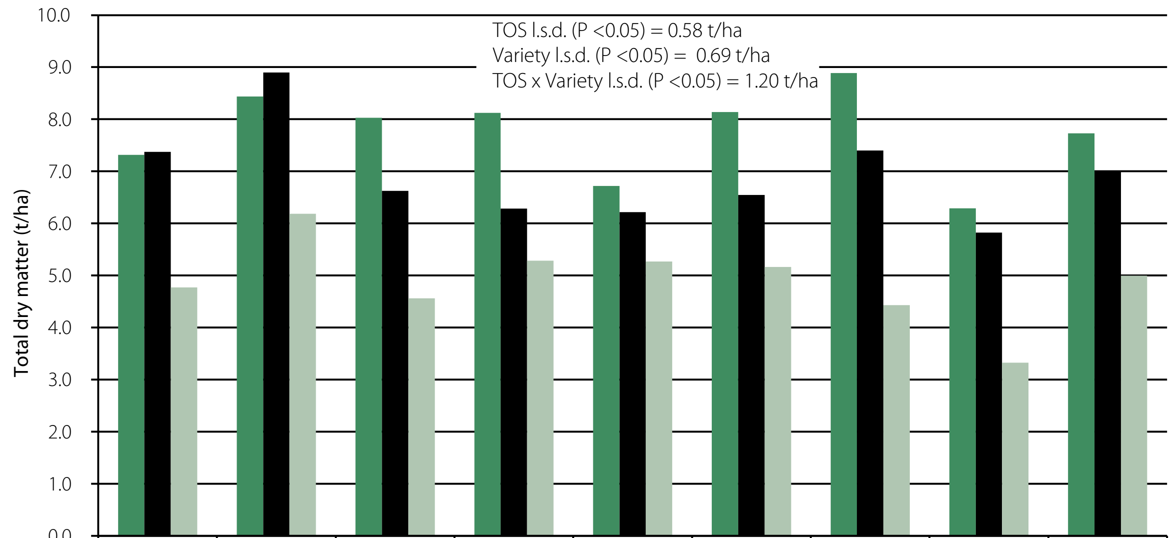


Figure 1. Mean faba bean grain yield from three sowing dates at Wagga Wagga in 2015.



	PBA Zahra	PBA Samira	PBA Rana	PBA Nasma	Nura	Fiesta VF	Farah	Determinant Type	MEAN
14 Apr	2.82	2.75	2.51	3.33	2.59	2.86	2.81	2.14	2.73
1 May	2.95	2.85	2.34	2.81	2.57	2.90	2.74	2.34	2.68
18 May	2.23	2.25	1.98	2.05	1.79	2.15	2.18	1.44	2.00

Figure 2. Grain yield of 10 faba bean varieties sown at three dates at Wagga Wagga in 2015.



	PBA Zahra	PBA Samira	PBA Rana	PBA Nasma	Nura	Fiesta VF	Farah	Determinant Type	MEAN
14 Apr	7.32	8.44	8.03	8.13	6.72	8.14	8.89	6.29	7.73
1 May	7.37	8.90	6.62	6.29	6.22	6.55	7.40	5.82	7.00
18 May	4.77	6.19	4.56	5.29	5.27	5.16	4.43	3.33	5.00

Variety

Figure 3. Total dry matter production of 10 faba bean varieties sown at three dates at Wagga Wagga in 2015.

Dry matter (DM) production was similar at the first two times of sowing (7.7–7.0 t/ha) but decreased significantly (by 29%) when sowing was delayed to 18 May (average 5.0 t/ha). The more vigorous growth of PBA Samira, Farah, PBA Zahra, PB Nasma and PBA Rana was reflected in higher DM at the first TOS.

There was a significant TOS and variety interaction for harvest index (HI). The harvest index increased significantly from TOS 1 (35.6%) to TOS 2 and TOS 3 with 40.1% and 40.5% respectively. Whilst TOS 2 and TOS 3 had significantly different grain yield and DM totals, they were similar in their efficiency of converting DM to grain. The implication here for a higher HI is more nitrogen (N) is exported in the grain, and less residual N remains with lower biomass plants.

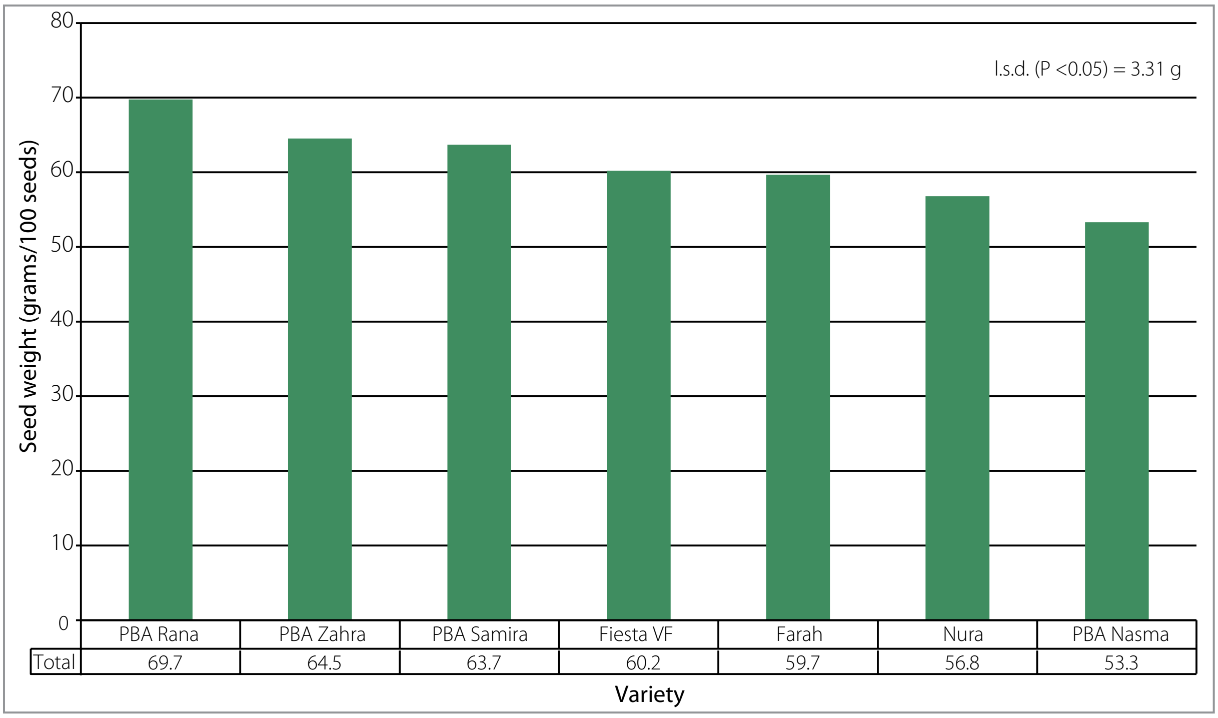


Figure 4. Grain weight of 10 faba bean varieties at Wagga Wagga in 2015.

Seed size

There was no significant variety and time of sowing interaction in this experiment. Variety had a significant effect on seed size (P <0.001) given the normal seed size variation between faba bean varieties. Whilst PBA Rana was significantly lower yielding than the other commercial varieties, it did have a significantly larger seed size at P <0.001 (Figure 4). In this experiment, PBA Nasma was significantly smaller seeded than all other varieties tested, at 53.3 g/100 seeds (Figure 4). This could be a consequence of a number of factors including its very early maturity, the early hot and dry finish and the fact that it out-yielded all other treatments.

Acknowledgements

This experiment was part of the project 'Expanding the use of pulses in the southern region', DAV00113 2013–16, a collaborative pulse project between state agencies in Victoria, NSW and South Australia, jointly funded by NSW DPI and GRDC.

Faba bean time of sowing – Junee Reefs 2015

Mark Richards, **Dr Eric Armstrong**, **Luke Gaynor**, **Karl Moore**, **Russell Pumpa** and **Jon Evans** NSW DPI, Wagga Wagga

Key findings

» The optimum time to sow faba beans at Junee in 2015 was mid-April.

» PBA Zahra, PBA Samira and PBA Nasma were the highest yielding varieties.

» Commercial yields of 3 t/ha are achievable with appropriate variety selection and management.

Introduction

This experiment aimed to compare the growth, development and yield of current commercial faba bean varieties and advanced breeding lines at two sowing times at Junee Reefs in southern NSW. This information will be used to confirm and update current agronomic recommendations for faba bean in this region.

Site details

Location	'Carinya' Hart Bros Seeds, Junee Reefs
Experiment design	Randomised complete block design with sowing date as the main blocks and varieties as the sub-plots; three replications
Sowing	Direct-drilled using a six-row cone seeder with 300 mm row spacings, press wheels and GPS auto-steer
Inoculation	Group F peat inoculant was mixed directly into an on-board 100 L water tank then pumped through micro-tubes into each sowing furrow
Soil type	Red-brown earth; pH_{Ca} 4.6 (0–10 cm)
Stubble management	Stubble was lightly burnt before sowing
Fertiliser	80 kg/ha grain legume super (N:P:K:S; 0:13.8:0:6.1) placed 50 mm below the seed
Plant population	Target 30 plants/m^2
Weed management Commercial practices were used with the aim of weed-free trials to eliminate both weed competition and weed seed set.	
Incorporated by sowing: 2 L/ha glyphosate (450 g/L), 2 L/ha Stomp® (440 g/L pendimethalin), 1.6 L/ha Avadex® (400 g/L tri-allate) and 900 g/ha Terbyne® (750 g/kg terbuthylazine)	
Post sowing: TOS 2 only for fumitory: 800 mL/ha Ecopar® (20 g/L Pyraflufen-ethyl), 1% BS1000 (26 June 2015)	
Insect and disease management Targeting *Helicoverpa* sp, lucerne flea and chocolate spot: Penncozeb 750 DF®(750 g/L Mancozeb) @ 1 kg/ha (4 June 2015) Penncozeb 750 DF®(750 g/L Mancozeb) @ 1 kg/ha (7 August 2015) Le-Mat® (290 g/L omethoate) @ 100 mL/ha (9 July 2015)	

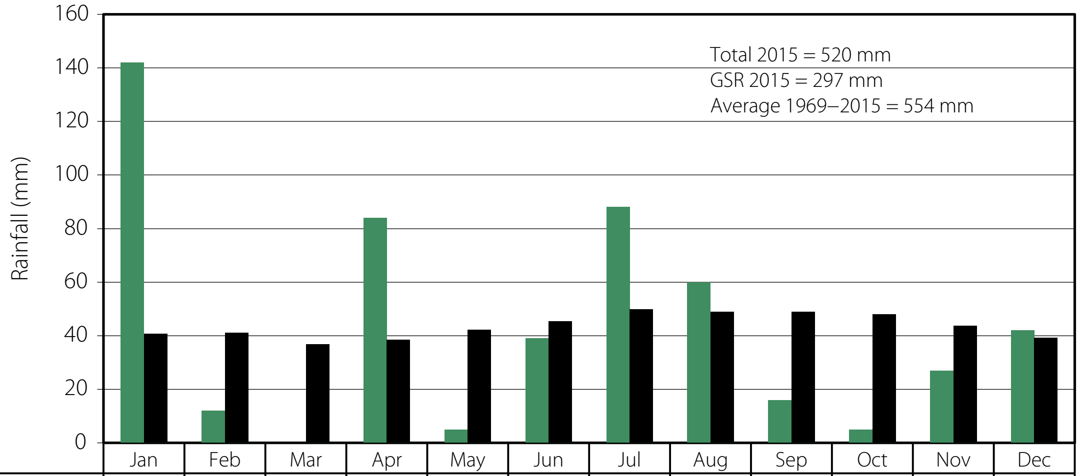
Pulse growth and rhizobia survival can be affected when soil pH falls below 5.0. This can lead to problems on the acidic red-brown soils that dominate the cropping zones of southern NSW. Growers need to be mindful of this and routinely monitor soil acidity aiming to maintain a base pH of approximately 5.0 through strategic lime incorporation.

Soil nitrogen (N) and phosphorus (P) in the top 10 cm of the profile were high at the time of sampling (Table 1).

Table 1. Site soil chemical characteristics for 0–10 cm depth at Junee Reefs in 2015.

Characteristic	Depth (0–10 cm)
pH (1:5 $CaCl_2$)	4.6
Aluminium Exc. (meq/100 g)	0.243
Nitrate N (NO_3) (mg/kg)	54
Ammonium N (mg/kg)	2
Sulfur (mg/kg)	9
Phosphorus (Colwell) (mg/kg)	79
Organic carbon (OC) (%)	1.47

The total rainfall received during 2015 was 520 mm. GSR was 297 mm (Figure 1).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	142	12	0	84	5	39	88	60	16	5	27	42
Long-term average	41	41	37	39	42	46	50	49	49	48	44	39

Figure 1. Total and growing season rainfall at Junee Reefs in 2015.

Treatments

Varieties (10)	PBA Zahra$^{\phi}$ PBA Samira$^{\phi}$ PBA Rana$^{\phi}$ PBA Nasma$^{\phi}$ Nura$^{\phi}$	Farah$^{\phi}$ Fiesta VF AF08207 AF10089 Determinant type
Time of sowing (TOS)	TOS 1: 16 April TOS 2: 6 May	

Results

PBA Zahra, PBA Samira, PBA Nasma and Fiesta VF were the highest yielding varieties at Junee Reefs in 2015. These varieties are also the highest yielding across south-eastern NSW in long-term experiments (2008–16) (Figure 2). PBA Nasma is a northern NSW variety susceptible to ascochyta blight and also has a smaller seed size in southern NSW than PB Zahra or PBA Samira, which could have marketing implications.

In this experiment, PBA Nasma was the smallest seeded variety with a mean grain weight of 50.8 g/100 seeds (Figure 3).

The 16 April (TOS 1) sowing yielded an average of 3.16 t/ha, which is 46% higher than the 6 May sowing (TOS 2) (Figure 4). Due to a fumitory infestation in the 6 May sowing, Ecopar® herbicide was applied, which caused some leaf burn on the faba beans. This could have had an effect on grain yield, but was unable to be measured.

The average commercial yield for faba beans across NSW is 1.83 t/ha compared with 1.46 t/ha, 1.35 t/ha and 1.28 t/ha for lupin, field pea and chickpea respectively. However, commercial faba bean yields have reached 4.0 t/ha and, in some instances, up to 6.0 t/ha. To achieve these yields, seasonal conditions (particularly moisture

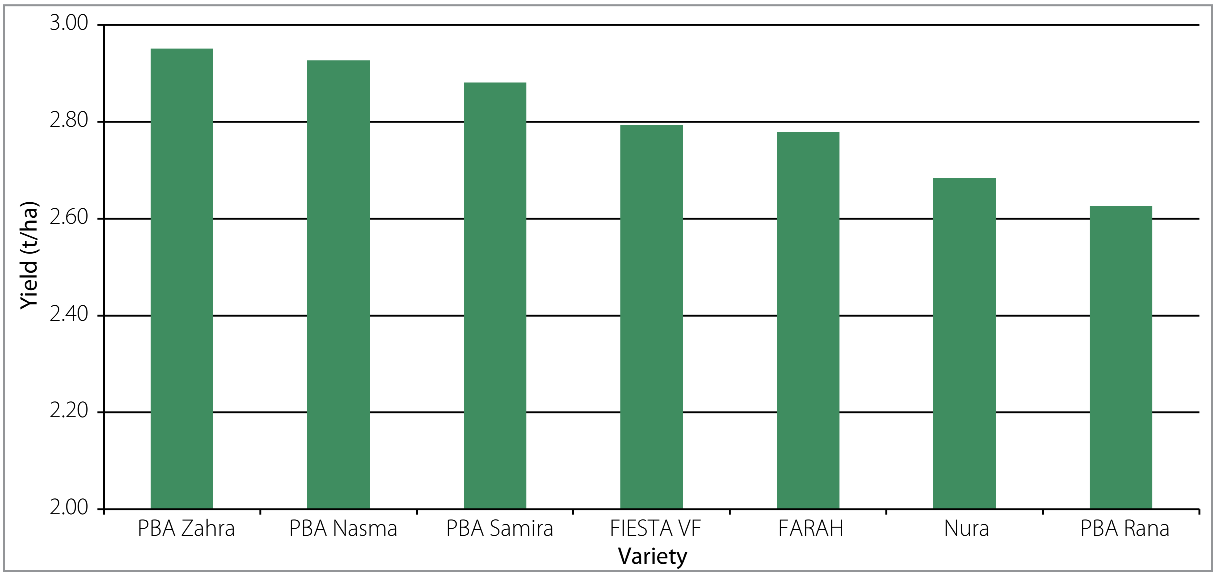


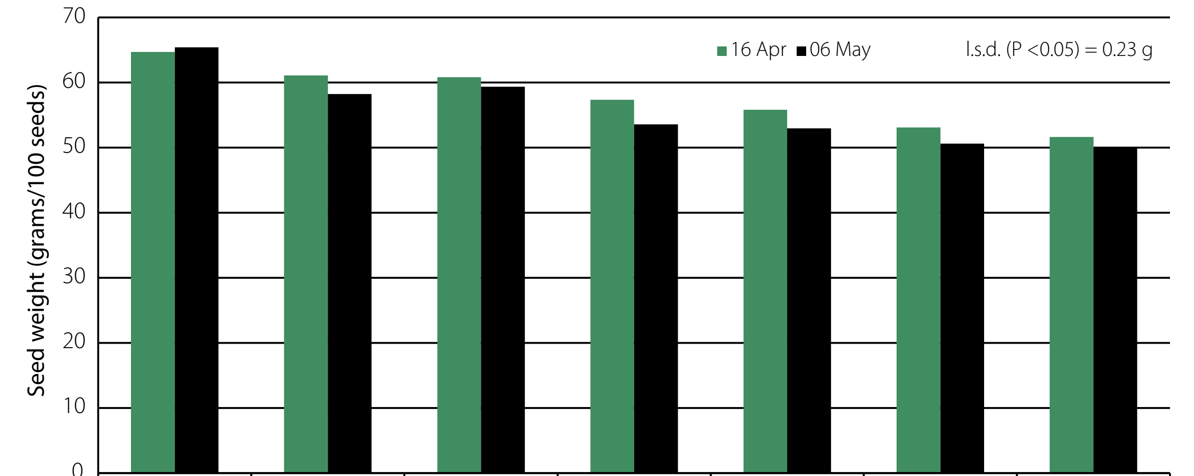
Figure 2. Long-term (2008–15) yield for faba bean varieties in south-eastern NSW.

and temperature) have to be ideal to reduce the high rates of flower abortion along the stems that was observed in this experiment.

These results are consistent with maximum faba bean yields from mid-April to early-May sowing in this region. Growers still need to consider the consequences of:

- sowing too early (before 15 April) – excessive height, lodging and disease
- sowing too late (after the middle of May) – short plants and restricted dry matter and grain yield.

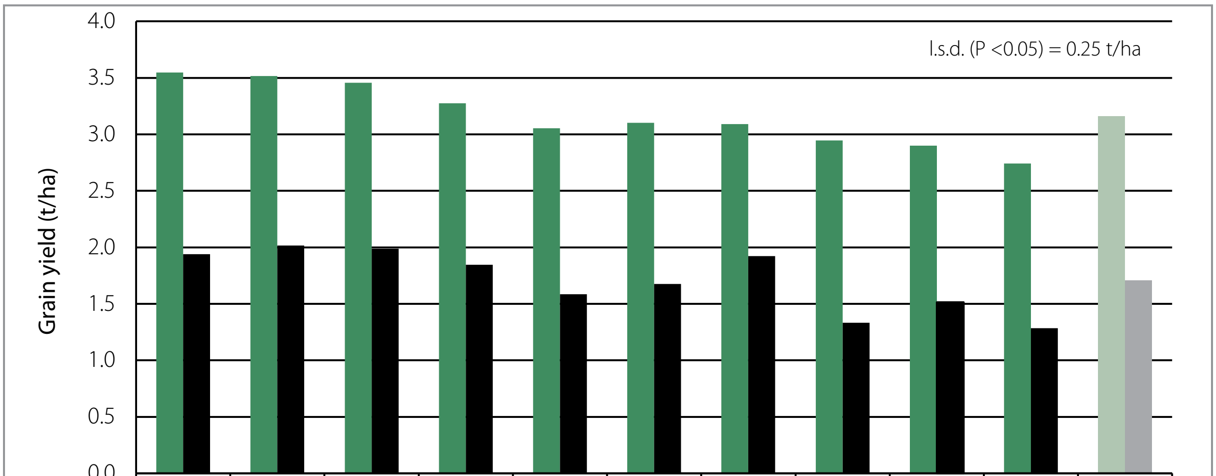
Growers also need to be aware that in cool, moist extended springs, even late April sowings can be subject to greater disease pressure and require careful monitoring and foliar fungicide sprays.



	PBA Rana	PBA Zahra	PBA Samira	Farah	Fiesta VF	Nura	PBA Nasma
16 Apr	64.7	61.1	60.8	57.4	55.8	53.1	51.6
06 May	65.4	58.2	59.4	53.6	53.0	50.6	50.0

Variety

Figure 3. Variety and time of sowing effect on seed weight at Junee Reefs in 2015.



	PBA Nasma	Fiesta VF	PBA Zahra	PBA Samira	PBA Samira 20	Nura	Farah	Determ. type	PBA Rana	PBA Rana 20	MEAN
16 Apr	3.55	3.52	3.46	3.28	3.05	3.10	3.09	2.95	2.90	2.74	3.16
6 May	1.94	2.02	1.99	1.85	1.58	1.68	1.92	1.33	1.51	1.28	1.71

Variety

Figure 4. Grain yield of eight faba bean varieties sown at two dates at Junee Reefs in 2015.

Acknowledgements

This experiment was part of the project 'Expanding the use of pulses in the southern region', DAV00113 2013–16, a collaborative pulse project between state agencies in Victoria, NSW and South Australia, jointly funded by NSW DPI and GRDC.

Faba bean time of sowing – Lockhart 2015

Mark Richards, **Dr Eric Armstrong**, **Luke Gaynor**, **Karl Moore**, **Russell Pumpa** and **Jon Evans** NSW DPI, Wagga Wagga

Key findings

» The optimum time to sow faba beans at Lockhart in 2015 was mid-April.

» PBA Nasma, PBA Samira and Fiesta VF were the highest yielding commercial varieties.

» The 23 April sowing had a mean bottom pod height of 42.3 cm, 29% higher than the 13 May sowing.

Introduction

This experiment aimed to compare the growth, development and yield of current commercial faba bean varieties and advanced breeding lines on two sowing dates at Lockhart in southern NSW. This information will be used to confirm and update current agronomic recommendations for faba bean in this region.

Site details

Site	'Warikirri', Lockhart
Soil type	Red clay loam, pH_{Ca} 5.6 (0–10 cm)
Trial design	Randomised complete block design with sowing date as the main blocks and varieties as the sub-plots; three replications
Stubble management	Heavy standing stubble; coulters used on time of sowing (TOS) 2 to help with the stubble flow
Fertiliser	40 kg/ha Granulock (N:P:S; 11:21.8:4) placed 50 mm below the seed
Plant population	Target 30 plants/m^2
Sowing	Direct-drilled using a six-row DBS cone seeder with 240 mm row spacings and GPS auto-steer
Inoculation	Group F peat inoculant was mixed directly into an on-board 100 L water tank then pumped through micro-tubes into each sowing furrow
Weed management Commercial practices used with the aim of weed-free trials to eliminate weed competition and weed seed set.	
Fallow weed control: Glyphosate (450 g/L) 1.5 L/ha, LI 700 105 mL/ha, AMS 270 g/ha (27 January 2015) Glyphosate (450 g/L) 1.5 L/ha, LI 700 86 mL/ha, AMS 216 g/ha, Amicide Advance 700® 300 mL/ha (23 March 2015)	
Pre-sowing: Terbyne® 1043 g/ha, AMS 435 g/ha, Sencor 750WG® 304 g/ha, Chemwet 1000® 113 mL/ha, Roundup DST® 1.0 L/ha (27 April 2015)	
Post sowing: Sequence® 500 mL/ha, Hasten® 678 mL/ha, AMS 534 g/ha (4 June 2015) Sequence® 500 mL/ha, AMS 539 g/ha, Hasten® 336 mL/ha (10 August 2015)	
Insect and disease management Targeting *Helicoverpa* sp, lucerne flea and chocolate spot: Penncozeb 750 DF® 1 kg/ha (4 June 2015) Fastac Duo® 250 mL/ha (15 October 2015) Spin flo® 500 g/L carbendazim 500 mL/ha (10 August 2015) Spin flo® 500 g/L carbendazim 500 mL/ha (2 September 2015)	
Harvest date	30 November

Pulse growth and rhizobia survival can be affected when soil pH falls below 5.0 especially with increasing free aluminium levels. This can lead to problems on the acidic red-brown soils that dominate the cropping zones of southern NSW. Growers need to consider this and routinely monitor soil acidity, aiming to maintain a base pH of approximately 5.0 through strategically incorporating lime. Problems caused by subsoil constraints were not evident at this site (Table 1).

Table 1. Site soil chemical characteristics for 0–10 cm depth at Lockhart in 2015.

Characteristic	Depth (0–10 cm)
pH (1:5 $CaCl_2$)	5.6
Aluminium Exc. (meq/100 g)	0.2
Zinc (mg/kg)	2.8
Sulfur (mg/kg)	16
Phosphorus (Colwell) (mg/kg)	45
Organic carbon (OC) (%)	2.4
Cation exchange capacity (CEC) (meq)	12.2

A total of 501 mm rainfall was recorded at the trial site during 2015. The growing season rainfall (GSR) was 299 mm (Figure 1).

Treatments

Varieties (10)	PBA Zahra$^{\Phi}$	Farah$^{\Phi}$
	PBA Samira$^{\Phi}$	Fiesta VF
	PBA Rana$^{\Phi}$	AF08207
	PBA Nasma$^{\Phi}$	AF10089
	Nura$^{\Phi}$	Determinant type

Time of sowing (TOS)	TOS 1: 23 April TOS 2: 13 May

Results

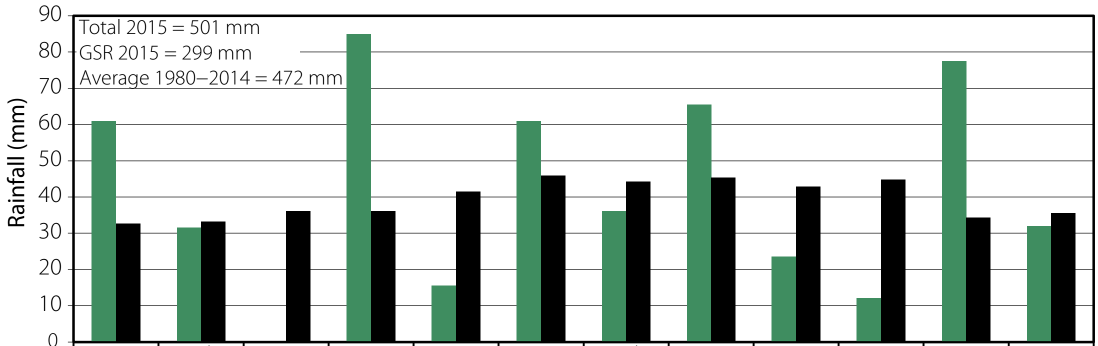
Establishment

Faba bean establishment was close to the target of 30 plants/m^2. TOS 1 achieved an average of 28.9 plants/m^2 while TOS 2 was slightly lower with 26.2 plants/m^2.

Grain yield

PBA Nasma was the highest yielding variety at Lockhart in 2015. PBA Nasma is a northern NSW variety susceptible to Ascochyta blight and its seed size in southern NSW is smaller than PBA Zahra or PBA Samira, which could have marketing implications. Further work is required to determine if this was only a seasonal influence.

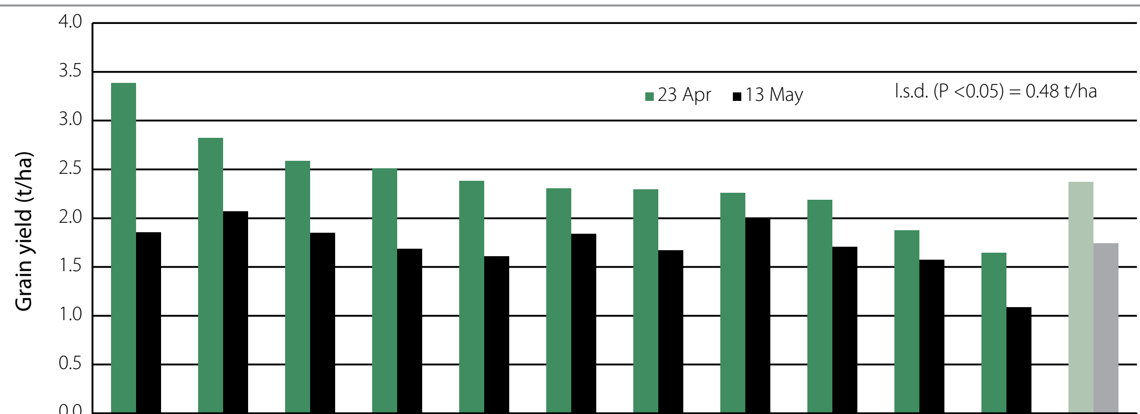
TOS 1 (23 April) yielded an average of 2.38 t/ha, which is 27% higher than TOS 2 (13 May), which yielded 1.74 t/ha (Figure 2).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	61	31.5	0	85	15.5	61	36	65.5	23.5	12	77.5	32
Long term av.	32.6	33.2	36	36.1	41.5	45.9	44.2	45.3	42.8	44.8	34.3	35.5

Month

Figure 1. Annual and growing season rainfall (GSR) for 'Warikirri' in 2015 and the long term average.



	PBA Nasma	Fiesta VF	PBA Samira	AF10089	PBA Samira 20	PBA Zahra	AF08207	Farah	Nura	Determ. type	PBA Rana	MEAN
23 Apr	3.39	2.82	2.59	2.51	2.38	2.30	2.29	2.26	2.19	1.87	1.65	2.38
13 May	1.86	2.07	1.85	1.69	1.61	1.84	1.67	2.00	1.71	1.58	1.09	1.74

Variety

Figure 2. Grain yield of 10 faba bean varieties sown at two dates at Lockhart in 2015.

The last significant rainfall event was on 4 September and the experiment suffered severe heat and moisture stress in the first week of October. This caused both TOS 1 and TOS 2 to abort flowers and mature prematurely. Due to the more advanced stage of development, TOS 1 was less severely affected. However, these results are consistent with maximum faba bean yields from sowing in mid-April–early-May in this region. Growers still need to consider the consequences of:

» sowing too early (before 20 April) – excessive height, lodging and disease risk;
» Sowing too late (after the middle of May) – short plants and restricted dry matter and grain yield.

Growers also need to be aware that in cool, moist, extended springs, even late April sowings can be subject to greater disease pressure and require careful monitoring and preventative foliar fungicide sprays. Whilst there was a wet winter and early spring at this site, a preventative fungicide program combined with dry spring conditions reduced disease levels to an insignificant level.

Height to bottom pod

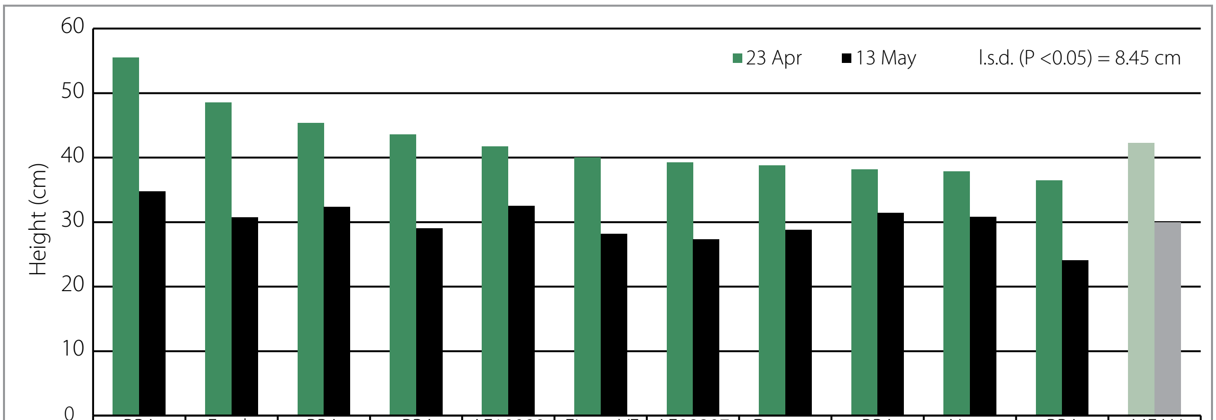
Height from the soil surface to the bottom pod was significantly affected by time of sowing (P <0.001) and variety (P <0.001). There was a significant interaction between variety and TOS (P <0.038) in this experiment (Figure 3).

TOS 1 had a mean bottom pod height of 42.3 cm, 29% higher than TOS 2 (30 cm) (Figure 3). Pod height influences header knife height at harvest and harvest efficiency, therefore pod height from TOS 1 is preferable to TOS 2.

Summary

Times of sowing, followed by variety, were the main influences on faba bean grain yield in 2015. This correlates to previous years' research, with the exception of 2014 where TOS showed no statistical differences. In 2014, there were severe vegetative/early flowering frost events that affected crops, which had greater effects on early-sown treatments.

Growers need to carefully manage disease by using preventative foliar sprays especially in wet or high rainfall zones.



	PBA Samira	Farah	PBA Rana	PBA Zahra	AF10089	Fiesta VF	AF08207	Determ. type	PBA Samira 20	Nura	PBA Nasma	MEAN
23 Apr	55	49	45	44	42	40	39	39	38	38	36	42.3
13 May	35	31	32	29	33	28	27	29	31	31	24	30.0

Variety

Figure 3. Height to bottom pod of 10 faba bean varieties sown at two dates at Lockhart in 2015.

Acknowledgements

This experiment was part of the project 'Expanding the use of pulses in the southern region', DAV00113 2013–16, a collaborative pulse project between state agencies in Victoria, NSW and South Australia, jointly funded by NSW DPI and GRDC.

Lentil time of sowing and sowing rate – Wagga Wagga 2015

Mark Richards, **Dr Eric Armstrong**, **Karl Moore**, **Russell Pumpa** and **Jon Evans** NSW DPI, Wagga Wagga

Key findings

- » PBA Ace⁽ᶲ⁾ and PBA Jumbo2⁽ᶲ⁾ performed very well across a range of agronomic characteristics compared with the other varieties in this experiment.
- » Sowing time was a critical management factor in the 2015 season.
- » Sow lentils in early to late May at 120 plants/m^2 in the eastern cropping region of southern NSW to avoid yield penalties.

Introduction

This experiment aimed to establish agronomic guidelines for lentil time of sowing (TOS) and seeding rate for current commercial lentil varieties and advanced breeding lines at Wagga Wagga. It also will determine if optimum plant density and sowing time remains constant across varieties in this environment. This information will be used to confirm and update current agronomic recommendations for lentil in this region.

Site details

Site	Wagga Wagga Agricultural Institute
Soil type	Red sandy loam, pH_{Ca} (0–10 cm) 5.4 (Table 1)
Trial design	Randomised complete block design with sowing date as the main blocks and varieties as the sub-plots; three replications.
Sowing	Direct-drilled using a six-row cone seeder with 300 mm row spacings, press wheels and GPS auto-steer. The site was rolled post-sowing.
Inoculation	Group F peat inoculant was mixed directly into an on-board 100 L water tank then pumped through micro-tubes into each sowing furrow
Stubble management	Stubble was burnt and the paddock worked up
Fertiliser	80 kg/ha grain legume super (N:P:K:S; 0:13.8:0:6.1) placed 30–40 mm below the seed
Plant population	Target 120 plants/m^2
Weed management	Commercial practices were used with aim of weed-free trials to eliminate weed competition and weed seed set Fallow weed control: glyphosate (450 g/L) 2.0 L/ha and 2,4-D LV ester (680 g/L) 1.0 L/ha Incorporated by sowing: glyphosate (450 g/L) 2.0 L/ha, Stomp® (440 g/L pendimethalin) 2.0 L/ha, Avadex® 2.0 L/ha (400 g/L tri-allate) and Terbyne® (750 g/kg terbuthylazine) 1 kg/ha Post sowing: Select® (240 g/L clethodim) 330 mL/ha, Verdict® (520 g/L haloxyfop) 100 mL/ha and Uptake® spraying oil 500 mL/100 L
Insect management	Targeting *Helicoverpa* sp.: Fastac Duo ® (100 g/L alpha-cypermethrin) 400 mL/ha at late pod fill

Table 1. Site soil chemical characteristics for this experiment at Wagga Wagga in 2015.

Characteristic	Depth	
	0–10 cm	10–30 cm
pH (1:5 $CaCl_2$)	5.8	5.0
Aluminium Exc. (meq/100 g)	<0.1	<0.1
Total nitrogen (%)	0.026	0.041
Sulfur (mg/kg)	5.1	6.4
Phosphorus (Colwell) (mg/kg)	21	47
Organic carbon (OC) (%)	0.51	0.37
Cation exchange capacity (CEC) (cmol(+)kg)	7.4	5.5

The 2015 growing season at Wagga Wagga was almost ideal for pulse production except for a dry and hot September–October period. Growing season rainfall (April–October) was close to the long-term average (333 mm) with 56 mm of this falling in early April, which enabled timely sowing. Rainfall in June, July and August was 50% above the long-term average and contributed to valuable sub-soil moisture.

However, the flowering and grain filling period of September–October had eight continuous weeks of no effective rainfall and wide temperature fluctuations (5 September to 31 October). Three consecutive days in late September (23–25 September) received below zero temperatures and damaging frosts only to be followed by an exceptionally hot, dry October. Average daily maximum temperatures for the month exceeded the long-term average by 8.3 °C and the first week experienced unseasonal temperatures in the mid-30s.

Treatments

Varieties	Six, small to medium seeded red lentils PBA Ace[⊕] BPA Bolt⊕ PBA Jumbo2⊕ Hurricane XT⊕ CIPAL1422 Nipper⊕
Time of sowing	TOS 1: 1 May 2015 (harvested 9 November 2015) TOS 2: 10 June 2015 (harvested 9 November 2015)

Results

Establishment

A significant variety by density interaction ($P < 0.05$) was observed for this experiment, however, all varieties followed the trend of achieving below target plant populations. The difference between the target and actual plant populations increased as the target population increased, which often occurs in plant density experiments (Figure 1).

Time of sowing, density, variety and grain yield

Lentil grain yield significantly reduced (by an average of 60%) when the sowing time was delayed from 1 May to 10 June (Table 2). The second sowing time (10 June) performed poorly due to the quick, dry finish. Like other pulses in southern NSW, the sowing date for lentil is one of the most critical management factors and determinants of growth, production and profit.

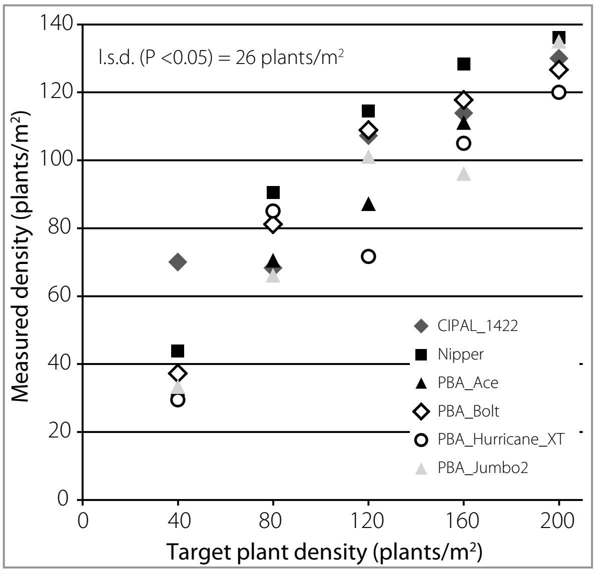


Figure 1. Measured plant densities closely followed targeted plant densities at Wagga Wagga in 2015.

This experiment suffered significant shattering from a hail storm on 1 November, just before harvest. Yield loss measurements were taken and a significant variety and sowing time interaction was observed ($P < 0.05$). TOS 1 lost 38% more grain (247 kg/ha) than TOS 2 (150 kg/ha). This was due to Nipper, PBA Bolt and CIPAL 1422 not being fully mature at TOS 2 and hence being more resistant to hail shattering losses.

Table 2. Grain yield of lentils for two sowing times at Wagga Wagga in 2015.

Sowing time	Grain yield (t/ha)
TOS 1: 1 May	1.09
TOS 2: 10 June	0.43
l.s.d. (P <0.05) = 0.43 t/ha)	

Above-ground dry matter ranged from 2.55 t/ha for Nipper, significantly less than all other varieties, to 4.41 t/ha.

Plant height and position of the lowest pod are critical attributes of lentil, particularly since lentil is a very short-growing winter pulse making it difficult to harvest. TOS 1 had a mean height to bottom pod of 31.45 cm that was 38% higher than TOS 2 at 19.5 cm. PBA Ace and PBA Jumbo2 were the tallest and most vigorous varieties giving significant benefits to harvest height and weed competition. They also had the additional benefit of positioning bottom pods highest off the ground, again assisting harvest (Figure 2). In comparison, Nipper and PBA Hurricane XT were disadvantaged by being relatively short.

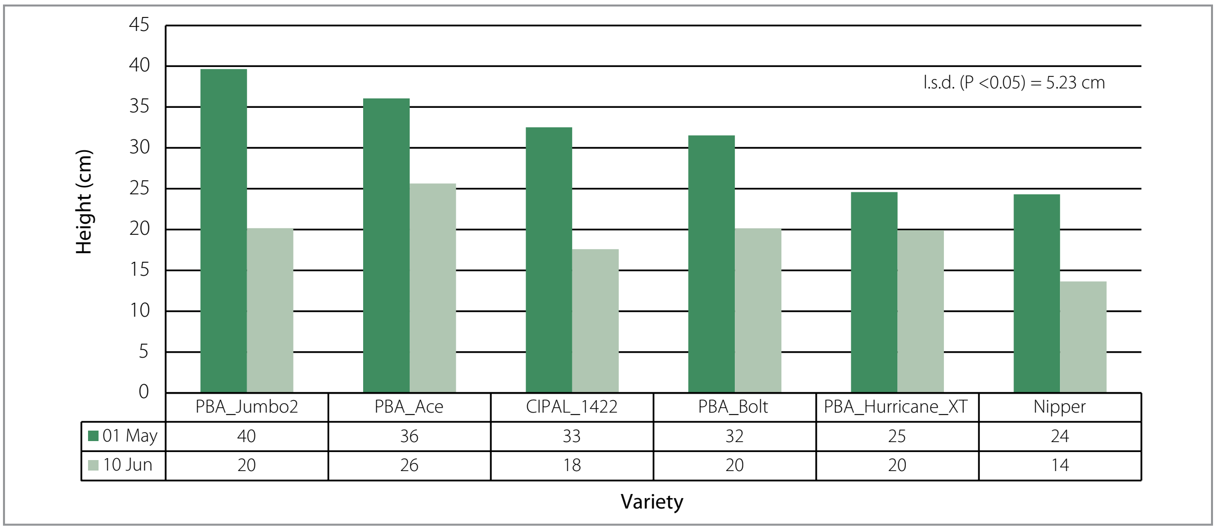


Figure 2. Height to bottom pod for six varieties and two sowing times at Wagga Wagga in 2015.

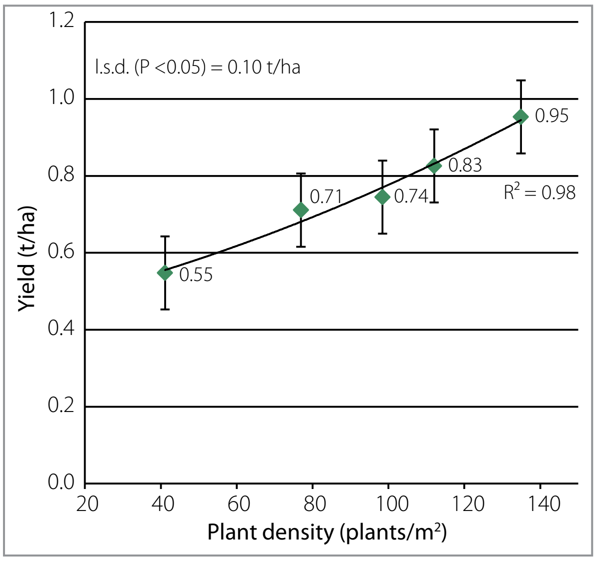


Figure 3. Grain yield response to plant density, averaged over sowing times, at Wagga Wagga in 2015.

A significant yield increase with increasing density was observed with 135 plants/m^2 yielding 20% higher than 77–112 plants/m^2 (Figure 3).

A significant interaction between variety and sowing time was observed ($P < 0.009$) with PBA Jumbo2, PBA Ace, PBA Bolt and CIPAL1422 yielding greater than PBA Hurricane and Nipper at TOS 1 and TOS 2.

Acknowledgements

This experiment was part of the project 'Expanding the use of pulses in the southern region', DAV00113 2013–16, a collaborative pulse project between state agencies in Victoria, NSW and South Australia, jointly funded by NSW DPI and GRDC.

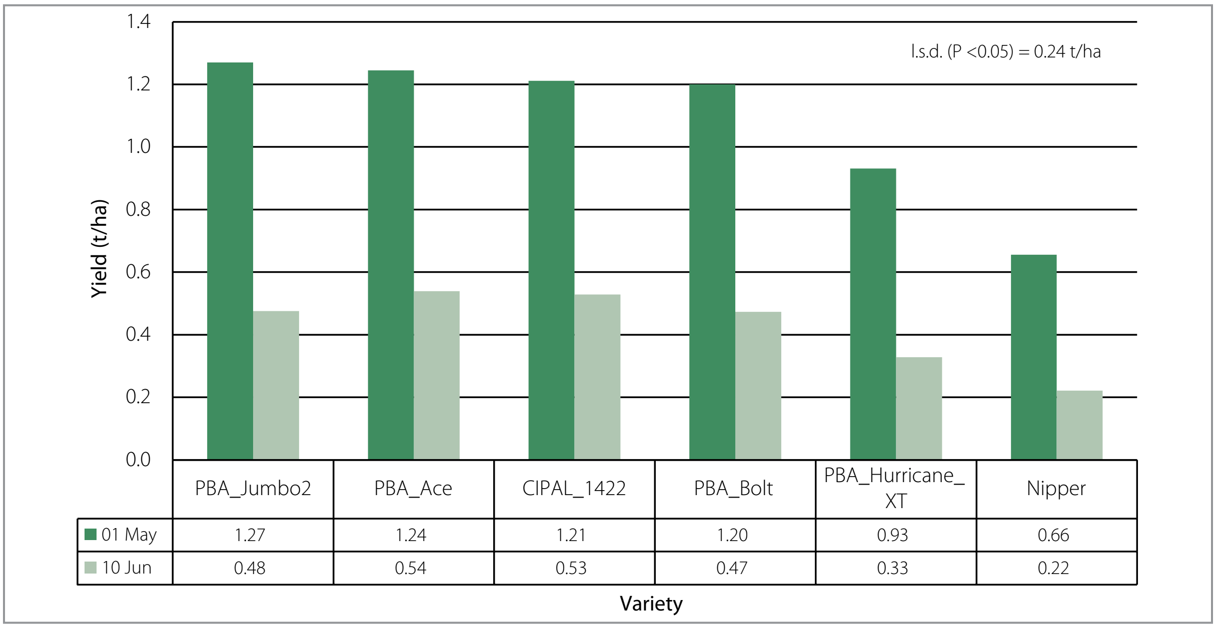


Figure 4. Grain yield of six lentil varieties at two sowing times at Wagga Wagga in 2015.

Lentil time of sowing and sowing rate – Yenda 2015

Mark Richards, **Dr Eric Armstrong**, **Karl Moore**, **Russell Pumpa** and **Jon Evans** NSW DPI, Wagga Wagga

Key findings

» Sowing time is a critical management factor in this environment.

» Sow lentils in late April to 10 May in the south-western cropping region of southern NSW.

» Target plant populations of 120 plants/m^2.

» Commercial lentil yields of 1.2–1.5 t/ha on acidic, red-brown earths of south-western NSW are now realistic, giving growers the confidence and economic viability to introduce this pulse into their cropping rotations.

Introduction

This experiment aimed to establish agronomic guidelines for sowing time and sowing rate for current commercial lentil varieties and advanced breeding lines at Yenda. It also determined if optimum plant density and sowing time remains constant across varieties in this environment. This information will be used to confirm and update current agronomic recommendations for lentil in this region.

Site details

Soil type	Red sandy loam, pH_{Ca} 5.4 (0–10 cm) (Table 1)
Trial design	Randomised complete block design with sowing date as the main blocks and varieties as the sub-plots; three replications
Sowing	Direct-drilled using a six-row cone seeder with 300 mm row spacings, press wheels and GPS auto-steer. The site was rolled post sowing.
Inoculation	Group F peat inoculant was mixed directly into an on-board 100 L water tank then pumped through micro-tubes into each sowing furrow
Stubble management	Sown into a medium density, standing wheat stubble
Fertiliser	80 kg/ha grain legume super (N:P:K:S; 0:13.8:0:6.1) placed 30–40 mm below the seed
Plant population	Target 120 plants/m^2
Weed management	Commercial practices used with aim of weed-free trials to eliminate weed competition and weed seed set Fallow weed control: glyphosate (450 g/L) 1.5 L/ha (over summer) Incorporated by sowing: glyphosate (450 g/L) 2.0 L/ha, Stomp® (440 g/L pendimethalin) 2.0 L/ha, Avadex® (400 g/L tri-allate) 1.6 L/ha and Terbyne® (750 g/kg terbuthylazine) 900 g/ha Post sowing: Select® (240 g/L clethodim) 500 mL/ha, Uptake® spraying oil 500 mL/100 L
Insect management	Targeting *Helicoverpa* sp.: Fastac Duo ® (100 g/L alpha-cypermethrin) 200 mL/ha (late pod fill)

Table 1. Site soil chemical characteristics for 0–10 cm and 10–20 cm depth at Yenda in 2015.

Characteristic	Depth	
	0–10 cm	10–20 cm
pH (1:5 $CaCl_2$)	5.5	5.0
Aluminium Exc. (meq/100 g)	<0.1	<0.1
Total nitrogen (%)	0.082	0.047
Sulfur (mg/kg)	8.6	6.4
Phosphorus (Colwell) (mg/kg)	47	9.4
Cation exchange capacity (CEC) (cmol(+)kg)	6.8	6.6

The 2015 growing season at Yenda was almost ideal for pulse production except for a dry and hot September–October. Growing season rainfall (April–October) was 264 mm, which is above the long-term average (231 mm). Of this, 47 mm fell in early April, allowing timely sowing. Rainfall in June, July and August was 63% above the long-term average and contributed to valuable sub-soil moisture.

However, the flowering and grain filling period of September–October experienced eight continuous weeks of no effective rainfall and wide temperature fluctuations (5 September to 31 October). The rapid change from cool temperatures to a number of consecutive hot days in the high 30 degrees in the first week of October caused crops to abort flowers and mature prematurely. This heatwave was followed by an exceptionally hot and dry October.

Treatments

Varieties	Six, small to medium seeded red lentils PBA Ace$^{\Phi}$ BPA Bolt$^{\Phi}$ PBA Jumbo2$^{\Phi}$ Hurricane XT$^{\Phi}$ CIPAL1422 Nipper$^{\Phi}$
Time of sowing	TOS 1: 29 April 2015 TOS 2: 28 May 2015 (both harvested 18 November 2015)

Results

Establishment

Measured plant densities correlated closely with target plant densities (P <0.001) at both sowing times (Table 2). Only variety and sowing rate means are presented here as there was no significant variety by sowing rate interaction for any of the variables measured. There was a small but significant difference (P <0.02) between some varieties for measured plant density with the large-seeded PBA Jumbo2 having the lowest plant density (Table 2).

Table 2. Mean plant density for six varieties at Yenda in 2015.

Variety	Plant density (plants/m^2)
CIPAL_1422	116.2
Nipper	107.1
PBA_Ace	111.2
PBA_Bolt	119.0
PBA_Hurricane_XT	114.6
PBA_Jumbo2	101.2

Time of sowing, density, variety and grain yield

Lentil grain yield was significantly reduced when sowing was delayed from 29 April to 28 May, falling by 50% on average (Table 3). The second sowing (28 May) performed poorly given the quick dry finish to the 2015 growing season. Like other pulses in southern NSW, the lentil sowing date is one of the most critical management factors and determinants of growth, production and profit.

Table 3. Lentil grain yield for two times of sowing at Yenda in 2015.

Sowing time	Grain yield (t/ha)
TOS 1: 29 April	1.51
TOS 2: 28 May	0.76
l.s.d. (P <0.05) = 0.199 t/ha)	

At the first TOS (29 April) the old variety Nipper was significantly lower yielding than the current commercial varieties PBA Bolt, PBA Hurricane, PBA Ace and PBA Jumbo2 (Figure 1). Grain yields from the 28 May sowing were generally low, but PBA Bolt, PBA Ace and PBA Jumbo2 were the highest yielding varieties (Figure 1).

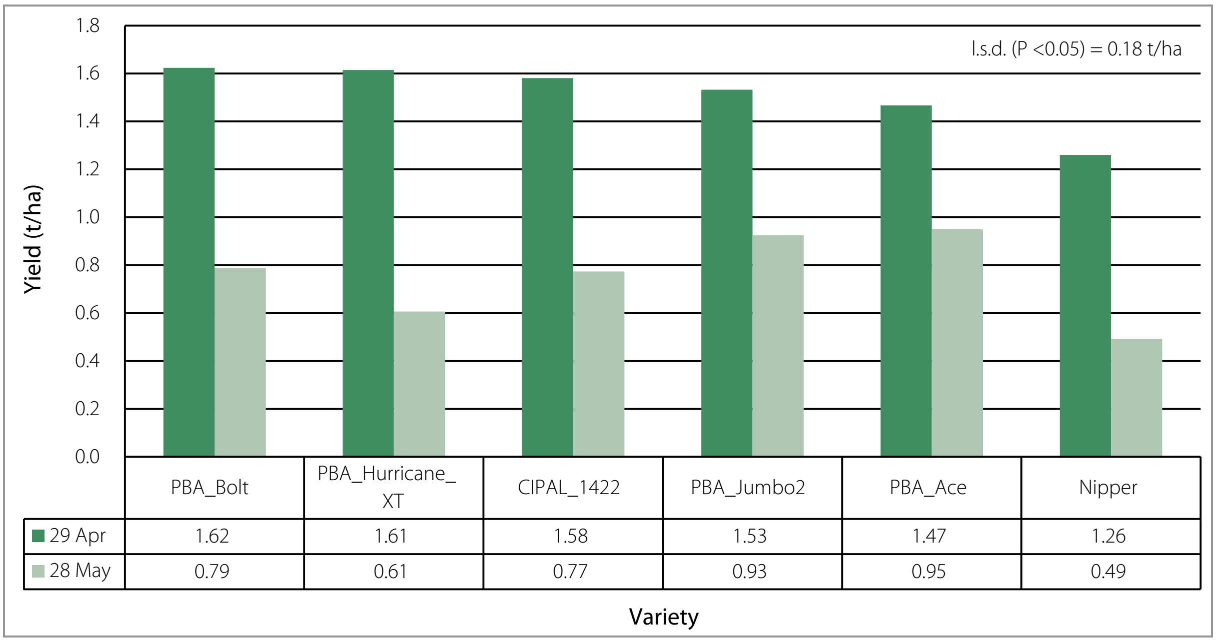


Figure 1. Grain yield of six lentil varieties at two sowing dates at Yenda in 2015.

A significant TOS and plant density interaction was observed in this experiment (P <0.001). There was no significant grain yield response to increasing plant density from 48 plants/m^2 to 170 plants/m^2, but there was a trend for increasing grain yield with increasing plant density at the 28 May sowing only (Figure 2). This would indicate that late sowing and a dry spring prevents lentils from producing sufficient biomass, even with very high plant populations, to maximise or maintain yield in this environment.

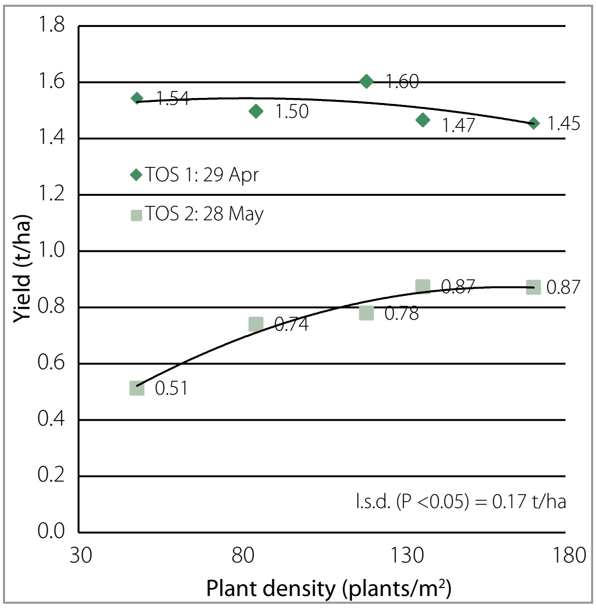


Figure 2. Lentil grain yield for various plant densities and two sowing times (29 April and 28 May) at Yenda in 2015.

Acknowledgements

This experiment was part of the project 'Expanding the use of pulses in the southern region', DAV00113 2013–16, a collaborative pulse project between state agencies in Victoria, NSW and South Australia, jointly funded by NSW DPI and GRDC.

Thank you to Nick and Kim Eckerman, 'Hillview', Yenda for hosting the pulse research trial site.

Lentil sowing rate – Yenda 2014

Dr Eric Armstrong, **Gerard O'Connor** and **Luke Gaynor** NSW DPI, Wagga Wagga

Key findings

» The low mean yield at this site (0.69 t/ha) was largely attributed to drought, and was exacerbated by late sowing, unfavourable sowing conditions and suspected herbicide damage.

» Small yield and 'normalised difference vegetation index' (NDVI) increases closely reflected increases in seedling density.

» PBA Giant$^{\phi}$ and PBA Jumbo2$^{\phi}$ produced more grain and green foliage cover, closely followed by PBA Ace$^{\phi}$. These rankings reflect the long-term, multi-environment trial (MET) yield analysis for lentil varieties for this region (Figure 5).

» Care should be taken when applying and incorporating herbicides on acidic, light textured soils, particularly when straw is present. Under these conditions, it is advisable to sow deeper to position seed below the herbicide band.

» Further lentil sowing rate investigations are required in this region to better understand variety responses to plant density, earlier sowing, season conditions and different environments.

Introduction

This experiment aimed to determine the optimal plant density for lentil in southern NSW cropping systems, and if the optimum plant density remains constant across varieties. This information would then be used to update local agronomic guidelines.

Site details

Site	'Hillview' Yenda, RK & JG Eckerman (paddock 'Wattle Park').
Sowing date	23 May 2014
Design	Randomised complete block design with three replications
Soil type	Acidic, red sandy loam, pH_{Ca} (0–10 cm) 4.6 (Table 1).
Paddock history	2014 wheat; 2013 Canola; 2012 Wheat; 2011 Lupin
Stubble management	Sown into a medium density, standing wheat stubble
Fertiliser	80 kg/ha Grain legume super (N:P:K:S 0:13.8:0:6.1) placed 30–40 mm below the seed
Sowing	Direct-drilled using a six-row cone seeder with 300 mm row spacing, press wheels and GPS auto-steer
Weed management	Commercial management practices used to establish and maintain weed-free conditions throughout the season, preventing weed competition and weed seed set
Disease management	No disease management required this season
Insect management	Targeting *Helicoverpa* sp.: 400 mL/ha Fastac® Duo (100 g/L alpha-cypermethrin) applied by the cooperator during late grain fill

Soil at this site was acidic with pH_{Ca} 4.6 (Table 1). Topography was slightly undulating; with light textured, red sandy loams along ridges (location of this experiment) leading to red loams in the hollows. Cereal stubble caused several blockages and patchy incorporation of herbicides at sowing, resulting in variable soil/seed coverage and some minor herbicide damage (Terbyne®, 750 g/kg terbuthylazine). In hindsight, these problems would have been alleviated by increasing sowing depth from 20 to 50 mm.

Treatments

Varieties	PBA Ace$^{\phi}$ – medium red lentil PBA Hurricane XT$^{\phi}$ – small red lentil PBA Jumbo2$^{\phi}$ – large red lentil PBA Giant$^{\phi}$ – large green lentil
Target densities	75, 100, 125, 150 and 175 plants/m^2 adjusted for seed size and germination

Table 1. Site soil-chemical characteristics for 0–10 cm and 10–20 cm depth at Yenda, 2014.

Characteristic	Depth	
	0–10 cm	10–20 cm
pH_{ca}	4.6	6.1
Aluminium Sat (%)	6.4	0
Nitrate nitrogen (mg/kg)	9.8	7
Ammonium N (mg/kg)	0.8	0
Phosphorus (Colwell) (mg/kg)	34	17
Cation exchange capacity (CEC) (cmol(+)kg)	2.8	3.6

Season

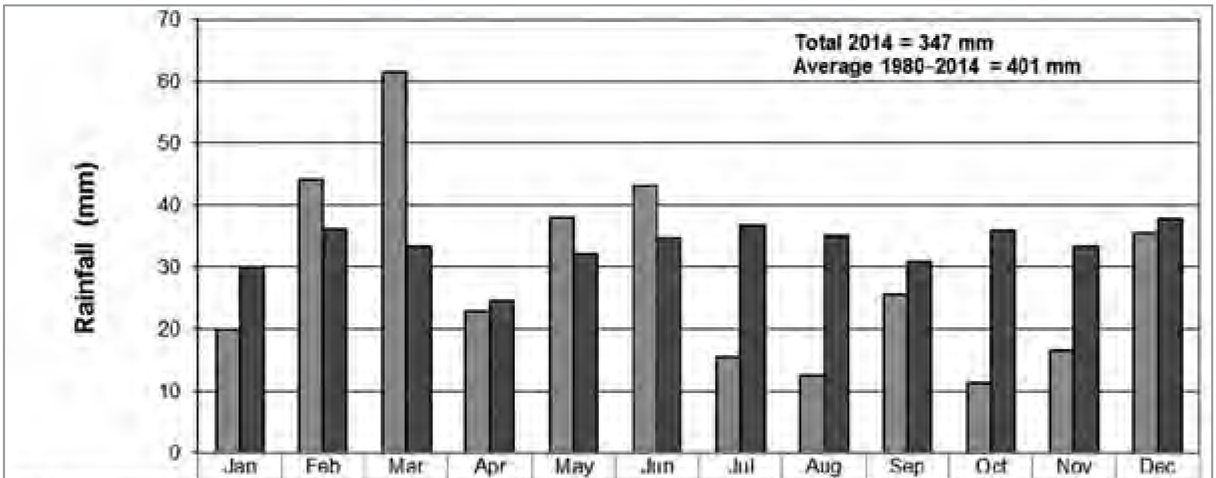
The 2014 season at Yenda was warmer, drier and shorter than normal. Rainfall during the critical four months of July to October was only one third of the long-term average (Figure 1); and when combined with warmer temperatures, the season was unfavourable and finished 2–3 weeks earlier than expected. Above average rainfall preceded the trial (particularly in March), providing much needed soil moisture, which helped crops to finish. Conditions were not conducive to disease, so disease levels were low and no fungicides required.

Background

Lentil is primarily a human consumption pulse and for this reason attracts a price premium over other pulses. Current grower perception is that the crop is not adapted to the acidic soils of southern NSW; it is too short in height and too susceptible to weed competition and weed seedbank blowouts. For these reasons, very few lentils have been grown in southern NSW – fewer than 1000 hectares each year. There is no section on lentil in the annual publication, Winter crop variety sowing guide and no local management guidelines. Historically, very little local agronomic research has been conducted into the crop in southern NSW.

However, lentil varieties have vastly improved over the past decade due to breeding efforts by Pulse Breeding Australia (PBA). The latest released varieties have improved vigour, height, disease resistance, pod shatter resistance and yield. To complement these new varieties, agronomic management has also improved, backed by recent NSW DPI research. We are increasing our knowledge on the crop's adaptation to the range of acidic soils and environments across southern NSW: which varieties perform best, what is the optimum time to sow, what plant density to target, and what seeding depth to sow. This new generation of varieties, combined with new management packages and ongoing technical support, will ensure a viable lentil industry in this region.

The recommended plant density for sowing lentil in other southern Australian production regions is 110–130 plants/m^2 (Pulse Australia, 2015). Sowing rates need to be adjusted according to seed size and germination. This equates to 45–55 kg/ha for small-seeded varieties (e.g. Nipper and PBA Hurricane XT), 55–70 kg/ha for medium-sized varieties (e.g. PBA Ace) and 75–90 kg/ha for large-seeded varieties (e.g. PBA Jumbo2 and PBA Giant). Lentil has excellent seedling vigour, making it one of the quickest pulses to emerge and establish. Therefore, lentil seeds can be sown deeper (4–6 cm) into safer zones below herbicide residues if present. Herbicide residues, poor soil moisture and unfavourable sowing conditions hinder achieving these target densities.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	20	44.3	61.5	23.0	38.0	43.3	15.5	12.5	25.5	11.3	16.5	35.5
Long-term average	29.9	36.2	33.4	24.5	32.2	34.7	36.8	35.2	31.0	35.9	33.4	37.8

Figure 1. Total monthly rainfall at 'Hillview' Yenda in 2014 compared with long-term monthly averages (1980–2014).

Table 2. Seed characteristics of lentil varieties evaluated at Yenda in 2014. The last column shows seed size (g/100 seeds) from the 2014 Yenda trial harvest.

Variety	Cotyledon colour	Seed size		
		Category	Range (g/100 seeds)	Harvested Yenda 2014 (g/100 seeds)
PBA Hurricane XT	red	small	3–4	3.39
PBA Ace	red	medium	4–5	3.97
PBA Jumbo2	red	large	4.5–6	4.95
PBA Giant	green	large	4.5–6	6.53

Results

Mean lentil yield at the Yenda site this season was 0.69 t/ha, which was well below the long-term (2010–14) mean for the region of 1.31 t/ha (National Variety Trials online data base). Several factors contributed to these low yields:

» The season was unfavourable and was exacerbated by later than ideal sowing (23 May).

» The soil at this site was light textured, acidic with moderate levels of free aluminium and considered not ideal for lentil production.

» Sowing was too shallow (should have been 40–60 mm sowing depth rather than the actual 20–40 mm on this light-textured soil).

» Terbyne® herbicide damage resulting from shallow, uneven incorporation due to the uneven spread of wheat stubble.

Nevertheless, growth and development evened out as the season progressed, and relevant local production issues were identified.

Measured plant densities correlated closely with target plant densities (P <0.001) (Figure 2). Only variety or sowing rate means are presented here since there were no significant variety × sowing rate interactions for any of the variables measured.

Yield increased modestly but significantly by 10%–11% (P <0.05) as measured plant density increased from 75 to 175 plants/m^2 (Figure 3B). Given such a low yield base, economic benefits from these yield increases would be marginal. GreenSeeker® (NDVI) readings also increased significantly as plant density increased (Figure 3A), closely resembling the yield responses. These measured differences in yield and NDVI, although real, were difficult to discern visibly in the field.

Variety comparisons are shown in figures 4A and 4B. Grain yield of PBA Ace , PBA Jumbo2 and PBA Giant were similar and higher than PBA Hurricane XT. PBA Giant and PBA Jumbo2 had the highest NDVI at 20 August (P <0.05), reflecting a more vigorous growth pattern at that stage. PBA Hurricane XT not only had the lowest grain yield but also the lowest NDVI. Seed size was unaffected by sowing rates and closely reflected expected variety differences (Table 2).

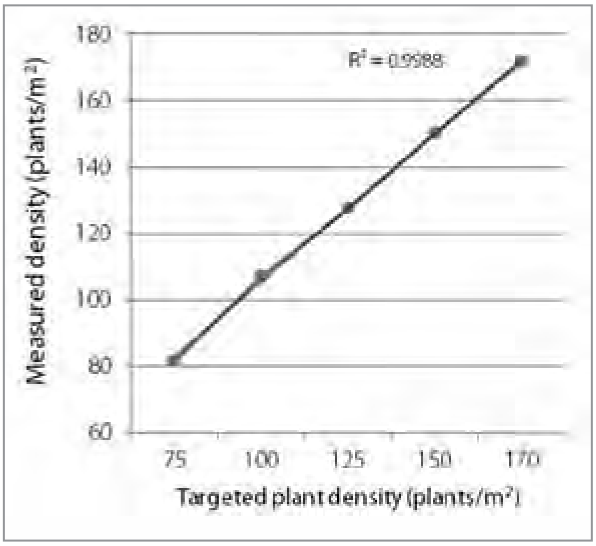


Figure 2. Measured plant densities closely followed targeted plant densities at Yenda, 2014.

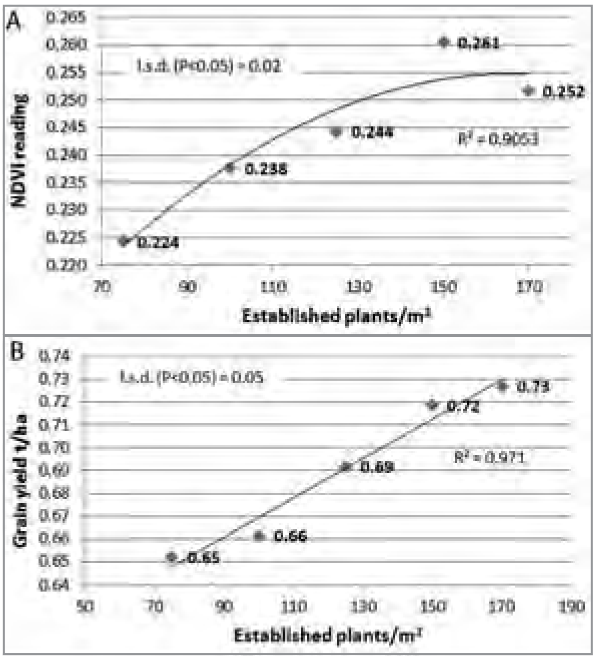


Figure 3. Plant density effects on NDVI (A) readings on 20 August and grain yield (B) of lentil at Yenda, 2014.

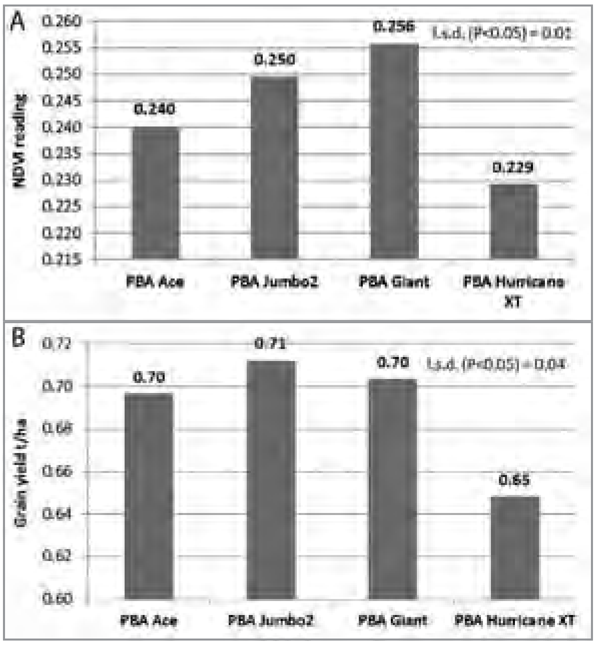


Figure 4. NDVI at 20 August (A) and grain yield (B) of four lentil varieties at Yenda, 2014.

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Acknowledgments

This experiment was part of the project 'Expanding the use of pulses in the southern region', DAV00113 2013–16, a collaborative pulse project between state agencies in Victoria, NSW and South Australia, jointly funded by NSW DPI and GRDC.

Thanks to Kim and Nick Eckerman for providing the site and trial management.

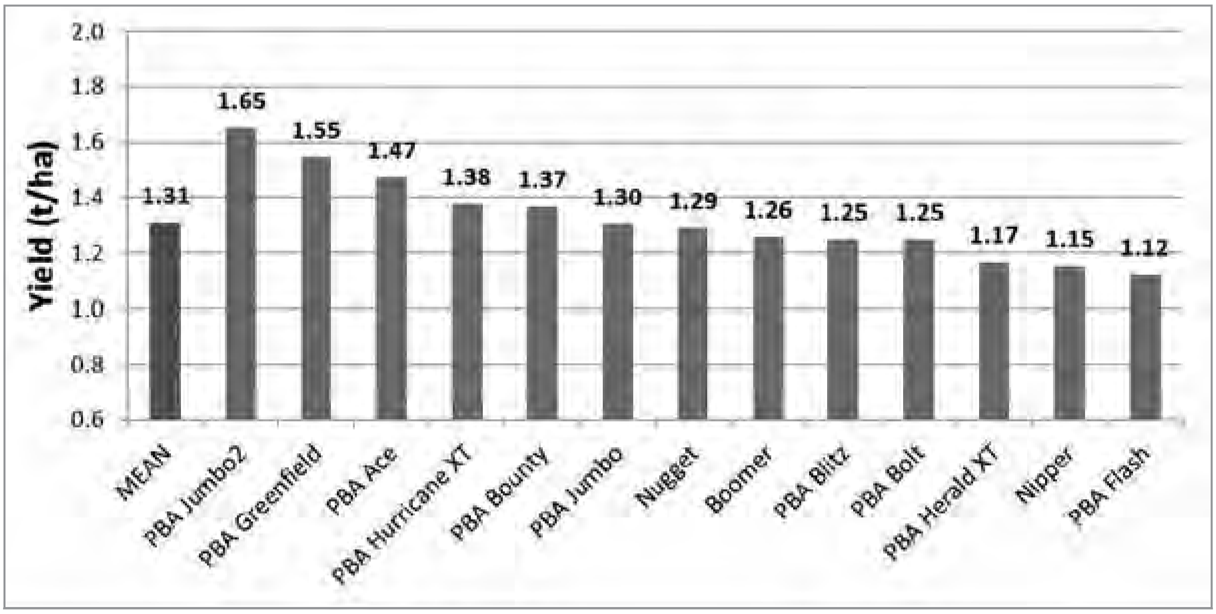


Figure 5. Long-term MET analysis of lentil variety and breeding-line yields at Yenda.

Imidazolinone-tolerant lentils– Wagga Wagga 2014

Dr Eric Armstrong, **Gerard O'Connor** and **Luke Gaynor** NSW DPI, Wagga Wagga

Key findings

- Yield of PBA Ace⌽ and PBA Jumbo2⌽ (the only two imidazilinone or IMI-sensitive varieties evaluated) was reduced by 70%–80% from applying imazethapyr.
- PBA Hurricane XT⌽ and PBA Herald XT⌽ are the only current commercial IMI-tolerant varieties. PBA Hurricane XT⌽ is better adapted, producing more dry matter and grain yield than PBA Herald XT⌽ in southern NSW.
- CIPAL1422 is a promising advanced Coordinated Improvement Program for Australian Lentils (CIPAL) breeding line with high grain yield. It is very IMI-tolerant, and tall and bulky with late maturity.
- Advanced breeding lines are equal to, or better than, PBA Ace⌽ and PBA Jumbo2⌽ in southern NSW. They bring additional features such as herbicide tolerance, extra bulk and height, and a wider range of maturity.
- IMI herbicide tolerance will expand weed-control options in lentil, which is a poorly competitive crop with a limited number of registered herbicides.
- These new varieties, coupled with new technologies, demonstrate considerable potential for expanding lentils across the better class of acidic, red-brown soils of southern NSW.

Introduction

This experiment evaluated the two new imidazolinone (IMI) herbicide-tolerant lentil varieties PBA Herald XT and PBA Hurricane XT alongside other commercial varieties and breeding lines for adaptation and production in southern NSW.

Both varieties have the potential to widen weed control options due to their tolerance to the Group B herbicides imazethapyr (e.g. Spinnaker® and Belta®) and flumetsulam (e.g. Broadstrike®). They are also less sensitive to the carryover residues of some sulfonylurea (e.g. Glean® and Logran®) and imidazolinone (e.g. Raptor®) herbicides applied in previous years.

Site details

Site	Paddock 20A, Wagga Wagga Agricultural Institute
Sowing date	8 May 2014
Soil type	Red-brown earth, pH_{Ca} 5.2 (0–10 cm) (Table 1). The site was limed in 2010
Design	Randomised complete block design with herbicide as the main blocks and varieties as the sub-plots; three replications
Paddock history	Sown to pasture in autumn 2013 but poor establishment led to chemical fallowing of the paddock in the spring. Therefore, stubble was absent for the 2014 season
Fertiliser	80 kg/ha SuPerfect® grain legume fertiliser (NPKS 0:13.8:0:6.1) placed 2 cm below the seed at sowing
Plant population	Target 120 plants/m^2
Sowing	Direct-drilled using a six-row cone seeder with 300 mm row spacing, press wheels and GPS auto-steer
Inoculation	Group F peat inoculant was mixed directly into an on-board 200 L water tank then pumped into each sowing furrow through micro-tubes

Weed management	Commercial weed management practices used to maintain weed-free conditions throughout the trial, eliminating weed competition and weed seed set. Fallow weed control: 2 L/ha glyphosate (450 g/L) and 1 L/ha 2,4-D LV ester (680 g/L) Incorporated by sowing: 2 L/ha glyphosate (450 g/L), 2 L/ha Stomp® (440 g/L pendimethalin), 2 L/ha Avadex® (400 g/L tri-allate) and 1 kg/ha Terbyne® (750 g/kg terbuthylazine) Post emergent: 330 mL/ha Select® (240 g/L clethodim), 100 mL/ha Verdict® (520 g/L haloxyfop) and 500 mL/100 L Uptake® spraying oil
Insect management	Targeting *Helicoverpa* sp.: 400 mL/ha Fastac® Duo (100 g/L alpha-cypermethrin) – 20 September and 24 October

Treatments

Varieties (54)	4 varieties:	PBA Ace PBA Jumbo2 PBA Herald XT PBA Hurricane XT
	3 CIPAL lines:	CIPAL1421 CIPAL1422 CIPAL1423
	47 PBA breeding lines	
Herbicides (2)	'Plus' and 'Minus' Belta® 700 WG (700 g/kg imazethapyr) applied at 400 g/ha on 22 June when seedlings were 3–5 cm high (**NB**: this is four times the highest recommended rate)	

Soil

Pulse growth and rhizobia survival can be affected when soil pH falls below five. This can lead to problems on the acidic, red-brown soils that dominate the cropping zones of southern NSW. Growers need to consider this and routinely monitor soil acidity to maintain a base pH of approximately five by strategically incorporating lime. The 2014 Wagga Wagga site was limed in 2010 and its top soil (0–10 cm) pH_{Ca} is now 5.2. Soil nitrogen levels were low and phosphorus levels medium (Table 1).

Table 1. Site soil chemical characteristics for 0–10 cm and 10–20 cm depth at Wagga Wagga, 2014.

Characteristic	Depth	
	0–10 cm	10–20 cm
pH_{Ca}	5.2	5.0
Aluminium Sat (%)	1.7	2.5
Nitrate nitrogen (mg/kg)	8.5	15
Ammonium N (mg/kg)	0.8	1.1
Phosphorus (Colwell) (mg/kg)	34	13
Cation exchange capacity (CEC) (cmol(+)kg)	7.0	6.5

Season

The 2014 season at Wagga Wagga was warmer, drier and shorter than normal (Figure 1, *Faba bean time of sowing Wagga Wagga 2015*). Early season rainfall (March–June) was 40% above the long-term average and, in combination with the mild temperatures during this period, conditions were ideal for plant establishment and early growth. This rain also replenished sub-soil moisture, benefiting grain fill at the end of the season when July to October rainfall was only half (93 mm) the long-term average. Crops finished 2–3 weeks earlier under these low rainfall and warm temperatures (1–2 °C above average).

There were 43 frost events in 2014 when temperatures fell below 2 °C. More severe frost occurred in July and August (18 events when temperatures dropped below 0 °C) causing isolated stem-splitting and some flower and pod loss. A further three significant frosts occurred in September (temperatures fell below –1 °C on 4, 19 and 20 September). Further flower and pod loss occurred as a result of these events; however, moisture and high temperature stresses ultimately became the overriding limitations to grain fill and yield.

These conditions were not conducive to disease and incidence was low.

Results

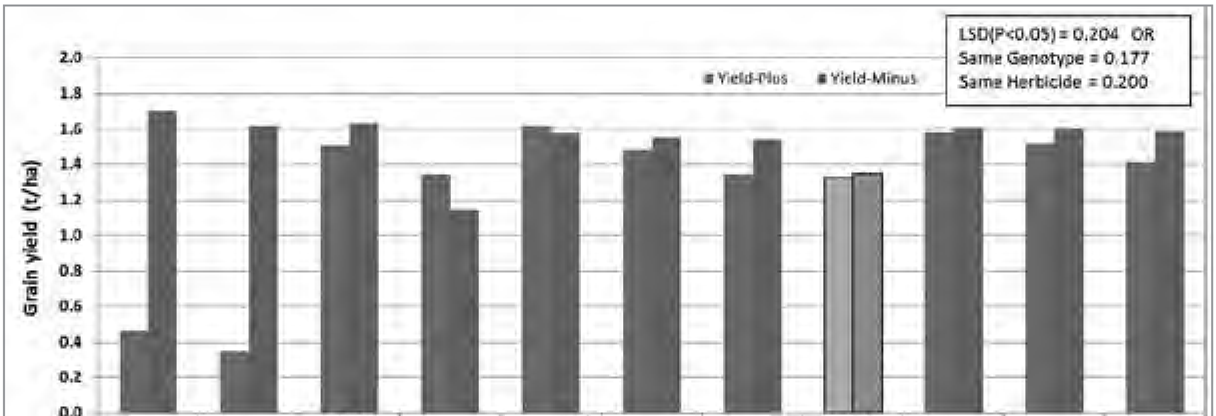
A total of 54 lentil varieties and breeding lines were evaluated for adaptation to southern NSW and tolerance to the IMI type herbicides. The trial was sown on 8 May and sprayed with 400 g/ha Belta® 700 WG (700 g/kg imazethapyr) on 22 June when seedlings were 3–5 cm with 3–4 true leaves. This is four times the highest recommended rate for this herbicide, considered sufficient to experimentally expose sensitivities in the 54 entries. Only the two controls PBA Ace and PBA Jumbo2 incurred significant damage: grain yield reduced by 70–80% (figures 1 and 2); green foliage cover normalised difference vegetation index (NDVI) reduced by 35–40%

(Figure 3); height scores almost halved (Table 2) and maturity significantly delayed (field observations). In comparison, PBA Herald XT and PBA Hurricane XT, along with all breeding lines, displayed a high level of tolerance to this same high rate of imazethapyr.

Breeding this new generation of lentil varieties has incorporated tolerance to Group B herbicides such as imazethapyr (e.g. Spinnaker® and Belta®) and flumetsulam (e.g. Broadstrike®), providing increased weed control options. This is particularly important in a poorly competitive crop with a limited number of registered herbicides. These breeding lines also have reduced sensitivity to some sulfonylurea herbicides (e.g. Glean®and Logran®) and imidazolinone herbicides (e.g. Raptor®). This has particular relevance in reducing the likely risk of lentil crop damage and yield loss from residues from these herbicides.

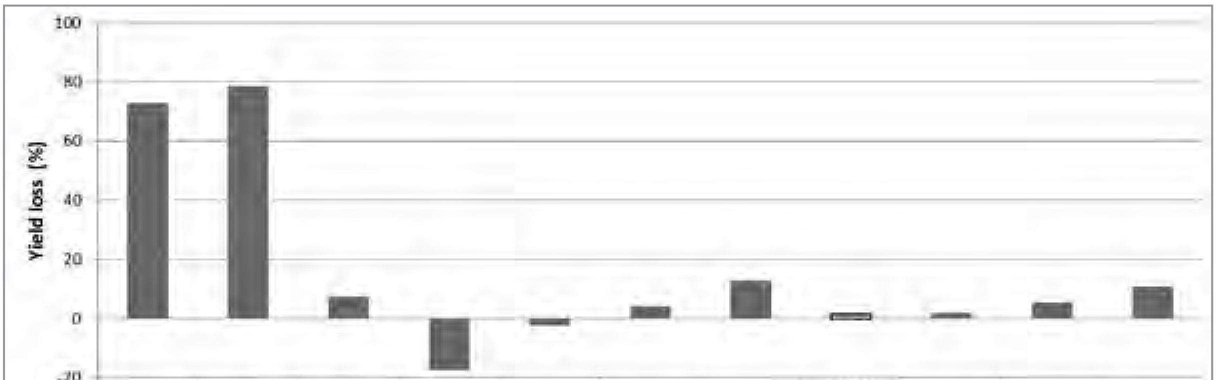
PBA Hurricane XT and PBA Herald XT are currently the only commercial IMI-tolerant varieties available in Australia. PBA Hurricane XT is the more recently released of the two and these results confirm it is better adapted, produces greater green foliage groundcover (NDVI) and yields more grain in southern NSW (figures 1, 2 and 3).

CIPAL1422 is a promising advanced-breeding line with a high grain yield. It has IMI-tolerance, and is tall and bulky with a very high NDVI reading. It is also a late maturing variety, and one of the highest yielding lines in the Plus and Minus treatments (figures 2 and 3).



	PBA ACE	PBA JUMBO2	PBA HURRICANE XT	PBA HERALD XT	CIPAL1422	CIPAL1421	CIPAL1423	MEAN Breeding Lines	Breeding 1	Breeding 2	Breeding 3
Yield-Plus	0.47	0.35	1.51	1.34	1.62	1.48	1.34	1.32	1.58	1.52	1.41
Yield-Minus	1.70	1.62	1.63	1.14	1.58	1.55	1.54	1.35	1.61	1.60	1.59

Figure 1. Grain yield of lentils (four commercial varieties, three CIPAL and three breeding lines) treated with 400 g/ha Belta® 700 WG (Plus) or untreated (Minus), Wagga Wagga, 2014.



	PBA ACE	PBA JUMBO2	PBA HURRICANE	PBA HERALD	CIPAL1422	CIPAL1421	CIPAL1423	MEAN Breeding Lines	Breeding 1	Breeding 2	Breeding 3
Yield loss	73	79	7	-17	3	4	13	2	2	5	11

Figure 2. Lentil yield losses (four commercial varieties, three CIPAL and three breeding lines) from a post-emergent treatment with 400 g/ha Belta® 700 WG (700 g/kg Imazethapyr) on 22 June, Wagga Wagga 2014.

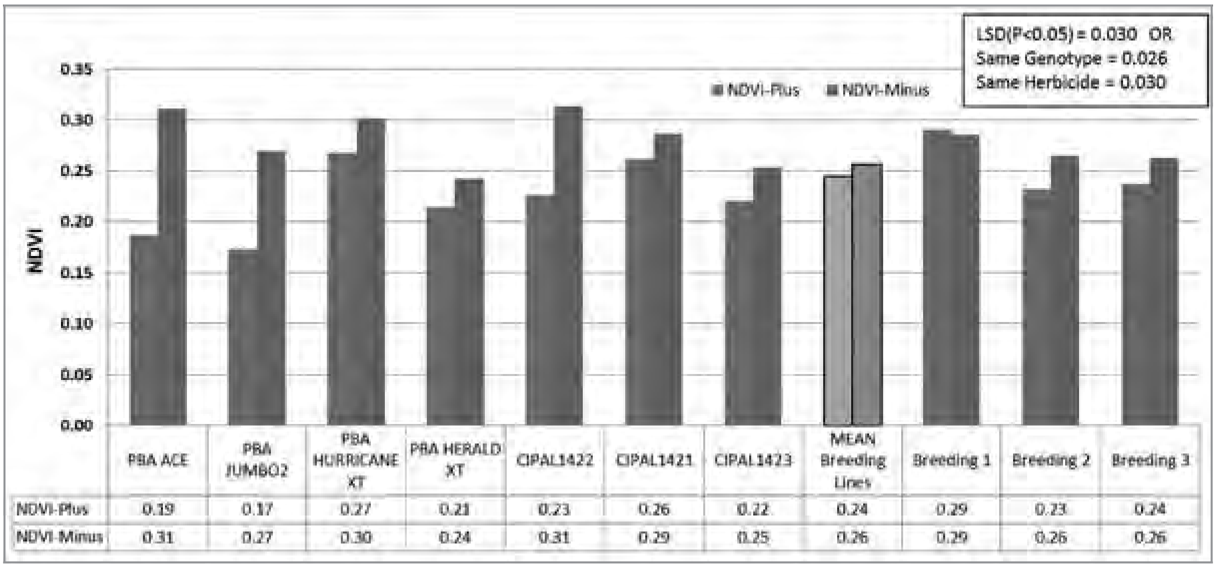


Figure 3. NDVI readings on IMI-susceptible (PBA Ace and PBA Jumbo2) and IMI-tolerant lentil lines (remaining entries) after being treated with 400 g/ha Belta® 700 WG on 22 June at Wagga Wagga in 2014. This figure shows PBA Ace and PBA Jumbo2 to be very susceptible, however the remaining lines show high but varying levels of tolerance.

A subset of three of the highest yielding breeding lines (under IMI-free conditions – Minus) is presented in figures 2, 3 and 4 here as well as the mean of all 47 breeding lines (MEAN Breeding Lines). Breeding 1 had the highest yield in the Plus treatments, excellent IMI tolerance, high NDVI, good standing ability and very early maturity (crop-topping potential) (Table 2). Its Height and Selection scores were, however, below those of PBA Ace and PBA Jumbo2.

Table 2. Maturity, Erect, Height and Selection scores* near maturity of the lentil IMI-tolerant variety trial, Wagga Wagga 2014.

Variety	Maturity		Erect		Height		Selection **	
	Plus	Minus	Plus	Minus	Plus	Minus	Plus	Minus
PBA Ace	8.0	3.9	8.0	5.7	4.7	8.0	2.4	8.0
PBA Jumbo2	7.9	4.2	7.0	6.7	4.7	7.3	1.7	7.0
PBA Hurricane XT	4.3	4.7	7.6	7.6	7.7	7.7	7.6	8.0
PBA Herald XT	4.1	4.5	7.4	6.7	7.0	7.0	7.0	6.3
CIPAL1422	6.3	5.1	7.7	6.6	9.0	8.6	8.9	7.9
CIPAL1421	4.7	3.4	7.0	6.7	7.7	7.9	7.7	7.6
CIPAL1423	4.5	4.1	7.7	7.7	7.0	7.4	8.1	7.4
Breeding 1 ***	2.1	2.4	8.0	8.0	6.0	6.0	6.3	6.4
Breeding 2 ***	3.9	4.5	8.0	7.6	7.0	7.3	7.3	7.7
Breeding 3 ***	4.2	4.3	8.0	8.1	8.0	7.8	7.7	8.1
Mean breeding lines ***	4.5	4.4	7.5	7.4	6.9	7.0	6.7	6.8
l.s.d. (P <0.05)	1.29		0.91		1.12		1.29	

* Scores range from 1 (least expression of the character) to 9 (maximum expression of the character).

** 'Selection' score is a subjective rating of agronomic type including height, erect growth, canopy density and ground cover, pod density and freedom from disease.

** Breeding lines 1, 2 and 3 are the highest yielding of the 47 breeding lines under evaluation, while 'MEAN Breeding Lines' is the mean of all breeding 47 lines.

Acknowledgements

This experiment was part of the project 'Expanding the use of pulses in the southern region', DAV00113 2013–16, a collaborative pulse project between state agencies in Victoria, NSW and South Australia, jointly funded by NSW DPI and GRDC.

Nodulation studies with pulses on acidic red-brown soils – Wagga Wagga 2014

Dr Eric Armstrong, **Gerard O'Connor** and **Luke Gaynor** NSW DPI, Wagga Wagga

Key findings

» Chickpea and lupin failed to nodulate without inoculation.

» Inoculation formula had minimal effects on growth and yield of pulses at this site.

» Peat and liquid formulations were consistently reliable inoculants across all pulses based on nodulation and grain yield.

» Differences measured in nodulation were not reflected in differences measured in crop growth and grain yield, suggesting soil nitrogen reserves were sufficient to make up most of the crop's needs.

» Field pea and lentil rhizobia appear more widespread in this environment and better adapted to the acidic soils, while chickpea rhizobia appear less adapted.

Aim

This experiment compared different rhizobia inoculant formulations on nodulation, growth and yield of field pea, lupin, faba bean, lentil and chickpea under varying rain-fed and soil moisture conditions on an acidic, red-brown earth at Wagga Wagga in the south-eastern cropping zone of southern NSW.

Site details

Site	Wagga Wagga Agricultural Institute
Sowing date	7 June 2014
Soil type	Acidic, red-brown earth, pH_{Ca} 5.2 (0–10 cm)
Design	Randomised complete block design with pulses as the main blocks and inoculation treatments as sub-plots; three replications
Paddock history	Sown to pasture in autumn 2013 but poor establishment led to chemical fallowing of the paddock in the spring
Stubble management	Stubble was absent from the preceding 2013 season
Fertiliser	80 kg/ha grain legume super (N:P:K:S 0:13.8:0:6.1) placed 30–40 mm below the seed
Plant population	Seeding rate was adjusted according to seed size and germination to target: 40 plants/m² for lupin, field pea and chickpea; 28 plants/m² for faba bean; and 130 plants/m² for lentil.
Sowing	Direct-drilled using a six-row cone seeder with 300 mm row spacing, press wheels and GPS auto-steer
Weed management	Commercial weed management practices used to maintain weed-free conditions throughout the trial, eliminating weed competition and weed seed set Fallow weed control: 2 L/ha glyphosate (450 g/L) and 1 L/ha 2,4-D LV ester (680 g/L) Incorporated by sowing: 2 L/ha glyphosate (450 g/L), 2 L/ha Stomp® (440 g/L pendimethalin), 2 L/ha Avadex® (400 g/L tri-allate) and 1 kg/ha Terbyne® (750 g/kg terbuthylazine) Post emergent: 330 mL/ha Select® (240 g/L clethodim), 100 mL/ha Verdict® (520 g/L haloxyfop) and 500 mL/100 L Uptake® spraying oil
Disease management	No disease management required this season
Insect management	Targeting *Helicoverpa* sp: 400 ml/ha Fastac® Duo (100 g/L alpha-cypermethrin)

nutrition & soil

Treatments

Pulse, Variety	1. Field pea – PBA Oura 2. Faba bean – PBA Rana 3. Lentil – CIPAL0901 4. Lupin – Mandelup 5. Chickpea – PBA Slasher 6. Chickpea – PBA Slasher – seed dressed with P-PICKEL T® fungicide one week before sowing (Chick+F)
Inoculation	1. Peat slurry on seed 2. Peat liquid injected into row 3. Granular (Becker Underwood)* 4. NIL – un-inoculated control
*Granular (Becker Underwood) inoculant for Lupin was unattainable and was substituted with Lupin+F (seed treated with P-PICKEL T® fungicide then coated with peat slurry just before sowing) Moisture conditions were ideal for sowing after above average autumn rainfall	

Soil

Pulse growth and rhizobia survival can be affected when soil pH falls below 5. This can lead to problems on the acidic red-brown soils that dominate the cropping zones of southern NSW. Growers need to consider this and routinely monitor soil acidity to maintain a base pH of approximately 5 by strategically incorporating lime. The 2014 Wagga Wagga site was limed in 2010, and its top soil (0–10 cm) pH_{Ca} is now 5.2. Soil nitrogen levels were low and phosphorus levels medium.

Season

The 2014 season at Wagga Wagga was warmer, drier and shorter than normal (Figure 1, *Faba bean time of sowing Wagga Wagga 2015*). Early season rainfall (March–June) was 40% above the long-term average and, in combination with the mild temperatures during this period, seasonal conditions were ideal for plant establishment and early growth. This rainfall also replenished sub-soil moisture, benefiting grain fill at the end of the season when July to October rainfall was only half (93 mm) of the long-term average. Crops finished 2–3 weeks earlier under these low rainfall and warm temperatures (1–2 °C above average).

There were 43 frost events in 2014 when temperatures fell below 2 °C. More severe frost occurred in July and August (18 events when temperatures dropped below 0 °C) causing isolated stem-splitting and some flower/pod losses. A further three significant frosts occurred in September (temperatures fell below –1 °C on 4, 19 and 20 September). Further flower and pod loss occurred as a result of these events; however, moisture and high temperature stresses ultimately became the overriding limitations to grain fill and yield.

These conditions were not conducive to disease and incidence was low.

Methodology

Inoculation

The un-inoculated control (NIL) was sown first to avoid residual rhizobia contamination. The liquid formulation followed, then the granules and finally the peat-coated seed. The cone and seed tubes were cleaned between treatments. The liquid preparation was formulated by mixing the peat-based product with water then injecting through micro-tubes running directly into the furrow at sowing. The granular formulation was mixed and sown with the seed. All treatments were at the recommended rate.

Nodule scores

Eight weeks after emergence (11 September), groups of plants with intact roots were randomly dug with a spade to a depth of 20 cm from four to five locations across each plot. The plants were immediately soaked in water to remove soil for nodule assessment. Plants from each of the four treatments (nil, peat, liquid and granular) were laid out on a table in the field to aid visual comparison and scoring (Figure 1). Nodulation was assessed independently by two operators on 10 plants per plot using a 0–5 scale. Data for each plant was recorded separately, but in this report was averaged across all 20 scores (Figure 2). A hand-held GreenSeeker was used on 1 September to record normalised difference vegetation index (NDVI) of plots to identify 'yellowing' in non-nodulating plots.

Figure 1. Scoring for nodulation at Wagga Wagga in 2014. All four samples of each treatment from each block (peat, liquid, granular and nil) were laid on a table in the field for scoring using a 0–5 scale.

Results

Nodulation patterns

Successful nodulation occurred in the NIL treatments of all field pea, lentil and faba bean plots (2–3 score), indicating that these species had effective background rhizobia at the Wagga Wagga site. However, without inoculant, chickpea and lupin failed to nodulate, indicating their specific rhizobia strains were absent. This reflects either no recent history of cultivation of these legume species at this site and/or poor rhizobia colonisation and survival.

Peat and liquid formulations were consistently reliable inoculants across all pulses based on both nodule appearance and grain yield. Granular inoculants were effective in field pea, lentil and faba bean. However, in chickpea, poor nodulation with granular inoculation was thought to be more the result of using the previous season's inoculant batch, since the current season's supply of Group N granular was unattainable at the time. Fungicide seed dressing of P-PICKEL T® had no visible detrimental effect on nodulation in chickpea and lupin.

When present, faba bean and chickpea nodules were almost exclusively restricted to the crown region of the stem and no lateral nodules were present. In contrast, field pea and lentil nodules were scattered throughout the whole root system. Lentil and field pea nodules were the smallest and most abundant. Lupin nodules were large and encircled the crown and upper portion of the tap root.

NDVI, dry matter, grain yield and seed size

The normalised difference vegetation index (NDVI) on 1 September averaged 6.0 for the whole trial with no significant differences between treatments (Table 1). At this time, all plots were growing rapidly with the spring flush approaching. The absence of any measurable differences in 'greenness' of the foliage across treatments at this stage suggested nutrients, including nitrogen (N), were being adequately supplied from the soil, nodules, or fertiliser (80 kg/ha grain legume super applied at sowing). However, the NIL lupin and chickpea plots became visibly yellow compared with the rest over the following month, suggesting N in these plots was becoming limited. This result would be expected given the heavy demand of N from the crop at this time and the absence of nodulated plants in these plots (figures 2 and 5).

Dry matter cuts were only taken in the peat and NIL treatments and results are presented in Figure 4. Dry matter (DM) production trended higher in peat-inoculated treatments (particularly field pea, lentil and lupin) compared with the NIL ($P < 0.05$), but this pattern did not mirror the magnitude of differences measured in nodulation in these treatments.

Harvested grain yield of un-inoculated plots tended to be lower (by around 10%, $P < 0.05$) compared with inoculated plots (Figure 3), however, differences in yields were generally small and again did not mirror the measured differences in nodulation in these treatments.

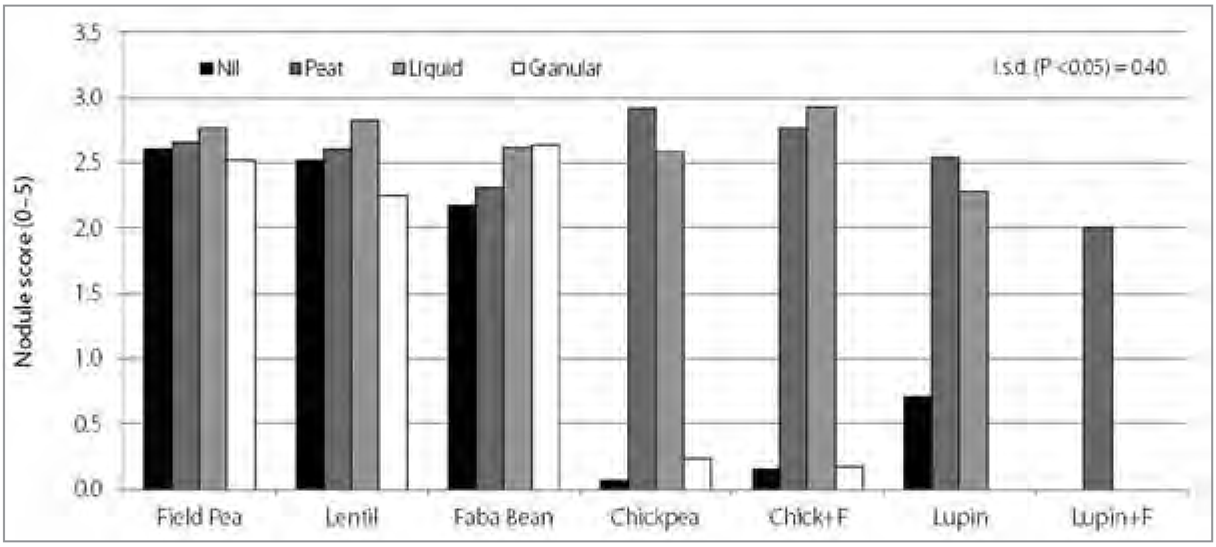


Figure 2. Nodule scores of five pulse species inoculated with different formulations of inoculant at Wagga Wagga in 2014. Chickpea included an additional treatment of fungicide seed dressing P-PICKEL T® (Chick+F). Since lupin granular was unavailable at the time, lupin plus P-PICKEL T® seed dressing (Lupin+F) was substituted. Nodule scores were taken on 20 August using a 0–5 scale; 0 = no nodules; 2 = just adequate; 5 = abundant.

These results need to be interpreted in the context of paddock history and soil nutrient status. This site was limed in 2010 lifting top soil pH_{Ca} (0–10 cm) to 5.2, which is a more favourable zone for rhizobia survival and nodulation. However, background rhizobia for these pulse species at this site could be expected to be low or absent since these species had not been cultivated here during the previous five years.

Also, the soil nutrient and moisture status of this site should have been boosted by the spring 2013 fallow (the result of a poorly established pasture sown in the proceeding autumn). Therefore, nutrient deficiencies during the growth of this experiment are much less likely compared with the more traditional situation where pulses follow an intense cropping program. This could explain why the measured differences in DM and grain yield between treatments in this experiment were only small or absent.

The fungicide seed dressing in chickpea and lupin had little or no effect on growth, nodulation or grain yield of all the pulses (Figure 3). Similarly, inoculant formulation had no effect on seed size (Table 1). Harvest index was significantly higher in chickpea (42%) compared with other pulses (~33%). Again, these patterns appeared independent of nodulation.

Table 1. Differences between pulse species for plant establishment (Estab.), seed size, NDVI and harvest index (HI).

Pulse	Estab. (plants/m²)	Seed size (g/100)	NDVI (1 Sept)	HI (%)
Field pea	49	22.1	0.58	34.3
Lentil	48	3.9	0.62	33.7
Faba bean	31	66.6	0.59	30.1
Chickpea	38	16.8	0.59	42.3
Chick+F	36	16.7	0.61	*
Lupin	41	14.5	0.61	33.2
Lupin+F	45	14.6	0.61	*
l.s.d. (P <0.05)	6.6	0.78	ns	5.60

* DM and HI% not measured in these treatments.

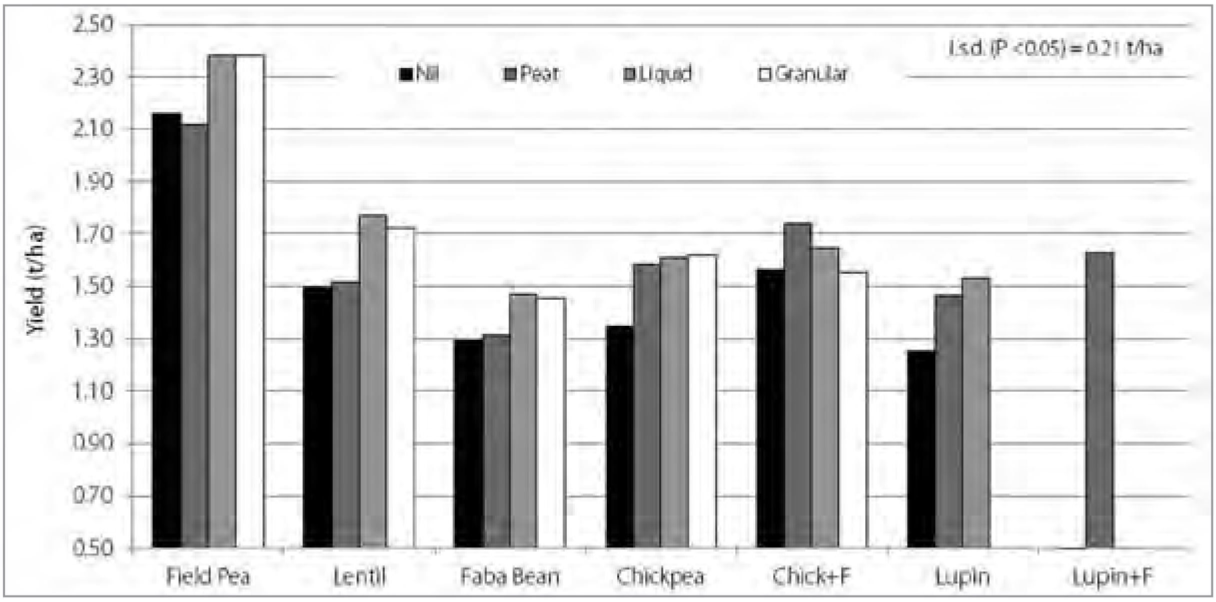


Figure 3. Grain yield (t/ha) of five pulse species inoculated with different formulations of inoculant at Wagga Wagga in 2014. Chickpea included an additional treatment of fungicide seed dressing P-PICKEL T® (Chick+F). Since lupin granular was unavailable at the time, lupin plus P-PICKEL T® seed dressing (Lupin+F) was substituted. Nodule scores were taken on 20 August using a 0–5 scale; 0 = no nodules; 2 = just adequate; 5 = abundant.

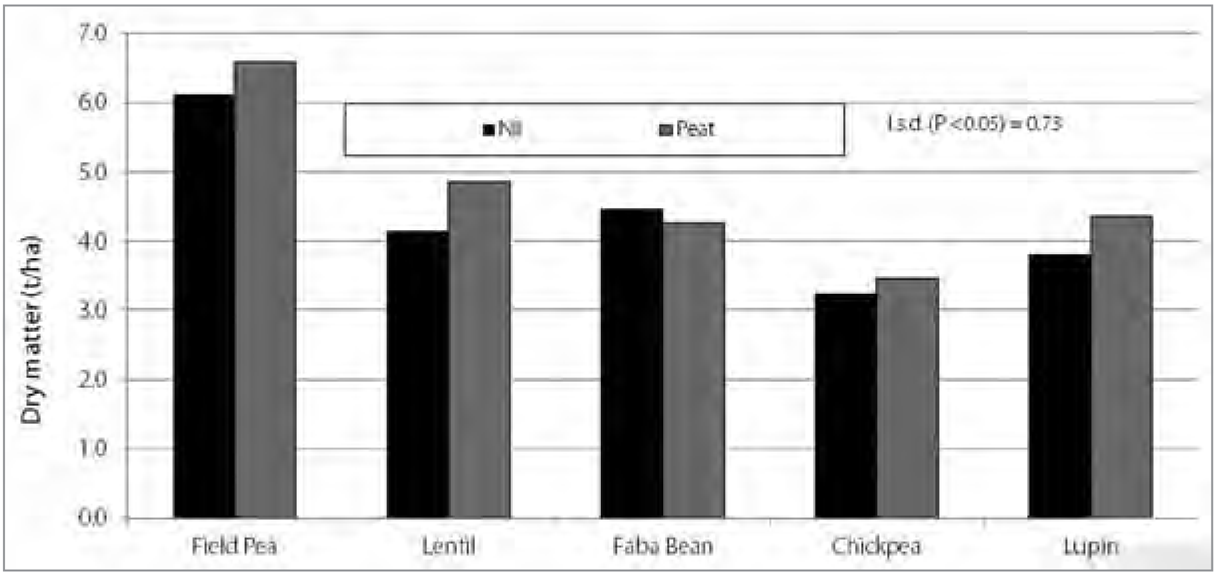


Figure 4. Dry matter (DM) of five pulse species inoculated with different formulations of inoculant at Wagga Wagga in 2014. Note: measurements only done on peat and NIL treatments.

Figure 5. The observed range of nodulation in chickpea at Wagga Wagga in 2014. The far right plant was sampled from the un-inoculated (NIL) treatment.

Nodulation comparison: Wagga Wagga and Yenda

» Nodulation of chickpea failed at both sites without inoculation.

» Field pea and lentil successfully nodulated at both sites without inoculation.

» Faba bean and lupin nodulation was site specific. The failure of lupin to effectively nodulate at Wagga Wagga was somewhat surprising.

» Field pea and lentil rhizobia appear more widespread and better adapted to the acidic soils of southern NSW, while chickpea rhizobia appear less adapted.

Acknowledgements

This experiment was part of the project 'Expanding the use of pulses in the southern region', DAV00113 2013–16, a collaborative pulse project between state agencies in Victoria, NSW and South Australia, jointly funded by NSW DPI and GRDC.

Nodulation studies with pulses on acidic red sandy soils – Yenda 2014

Dr Eric Armstrong, **Gerard O'Connor** and **Luke Gaynor** NSW DPI, Wagga Wagga

Key findings

» Peat and liquid formulations were the most consistent inoculants across all pulses, having the highest nodule scores and equal or highest grain yields compared with the remaining treatments.

» Without inoculation, faba bean and chickpea failed to nodulate indicating host rhizobia were absent at this site. This consequently lowered their grain yields.

» On the other hand, lupin, field pea and lentil effectively nodulated without inoculation, indicating their respective rhizobia had colonised this site.

» Fungicide seed dressing (P-PICKEL T®) did not affect pulse nodulation, but did increase grain yield in chickpea. Further investigation is needed to establish the reasons.

Aim

The aim was to compare different rhizobia inoculant formulations for nodulation, growth and yield of field pea, lupin, faba bean, lentil and chickpea under varying rain-fed and soil moisture conditions on an acidic sandy loam at Yenda in the south-western cropping zone of southern NSW.

Site details

Site	'Hillview' Yenda, RK & JG Eckerman (Paddock 'Wattle Park')
Sowing date	26 May 2014
Soil type	Acidic, red sandy loam, pH_{Ca} (0–10 cm) 4.6 (Table 1)
Design	Randomised complete block design with pulses the main blocks and inoculation treatments sub-plots; three replications.
Paddock history	2014 wheat; 2013 Canola; 2012 Wheat; 2011 Lupin
Stubble management	Sown into a medium density, standing wheat stubble
Fertiliser	80 kg/ha Grain legume super (N:P:K:S 0:13.8:0:6.1) placed 30–40 mm below the seed
Plant population	Sowing rate was adjusted according to seed size and germination to target: 40 plants/m² for lupin, field pea and chickpea; 28 plants/m² for faba bean; and 130 plants/m² for lentil
Sowing	Direct-drilled using a six-row cone seeder with 300 mm row spacing, press wheels and GPS auto-steer
Weed management	Commercial weed management practices used to maintain weed-free conditions to eliminate weed competition and prevent weed seed set
Disease management	No disease management was required this season at Yenda
Insect management	Targeting *Helicoverpa* sp.: 400 ml/ha Fastac® Duo (100 g/L alpha-cypermethrin) applied by the cooperator during late grain fill

Treatments

Varieties (6)	1. Field pea – PBA Oura 2. Faba bean – PBA Rana 3. Lentil –CIPAL0901 4. Lupin – Mandelup 5. Chickpea – PBA Slasher 6. Chickpea – PBA Slasher -seed dressed with P-PICKEL T® fungicide one week before sowing (Chick+F)
Inoculation (4)	1. Peat slurry on seed 2. Peat liquid injected into row 3. Granular (Becker Underwood)* 4. NIL – un-inoculated control

*Granular (Becker Underwood) inoculant for lupin was unattainable and was substituted with Lupin+F (lupin seed treated with P-PICKEL T® fungicide then coated with peat slurry just prior to sowing)

Moisture conditions were ideal for sowing after above average autumn rainfall

Soil

Soil at this site was acidic with pH_{Ca} 4.6 (Table 1) and varied according to the slightly undulating topography. It was a light textured, red sandy-loam along the ridges leading to red loam in the hollows.

Table 1. Site soil chemical characteristics for 0–10 cm and 10–20 cm depth at Yenda, 2014.

Characteristic	Depth	
	0–10 cm	10–20 cm
pH_{Ca}	4.6	6.1
Aluminium Sat (%)	6.4	0
Nitrate nitrogen (mg/kg)	9.8	7
Ammonium N (mg/kg)	0.8	0
Phosphorus (Colwell) (mg/kg)	34	17
Cation exchange capacity (CEC) (cmol(+)kg)	2.8	3.6

Season

The 2014 season at Yenda was warmer, drier and shorter than normal. Rainfall during the critical four months of July to October was only one third of the long-term average (Figure 1, *Lentil sowing rate – Yenda 2014*) and, when combined with warmer temperatures, the season was unfavourable and finished 2–3 weeks earlier than expected. Above-average rainfall preceded the trial (particularly in March), providing valuable soil moisture to help crops to fill grain and finish. Conditions were not conducive to disease, with disease levels low and no fungicides required.

Methodology

Inoculation

The un-inoculated control (NIL) was sown first to avoid residual rhizobia contamination. The liquid formulation was next, followed by the granules and finally the peat-coated seed. The cone and seed tubes were cleaned between treatments. The liquid preparation was formulated by mixing the peat-based product with water then injecting through micro-tubes running directly into the furrow at sowing. The granular formulation was mixed and sown with the seed. All treatments were applied at the recommended rate. Moisture conditions were ideal for sowing after above average autumn rainfall.

Nodule scores

Eight weeks after emergence (20 August), groups of plants with intact roots were randomly dug up with a spade to a depth of 20 cm from four to five locations across each plot. The plants were immediately soaked in water to remove soil for nodule assessment. Plants from each of the four treatments (NIL, peat, liquid and granular) were laid out on a table in the field for visual comparison and scoring (figures 1 and 5). Nodulation was assessed independently by two operators on 10 plants per plot using a 0–5 scale. Data for each plant was recorded individually, but in this report averaged across all 20 scores.

A hand-held GreenSeeker® was used to record the normalised difference vegetation index (NDVI) of plots on 20 August, specifically aiming to quantify nitrogen deficiencies and non-nodulating plots.

Figure 1. Plants from each of the four treatments at Yenda were sampled on 20 August, 2014. They were washed and laid out on a table in the field to allow nodulation scoring.

Results

Nodulation and normalised difference vegetation index (NDVI)

Faba bean and chickpea nodules were almost exclusively restricted to the crown region of the stem and no lateral nodules were present. In contrast, field pea and lentil nodules were scattered throughout the whole root system. Lentil nodules were the smallest and most abundant. Lupin nodules were large and encircled the crown and upper portion of the tap root.

Without inoculation, faba bean and chickpea failed to nodulate at this site (Figure 2), indicating these pulse species had not been cultivated recently and/or had poor colonisation of rhizobia in the soil. Lupin, field pea and lentil however, nodulated abundantly even without inoculation, indicating that effective background rhizobia populations were present.

The peat and liquid inoculant formulations resulted in the most consistent nodulation and the highest nodule scores across all pulses. The liquid formulation resulted in better nodulation of field pea, lentil and faba bean than the other formulations.

Fungicide seed dressing (P-PICKEL T®) had no effect on nodulation at this site.

GreenSeeker® (NDVI) measurement of the plot green-area cover was influenced more by pulse species than inoculant formulation (Figure 3). It was significantly greater in lupin (~0.42), followed by field pea (~0.34), than the other pulses (~0.24). Peat inoculation in faba bean and lupin, however, had a significantly higher NDVI ($P < 0.05$) compared with other inoculant formulations.

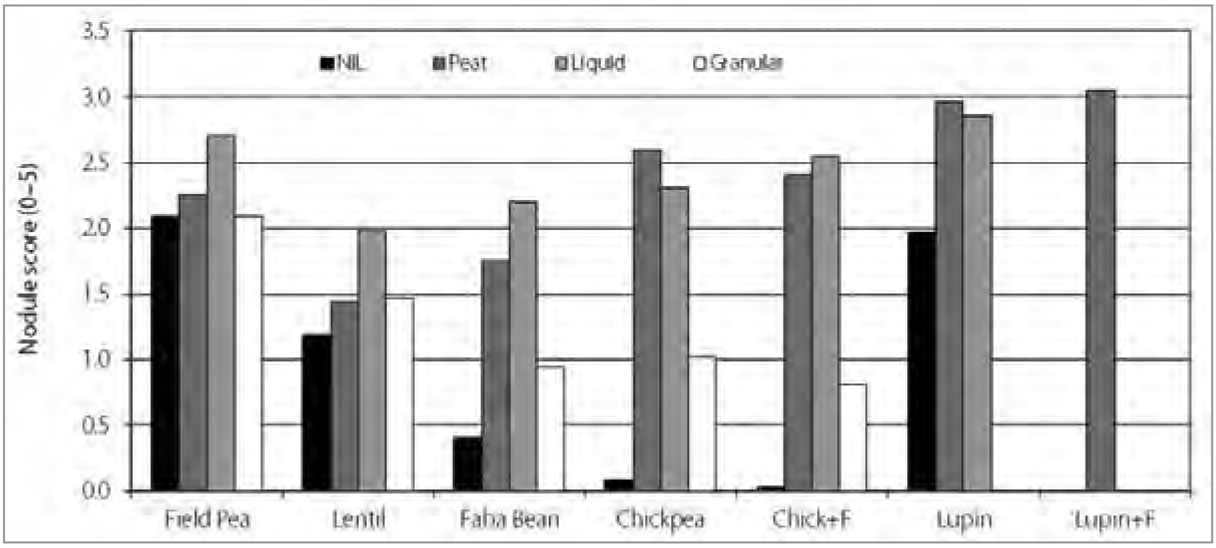


Figure 2. Nodule scores of five pulse species inoculated with different formulations of inoculant at Yenda in 2014. Chickpea included an additional treatment of fungicide seed dressing P-PICKEL T® (Chick+F). Since lupin granular was unavailable at the time, lupin plus P-PICKEL T® seed dressing (Lupin+F) was substituted. Nodule scores were taken on 20 August using a 0–5 scale; 0 = no nodules; 2 = just adequate; 5 = abundant.

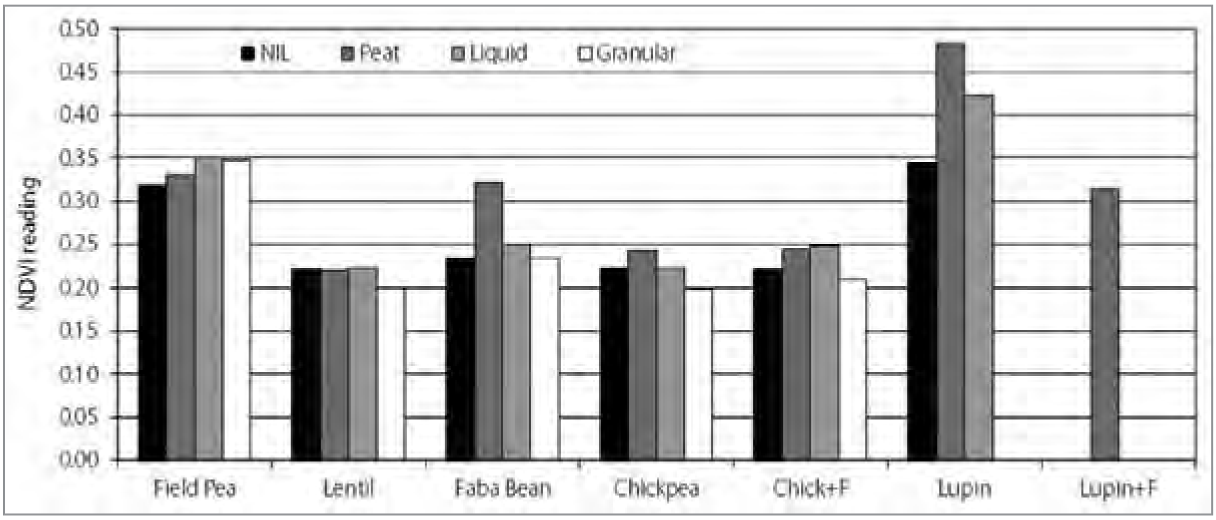


Figure 3. Green-area cover (NDVI) of five pulse species at 20 August when inoculated with different formulations of inoculant at Yenda in 2014.

Grain yield and seed size

Grain yields of the NIL treatment of faba bean and chickpea were significantly lower than other treatments (Figure 3), reflecting their poor nodulation leading to sub-optimal nitrogen nutrition.

Peat and liquid formulations not only resulted in better nodulation (see above), but also higher grain yield (Figure 4).

The P-PICKEL T® seed dressing significantly improved the grain yield in chickpea by around 20% when averaged across the peat, liquid and granular formulations (Figure 4); this result occurred independent of nodulation (Figure 2). The reason for this was not clear.

Inoculant formulation had little or no effect on seed size (g/100 seeds). The average seed sizes for field pea, lentil, faba bean, chickpea and lupin were 21.0, 3.9, 65.1, 18.9 and 14.9 g/100 seeds respectively.

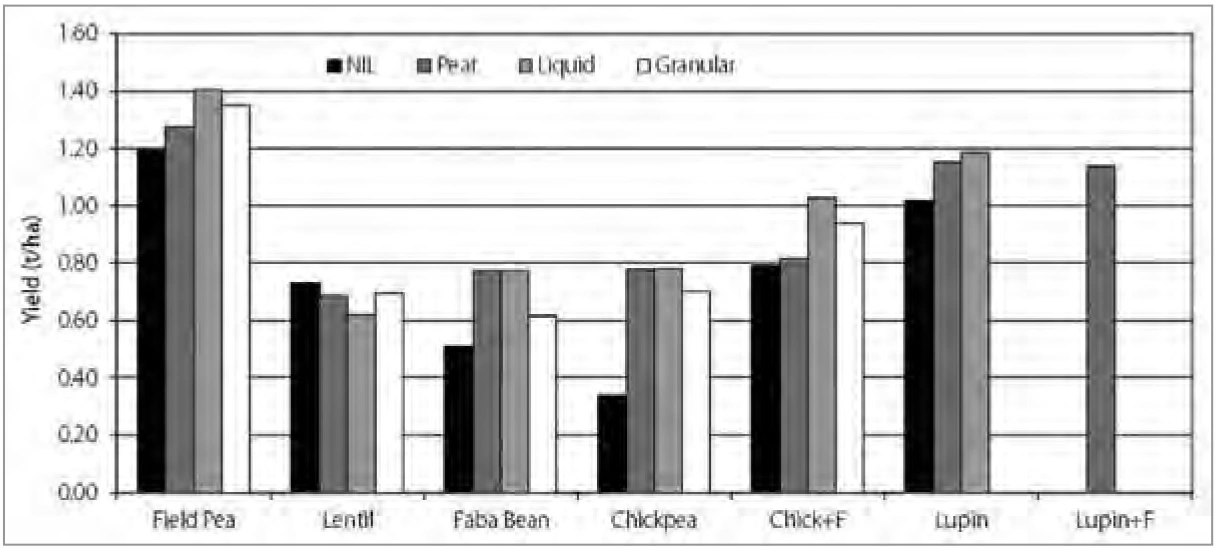


Figure 4. Grain yield (t/ha) of five pulse species inoculated with different formulations of inoculant at Yenda in 2014. Chickpea included an additional treatment of fungicide seed dressing P-PICKEL T® (Chick+F). Also, lupin granular was unavailable at the time so lupin plus P-PICKEL T® seed dressing (Lupin+F) was substituted.

Figure 5. Examples of chickpea plants treated with different inoculant formulation, Yenda 2014. The respective nodule scores from left to right are 0, 1, 2 and 3.

Acknowledgements

This experiment was part of the project 'Expanding the use of pulses in the southern region', DAV00113 2013–16, a collaborative pulse project between state agencies in Victoria, NSW and South Australia, jointly funded by NSW DPI and GRDC.

Use of quality legume inoculants to get the most from nitrogen fixation

Elizabeth Hartley, **Greg Gemell** and **Jade Hartley** NSW DPI, Ourimbah

Key points

- Rhizobia symbiotically fix close to three million tonnes of nitrogen a year worth $4 billion.
- The Australian Inoculants Research Group (AIRG) and its predecessors have controlled and maintained the quality of legume inoculants through collaboration with industry, universities and R&D bodies for close to 60 years.
- A symbol of inoculant quality assessment by an independent laboratory is the display of the green tick logo.
- There are different inoculant groups specific for different legumes.
- Correct storage is important to maintain high numbers of rhizobia in the inoculants.
- The AIRG continues to monitor the quality of legume inoculants at different points in the supply chain and works closely with the manufacturers to ensure that Australia's growers have ongoing access to efficacious products.

Introduction

Each year in Australia, legumes grown in association with their mutually beneficial rhizobia are estimated to symbiotically fix close to three million tonnes of nitrogen, worth $4 billion. The biological process of nitrogen fixation, where rhizobia located in legume root nodules convert atmospheric di-nitrogen (N_2) into ammonia (NH_3) for plant growth, is one of the great agriculture success stories. About 120 years ago in the *Agricultural Gazette of New South Wales*, Guthrie (1896) stated 'It will prove to be one of the most valuable contributions ever made by science to practical agriculture. It is of special interest to us in Australia'.

For close to 60 years, AIRG and its predecessors have undertaken a state and national responsibility for independent quality control and quality assurance of legume inoculants and, more recently, other beneficial microbes. AIRG controls and maintains the quality of legume inoculants through collaboration with industry, universities and R&D bodies.

The outcome of this collaboration between AIRG and industry has improved the quality of legume inoculants over the years. The AIRG laboratory pass rate for quality testing inoculants has increased to be consistently greater than 90% at the point of manufacture (Figure 1).

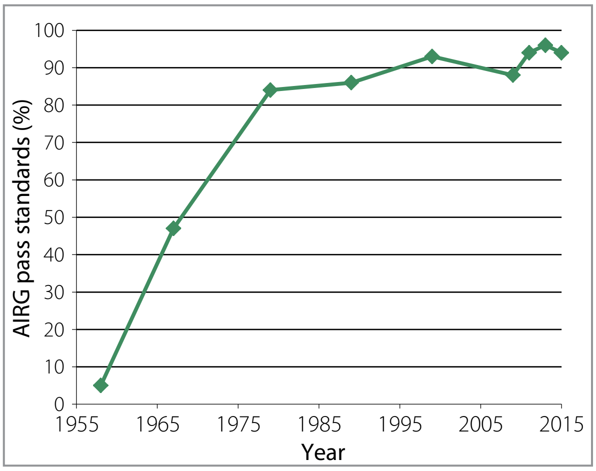


Figure 1. The AIRG laboratory pass standards from 1955 to 2015.

To achieve this:

- AIRG, part of NSW DPI's Soils Unit, has an Australia-wide mandate to ensure that the country's growers and producers have access to high quality legume inoculants and inoculant products containing prescribed numbers of either effective root nodule bacteria (rhizobia) or other beneficial microbes.
- There is a continual Australia-wide commitment to legume inoculant R&D by federal and state governments, universities and various R&D funding bodies.

- AIRG bridges the gap between inoculant R&D and commercial legume inoculant production.
- AIRG conducts quality assessments of rhizobial inoculants at point-of-manufacture and at point-of-sale.
- AIRG has a link with NSW DPI, University of Sydney and other institutions' researchers for ongoing collaborative R&D.
- AIRG operates under ISO9001: 2008 certification.

Each year, AIRG supplies a fresh set of cultures of recommended inoculant strains for temperate and tropical legumes to the inoculant manufacturers for commercial use (Figure 2). These cultures must meet stringent criteria before being released by AIRG. AIRG also holds and distributes a limited number of non-rhizobial cultures used in commercial manufacture.

Figure 2. Rhizobia 'mother' culture preparation.

Code of practice

AIRG has developed a code of practice that incorporates a set of independent protocols and standards for assessing legume inoculant products for quality. Manufacturers produce commercial batches of legume inoculants from the cultures supplied by AIRG.

A sample of each inoculant batch produced is submitted to AIRG and assessed to ensure that inoculants released for sale have:

- the approved and correct strain of rhizobia for the legume group
- high numbers of live rhizobia (the standard for all inoculants is 1,000 million/g fresh peat except Lotononis, which is 500 million/g peat)
- minimal numbers of other contaminant microorganisms i.e. less than 1 million/g peat
- optimum peat moisture for growth and survival of the rhizobia after manufacture and during storage
- optimum capacity for nitrogen fixation with its legume test plant.

Only when these standards have been met does AIRG approve the batch for sale and supplies an expiry date. Inoculant companies, who are signatory to the code and produce inoculants that comply to the standards, can display a NSW DPI registered trade mark green tick quality logo on their product (Figure 3).

Figure 3. NSW DPI green tick registered trademark.

During the period 2005–15, AIRG:

- processed and quality tested >15,000 inoculants at time-of-manufacture and point-of-sale
- processed and quality tested >700 samples of pre-inoculated and custom-inoculated seed
- supplied 1–4 manufacturers with subcultures of 35–40 strains of rhizobia annually (total of about 3,200 subcultures)
- ratified strain changes for 20 inoculant groups
- developed and ratified standards for the new inoculant formulations (granular, liquid and freeze-dried)
- maintained the core Rhizobium strain collection of nearly 2,000 strains.

How to maximise the nitrogen fixation potential of inoculated legumes

To ensure users, i.e. growers, maximise the nitrogen fixation potential of inoculated legumes, AIRG advises the following:

- use quality inoculants
- don't use inoculants that have passed the expiry date
- sow freshly inoculated seed as soon as possible and definitely within 24 hours of inoculation
- use clean potable water when preparing liquids or slurries and make sure holding tanks are free from chemical and fertiliser residues
- never mix rhizobial inoculant with pesticides, or mineral or organic fertilisers, as many are toxic to rhizobia
- rhizobia can be compatible with seed pickles or dressings for a limited time before sowing (see Inoculating legumes: a practical guide from GRDC (2012) for manufacturer's guidelines and

Table 5.4 on page 40). Always apply the seed dressing first and allow it to fully dry before applying the rhizobia as a second process

» match the correct inoculant group to the specific legume.

Inoculants for some of the common legume species, legume inoculant groups and the amount of seed that can be treated by a 250 g bag of peat inoculant are shown in Table 1.

Storing inoculant

One of the main factors affecting the quality of legume inoculants is storage temperature. Legume inoculants contain live rhizobia. It is important to make sure they are kept in moderate temperatures (less than 30 °C and not frozen) away from sunlight and chemicals. For many years, AIRG staff members have monitored inoculant quality at the point of sale. Inoculants were purchased from retail outlets covering the grain cropping areas across Australia and the number of rhizobia in each packet or container counted. Temperatures and conditions of storage were recorded. Generally, rhizobial numbers in the inoculants remain high because the product at the point of manufacture had been prepared in a suitable carrier that prolongs rhizobial survival. However, numbers for the common legume host groups decline in rhizobial number when stored at ambient to high temperature compared to those stored at less than 10 °C (refrigerated) (Table 2).

Table 1. Common legumes species, legume inoculant groups and the amount of seed that can be treated by a 250 g bag of peat inoculant.

Common legume	Legume inoculant group	Seed size	Maximum weight of seed treated with 250 g peat inoculant
Grains			
Pea, field pea, vetch, narbon bean, lathyrus	E	Large	100 kg
Faba bean, broad bean, lentil	F	Medium–large	50–100 kg
Lupin	G	Large	100 kg
Chickpea	N	Large	100 kg
Cowpea, mungbean (green and black gram)	I	Large	100 kg
Peanut or groundnut	P	Large	100 kg
Soybean	H	Large	100 kg
Pastures			
Lucerne, strand and disc medics, melilotus albus	AL	Small	25 kg
Barrel, burr, snail, sphere, gama, murex medics	AM	Medium	50 kg
White, red, strawberry, alsike, Berseem, cluster or ball, suckling, talish clovers	B	Small	25 kg
Subterranean, crimson, cupped, helmet, purple, rose, arrowleaf, balansa, bladder, gland, persian clovers	C	Small–medium	25–50 kg
Greater lotus	D	Small	10 kg
Serradellas	S	Medium	50 kg
Biserrula	Biserrula	Small	10 kg
Birdsfoot trefoil	Lotus	Small	10 kg
Sulla	Sulla	Medium	10 kg

Table 2. Effect of retail storage temperature on rhizobial survival in peat inoculants.

Group	Legume	Million rhizobia/g peat		
		Refrigerated <10 °C	Ambient >20 °C	Difference (%)
E	Pea/field pea	831	614	-26
F	Faba bean	934	612	-34
G	Lupin	1,661	1,226	-26
N	Chickpea	2,282	1,764	-23
AL	Lucerne	2,503	2,888	15
AM	Annual medic	1,212	1,366	13
C	Subclover	676	526	-22

For the groups E, F, G, N and C there is a reduction of 22% or more in rhizobial numbers when the products are not refrigerated. Lucerne and annual medic were not affected by storage temperatures higher than 20 °C.

Carefully handling inoculants before, and at, sowing ensures that the maximum number of viable rhizobia is applied to the seed or seed furrow. The potential response to inoculation is thus maximised for crop or pasture yield. The AIRG continues to monitor the quality of legume inoculants at different points in the supply chain and work closely with the manufacturers to ensure that Australia's growers have ongoing access to efficacious products.

Reference

Guthrie, FB 1896, 'Inoculation of soil for leguminous crops', *Agricultural Gazette of New South Wales*, vol. 7, pp. 690–694.

Acknowledgments

This work is jointly funded by NSW DPI and GRDC 'AIRG: National independent quality assurance and germplasm maintenance for Rhizobium inoculants – Continuation', DAN00189, 2013–17; and the Australian Legume Inoculant manufacturers BASF Agricultural Specialties Pty Ltd, New-Edge Microbials Pty Ltd and Novozymes BioAg Ltd.

The eXtensionAUS Crop Nutrition online learning network

Luke Beange NSW DPI, Dubbo; **Sally Friis** and **Julie White** NSW DPI, Paterson; **Fleur Muller** NSW DPI, Wagga Wagga; **Stephanie Alt** Give Soil a Chance

Key points

At the eXtensionAUS website you can:

» find the most recent information on emerging crop nutrition issues
» watch an interview with one of our experts
» follow us on Twitter
» sit in on a webinar
» ask a question of our national team of experts at any time
» become part of Australia's largest, research-based learning network.

Introduction

What is eXtensionAUS Crop Nutrition?

If you are a grower or adviser, or looking for the most up-to-date information on crop nutrition, then eXtensionAUS Crop Nutrition can provide you with the most innovative option in Australia to date.

As an online learning network, eXtensionAUS Crop Nutrition is located within the eXtensionAUS website and can be accessed to complement your regular knowledge and information gathering systems. So think of eXtensionAUS as exactly that – an extension of your current advice channels that contains a wealth of information and advice – direct from the experts, in real time.

Based on a successful long-term eXtension Program in the USA, eXtensionAUS is quickly gaining in popularity amongst grain growers and industry. NSW DPI has gathered experts from across the country to take part in the program so we can deliver timely, relevant, evidence-based information to you when you need it. Also available on the eXtensionAUS network is eXtensionAUS Field Crop Diseases.

How does it work?

At the eXtensionAUS website you can find the most recent information on emerging crop nutrition issues, watch an interview with one of our experts, follow us on Twitter or sit in on a webinar. You can ask a question of our national team of experts at any time. You can even join us and become part of Australia's largest, research-based learning network, working alongside your peers in a Community of Practice (CoP).

How do I access eXtensionAUS Crop Nutrition?

Visit www.extensionaus.com.au and select Crop Nutrition, or follow us on Twitter @AuCropNutrition, and become part of the network (Figure 1).

What information is available?

Information found on eXtensionAUS is sourced from experts in state departments of agriculture, universities, CSIRO and industry bodies. Sources are typically the same people you would see presenting at GRDC cropping updates such as Mark Conyers (southern NSW), Chris Dowling and Mike Bell (northern zone), Roger Armstrong (Vic.), Nigel Wilhelm (SA) and Craig Scanlan (WA). Published articles cover important crop nutrition issues, timed as much as possible to be released when relevant to the topic or responding to issues emerging in the current season.

As eXtensionAUS Crop Nutrition is led by a CoP that includes many of Australia's leading crop nutritionists, each article must be approved by two members of the CoP before it can be published. So you can be confident the information is of the highest quality and relevance. Visit the website to see more about the CoP.

The top 10 eXtensionAUS Crop Nutrition articles in 2015 were:

1. Do you know your nitrogen use efficiency?
2. What happens to P (phosphorus) from crop residues?
3. What nutrients are lost when making hay from failed crops?
4. Spotlight: Fertiliser calculator
5. How critical is the critical level?

6. What is the value of fixed N (nitrogen)?
7. No-till soils and strategic tillage
8. Manage pH for profit
9. 2015 crop prospects and nitrogen
10. Uneven urea spreading costs $$$.

Examples of other published articles on eXtensionAUS Crop Nutrition include:

- Soil test deeper to predict response to potassium fertiliser
- Potassium and crop stress
- Using deep soil cores for nitrogen, potassium and sulfur
- Webinar: Review crop nutrition in your paddocks (Dec. 2015)
- Research spotlight: Fertiliser recommendations and soil tests
- Nitrogen use efficiency training on-line
- Zinc deficiency shows up in the cold
- Data gold from your test strip at harvest
- Reducing nitrous oxide emissions from dryland grains soil
- Grain analysis for nutrient strategy
- Understanding and managing multiple nutrient deficiency.

Figure 1. The eXtensionAUS homepage highlighting the location of the eXtensionAUS Crop Nutrition site.

From February 2015 to February 2016 there have been 1,559 views of eXtensionAUS Crop Nutrition YouTube videos. This totalled 3,348 minutes with an average viewing duration of 2:08 minutes. These videos provide a quick summary by the expert of the key points of a topic. The viewer can then choose to follow up if they want more detail.

A YouTube highlight was the 90 views of the Better Fertiliser Decisions for Cropping (BFDCII) webinar as at January 2016. The number of followers of @AuCropNutrition on Twitter is currently 1,494.

The eXtensionAUS Crop Nutrition network is also closely linked to the More Profit from Crop Nutrition (MPCNII), and the Making Better Fertiliser Decisions for Cropping Systems in Australia (BFDCII) programs. These programs support current crop nutrition research. BFDCII provides access to the best verified soil test crop calibrations on nitrogen, phosphorus, potassium and sulfur by location in Australia. Hence eXtensionAUS Crop Nutrition helps make this information accessible as it becomes available.

Summary

The eXtensionAUS Crop Nutrition online learning network connects experts and practitioners in crop nutrition. You can find the latest scientifically verified crop nutrition information through its website, Twitter feed and YouTube videos.

Acknowledgements

NSW DPI manages eXtensionAUS Crop Nutrition. Funding is jointly provided by NSW DPI and GRDC.

The effect of nitrogen application on grain yield and grain protein concentration of six wheat varieties – Parkes 2015

Ian Menz, **Nick Moody** and **Daryl Reardon** NSW DPI, Condobolin

Key findings

» Suntop$^{\phi}$ was the highest yielding variety (4.48 t/ha).

» Lancer$^{\phi}$ achieved high protein, high test weight and low screenings at all nitrogen application rates.

» Grain yield increased as nitrogen application rates increased, but there was no significant increase in yield above 20 kg N/ha applied nitrogen.

» Applying 160 kg N/ha resulted in a yield decrease.

Introduction

This experiment evaluated the effect of variety and nitrogen rate on grain yield and protein concentration for six wheat varieties.

Site details

Location	North Parkes Mines
Soil type	Red clay loam
Previous crop	Canola 2014
Sowing date	14 May
Fertiliser	70 kg/ha MAP + Sapphire
Available N	68 kg/ha (0–60 cm)
In-crop rainfall (April–October)	249.5 mm
Harvest date	24 November

Treatments

Wheat varieties	Condo$^{\phi}$ EGA_Gregory$^{\phi}$ Lancer$^{\phi}$ Spitfire$^{\phi}$ Suntop$^{\phi}$ Viking$^{\phi}$
Nitrogen rates	0, 20, 40, 80, 40 + 40 split * and 160 kg N/ha * split application 40 kg N/ha at sowing + 40 kg N/ha at growth stage 31 (GS31)

Seasonal conditions

In 2015, the experiment site received above average growing season rainfall of 249.5 mm (April–October; 10-year average is 240 mm). Of this, 73 mm fell in April (Table 1). Below average rainfall was recorded in September (9.5 mm).

The site experienced 15 frost events in August and four in September (–3.9 °C was recorded on 19 August). Temperatures in the mid to high thirties were recorded during October, which coincided with the flowering window for many wheat varieties sown. The highest recorded temperature at the site was 41.7 °C on 17 October.

The experiments were sown into adequate moisture, had even establishment and were weed-free.

Results

Grain yield

Variety and nitrogen rate both had a significant effect on grain yield. Suntop (4.48 t/ha), Condo (4.44 t/ha) and EGA_Gregory (4.31 t/ha) were the highest yielding varieties and Dart (4.22 t/ha) was the lowest yielding variety (Table 2). Grain yield increased when nitrogen (N) rate increased from 0 kg N/ha (4.25 t/ha) to 20 kg N/ha (4.35 t/ha), but did not increase with further increases in N rate. The highest rate of 160 kg N/ha resulted in a significant yield decrease (4.21 t/ha). The variety × N rate interaction did not affect grain yield (Table 3).

Table 1. Parkes rainfall 2015.

Parkes rainfall for 2015 (mm)														
Dec 2014	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	In-crop
89.6	52.0	36.0	1.0	73.0	34.5	14.0	61.0	33.0	9.5	24.5	52.0	9.0	399.5	249.5

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Table 2. Grain yield and qrain quality for six wheat varieties sown 14 May at Parkes 2015.

Variety	Grain yield (t/ha)	Grain protein (%)	Grain nitrogen yield (kg N/ha)	Screenings (%)	Test weight (kg/hL)
Condo	4.44	11.49	89.3	1.20	78.26
Dart	4.22	11.67	86.2	1.58	78.66
EGA_Gregory	4.31	11.40	86.0	1.30	78.87
Lancer	4.23	12.36	91.5	0.75	79.65
Spitfire	4.27	12.31	92.0	1.31	80.68
Suntop	4.48	11.55	90.6	1.76	79.45
l.s.d. (P = 0.05)	0.09	0.21		0.13	0.27

Table 3. Grain yield and grain quality for six nitrogen application rates across all varieties for 14 May sown wheat varieties at Parkes 2015.

Nitrogen rate (kg N/ha)	Grain yield (t/ha)	Grain protein (%)	Grain nitrogen yield (kg N/ha)	Screenings (%)	Test weight (kg/hL)
0	4.25	10.07	74.9	0.93	79.79
20	4.35	10.68	81.2	0.99	79.87
40	4.38	11.19	85.7	1.13	79.62
80	4.38	12.20	93.5	1.45	78.98
40 + 40 split	4.39	12.62	96.9	1.45	78.97
160	4.21	14.02	103.4	1.95	77.75
l.s.d. (P = 0.05)	0.09	0.21		0.13	0.28

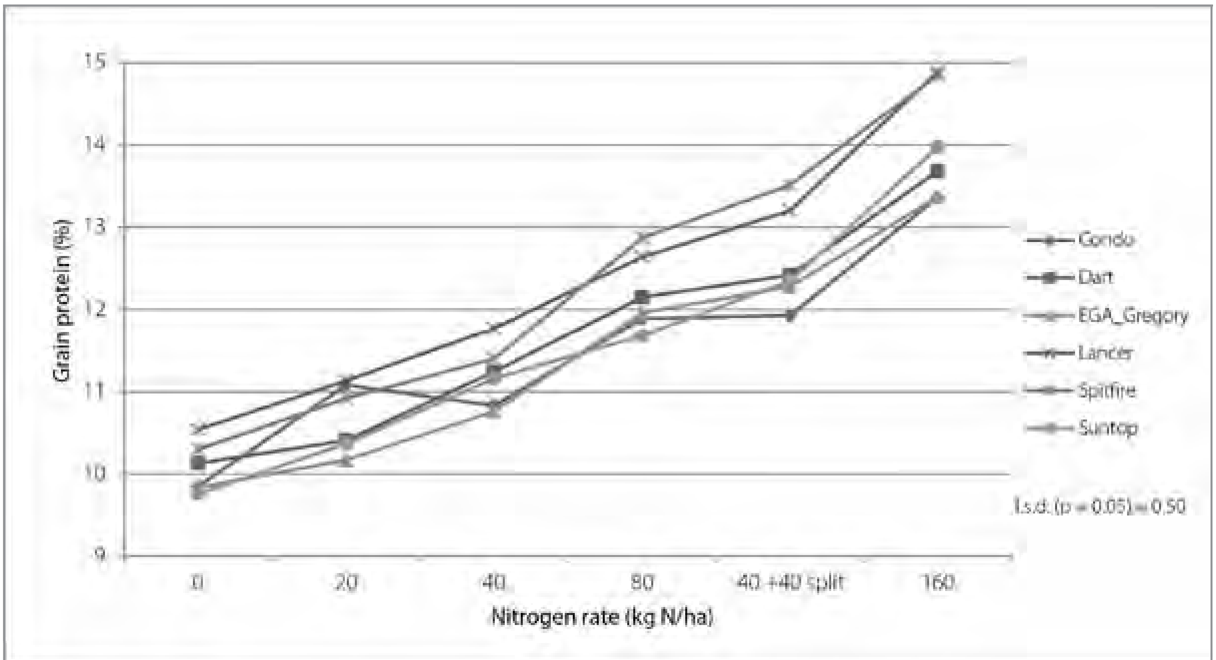

Figure 1. Grain protein of six wheat varieties by six N rates at Parkes 2015.

Grain quality

Variety and N rate both significantly affected grain protein, screenings and test weight. Lancer had the highest grain protein content (12.36%) followed by Spitfire (12.31%) and Dart (11.67%) (Figure 1). Lancer had significantly lower screenings than all other varieties (0.75%). Spitfire had the highest test weight (80.68 kg/hL) followed by Lancer (79.65 kg/hL).

All varieties except Suntop maintained screening percentages below 5% when 40 kg N/ha was applied. The increased application rates of nitrogen resulted in EGA_Gregory, Dart and Suntop having screenings higher than the acceptable level of 5%.

Spitfire, Lancer and Condo achieved standard grade levels of screenings up to 80 kg N/ha (both upfront and split application). Suntop and Dart had screenings above the 5% level.

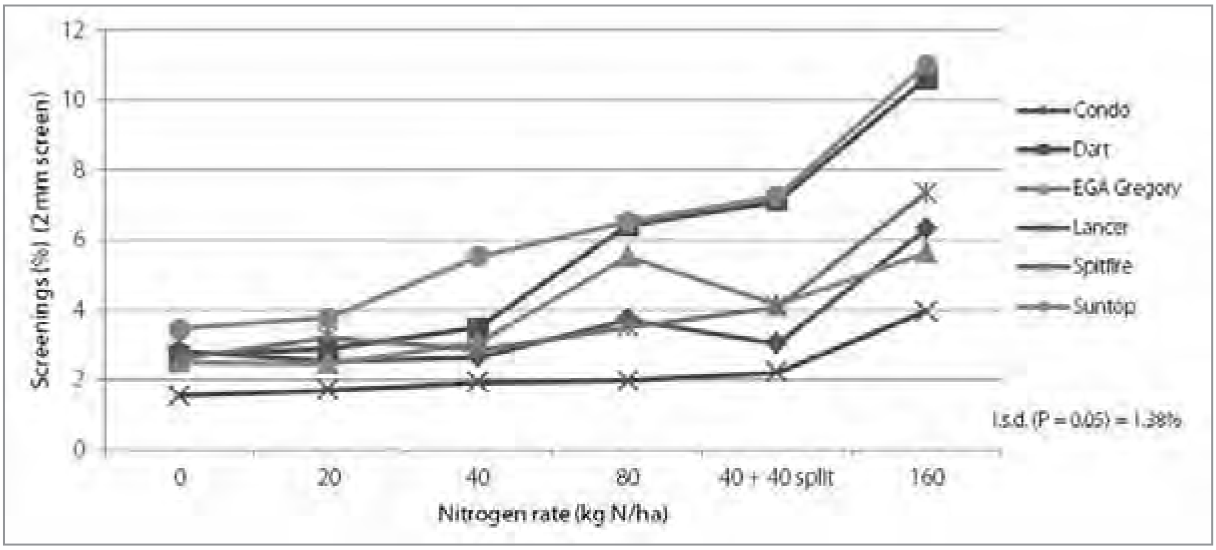

Figure 2. Screenings of six wheat varieties by six N rates (kg N/ha) at Parkes 2015.

All varieties had the highest screenings when 160 kg N/ha was applied. All varieties except Lancer had screenings over 5% at this nitrogen rate (Figure 2).

Summary

The Parkes site is in the medium rainfall zone of central NSW. Suntop performed well in this environment being the highest yielding of the six varieties (4.48 t/ha) followed by Condo (4.44 t/ha). There was little difference between Condo and Suntop in yield, but they were significantly different from the third highest yielding variety, EGA_Gregory (4.31 t/ha). All three varieties are quick maturing which allowed them to finish before the high temperatures in October 2015.

There was no significant yield increase after 20 kg N/ha (4.35 t/ha) of N was applied. There was no indication that the split application benefitted the crop, as the 40 + 40 kg N/ha split (4.39 t/ha) did not yield significantly higher than the 80 kg N/ha upfront (4.38 t/ha). Applying 160 kg N/ha resulted in the lowest yield of all nitrogen treatments when averaged across all varieties (4.21 t/ha).

Lancer was able to maintain high grain protein, high test weight and low screenings across all the nitrogen application rates.

Acknowledgements

This experiment is part of 'Variety Specific Agronomy Packages for southern, central and northern New South Wales', DAN00167, 2013–17, jointly funded by GRDC and NSW DPI.

Thanks to Ryan Potts, Broadacre Cropping Unit, Dubbo, Daryl Reardon and Nick Moody, Condobolin Agricultural Research and Advisory Station and Dr Neroli Graham for statistical analyses.

Effect of nitrogen rate and sowing rate on the grain yield and quality of barley

David Burch, Nick Moody and **Ian Menz** NSW DPI, Condobolin

Key findings

» La Trobe and Compass displayed the best combination of yield and quality traits for achieving malt specification.

» The environment, or experiment site, had a greater effect on yield than variety, nitrogen (N) rate or sowing rate. Low rainfall at Condobolin resulted in significantly lower yields than at Parkes.

» The sowing rate did not significantly affect yield above 150 plants/m^2 at Condobolin or Parkes.

» Nitrogen (N) applications, in the absence of adequate rainfall, can have a negative effect on yield.

Introduction

Eight barley varieties were sown at Condobolin and Parkes to assess the varietal response to N application and seeding rate on grain yield and quality.

Site details

Location	Condobolin	Parkes
Sowing date	25 May 2015	14 May 2015
Soil type	Red chromosol	Red dermosol
Previous crop	Wheat	Canola
Rainfall	198 mm Apr–Sep.	326 mm Apr–Oct.
Fertiliser	MAP 70 kg/ha	Granulock 90 kg/ha
Available N	60.7 kg/ha	42.6 kg/ha

Treatments

N rates	0, 30 and 90 kg/ha at sowing
Sowing rates	75, 150 and 300 seeds/m^2 *
Varieties	Bass$^{\phi}$ Buloke$^{\phi}$ Commander$^{\phi}$ Compass$^{\phi}$ Flinders$^{\phi}$ GrangeR$^{\phi}$ La Trobe$^{\phi}$ Wimmera$^{\phi}$

*Seeding rates of 75, 150 and 300 seeds/m^2 is equivalent to 34, 68 and 135 kg seed per ha, assuming a grain size of 45 mg.

Results

Parkes was the highest yielding site, with significant differences between sowing rate, N rate and variety (tables 1 and 2). La Trobe yielded the highest at 30 kg/ha of N and a sowing rate of 150 plants/m^2. Higher sowing and N rates had no significant effect on any variety. At Condobolin, there were significant effects from seeding density and N rate, although there was no varietal interaction between the two variables (tables 3 and 4).

Table 1. Grain yield (t/ha) of eight barley varieties with three nitrogen rates applied at sowing at Parkes, 2015.

Variety	N applied (kg/ha)		
	0	30	90
Bass	4.94	5.11	5.15
Buloke	5.04	5.18	4.91
Commander	5.35	5.27	5.20
Compass	5.49	5.79	5.56
Flinders	5.19	5.20	5.11
GrangeR	5.34	5.60	5.38
La Trobe	5.64	5.80	5.60
Wimmera	5.29	5.30	4.72
l.s.d. (P = 0.05)	26		

Table 2. Grain yield (t/ha) of eight barley varieties sown at three sowing rates at Parkes, 2015.

Variety	Sowing rate (plants/m^2)		
	75	150	300
Bass	5.01	5.10	5.09
Buloke	5.05	5.05	5.04
Commander	5.16	5.41	5.25
Compass	5.45	5.61	5.78
Flinders	5.11	5.17	5.22
GrangeR	5.18	5.50	5.64
La Trobe	5.52	5.78	5.74
Wimmera	5.10	5.09	5.12
l.s.d. (P = 0.05)	0.21		

Table 3. Grain yield (t/ha) of eight barley varieties with three nitrogen rates at Condobolin, 2015.

Variety	N rate (kg/ha)		
	0	30	90
Bass	1.06	0.88	0.58
Buloke	1.04	0.95	0.69
Commander	0.60	0.52	0.37
Compass	1.25	1.12	0.86
Flinders	0.70	0.59	0.52
GrangeR	0.73	0.57	0.36
La Trobe	1.33	1.43	0.90
Wimmera	0.636	0.79	0.41
l.s.d. (P = 0.05)	0.22		

Table 4. Grain yield (t/ha) of eight barley varieties sown at three sowing rates at Condobolin, 2015.

Variety	Sowing rate (plants/m²)		
	75	150	300
Bass	0.82	0.86	0.84
Buloke	0.83	0.90	0.95
Commander	0.41	0.55	0.53
Compass	1.07	1.07	1.09
Flinders	0.56	0.66	0.60
GrangeR	0.46	0.60	0.59
La Trobe	1.19	1.26	1.21
Wimmera	0.50	0.71	0.61
l.s.d. (P = 0.05)	0.64		

Varieties

Compass and La Trobe were the highest yielding varieties, with significant yield increases over all other varieties at Parkes, and all but Buloke at Condobolin (Figure 1). The lowest yielding varieties were Commander at Condobolin (0.50 t/ha) and Buloke at Parkes (5.04 t/ha).

Effect of sowing rate

There was a significant yield improvement at both sites when sowing rate was increased from 75 to 150 plants/m^2, but there was no significant difference when sowing rate was increased from 150 to 300 plants/m^2 (Figure 2).

There was a significant difference in ear number between all sowing rates at both sites as shown in Figure 3. This implies grain number per head was affected by sowing rate.

Nitrogen effect

At the Condobolin trial there was a significant yield decrease (P=0.05) at N rates of 90 kg/ha, while the Parkes trial did not demonstrate significant differences in yield from any N treatment (Figure 4). Low rainfall during the grain-filling period at Condobolin decreased yield relative to Parkes. This increased available N per plant, concentrating the impact of N on overall yield.

Grain quality

The Parkes protein and screenings data is presented in this paper as the site was more representative of the conditions in southern NSW in 2015 (Figure 5). Malting barley must have a grain protein concentration of 9%–12% to meet malt specifications. By adding 90 kg/ha N at Parkes, all varieties exceeded that limit, with the lowest concentrations being La Trobe (12.2%) and Compass (12.3%). Compass displayed significantly lower N accumulation at 30 kg/ha (9.6%) than any other variety, and at 0 kg/ha of N, also had the lowest protein concentration, possibly due to its high yield distributing N across a greater sink.

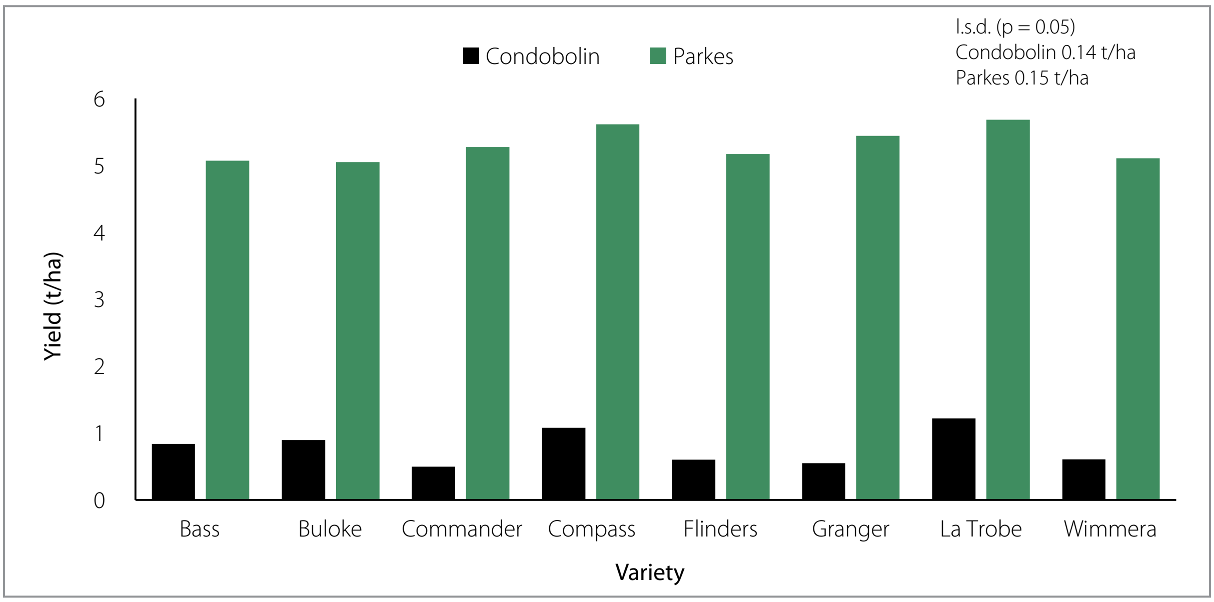

Figure 1. Yield of eight barley varieties at Condobolin and Parkes across all sowing and nitrogen rates.

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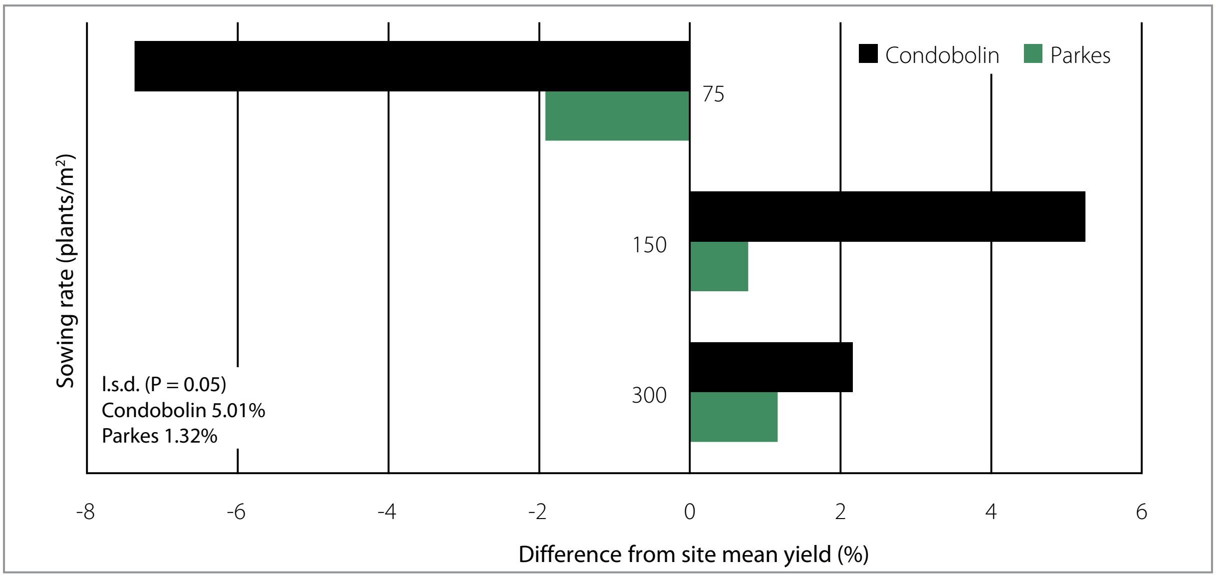

Figure 2. Yield differences at different sowing rates of barley across two sites in 2015. The site mean for Parkes was 5.30 t/ha and the site mean for Condobolin was 0.79 t/ha.

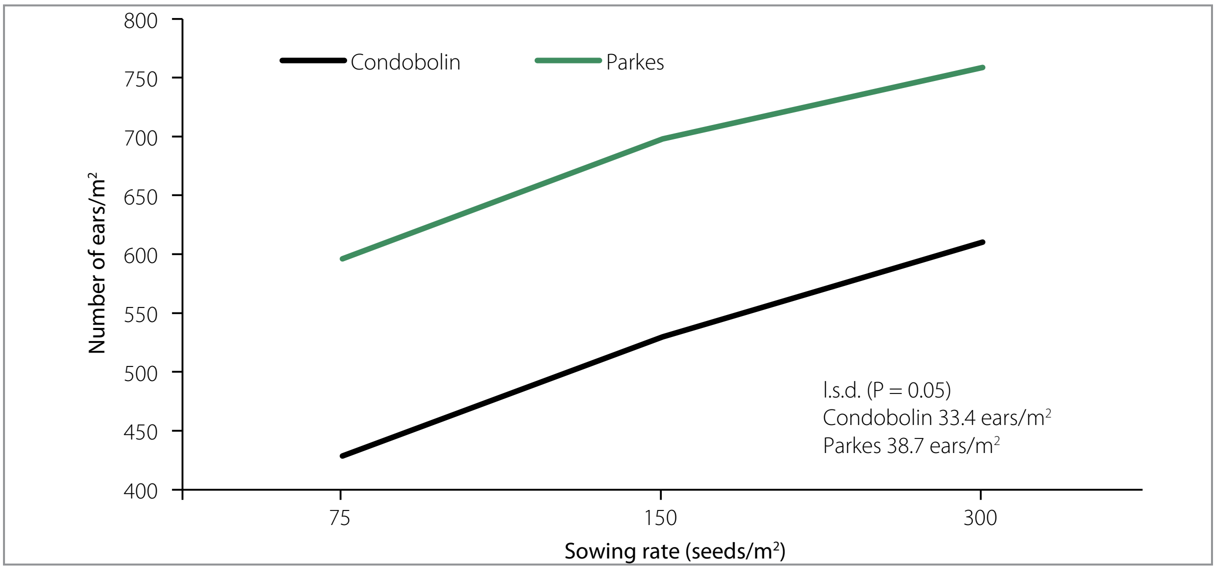

Figure 3. The effect of sowing density on number of ears/m² at anthesis across two sites in 2015.

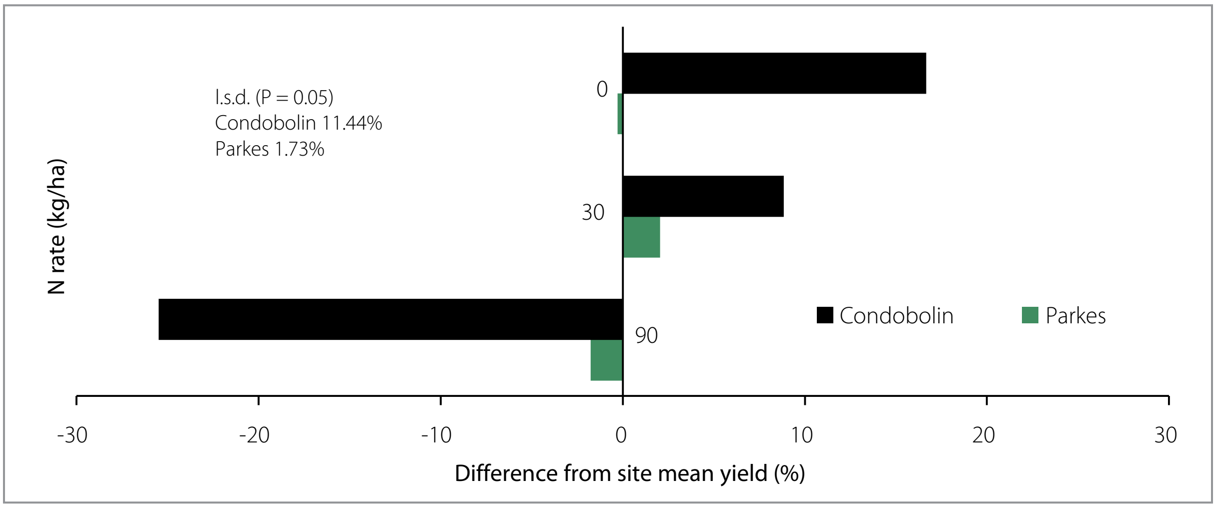

Figure 4. Yield difference under different N rates across two sites in 2015. The site mean for Parkes was 5.30 t/ha and the site mean for Condobolin was 0.79 t/ha.

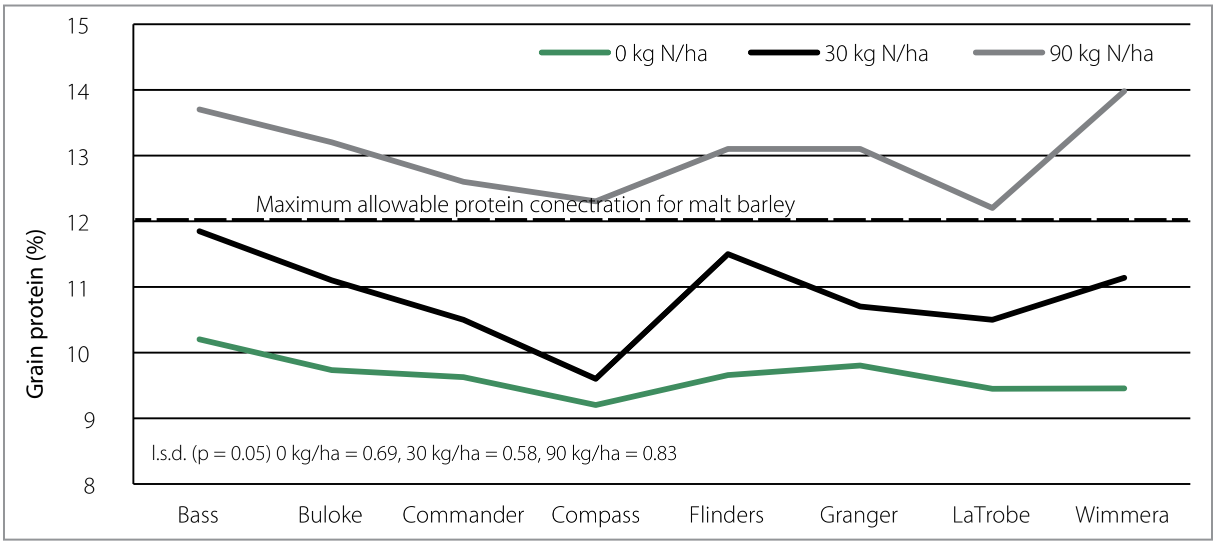

Figure 5. Grain protein concentration of eight barley varieties sown at Parkes and treated with 0, 30 and 90 kg/ha of N at sowing.

Screenings data indicated that seed rate had no significant effect on grain weight. Seed rate did not cause any significant difference to screenings above 2.5 mm, or below 2.2 mm sieve.

Nitrogen rate significantly decreased ($P < 0.001$) the material that was retained above the 2.5 mm sieve. As N rate increased from 0 to 90 kg/ha, retention decreased from 91.6% to 70.0%.

As N rates increased, the percentage of grain plumper than 2.5 mm decreased from 91.6% to 70.0%, while grain below 2.2 mm plumpness increased from 0.94% to 4.9% ($P < 0.0001$). In order to achieve malt standard, a barley sample must contain more than 70% of grain plumper than 2.5 mm and less than 7% of grain smaller than 2.2 mm.

Summary

The agronomic characteristics of both La Trobe and Compass made them the standout varieties at both Condobolin and Parkes in 2015. La Trobe, a successor and sister line to Hindmarsh, was malt accredited in 2015, and has demonstrated consistently competitive yields in both medium and low rainfall environments. Compass significantly out-yielded its predecessor Commander, at both sites, and has entered the malt accreditation process with its earliest accreditation date estimated as 2018. Compass and La Trobe demonstrated the lowest grain protein concentrations under all three N rates.

Seed and fertiliser are two of the most expensive inputs in sowing a crop. Understanding varietal responses to both sowing rates and nitrogen are vital in order to best tailor sowing rates and N fertiliser rates to particular varieties. Increased sowing rates did not have a significant effect on yields above 150 plants/m^2. N applied at 90 kg/ha significantly reduced yield at Condobolin, however at Parkes, there was no significant difference in yield when N rate was increased from 30 to 90 kg/ha. N rates of 90 kg/ha at Parkes did significantly decrease retention above 2.5 mm or increase screenings, demonstrating the necessity to properly manage N fertiliser applications. High rates of N need to be carefully managed when targeting malting grades. Sowing density did not affect grain plumpness, screenings or retention at Parkes.

Acknowledgements

This experiment was part of 'Management of barley and barley cultivars for the southern region', DAN00173, 2013–18, jointly funded by GRDC and NSW DPI.

Thank you to the Dubbo Broadacre Crop Evaluation Unit for sowing and harvesting the experiment. Matthew Burkitt and North Parkes Mine are gratefully acknowledged. The biometric analysis performed by Dr Neroli Graham, and technical assistance provided by Sarah Baxter, Daryl Reardon, Nick Hill, Fraser Campbell, Linda Brangwin and Kate Gibson is gratefully acknowledged.

Managing barley on acidic soil in southern NSW – Wagga Wagga 2015

Rohan Brill, **Paula Charnock**, **Warren Bartlett** and **Sharni Hands** NSW DPI, Wagga Wagga

Key findings

» There was no effect on barley yield from applying lime in this experiment, despite the low soil pH_{Ca} of 4.5, potentially due to the low levels of exchangeable aluminium in the soil.

» The highest yield came from planting either Compass or La Trobe on 8 May, applying 80 kg/ha of nitrogen (N) at sowing. Applying N did not increase grain yield in the 28 May sowing treatments.

» The acid tolerant barley variety Litmus yielded less than Compass or La Trobe from the 8 May sowing. Delayed sowing reduced the grain yield of Compass and La Trobe, but not of Litmus.

» Applying phosphorus (P) (20 P kg/ha) did not increase grain yield at either sowing time.

Introduction

Barley cultivation in southern NSW has increased markedly in recent seasons, especially in the higher rainfall zones of the South West Slopes where soils are often acidic. This experiment aimed to evaluate agronomic management options that enhance the yield potential on this specific soil type.

Site details

Soil type	Red dermosol (Table 1)
Previous crop	Canola
Rainfall	333 mm April–October + 160 mm December 2014–March 2015

Table 1. Soil test results for experimental site at Wagga Wagga – 1 May 2015.

	0–10 cm	10–30 cm	0–120 cm
pH (Ca)	4.5	4.7	–
Phosphorus (Colwell mg/kg)	71.0	13.0	–
Exc. aluminium (%)	3.8	3.7	–
Available nitrogen (kg/ha)			115.0

Treatments

Treatment details are summarised in Table 2. Three varieties were sown on two sowing dates. Within each sowing date and for each variety, a 'best bet' rate of nitrogen, phosphorus, fungicide and lime were applied at rates to maximise the yield, which becomes the 'All' treatment. In turn, each nitrogen treatment (80 kg N/ha, applied as urea pre-drilled), phosphorus (20 kg P/ha, applied as Triple Super at sowing), fungicide (300 mL/ha Prosaro applied three times before major rain events in June, July and August) and lime (4 t/ha lime applied and incorporated pre-sowing) were excluded to determine their absolute contribution to grain yield.

Table 2. Sowing date, varieties and treatments applied in a barley experiment at Wagga Wagga 2015.

Sowing dates	Varieties	Treatment	Treatment description
8 May 28 May	Compass La Trobe Litmus	All	N + P + fungicide + lime
		Nil N	P + fungicide + lime
		Nil P	N + fungicide + lime
		Nil lime	N + P + fungicide
		Nil fungicide	N + P + lime

Results

Early sowing resulted in higher grain yield for Compass and La Trobe (Table 3, Figure 1) but not for Litmus.

Table 3. Grain yield (t/ha) of three barley varieties (averaged across treatments) sown at two sowing dates at Wagga Wagga in 2015.

Variety	Grain yield (t/ha)	
	8 May	28 May
Compass	5.49	4.82
La Trobe	5.47	4.36
Litmus	4.70	4.55

Excluding N from the 'All' treatment resulted in a significant grain yield reduction (0.6 t/ha) from the early sowing, but not the later sowing (Figure 1).

Excluding fungicide resulted in a significant grain yield reduction from the later sowing (0.3 t/ha), but not the early sowing. There was no effect on grain yield from excluding lime or phosphorus at either of the sowing dates. Grain quality is yet to be analysed.

Summary

The most important management factors for improving barley yield on this acidic soil site were to sow either Compass or La Trobe early and to apply nitrogen, with delayed sowing and/or excluding nitrogen reducing grain yield. Despite the low soil pH at the site, there was no benefit from applying lime. The effect of liming might not have been apparent as it was applied close to sowing and the exchangeable aluminium level was quite low.

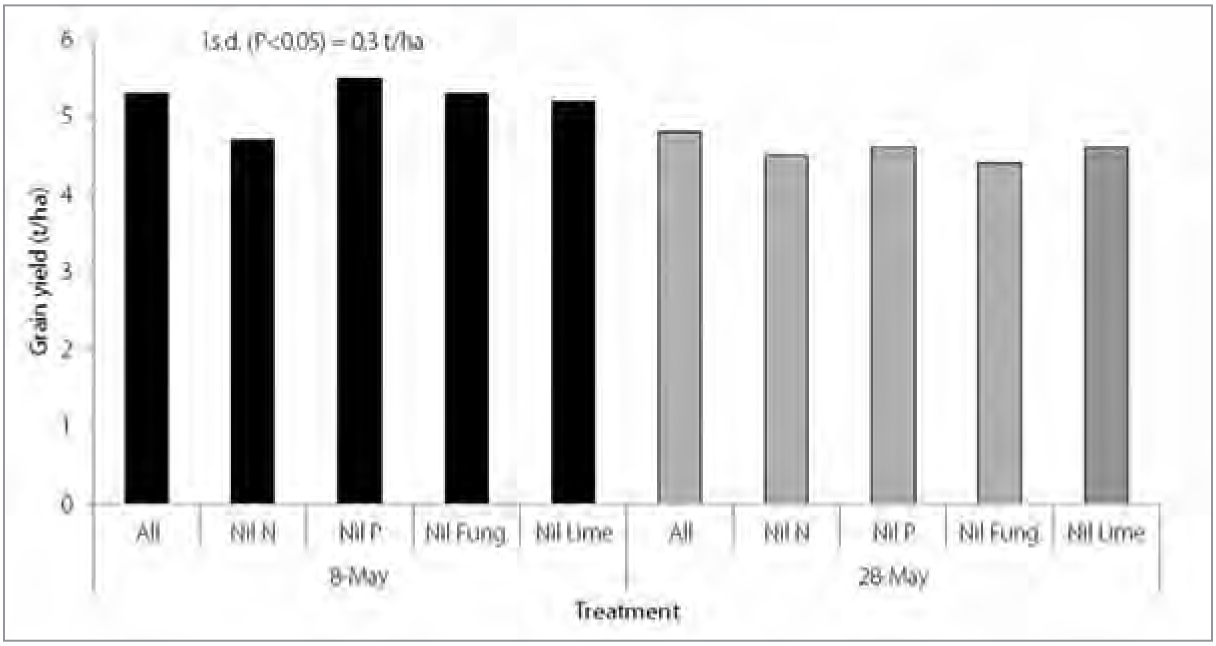

Figure 1. Effect of sowing date and treatment on grain yield of barley (average of three varieties) at Wagga Wagga in 2015.

Acknowledgements

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Factors affecting critical phosphorus values and responsiveness in different soil types

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Key findings

- The Making Better Fertiliser Decisions for Cropping Systems in Australia (BFDC) database allows us to search for soil test calibrations for four macronutrients across a range of crops, soils types, regions and time spans.
- As an example, the critical range for soil test P (Colwell) for wheat grown in red chromosols in NSW has increased under minimum-tillage management.

Introduction

The Making Better Fertiliser Decisions for Cropping Systems in Australia project (BFDC) aims to provide the fertiliser industry, agency staff, agribusiness advisors and growers with the knowledge and resources to improve nutrient recommendations for optimising crop production. The BFDC database is a national database of historical fertiliser response data for the main grain crops grown in Australia. BFDC is recognised by Fertilizer Australia, the peak body for the industry, as the best available data for supporting the decision tools that fertiliser industry members use as the basis for interpreting soil tests and formulating recommendations.

Fertiliser decisions made by grain growers and their advisers should all start with, and rely on, objective knowledge about their paddock fertility status. These decisions need to account for the plant nutrient requirements for growth, nutrient availability in soils, and nutrient losses that can occur during crop growth (e.g. de-nitrification or erosion).

Making better decisions about soil nutrient management and crop nutrition starts with gaining an understanding of how soil fertility fits into the whole crop production process. The BFDC Interrogator provides information about soil test critical levels for the four nutrients that frequently account for 20–30% of variable crop production costs: nitrogen (N), phosphorus (P), potassium (K) and sulfur (S).

Different soils have different critical nutrient ranges and differing P availability. Understanding your soil type and its critical P values is crucial to making informed fertiliser decisions in cropping. BFDC allows you to look at different soil types, cropping scenarios and many other agronomic factors that may come into play in a season.

Methodology

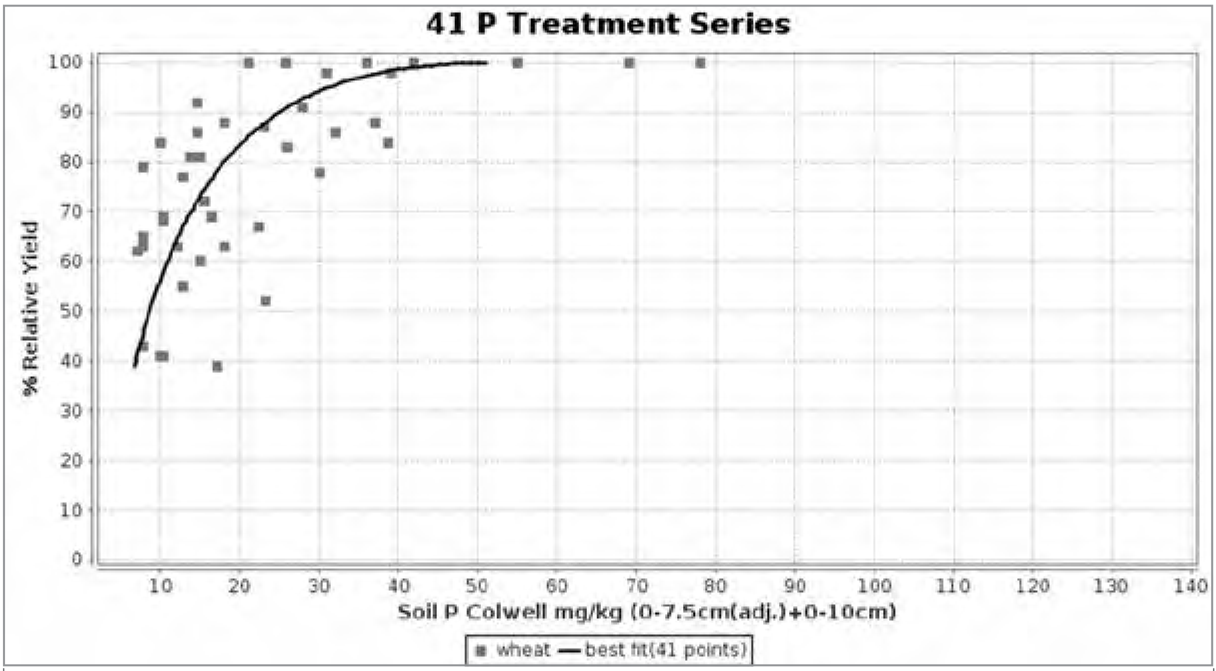
Fifty years of soil test crop response experiments were manually entered into the BFDC database. This historic data was then used, together with current research data sets, to produce soil test calibrations for N, P, K and S. The data is presented in critical nutrient levels for 80%, 90% and 95% of relative yield as well as a confidence range for the relative yield levels. The critical nutrient ranges are across all soil types and can be interrogated for many agronomic fields such as rainfall, soil pH and yield. The major crops are included in the database and the soils are classified under the Australian Soil Classification system. The data sets are classified into A and B data sets depending on how much information is supplied and the experiment's scientific vigour. When filters are applied to the database it can be interrogated to evaluate factors that can affect P responsiveness.

The BFDC database holds extensive historic data for 5698 key N, P, K and S experiment treatment series for different grain crops and soil types across Australia. Each experiment has a soil test and relative grain yield data that enables users to determine the critical soil test values for a range of management and growing conditions. These include farming system, growing season rainfall and paddock history.

The data set is currently still being added to by researchers from the More Profit from Crop Nutrition (MPCNII) program, as well as agency researchers and agribusiness via the online data entry tool.

Results and discussion

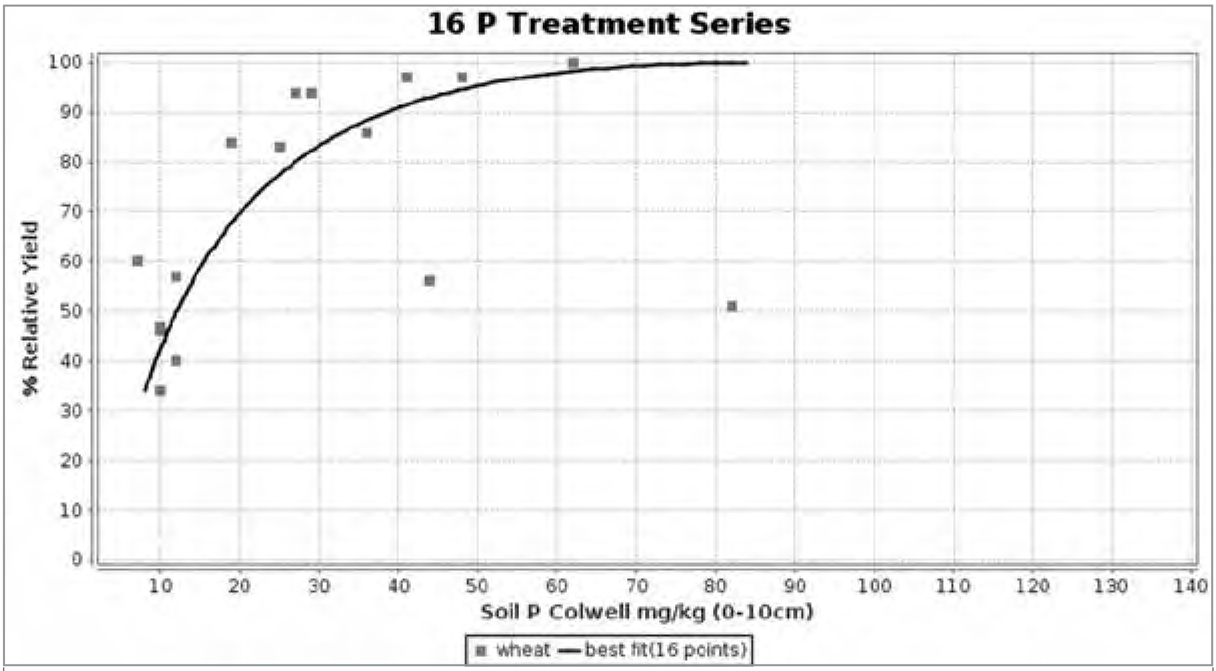
The database allows the authorised user to interrogate the database across different soil tests, tillage systems and growing seasons, which enables the user to calibrate a soil test crop response for their own particular conditions. For example, a consultant wishing to know the critical P range for wheat on a red chromosol can interrogate the database and find the levels required for 80%, 90% and 95% relative yield pre-1987 when full cultivation was common (Figure 1), or from 1990 when minimum tillage became more common (Figure 2).



Soil test calibration:

80% Relative yield: 18.0 (15.0–22.0)	Correlation R: 0.73	Slope RY(50–80): 3.2 (2.2–4.2)
90% Relative yield: 25.0 (20.0–31.0)	Regression equation: $x = e^{(2.2924(\arcsin(\mathrm{sqrt}(y/100))) + 0.35343)}$	
95% Relative yield: 31.0 (24.0–40.0)	70% confidence limit at 90% Relative Yield: 25.0 (22.0–28.0)	

Figure 1. Calibration of relative yield of wheat with Colwell P on red chromosols pre-1987.



Soil test calibration:

80% Relative yield: 27.0 (15.0–47.0)	Correlation R: 0.61	Slope RY(50–80): 2.0 (0.54–3.5)
90% Relative yield: 38.0 (20.0–75.0)	Regression equation: $x = e^{(2.5023(\arcsin(\mathrm{sqrt}(y/100))) + 0.52267)}$	
95% Relative yield: 49.0 (22.0–110.0)	70% confidence limit at 90% Relative yield: 38.0 (27.0–54.0)	

Figure 2. Calibration of relative yield of wheat with Colwell P on red chromosols post-1990.

The data shows that the apparent critical P range was lower under conventional tillage practice. This could be attributed to the nutrient stratification that can occur in minimum or no till situations. The P might be concentrated in the top few centimetres and not throughout the surface 10 cm where the crop can more readily access it.

Col McMaster, Research Agronomist at Cowra is continuing this work by evaluating response to different rates of P under contrasting cultivation regimes. Other team members are evaluating N × P interactions at high rates on N and the corresponding rates of P required to meet crop demand (projects UA00154, DAN00168).

Acknowledgements

This study is part of the project 'Making better fertiliser decisions for cropping systems in Australia (phase 2)' (DAN00166, 2012–17) and jointly funded by GRDC and NSW DPI.

See more at grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/BFDC-Interrogator#sthash.8XA7MxF6.dpuf

Critical external phosphorus requirements of pasture legumes

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NSW DPI, Wagga Wagga; **Dr Richard Simpson**, **Adam Stefanski** and **Dr Rebecca Haling**
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Key findings

- *Ornithopus sativus* (French serradella) was capable of yielding as much as *Trifolium subterraneum* (subterranean clover) with 30% less phosphorus (P).
- *Ornithopus compressus* (yellow serradella) required 30% less P than *T. subterraneum* to produce the maximum yield, however its maximum yield was often lower than that of *T. subterraneum*.

Introduction

This research aimed to determine the external critical phosphorus (P) requirement (i.e. the soil extractable-P concentration required to achieve 90% of maximum yield) of a range of pasture legume species under field conditions. This information can be used as a benchmark for soil testing and soil P fertility management on farms.

Sites

Four sites were established near Yass (340 56′54.02″ S and 1480 55′48.02″ E), Burrinjuck (340 52′11.80″ S and 1480 40′ 21.45″ S), Belfrayden (350 06′58.06″ S and 1460 59′34.51″ E) and Beckom (340 12′10.56″ S and 1470 01′59.22″ E) in southern NSW.

Procedures

Phosphorus was applied by hand from two pre-weighed bags per plot to establish six equal P fertility levels. Rates included 0, 15, 30, 45, 60 and 80 kg P/ha at Yass (2012) and Burrinjuck (2013) with slightly different rates of 0, 15, 30, 50, 65 and 85 kg P/ha at Belfrayden and Beckom (2014). P was applied as triple-superphosphate (P = 20.7%, S = 1.5%). Basal nutrients (potassium sulfate 100 kg/ha, magnesium sulfate 60 kg/ha, molybdenum trioxide 0.07 kg/ha, boric acid 1.75 kg/ha, copper sulfate 1.75 kg/ha and zinc sulfate 3.5 kg/ha) were applied at each site through a boom spray at 100 L/ha of water carrier.

Varieties tested in 2014 were inoculated with their appropriate rhizobia strain before sowing (Table 1). At peak spring growth, shoots were cut from three quadrats (200 × 500 mm) in each plot. Shoots were dried at 70 °C for 72 hours and weighed to provide an estimate of the dry matter production for each plot.

Soil P levels were determined at the time of the peak spring growth by sampling 24 cores (0–10 cm depth) from each plot. Soils were then homogenised and dried at 40 °C. Once dry, the soil samples were again homogenised and subsampled to determine the Colwell P extractable-P concentration (Colwell 1963).

Experimental designs were generated using DiGGer® (Coombes 2009) to produce a design that avoids row, column and diagonal treatment duplicates with three replicates, six P rates and 12 varieties. Where results for fewer than 12 varieties are shown (Table 1), it highlights variety failure at that specific location. Results were analysed using R version 3.3.1.1. Dry matter and soil test data were first analysed using Asreml and the fixed model applied as cultivar plus P rate with testing for linear column and row effects, which were checked for significance using the Wald test. The random model included row, column, rep and rep.plot effects with testing for auto-regressive correlations using loglik differences greater than 3.84. This analysis showed that P rate and cultivar effects were significant ($P > 0.05$), but not P rate × cultivar effects. Estimates of l.s.d. values at the 5% level were calculated for Colwell P and dry matter measurements. Fitted data from Asreml at the plot level was then used to fit Mitscherlich equation [y = a – b*(–cx)] where y is the shoot dry matter (kg/ha) and x is the soil Colwell P (mg/kg) to provide an estimate of critical Colwell P (i.e. the Colwell P concentrations coinciding with 90% of maximum dry matter).

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Results

Subterranean clover (cvs. Leura, Narrikup, Izmir) was used as a benchmark/control species as it is the most commonly grown legume in permanent pastures and mixed crop-pasture systems in southern Australia. It is also known to have a high critical external requirement for P, which is the basis of the soil test P benchmarks that are currently used for pasture management in southern Australia (Gourley et al. 2007; Moody 2007). Results for 2014 are presented below.

Table 1. Critical Colwell P requirements (mg P/kg soil) of pasture legumes determined as the soil test P (STP) concentration required to achieve either 90% of maximum herbage yield (kg dry matter/ha) for peak spring growth. Parameters were derived by fitting a Mitscherlich response (yield = a – b *(e – c*Colwell P)) to data collected from the Yass, Burrinjuck, Beckom and Belfrayden sites. Maximum yield is predicted by a, the asymptote; responsiveness to P is reflected in c, the curvature parameter; and the intercept (a-b) is an extrapolation reflecting yield at a theoretical Colwell P value of zero.

Site and species	Cultivar	90% Critical STP concentration (mg/kg)		Parameter		
		Colwell P	Intercept	a	b	c
Yass 2014						
Ornithopus compressus	Avila	20	-1305	3984	-5289	0.8801
Ornithopus compressus	Santorini	19	-977	5976	-6953	0.8784
Ornithopus sativus	Margurita	17	-2461	6987	-9448	0.8572
Trifolium subterraneum	Leura	31	-2095	6715	-8810	0.9200
T. subterraneum+ Lupinus albus	Leura + Luxor	19	-3293	5518	-8811	0.8663
Trifolium purpureum	Electra	25	-1898	5652	-7550	0.9015
Burrinjuck 2014						
Trifolium incarnatum	Dixie	20	-17915	10726	-28641	0.8502
Trifolium subterraneum	Leura	27	-5472	9489	-14961	0.9037
Ornithopus sativus	Margurita	17	-29840	9267	-39107	0.807
Trifolium michelianum	Bolta	22	-5474	11903	-17377	0.8836
Beckom 2014						
Trifolium spumosum	Bartolo	21	512	3542	-3030	0.902
Biserrula pelecinus	Casbah	18	-1764	2549	-4313	0.8524
Trifolium incarnatum	Dixie	19	1552	3618	-2066	0.9127
Trifolium hirtum	Hykon	19	-284	3117	-3401	0.8804
Trifolium subterraneum	Izmir	25	1052	2591	-1539	0.9323
Ornithopus sativus	Margurita	10	-1336	2576	-3912	0.7580
Trifolium subterraneum	Narrikup	26	746	3488	-2742	0.9234
Trifolium glanduliferum	Prima	33	296	2467	-2171	0.9356
Ornithopus compressus	Santorini	7	-102963	2009	-104972	0.385
Medicago truncatula	Sultan-SU	30	410	3631	-3221	0.9303
Trifolium vesiculosum	Zulu II	12	-2838	2945	-5783	0.7792
Belfrayden 2014						
Trifolium spumosum	Bartolo	39	460	7518	-7058	0.9436
Biserrula pelecinus	Casbah	42	1215	7012	-5797	0.9515
Trifolium incarnatum	Dixie	41	2518	9120	-6602	0.9531
Trifolium hirtum	Hykon	29	-3649	7421	-11070	0.9103
Trifolium subterraneum	Izmir	48	-52	6053	-6105	0.9528
Ornithopus sativus	Margurita	24	-1927	5054	-6981	0.8976
Trifolium subterraneum	Narrikup	48	2143	7489	-5346	0.9598
Trifolium glanduliferum	Prima	46	280	5694	-5414	0.9526
Ornithopus compressus	Santorini	24	534	4331	-3797	0.9125
Medicago truncatula	Sultan-SU	47	2508	6642	-4134	0.9617
Trifolium vesiculosum	Zulu II	24	-459	5694	-6153	0.9057
	l.s.d. (P = 0.05)	8.0				

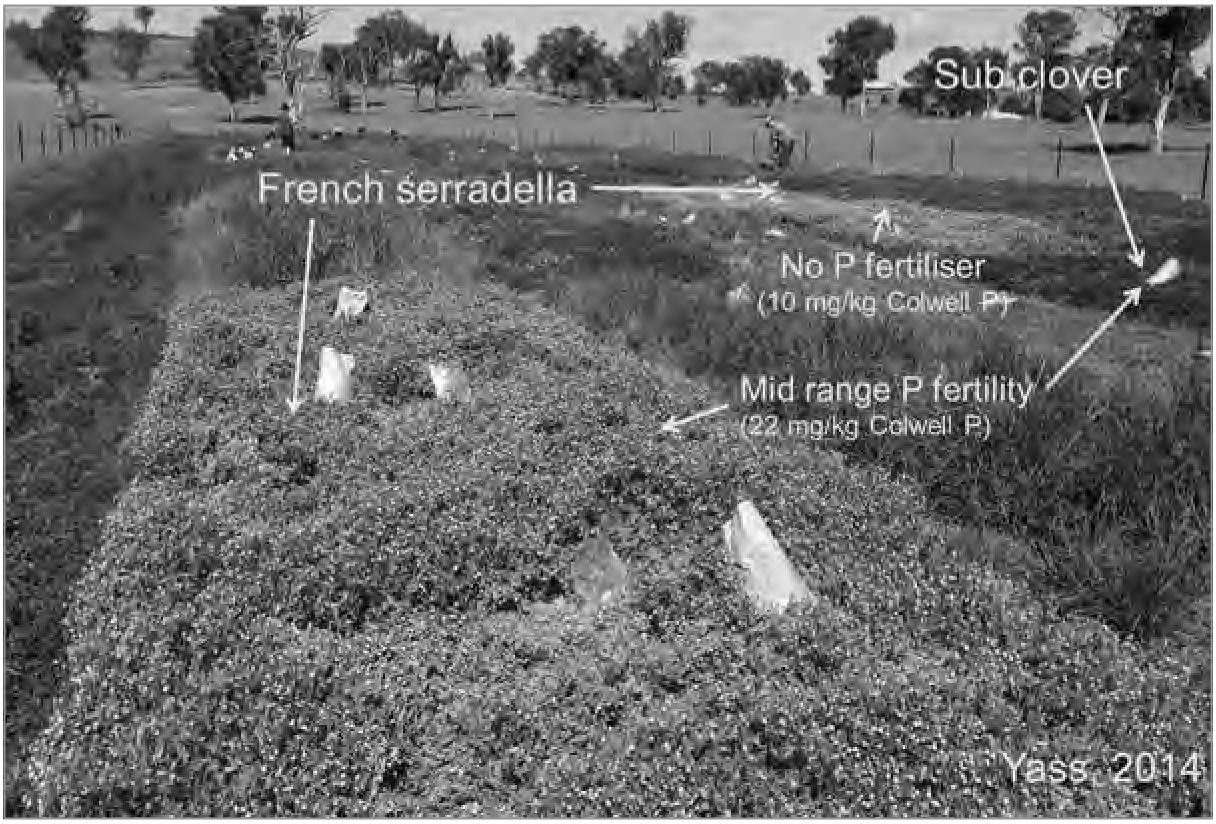

Figure 1. French serradella grown at 22 mg/kg Colwell P (foreground) and subterranean clover (back right) also grown at 22 mg/kg Colwell P.

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Yass

The critical Colwell P requirement of subterranean clover was 31 mg P/kg. Yellow serradella (cvs. Avila: 20 mg P/kg, Santorini: 19 mg P/kg) and French serradella (cv. Margurita: 17 mg P/kg) had critical Colwell P requirements approximately 60% of that for subterranean clover and yielded as well as subterranean clover (with the exception of cv. Avila). The mixture of white lupin and subterranean clover had a lower critical Colwell P requirement, but also a lower yield than the subterranean clover.

Burrinjuck

The critical Colwell P requirement for subterranean clover was 27 mg P/kg. French serradella (cv. Margurita) yielded as well as subterranean clover but had a critical Colwell P requirement of 17 mg P/kg. Crimson clover (cv. Dixie: 20 mg P/kg) and Balansa clover (cv. Bolta: 22 mg P/kg) yielded more than subterranean clover, but did not differ in critical P requirement.

Belfrayden

The critical Colwell P requirement of subterranean clover (cvs. Izmir and Narrikup) was 48 mg P/kg. Bladder clover (cv. Bartolo), Biserrula (cv. Casbah), gland clover (cv. Prima), crimson clover (cv. Dixie) and barrel medic (cv. Sultan-SU) had critical P requirements that did not differ from subterranean clover. Rose clover (cv. Hykon: 29 mg P/kg), French serradella (cv. Margurita: 24 mg P/kg), yellow serradella (cv. Santorini: 24 mg P/kg) and arrowleaf clover (cv. Zulu II: 24 mg P/kg) had critical P requirements up to half that of subterranean clover. Serradella species yields were not significantly different from subterranean clover cv. Izmir, but were lower than that of cv. Narrikup.

Beckom

Dry matter yields and critical P requirements were lower than those measured at Belfrayden. The critical Colwell P requirement of subterranean clover (cvv. Izmir and Narrikup) was 25–26 mg P/kg. French serradella (cv. Margurita: 10 mg P/kg), yellow serradella (cv. Santorini: 7 mg P/kg) and arrowleaf clover (cv. Zulu II: 12 mg P/kg) had critical P requirements less than half that of subterranean clover. The French serradella yield was not significantly lower than that of subterranean clover. The remaining clover species, barrel medic (cv. Sultan-SU: 30 mg P/kg) and biserrula (cv. Casbah 18 mg P/kg) had similar critical P requirements and yields to subterranean clover (25–26 mg P/kg).

Conclusion

The field experiments have identified for the first time that French serradella (cv. Margurita) has a significantly lower critical P requirement than subterranean clover and is also capable of producing equivalent peak spring biomass. This result, similar to that for yellow serradella, confirmed the substantial differences in critical STP requirements of the serradella species relative to subterranean clover. These differences in external P requirement occurred whilst roots of all species were highly colonised by arbuscular mycorrizhal fungi, despite their reputed role in P nutrition of pasture legumes. The results indicate that the serradella species could potentially be used to achieve productive, low P-input pasture systems.

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Understanding differences in critical external phosphorus requirements of pasture legumes

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Key findings

» *Ornithopus sativus* (French serradella) and *O. compressus* (yellow serradella) had a significantly high root hair cylinder volume compared with *Trifolium subterraneum*, which provides for a great phosphorus (P) foraging ability and helps explain why the *Ornithopus* species has lower critical P requirements than *T. subterraneum*.

Introduction

This research identified the plant traits most likely to determine differences in external critical phosphorus (P) requirements (i.e. the soil extractable-P concentration required to achieve 90% of maximum yield) of pasture legume species. Understanding trait differences that affect critical P requirements of pasture legumes is important in providing confidence around field differences in external critical P requirement.

Experiment

A glasshouse experiment was established to identify the traits influencing the external critical P requirement of pasture legumes. Twelve pasture legumes (Table 1) were sown at a rate of 50 mg of viable seed per pot. After seven days, pots were inoculated with a slurry of peat containing an appropriate rhizobium strain and placed in a temperature-controlled glasshouse (maximum 20 °C, minimum 16 °C) under natural light (July–August, Wagga Wagga, NSW, Australia).

PVC pots (90 mm diameter; 210 mm height) were filled with 1.2 kg of a low P soil (6 mg/kg Colwell P) with no applied P (subsoil 50–200 mm depth). An additional 403 g of P-amended (topsoil 0–50 mm depth) was then added to the top of each pot. Five replicates of each P rate (0, 15, 30, 60, 90, 140 and 250 mg/kg) were prepared for each pasture legume species. This was used to mimic the stratification of P that occurs with surface fertiliser application on pastures.

Pots were maintained at approximately 80% field capacity by watering to weight three times a week. Plants were harvested six weeks after sowing. Shoots were cut at soil level. Soil was removed from the pot as an intact core and cut at the interface of the P-amended topsoil (0–48 mm height) and un-amended subsoil.

Table 1. Rhizobium inoculant group and strain for different pasture species.

Scientific name	Common name	Cultivar	Rhizobium inoculant group and strain
Ornithopus compressus L.	yellow serradella	Santorini	Group S, WSM471
Ornithopus sativus Brot.	French serradella	Margurita	Group S, WSM471
Biserrula pelecinus L.	biserrula	Casbah	Biserrula special, WSM1497
Trifolium michelianum Savi.	balansa clover	Bolta	Group C, WSM1325
Trifolium vesiculosum Savi.	arrowleaf clover	Zulu II	Group C, WSM1325
Trifolium glanduliferum Boiss.	gland clover	Prima	Group C, WSM1325
Trifolium hirtum All.	rose clover	Hykon	Group C, WSM1325
Trifolium purpureum Loisel.	purple clover	Electra	Group C, WSM1325
Medicago truncatula Gaertn.	barrel medic	Sultan-SU	Group AM, WSM1115
Trifolium incarnatum L.	crimson clover	Dixie	Group C, WSM1325
Trifolium spumosum L.	bladder clover	Bartolo	Group C, WSM1325
Trifolium subterraneum L.	subterranean clover	Leura	Group C, WSM1325

Roots were washed from each section of the topsoil core, and the entire core of subsoil. Roots from one of the quarters of the topsoil core were immediately scanned using a flatbed scanner and analysed for root length and average root diameter using WinRHIZO (Regent Instruments Inc., Quebec, Canada). Using these roots, two images of fully elongated root hairs were taken using a Nikon SMZ25 stereomicroscope fitted with a high resolution DS-Fi2 digital camera and digital sight DS-U3 camera controller.

Shoots and roots were dried at 70 °C before being weighed for dry mass. Root dry mass from the quarter of topsoil that was scanned was used to calculate specific root length (length per unit dry mass). The total length of roots in the topsoil was then calculated based on the total dry mass measured in the topsoil and the specific root length of the scanned quarter. Root hair length was determined by measuring the length of 10 root hairs (five per image) using the software package ImageJ (Rasband 1997–2014).

Results

Shoot dry matter

Maximum shoot dry matter ranged from 1.75 g/pot (*Biserrula pelecinus*) to 2.53 g/pot (*Medicago truncatula*) (1.4-fold) while critical external requirements for P ranged from 57 (*Ornithopus sativus*) to 203 mg applied P/kg soil (*Trifolium subterraneum*) (3.6-fold, Figure 1). Lower critical external requirements for P were not associated with a lower maximum yield. The *Ornithopus* spp. had significantly lower critical external requirements for P than all other species (57–63 mg applied P/kg soil).

Root dry matter

Topsoil root dry matter for most species increased in response to declining P. However, species generally reached a low-P threshold below which root dry matter was not maintained. Both the peak in topsoil root dry matter and the rate of P application at which it occurred varied between species. *Trifolium subterraneum* and *T. versiculosum* had the most prominent peaks in topsoil root dry matter (0.52–0.47 g) and these peaks occurred at a higher rate of P application (90 mg P applied/kg) than that observed for any other species.

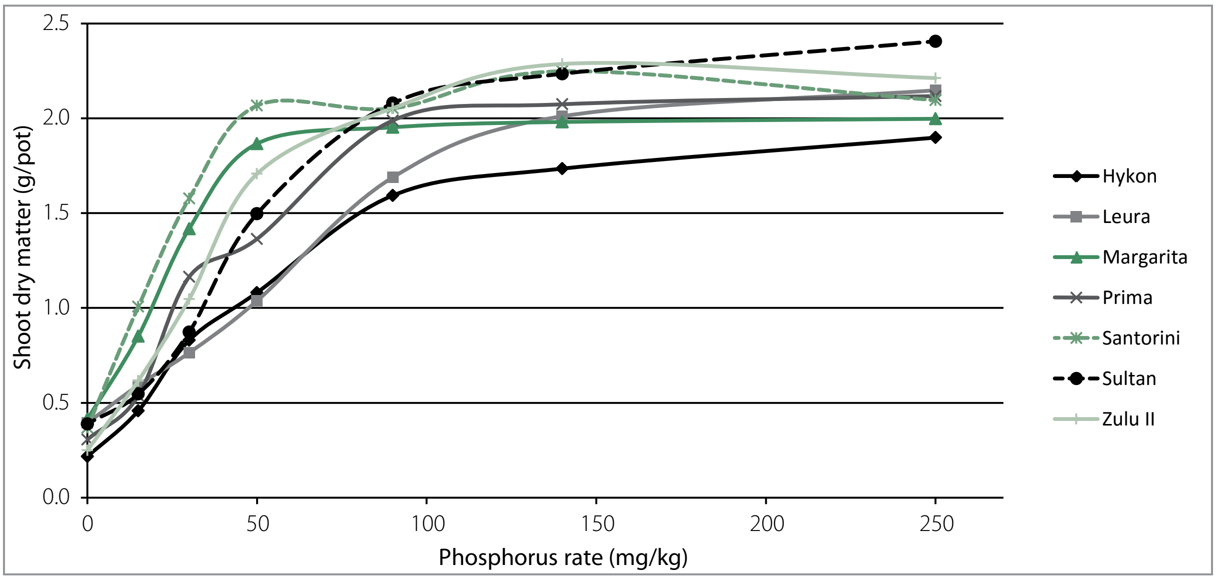

Figure 1. Shoot dry matter in response to P applied for seven of the 12 legume species. l.s.d. = 0.05 g for species × P applied ($P < 0.05$; n = 5).

Root hair cylinder volume (RHCV)

RHCV of the species increased between 2.0 (*T. purpureum*) and 4.3-fold (*O. compressus*) in response to low P supply (figures 2 and 3). The *Ornithopus* spp. and *B. pelecinus* achieved the largest root hair cylinder volumes (136–168 cm^3), which represented approximately 50% of the volume of the topsoil. These maximums occurred at very low levels of applied P relative to most other species (15–30 mg P applied kg). *Trifolium subterraneum* consistently had amongst the lowest root hair cylinder volumes (up to 41.7 cm^3), which represented less than 15% exploration of the volume of the topsoil. Amongst the species, the specific surface area of the root hair cylinder (i.e. surface area of root hair cylinder per unit root dry mass) was negatively correlated with the critical external P requirement. The relationship was generally strongest at lower levels of applied P (e.g. at 15 mg/kg R^2 = 0.87).

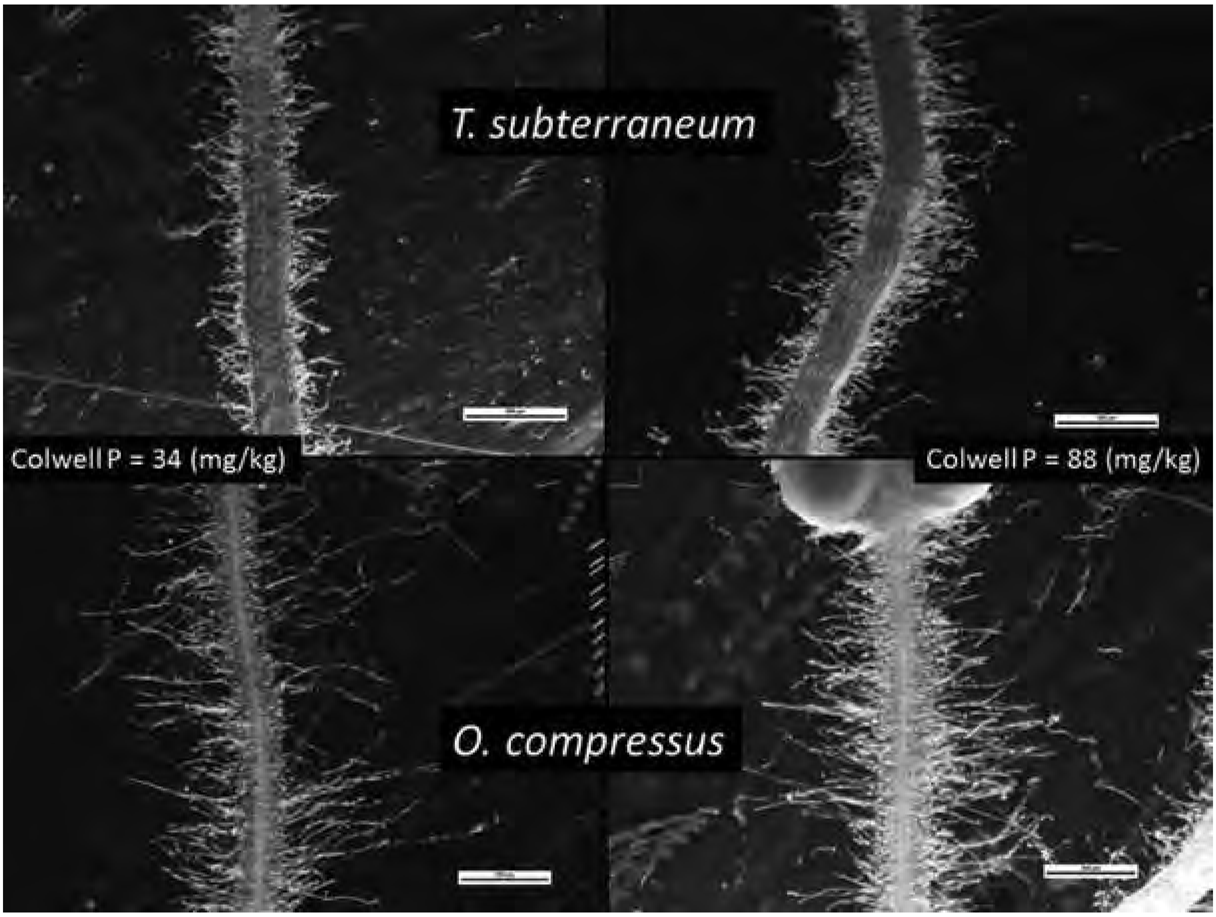

Figure 2. Root hairs of *T. subterraneum* cv. Leura (top half) and *O. compressus* cv Santorini (bottom half) at Colwell P levels of 34 (left hand side) and 88 mg/kg (right hand side). Scale bar: 500 micrometres.

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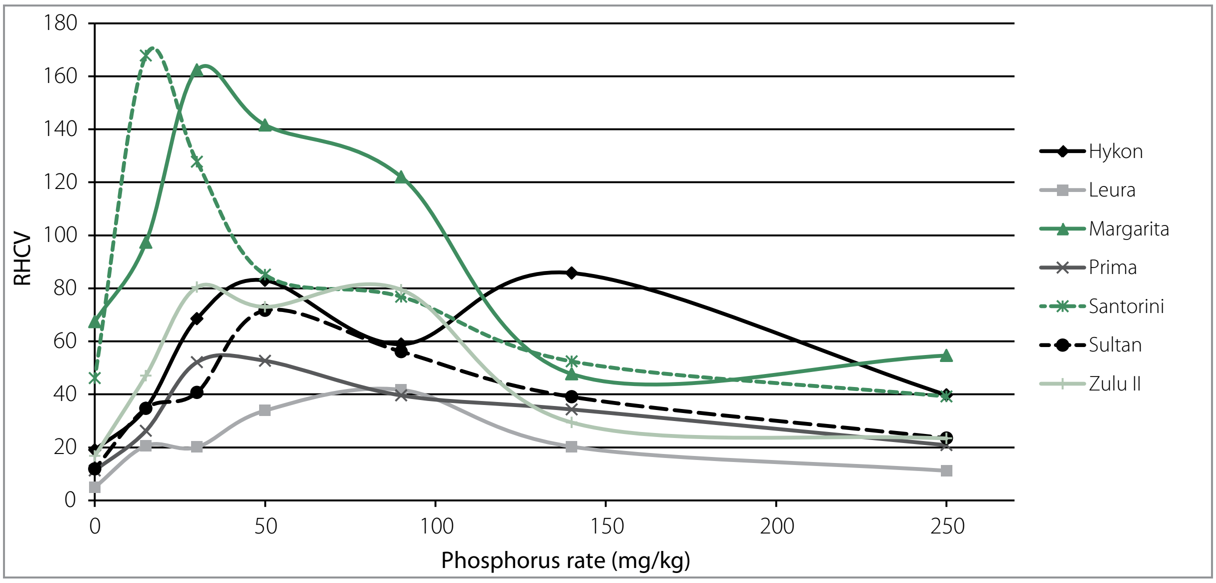

Figure 3. Root hair cylinder volume (RHCV) in response to P applied for seven of the 12 legume species. l.s.d. = 0.05 for species × P applied (P <0.05; n = 5).

Discussion

Long roots combined with long root hairs resulted in a large RHCV, which proved to be an efficient strategy for acquiring P and maximising shoot growth in lower P soils. Among the wider range of species in the present experiment, the *Ornithopus* species demonstrated the greatest ability to achieve a large root hair cylinder. Consistent with findings by Yang et al. (2015) and Haling et al. (2016), *T. subterraneum* ranked amongst the poorest species for nutrient foraging potential because of its very short root hairs.

Conclusion

The results indicate that the *Ornithopus* species has a greater P foraging ability than *T. subterraneum*, which is likely to explain the lower external critical P requirement of *Ornithopus* species. This is further supported by data showing that internal P efficiencies were similar for all legume species. The very low ranking of *Ornithopus* species critical P requirements relative to *T. subterraneum* suggests that pastures based on the *Ornithopus* spp. could deliver an approximately one third reduction in P fertiliser inputs.

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Acknowledgements

Meat and Livestock Australia, along with Australian Wool Innovation, NSW DPI, CSIRO and UWA financially supported this research through the project 'Phosphorus efficient legume pasture systems' (B.PUE.0104). Results presented here are a small component of a larger research effort supported by the above organisations.

Increasing on-farm adoption of broadleaf species in crop sequences to improve grain production and profitability

Dr Guangdi Li, **Richard Lowrie**, **Graeme Poile** and **Adam Lowrie** NSW DPI, Wagga Wagga

Key findings

- The rotation with canola as a single break crop (canola–wheat–wheat rotation) had the highest average gross margin ($529/year) across three years.
- The profit/cost ratio was the highest when canola was used as a single break crop (2:8) and the lowest for all brown manure treatments as well as continuous cereal without nitrogen input.

Introduction

Including break crops into cropping rotations can improve soil fertility and give growers more options to manage difficult weeds as well as control crop diseases. However, the high input cost and low/variable income from break crops give growers an impression that broadleaf options are not as profitable as cereals. Indeed, some of the management options, such as brown manuring grain legume crops, will result in nil income for the year. The question is whether the nitrogen (N) benefits to subsequent cereals from the break crops, and savings from weed control, could offset the loss of income from break crops in the longer term.

At the Graham Centre site at Wagga Wagga, a four-year crop sequence experiment was conducted from 2011–2014 that focused on the N benefits of break crops to subsequent crops. There were three sets of treatments phased across years with single break (break crop used once in four years) and double breaks (break crop used twice in four years) with a range of crop sequences.

The break crops were canola, lupins, field pea, vetch or high density legume pasture. Wheat–wheat–wheat with and without N were used as control. Field peas were harvested for grain or brown manured at peak dry matter (DM), vetch and legume pasture was cut for hay or brown manured at peak DM, and lupins and canola were harvested for grain.

Figure 1. Crop sequence experiment at Paddock 45 in spring 2013.

Results

Grain yield

Grain yield increased significantly for the first wheat crop following any break crop (field pea, vetch and pasture) when brown manured (Table 1). The benefit from break crops diminished in the second wheat crop (in year three (Y3)) although the grain yields tended to be higher on the brown manure treatment. When field pea was brown manured, grain yield from the first wheat crop in year two (Y2) was 10% higher than field pea harvested for grain in year one (Y1) ($P = 0.055$). In contrast, when pasture was brown manured, the wheat grain yield in Y2 was 18% higher than pasture cut for hay in Y1. There was no difference in grain yield when vetch was brown manured or cut for hay.

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Table 1. Crop yield for the various crops under different crop management.

2011	Crop	2012	2013	Grain (t/ha)		
Y1	management	Y2	Y3	Y1	Y2	Y3
Field pea	Grain	Wheat	Wheat	2.5	3.5	3.5
	Brown manured	Wheat	Wheat		3.7	4.1
	Significance				P = 0.055	n.s.
Vetch	Hay cut	Wheat	Wheat		3.4	3.6
	Brown manured	Wheat	Wheat		3.7	3.8
	Significance				n.s.	n.s.
Pasture	Hay cut	Wheat	Wheat		3.1	3.5
	Brown manured	Wheat	Wheat		3.6	3.6
	Significance				P = 0.01	n.s.
Wheat+N	Grain	Wheat–N	Wheat–N	5.2	2.4	3.1
	Grain	Wheat+N	Wheat+N		3.5	3.6
	Significance				P <0.05	P <0.05

n.s. not significant.

Under brown manure treatments, there was no difference in wheat grain yield in Y2 between break crops (field pea, vetch and pasture) (Table 1). For the second wheat crop, the grain yield from the field pea brown manure treatment was significantly higher than those from vetch and pasture. For the hay cut treatment, wheat following vetch produced more grain than that following pasture (Table 1). There was no difference in grain yield whether wheat crops followed field pea or lupins in Y2 or Y3.

For continuous cereal (control), the grain yield was 48% higher on the 75 kg N/ha treatment (25 kg N/ha at sowing and 50 kg N/ha at tillering) compared with the nil N treatment (Table 1). The yield increase was lower in Y3 compared with Y2. However, the grain yield from the N treatment was much lower than those following break crops, indicating that the N benefit from break crops was greater than fertiliser N for at least two wheat crops after the break crop.

Gross margin analysis

Gross margin analysis showed that averaged across two phases, the rotation with canola as a single break crop (canola–wheat–wheat rotation) had the highest average gross margin ($529/year) across three years (Table 2). Cutting for hay significantly improved financial return for the rotation including vetch ($482/year) or pasture ($453/year) as a break crop compared with the brown manure option, which is higher than the continuous-wheat option with N fertiliser applied. Due to the loss of a year's income when break crops were brown manured, the gross margin was lower than grain harvested.

The profit/cost ratio was the highest when canola was used as a single break crop (2:8) and the lowest for all brown manure treatments as well as continuous cereal without N input (Table 2). Results indicated that the nitrogen benefit from the brown manured treatments itself could not offset the cost of establishment of break crops and loss of production. Nevertheless, the brown manure option could offer a great opportunity to reduce herbicide cost if the paddock has a weed problem, or had herbicide-resistant weeds.

In general, the double break crop option improves the gross margin of all the crop management options, particularly for the brown manure options. The gross margin increased more than $100/year when canola was used as a break crop in combination with the brown manure option with pasture and pea, compared with rotation with a single break crop (Table 2).

Pasture cutting for hay with one canola crop as double-break crops had the highest gross margin ($524/year), which is much higher than continuous cereals with N fertiliser. Double-break crops offer more opportunity to reduce disease incidence, as well as more options to control difficult weeds.

Table 2. Average gross margin analysis under different crop sequences at the Graham Centre site.

Crop management	Treatment	Income	Variable cost	Gross margin	Profit/cost ratio
Single break					
Brown manure	Pea	$558	$255	$303	2.2
	Vetch	$553	$257	$296	2.2
	Pasture	$530	$246	$284	2.2
Hay	Vetch	$825	$342	$482	2.4
	Pasture	$776	$323	$453	2.4
Grain	Pea	$695	$287	$407	2.4
	Lupin	$682	$279	$403	2.4
	Canola	$826	$297	$529	2.8
Double break					
Brown manure	Pasture	$664	$271	$393	2.5
Brown manure	Pea	$678	$277	$401	2.4
Hay	Pasture	$853	$328	$524	2.6
Grain	Lupin	$781	$295	$486	2.6
Grain	Pea	$770	$301	$469	2.6
Continuous cereals					
Grain	+N	$875	$415	$460	2.1
Grain	–N	$663	$274	$390	2.4

Acknowledgments

This experiment is part of the project 'Facilitating increased on-farm adoption of broadleaf species in crop sequences to improve grain production and profitability', CSP00146, 2012–15, jointly funded by NSW DPI and GRDC.

Options for reducing nitrous oxide emissions from dryland cropping in the southern NSW grains region

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Key findings

- Nitrous oxide (N_2O) emissions respond to large rainfall events.
- Most N_2O emissions were generated after the crop was harvested.
- Tillage did not increase N_2O emissions significantly in the first two years under wheat and canola.
- Including perennial grass into legume-based pastures would reduce N_2O emissions.

Introduction

A four-year rotational experiment with wheat–canola–legumes–wheat in sequence was established at Wagga Wagga in 2012. The soil is a red kandosol and the long-term average rainfall at the site is 541 mm.

The objectives were to:

1. reduce nitrous oxide emissions from dryland grains cropping.
2. improve nitrogen use efficiency.
3. validate and develop process-based biogeochemistry models.
4. simulate net greenhouse gas emission under current and projected future climate scenarios.

This article reports on the N_2O emissions from different crops under different tillage systems.

Treatment and design

The crop sequence was wheat–canola–legumes–wheat from 2012 to 2015. The experimental area was divided into four quadrants. The gas emissions equipment was installed in one quadrant and moved to another quadrant each year (Figure 1).

The experimental design was a randomised split-plot design with tillage (tilled vs. no-till) for the whole plot and nitrogen rates (0, 20, 50 and 100 kg N/ha) as subplots in 2012 (year 1) and 2013 (year 2), or legume types as subplots in 2014 (year 3).

In 2014, grain legumes (field pea and lupins) were either harvested for grain or brown manured. Forage legumes (vetch and annual legumes) were either cut for hay or brown manured.

In 2015 (year 4), a wheat crop was sown to capture any residual nitrogen fixed from the legume crops. The N_2O emission from legume-derived nitrogen was measured during the final crop (wheat).

Measurements

An automated gas chromatograph system was setup on the site (Figure 2). The system consisted of 12 pneumatically operated static chambers linked to an automated sampling system to measure N_2O, CH_4 and CO_2 eight times a day over 24 hours for three years. Manual chambers (24 chambers) were also installed to cover more treatments than the automated system allowed.

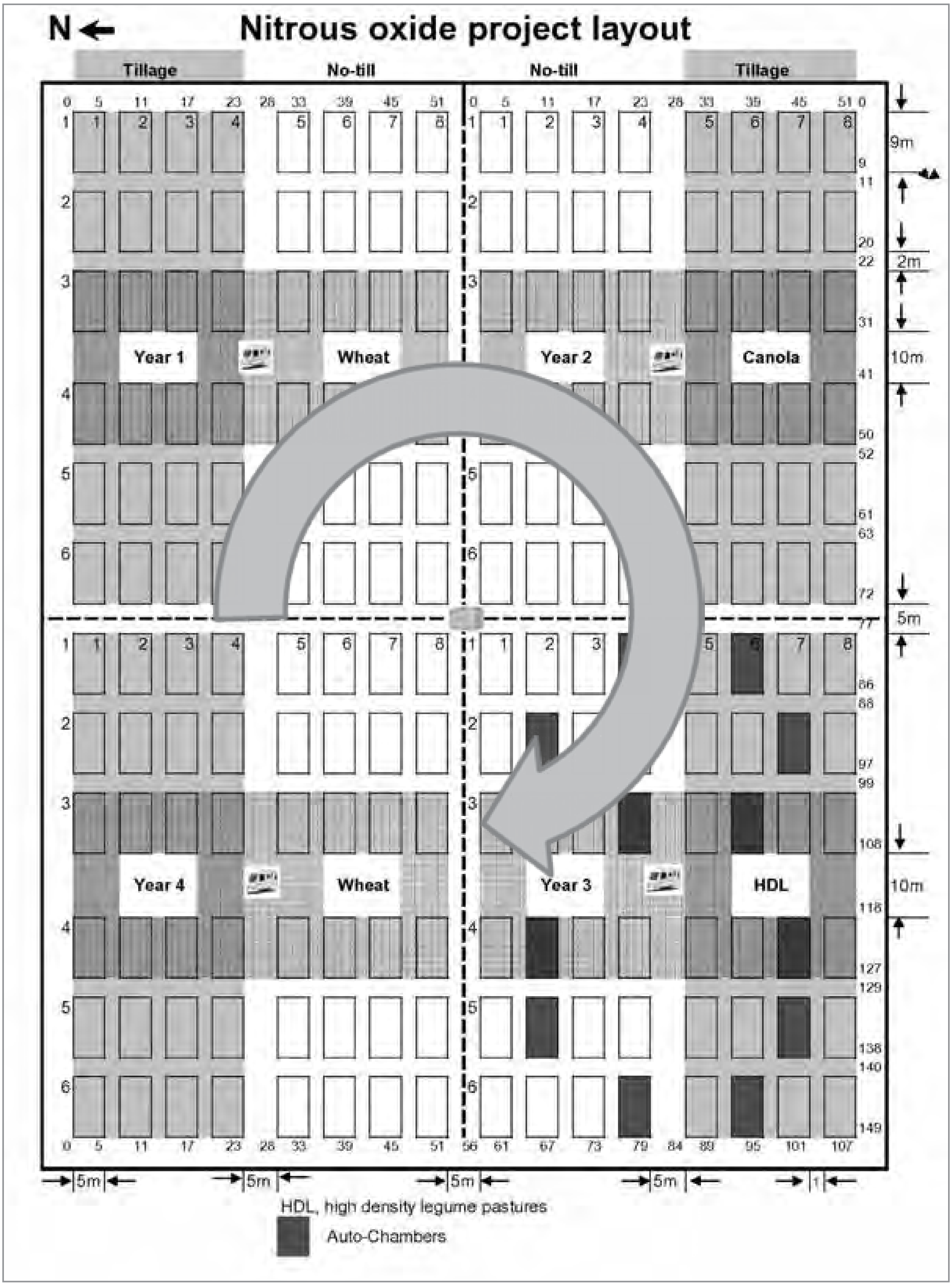

Figure 1. Crop sequence and treatment layout for the N_2O project.

Figure 2. An automated greenhouse gas measurement system setup with solar power supply. Dr Yantao Song is taking gas samples in the field (bottom right).

Results

N_2O emission under crops

Total N_2O emitted was 81–343 g N_2O-N/ha for a wheat crop in 2012 and 154–354 g N_2O-N/ha for a canola crop in 2013 (Table 1). The daily N_2O emission rate was relatively low ranging from –0.81 to 6.71 g N_2O-N/ha/day measured from auto-chambers on canola in 2013. These losses are comparable with those recorded for rain-fed wheat in other temperate regions of south-eastern Australia.

The emission factor (%N emitted as N_2O compared with N applied in fertiliser) averaged 0.06% based on data over two years. This was nearly identical to that measured from a canola crop grown on a sandy soil (0.06%) in Western Australia, but only a quarter of the current emission factor for all non-irrigated N-fertilised crop in Australia (0.2%).

There was no significant difference in N_2O emissions between tillage and no-till treatment in any year. However, applying N fertiliser at a higher rate increased N_2O emissions compared with nil nitrogen treatments (Table 1).

In a wheat crop in 2012, the nitrogen inhibitor Entec® significantly reduced N_2O emissions compared with normal urea, but no difference was detected between normal urea and Green Urea™ (urease inhibitor). For the canola crop in 2013, there was no difference in N_2O emissions between nitrogen rates when Entec® was used.

There was no yield benefit from using N inhibitors. As a result, the gross margin was lower when N inhibitors were used simply due to the higher input costs.

Table 1. N_2O emissions and emission factors.

Treatment	N rate (kg N/ha)	N_2O-N emission (g/ha)		Significance	Emission factor (%)	
		No-till	Till		No-till	Till
Wheat – 2012		**Manual chambers (219 days from 7/8/2012 to 14/3/2013)**				
Urea	0	81	130	Tillage, NS		
	100	179	294	N rate, P <0.01	0.10	0.16
Entec®	100	105	218	N type, P <0.05	0.02	0.09
Green Urea™	100	172	343		0.09	0.21
Canola – 2013		**Manual chambers (334 days from 23/5/2013 to 22/4/2014)**				
Entec®	0	250	332			
	25	305	354	Tillage, NS	0.05	0.02
	50	319	305	N rate, NS	0.07	-0.03
	100	300	306		0.05	-0.03
Canola – 2013		**Auto-chambers (366 days from 23/5/2013 to 22/4/2014)**				
Urea	0	154	196	Tillage, NS		
	100	186	263	N rate, P = 0.058	0.03	0.07

There was a distinct seasonal variation in N_2O emission rates that followed the rainfall pattern, though temperature changes could also have contributed. Significant rainfall events stimulated N_2O emissions, particularly summer storms delivering more than 10 mm of rain (Figure 3). Most N_2O emissions occurred after the crop was harvested.

Immediately after tillage and sowing operations (tillage on the tilled treatments was carried out one day before sowing), N_2O emission from both tilled and no-till treatments increased coinciding with two significant rainfall events in late May and June (Figure 3). The N_2O emissions were slightly higher in the tilled treatment during winter, late spring, early summer and early in the following autumn compared with the no-till treatment. However, there was no overall significant difference in daily N_2O emitted between tilled and no-till treatments.

N_2O emission under legumes

There were no significant differences in N_2O emissions between different legume crops under different crop managements. However, N_2O emissions tended to increase after tillage compared with no-till treatments (P = 0.09) (Table 2). Averaged across all crops, the cumulative N_2O emission was 354 g N_2O-N/ha/day under tillage treatment and 280 g N_2O-N/ha/day under no-till treatment. No-till treatment reduced N_2O emission by 21% compared with tillage treatment (Table 2).

Table 2. N_2O emission under legumes.

Legumes – 2014	Manual chambers (279 days from 28/5/14 to 3/3/15)			
Crop type	No-till	Till	Significance	Emission reduction
Lupin (grain harvested)	255	335		23.9%
Pea (grain harvested)	280	353	Tillage, P = 0.09	20.6%
Vetch (hay cut)	262	334	Crop type, NS	21.5%
Pasture (hay cut)	321	394		18.4%
Mean	280	354		21.0%
Pasture – 2013–2015	**Manual chambers 658 days from 14/5/2013 to 3/3/15)**			
Treatment	N_2O-N emission (g/ha)		Emission reduction	
Lucerne monoculture (L)	517			
Subclover monoculture (S)	417		-19.3% (L vs S)	
Phalaris–lucerne mix (PL)	438			–15.2% (L vs PL)
Phalaris–subclover mix (PS)	405		-7.6% (PL vs PS)	–3.0% (S vs PS)
Significance	P = 0.057			

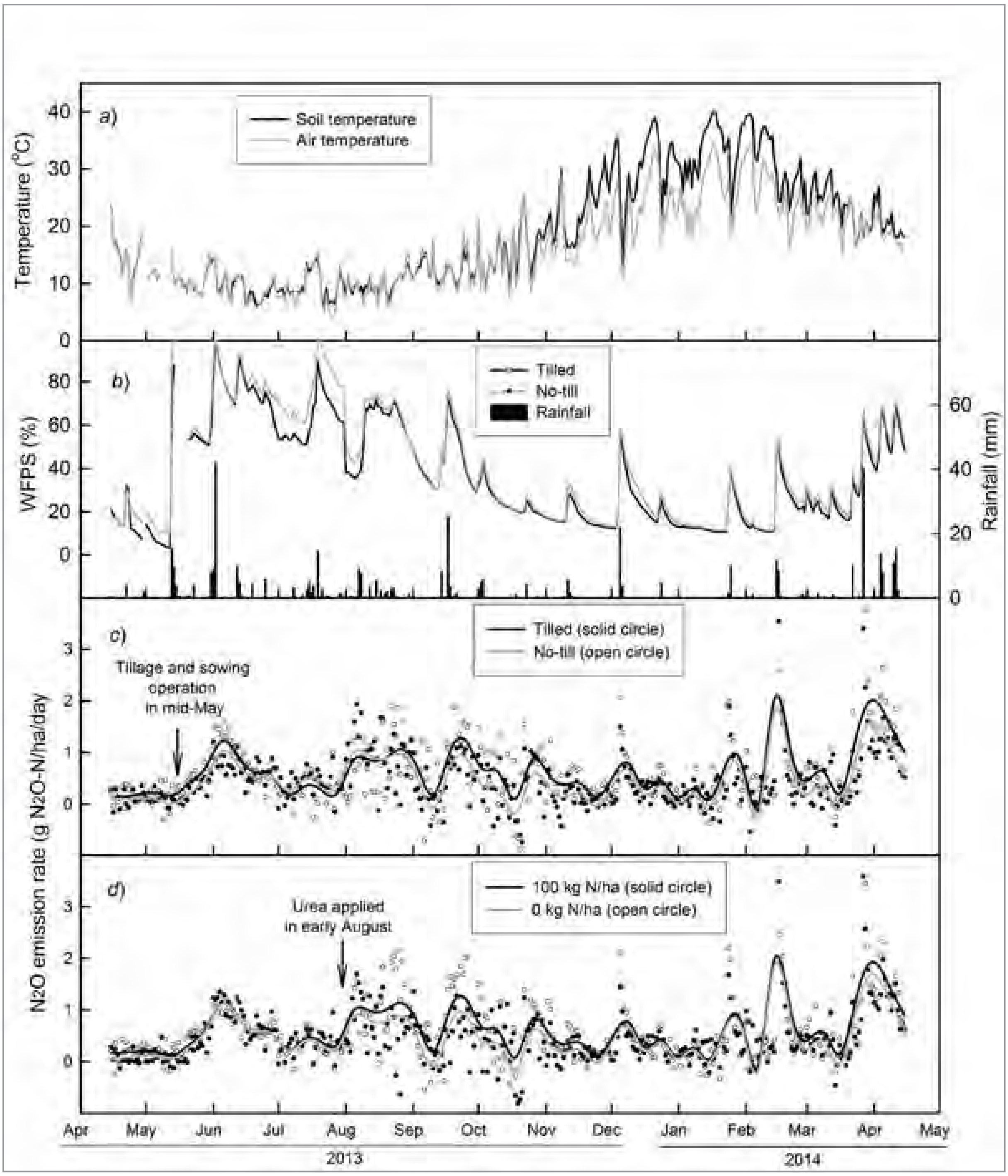

Figure 3. a) Air and soil temperatures (°C); b) Rainfall (mm) and water-filled pore space (WFPS, %) under tilled and no-till treatments; c) Daily N_2O emission rate (g N_2O-N/ha/day) under tilled and no-till treatments; d) Daily N_2O emission rate (g N_2O-N/ha/day) under 0 and 100 kg N/ha treatments for a canola crop in 2013. Lines on c) to d) are fitted splines for respective treatments.

At the perennial pasture site, the N_2O emission has been monitored over two years since May 2013. The pastures were sown in May 2012 and sprayed out in October 2014 in preparation for cropping in 2015. The rainfall events during the summer months stimulated N_2O emissions when subclover had died out or lucerne and phalaris were less active, compared with the growing season when all pasture species were actively growing (Figure 4). After the pasture was sprayed out, the N_2O emissions increased dramatically when large rainfall events occurred.

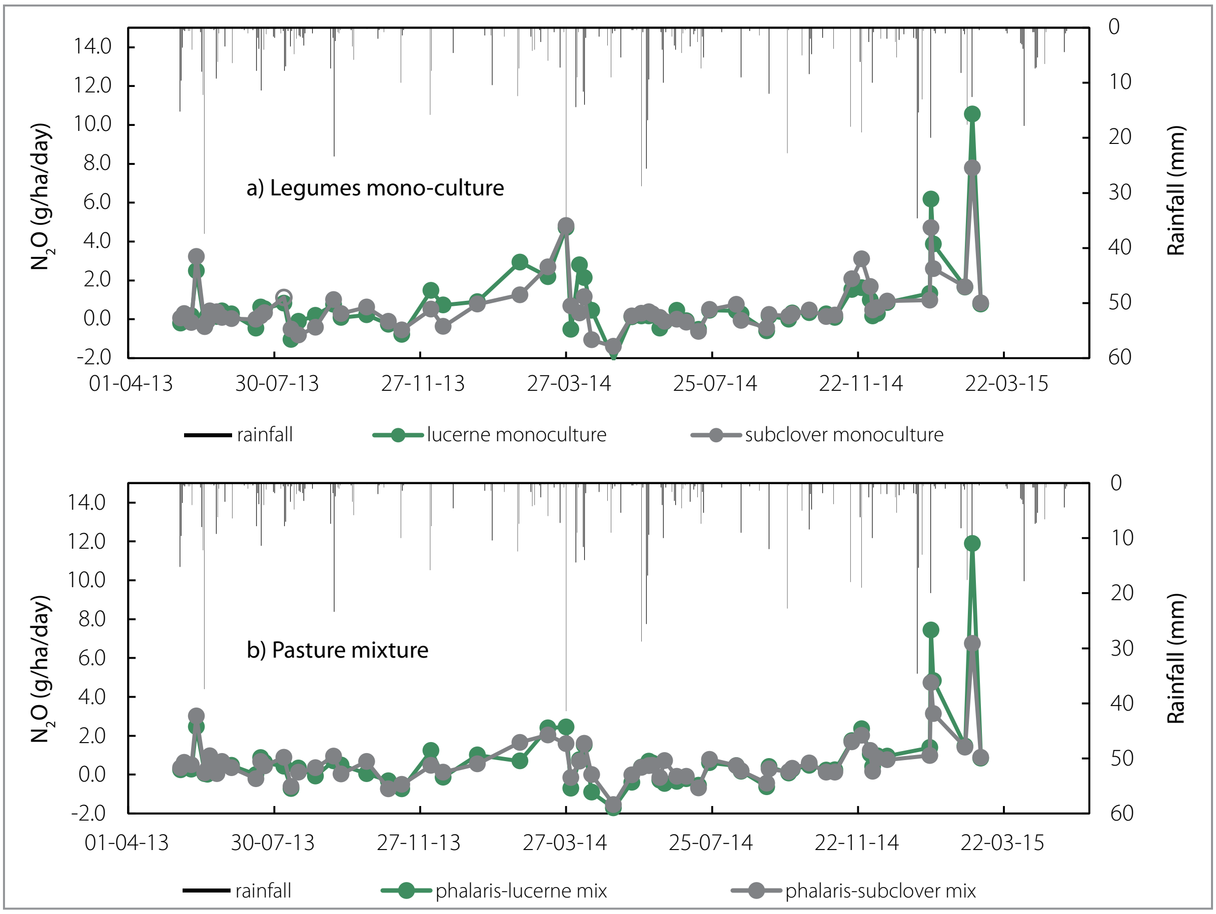

Figure 4. N_2O emissions under a) lucerne vs subclover, and b) phalaris mixed with lucerne and subclover over two years from May 2013 to May 2015; measured using manual chambers.

There was a significant difference in cumulative N_2O emissions between pasture types (P = 0.057). Over 658 days, lucerne monoculture had the highest N_2O emission (517 g N_2O-N/ha) and phalaris–subclover had the lowest emission (405 g N_2O-N/ha) (Table 2). When legumes were sown as a monoculture, the N_2O emissions were reduced by 19% compared with the annual system (Table 2). However, when legumes were mixed with phalaris, N_2O emissions were reduced compared with corresponding legume monocultures. For example, the N_2O emissions were reduced by 15% in phalaris–lucerne mixture swards compared with lucerne grown on its own (Table 2).

Acknowledgments

We are grateful to Adam Lowrie, Graeme Poile, Richard Lowrie, Albert Oates, Binbin Xu and Vince van der Rijt from NSW DPI for field assistance; and Christian Brunk from Queensland University of Technology for technical support while setting up the automated chamber system. The project (Filling the Research Gap Australian Government National Agricultural Nitrous Oxide Research Program: 01202.027, 'Options for reducing nitrous oxide emissions from the New South Wales dryland grains industry', 2011–15) was conducted at the Wagga Wagga Agricultural Institute and funded by NSW DPI with financial support from the Department of Agriculture and Water Resources and GRDC.

Nutrient supply from soil organic matter under different farming practices in the Central West of NSW

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Key findings

- Conventional tillage enhances soil organic carbon (SOC) turnover with the potential to simultaneously increase plant available nutrients [nitrogen (N), phosphorus (P), sulfur (S)] in the soil compared with no-till and perennial pasture.
- Across farming management practices and under ideal soil moisture, soil organic matter (SOM) could have supplied up to 45 kg N, 16 kg P and 19 kg S/ha in the absence of plant carbon (C) input.
- Over a longer period (126 days), particularly if there is a lack of plant C input (e.g. a normal fallow period), any P or S released via native SOM turnover over a shorter period (e.g. over 30 days) would have been immobilised by microorganisms and/or adsorbed to soil minerals, hence decreasing P and S availability for crop uptake.

Introduction

Soil organic matter is an important source of nutrients, including nitrogen, phosphorus and sulfur, for plants and a key indicator of soil quality. However, decomposition of SOM and its nutrient supply potential could vary with farming management practices. It is important to understand the supply of nutrients under different farming practices to optimise grain cropping systems productivity and profitability.

The aim of this study was to examine the impact of long-term farming practices on SOM decomposition and N, P and S net release in soil, thus evaluating the nutrient supply value of SOM in grain cropping systems.

Site description and methodology

Location	Condobolin Agricultural Research and Advisory Station NSW
Coordinates	33°05'19"S and 147°08'58"E, (195 m above sea level)
History	Established in 1998, (16-year-old farming systems trial)
Climate	Hot, semi-arid climate
Soil	Red chromosol, 27% clay (sandy clay loam)
Total C (0–10 cm)	1.2%–1.4%
Total N (0–10 cm)	0.10%–0.12%
pH (water)	5.5–6.3

Farming practices

The site has four farming practices (see http://cwfs.org.au/2015/12/10/cwfs-aog-soil-carbon-results-summary for more information (sighted 22-02-2016)).

The selected rotation treatments in each of the farming practices in May 2014 (i.e. at end of the fallow period) were:

- CT (Pa_LFW) = conventional tillage (pasture in 2013, long fallow wheat in 2014)
- CT (SFWus_Pa) = CT (short fallow wheat/undersown pasture in 2013, pasture in 2014)
- RT (Pa_LFW) = reduced tillage (pasture in 2013, long fallow wheat in 2014)
- RT (LFWus_Pa) = RT (long fallow wheat/undersown pasture in 2013, pasture in 2014)
- NT (Ba_Pu) = no-till (barley in 2013, pulse in 2014)
- PP = perennial pasture

Soil samples were collected (0–10 cm) from each plot, sieved (6.5 mm sieve), air dried and stored at 4 °C for various analyses (Table 1).

Table 1: Basic properties of soil (0–10 cm). Values in brackets are ± standard errors.

Treatment	Total C (%)	Total N (%)	Before incubation (day zero)		
			Mineral N	Mineral P	Mineral S
CT (Pa_LFW)	1.4 (±0.1)	0.12 (±0.00)	18.5 (±4.1)	17.3 (±3.9)	1.4 (±0.8)
CT (SFWus_Pa)	1.3 (±0.1)	0.11 (±0.00)	3.2 (±0.8)	22.2 (±3.6)	9.7 (±0.5)
RT (Pa_LFW)	1.2 (±0.1)	0.11 (±0.01)	22.0 (±3.4)	11.9 (±1.9)	0.1 (±0.1)
RT (LFWus_Pa)	1.4 (±0.1)	0.12 (±0.00)	1.7 (±0.5)	30.6 (±2.5)	2.3 (±1.5)
NT (Ba_Pu)	1.3 (±0.0)	0.11 (±0.00)	12.5 (±1.3)	14.6 (±0.4)	16.2 (±0.7)
PP	1.4 (±0.1)	0.12 (±0.01)	3.2 (±0.8)	7.3 (±1.3)	1.4 (±0.8)

Laboratory incubation and analyses

Soil samples (35 g) were weighed into 70 mL plastic vials with their moisture content adjusted to 60% of WHC. The soils were incubated in a sealed, one litre bucket at 22 ± 0.5 °C for 18 weeks. Soil-respired CO_2-C (mineralisable C), 2 M KCl-extractable mineral N (NH_4^+-N and NO_3^--N), 0.016 M KH_2PO_4-extractable SO_4^{2-}-S, and 0.5 M $NaHCO_3$-extractable PO_4-P (standard Colwell-P) were periodically measured. Net nutrient availability for N, P or S following the simultaneous mineralisation (organic to inorganic forms), immobilisation (inorganic to organic forms) and fixation (adsorption on soil minerals and/or precipitation with metal cations) processes during SOM turnover over 30 or 126 days was quantified using the following equations:

1. Net mineralisable N = extractable mineral $N_{day30\ or\ day126}$ – extractable mineral N_{day0}

2. Net mineralisable S = extractable mineral $S_{day30\ or\ day126}$ – extractable mineral S_{day0}

3. Net available P = Colwell $P_{day30\ or\ day126}$ – Colwell P_{day0}

Results

Soil organic carbon turnover

Over 126 days of incubation, 185–370 mg CO_2-C/kg soil was released across different farming practices (Figure 1). There was a greater turnover of SOC under conventional tillage, whether rotational phases transitioning to pasture [CT (SFWus_Pa)] or wheat [CT (Pa_LFW)] than the PP, NT or RT (Pa_LFW) treatments. Less soil disturbance in the PP, NT and RT (Pa_LFW) treatments might have enhanced SOM soil aggregation and decreased decomposability to microbial attack compared with the CT treatments. Changes in organic chemical compounds might have also contributed to differences in SOC turnover across the farming practices.

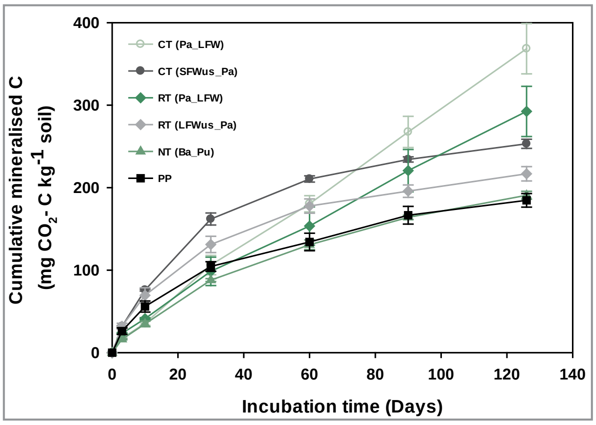

Figure 1. Cumulative SOC mineralised under different farming practices over 126 days of laboratory incubation. See details of abbreviated legends in the main text of the paper.

Nutrient supply potential of SOM

Net mineralisable N was 8–22 mg/kg soil over 30 days (Figure 2) and 11–40 mg/kg soil over 126 days of incubation (Figure 3). Consistent with SOC turnover, net mineralisable N was higher in the CT treatments, particularly in CT (Pa_LFW), than the other farming practices.

Net available P was 3–16 mg/kg soil over 30 days of incubation across all the treatments except in CT (Pa_LFW) where there was a decrease in available P (–5 mg/kg soil). However, over 126 days of incubation, net available P was negative, ranging between 3 and –23 mg/kg soil, with the RT having the greatest decrease and PP the lowest, relative to the other treatments (Figure 3). This could be due to microbial immobilisation and/or fixation of inorganic P by clay minerals and metal cations.

Consistent with the dynamics of net available P, there was a net release of mineral S (4–20 mg S/kg soil) over 30 days of incubation across the farming treatments. Thereafter (over 126 days), there was a net S immobilisation of up to 11 mg/kg soil (Figure 3), which might be due to S microbial immobilisation.

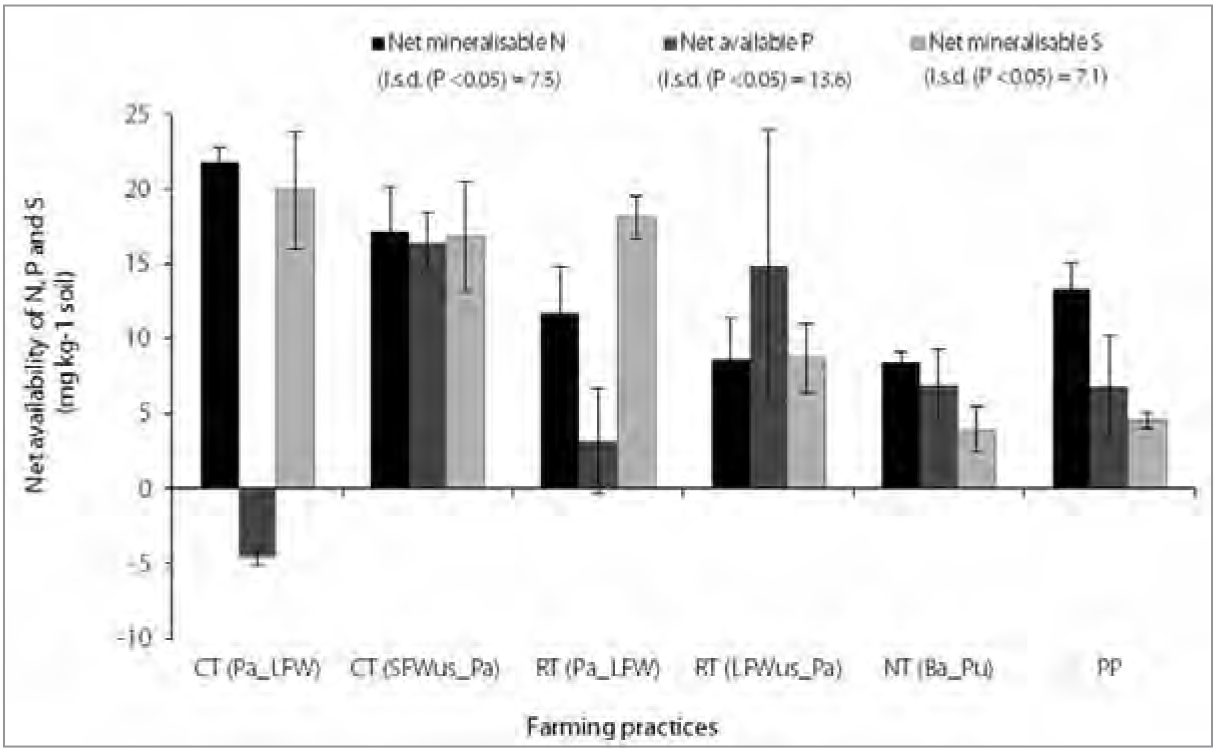

Figure 2. Effect of farming practices on net nutrient availability in soil over 30 days of laboratory incubation. See details of abbreviated legends in the main text of the paper.

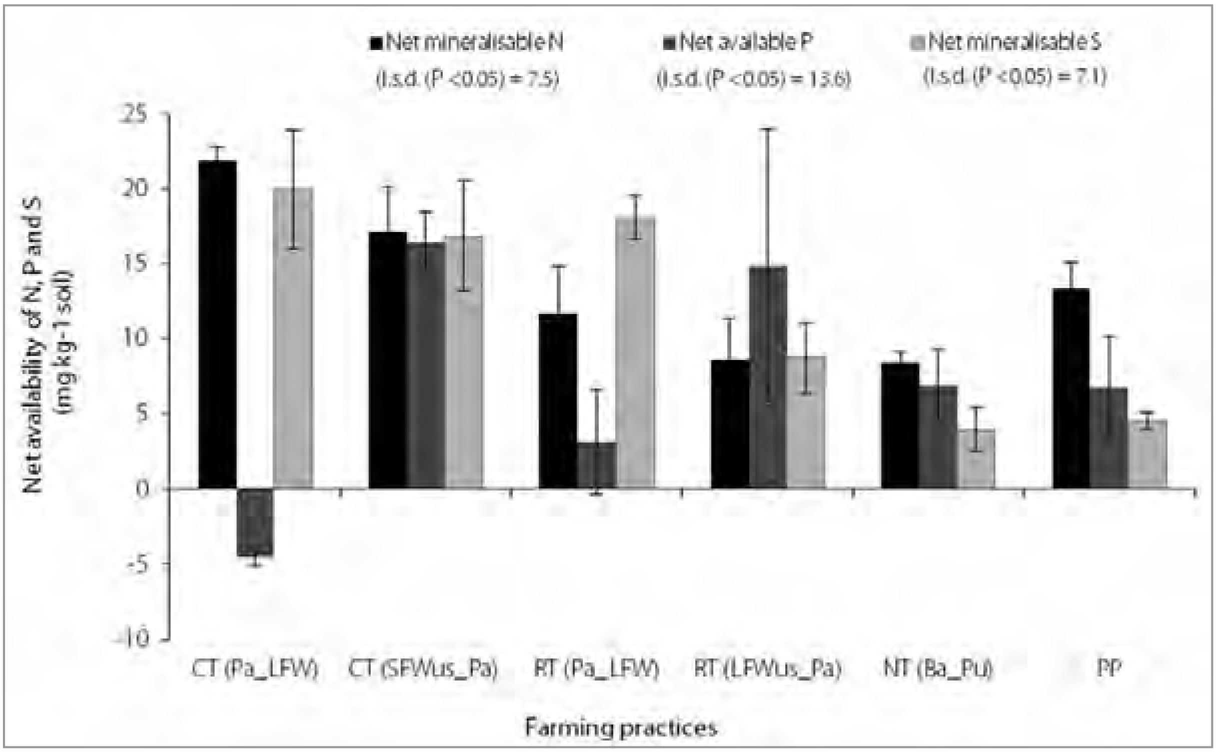

Figure 3. Effect of farming practices on net nutrient availability in soil over 126 days of laboratory incubation. See details of abbreviated legends in the main text of the paper.

Nutrient value of SOM

This study suggests that SOM can slowly release mineral N over a four-month period, while mineral P and S could also be released over a one-month period under ideal soil moisture conditions. Considering the soil bulk density of 1.3 t/m^3 (0–10 cm depth), our study suggests that SOM could supply 13–52 kg N, 4–21 kg P and 5–26 kg S per hectare. Our data also suggest that any short-term released mineral P and S could be locked up in soil over the longer term (126 days). Thus, these essential nutrients need to be supplied to counteract the nutrient locking effect, for example via microbial immobilisation or adsorption on minerals in soil.

Summary

NSW DPI data indicate that native SOM has a fertiliser value in terms of N, P and S supply to support crop productivity. However, after the initial nutrients release from SOM, mineral P and S in particular could be locked up by microorganisms and/or minerals in the soil. Hence, additional supply of these nutrients (including N as required) is needed to meet crop demand. The results on the effect of farming practices suggest that the conventional tillage increased SOC turnover and net nutrient release from SOM relative to no till or long-term perennial pasture. There is a trade-off between enhancing SOC turnover via conventional tillage that disrupts soil aggregates and exposes SOM for microbial attack versus slowing SOC loss and nutrient turnover while improving soil structure via no-till or including long-term pasture phases.

Acknowledgements

This experiment is part of the project 'Building resilient and profitable grain cropping systems through improved knowledge of soil organic carbon fractions and their functionality', DAN00169, jointly funded by NSW DPI and GRDC. It also involves Central West Farming Systems and on-farm collaborators.

Carbon allocation dynamics in contrasting crop-soil system trials in southern NSW

Dr Bhupinder Pal Singh, **Yunying Fang** and **Jharna R Sarker** NSW DPI, Menangle

Key findings

- Although high below-ground carbon input by plants is important to enhance soil organic matter, only a few studies have quantified carbon allocation dynamics in crop-soil systems in dryland regions under contrasting management practices.
- There seems to be environmental constraints and features of dryland farming systems (such as high aridity and low rainfall, low soil carbon and low moisture) that limit the extent of below-ground carbon allocation as found in this study. It is thus challenging to enhance soil organic matter stocks in the dryland regions through conservation tillage only.
- The majority of newly assimilated carbon remained in above-ground plant material, particularly in the wheat-soil system at Condobolin, which is a relatively drier climate than Wagga Wagga.
- A larger proportion of newly assimilated carbon was translocated to below-ground carbon pools in the canola-soil system at Wagga Wagga (7%–11%) than in the wheat-soil system at Condobolin (2%).
- Tillage practices had no effect on the allocation and storage of newly assimilated carbon in the crop-soil systems. Moreover, the management practices had no significant effect on grain yield, soil carbon stocks or bulk density.
- These results suggest that reduced tillage or no-till can maintain equivalent soil functionality relative to conventional tillage while reducing operational costs associated with energy and machinery inputs.

Introduction

Organic matter (OM) plays a vital role in maintaining soil functions such as carbon (C) storage and nutrient cycling. It is hypothesised that improved crop management practices can increase soil C, for example by increasing plant-derived organic matter input into the soil, and influence nutrient use efficiency and crop yield. This understanding can be enhanced through using in-situ techniques to examine above-ground and below-ground allocation of newly assimilated C and its stabilisation and interaction with nitrogen (N) in soil under contrasting crop management practices. The aim of these experiments is to examine how tillage intensity influences allocation and stabilisation (storage) of newly assimilated C in canola crop-soil and wheat crop-soil systems at Wagga Wagga and Condobolin.

Site details

Two trial sites were selected: one short-term trial at Wagga Wagga and one long-term trial at Condobolin (Table 1).

Table 1. Sites for the carbon isotope labelling studies.

Location	Wagga Wagga	Condobolin
Coordinates	35°07' S and 147°22' E	33°05' S and 147°08' E
History	Established in 2012	Established in 1998
Experiment period	Sep–Nov 2013	Sep–Nov 2014
Total C (0–10 cm)	1.5%	1.2%
Total N (0–10 cm)	0.13%	0.10%–0.12%
pH	5.8	5.8
Bulk density (0–10 cm)	1.3 g/cm^3	1.3 g/cm^3
Soil classification	Red kandosol	Red chromosol
Soil texture	Sandy clay loam	Sandy clay loam
Crop	Canola	Wheat

Location	Wagga Wagga	Condobolin
Management practices	1. Conventional tillage 2. No tillage	1. Conventional tillage 2. Reduced tillage
Fertiliser	100 kg urea-N/ha	Farmer's practice
Annual rainfall (long-term)	~570 mm	~435 mm

Methods and treatments

An in-situ C isotope labelling technique was used that allows the fate of newly assimilated atmospheric carbon to be traced. We exposed crop-soil systems to $^{13}CO_2$ (5 L or 10 L of 99 atom %) for fixation by plants via photosynthesis. The crop-soil system areas used for pulse labelling were 1.5 m wide × 2.0 m long at Wagga Wagga (Figure 1. photos 1a and 1b) and 1.8 m wide × 2.0 m long at Condobolin (Figure 1. photos 1c and 1d). In the Wagga Wagga crop rotation trial (wheat–canola–legume–wheat), canola was grown in 2013 in a factorial combination of four treatments (0 kg N/ha and 100 kg N/ha under conventional tillage, and no till, with three replicates each). In the Condobolin mixed farming system trials (five rotational phases of wheat and pastures), the wheat crop rotation was selected in 2014 across the conventional versus reduced tillage treatments.

Results

At both sites, management practices had no significant effect on grain yield and soil C and N stocks in the years the labelling study was conducted. At Wagga Wagga, soil organic C (0–30 cm) ranged from 30 t/ha in no till to 40 t/ha in conventional tillage. Grain yield for the canola crop was 1.2 t/ha in no till and 1.6 t/ha in conventional tillage. At Condobolin, soil organic C (0–30 cm) ranged from 36 t/ha in conventional tillage to 40 t/ha in reduced tillage. Grain yield for the wheat crop was 2.3 t/ha in conventional tillage and 2.1 t/ha in reduced tillage.

The allocation and storage of newly assimilated C in plant and/or soil components varied at these two sites. At Wagga Wagga, 43%–55% of the added $^{13}CO_2$-C remained in the crop-soil system after 45 days, while 36%–45% of the 'new' C was recovered in the shoot, 1.8%–2.8% in the tap root, and 5.6%–7.8% in the soil plus fine roots at grain harvesting in November 2013 (Figure 2a). At Condobolin, 77%–80% of the added $^{13}CO_2$-C remained in the wheat crop-soil system after 50 days, with 74% of the 'new' C recovered in the shoot, 0.3%–0.5% in the nodal roots, 1.2%–1.3% in the soil plus fine roots, and 2.3%–3.3% was respired CO_2 at grain harvesting in November 2014 (Figure 2b).

Figure 1. In-situ stable carbon and nitrogen isotope labelling of a canola-soil system at Wagga Wagga (a and b) and a wheat-soil system at Condobolin (c and d).

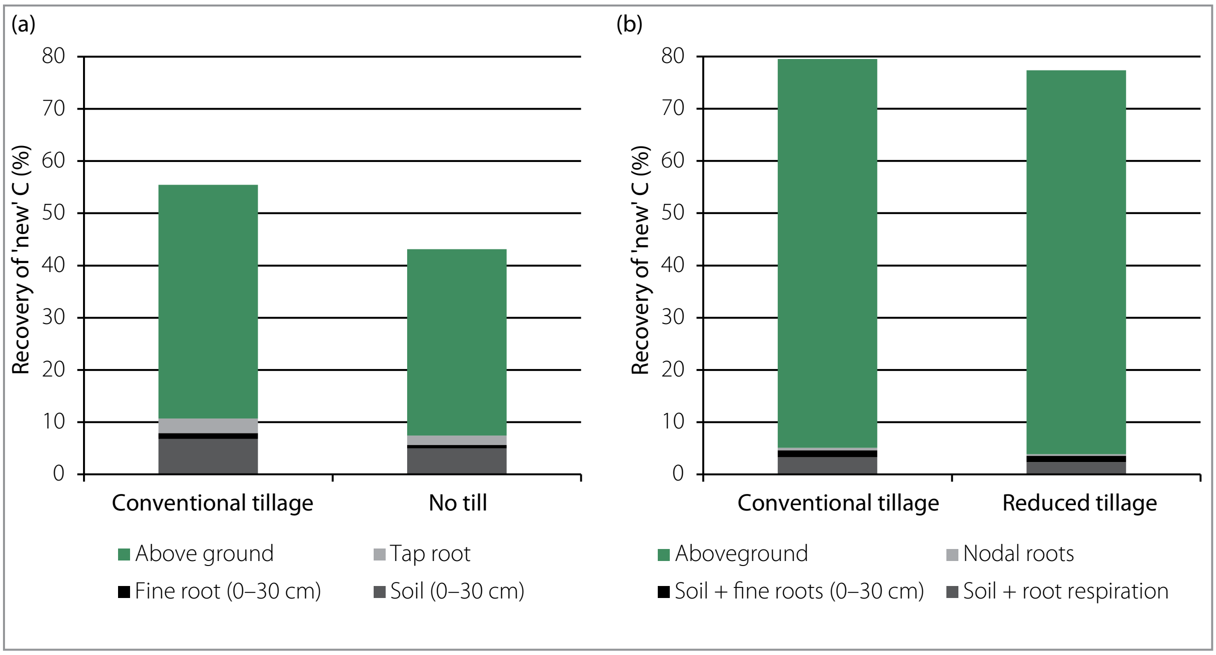

Figure 2. Allocation of isotopically-labelled 'new' carbon in a canola crop-soil system at the grain harvesting stage at Wagga Wagga (a) and Condobolin (b). 'New' carbon means the newly assimilated isotopically labelled-C.

The contrasting tillage practices had no effect on allocation and storage of new C among plant, soil and/or respiration C pools (figures 2a and 2b).

Our results show that the majority of newly assimilated C remained above-ground and only a small amount was translocated to below-ground in both crop-soil systems. This pattern could be attributed to both:

1. smaller below-ground plant C pools (i.e. root biomass) relative to above-ground plant C pools
2. dry conditions hampering C translocation from shoots to roots and root-derived organic matter (exudates).

Less assimilated C was translocated to below-ground in the Condobolin wheat-red chromosol system than in the Wagga Wagga canola-red kandosol system. This was possibly due to the relatively dry environment at Condobolin compared with that of Wagga Wagga, and Condobolin's soil-gravimetric moisture at 4%–8%, which was lower than that recorded at Wagga Wagga (7%–16%) during the C tracing period.

Summary

The results reveal no effect of contrasting tillage practices on the dynamics and magnitude of 'new' C (^{13}C-labelled) allocation and storage in the crop-soil system, soil C stock or crop yield. These results suggest that reduced tillage or no till could maintain the same level of soil functionality as conventional tillage in the low to medium rainfall regions. It seems that the climate and low soil C features of the dryland regions limit the effect of tillage management on below-ground C input and crop productivity.

Acknowledgements

These experiments involved collaborations with Guangdi Li (Wagga Wagga trial), Annette Cowie (Wagga Wagga trial), Warwick Badgery (Condobolin trial) and Xinhua He (both trials). As part of the project 'Building resilient and profitable grain cropping systems through improved knowledge of soil organic carbon fractions and their functionality', DAN00169, the experiment was jointly funded by NSW DPI and GRDC. It also involved Central West Farming Systems and on-farm collaborators. We acknowledge technical input from Khushbu Gandhi, Adam Lowrie, Richard Lowrie, Rebecca Coburn, Michael McLean, Satvinder Bawa, Dougal Pottie, Luke Beange, Nilusha Henaka Arachchi, Kamal Hossain and Mathew Coggan. We also thank Central West Farming Systems for allowing access to the long-term trial.

Modelling soil organic carbon changes in cropping and grazing systems

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Key findings

» The difference in soil organic carbon (SOC) changes between nine sites across eastern Australia was largely characterised by mean temperature and rainfall.

» High temperature strongly interacted with management practices (stocking rate, nitrogen application and residue incorporation) to reduce carbon sequestration despite favourable rainfall.

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Introduction

SOC levels in agricultural systems depend largely on rates of carbon input and decomposition under various agronomic practices such as stubble (crop residue) management and fertiliser application. This project explored the extent to which various crop and pasture management options effected changes in SOC, from sub-tropical to temperate environments.

Site details

The Agricultural Production Systems Simulator (APSIM)-Wheat and APSIM-Agpasture models were used to simulate changes in SOC in a range of crop and pasture management systems across nine locations in eastern Australia: central and southern New South Wales (Deniliquin and Wagga Wagga), northern NSW (Narrabri and Nyngan), south-western Queensland (Roma and Dalby), northern Victoria (Rutherglen) and western Victoria (Horsham and Hamilton).

Treatments

The effect of nitrogen fertilisation, stubble management and stocking rate on SOC, and what strategies growers might use to increase SOC sequestration across eastern Australia were investigated. A continuous cropping regime, continuously grazed pasture and mixed cropping and pasture rotation were all modelled.

Results

Continuous cropping

Under continuous cropping, higher nitrogen application and higher amounts of stubble incorporation increased the SOC levels at all locations. At Roma, the northern-most site, there was little additional gain in SOC from increasing nitrogen application above 70 kg N/ha, but most other sites showed benefits above 70 kg N/ha. The most influential factor for boosting SOC under cropping was the level of stubble incorporation.

Continuous grazing

At all but one site of continuously grazed pasture generally resulted in SOC increases over 60 years. However, increasing stocking rates decreased the rates of SOC change at all sites.

Mixed cropping and pasture rotation

In crop–pasture rotations, even four years of pasture is likely to be significant in reducing the decline in SOC levels at low nitrogen applications during cropping phases. Nitrogen fertilisation and stubble incorporation ameliorated the stocking rate effect seen in continuous grazing, thereby reducing the decline in SOC.

Summary

» The difference in SOC changes between nine sites across eastern Australia was largely characterised by mean temperature and rainfall.

- High temperature strongly interacted with management practices (stocking rate, nitrogen application and residue incorporation) to reduce carbon sequestration, despite favourable rainfall.
- A mean annual temperature higher than about 20 °C can switch a soil from net sink into a net source of atmospheric CO_2 if other factors affecting soil carbon changes such as stubble incorporation, stocking rate and site rainfall, are constant.

Acknowledgements

This study was completed as part of the project 'Increasing soil carbon in eastern Australian farming systems: linking management, nitrogen and productivity', 01203.013, 2012–15, jointly funded by NSW DPI, Department of Agriculture and Water Resources (Australian Government), Department of Economic Development, Jobs, Transport and Resources (Victoria), Department of Science, Information Technology and Innovation (Queensland) and the University of New England.

Rebecca Lines-Kelly collated the key messages from Liu, DL, O'Leary, G, Ma, Y, Cowie, A, Li, FY, McCaskill, M, Conyers, M, Dalal, R, Robertson, F & Dougherty, W 2016, 'Modelling soil organic carbon 2. Changes under a range of cropping and grazing farming systems in eastern Australia', *Geoderma* vol. 265, pp. 164–175.

Soil carbon in the Monaro region: a report from 'Action on the ground'

Susan Orgill NSW DPI, Wagga Wagga

Key findings

- Seasonal conditions and soil type have a greater effect on carbon than management.
- Providing necessary nutrients and pH for optimum pasture production will potentially increase soil carbon.
- Cropping in a good season might not decrease soil carbon stocks. Opportunities could exist for Monaro landholders to diversify their enterprises when the conditions are right without depleting their soil carbon.
- A rapid increase of soil carbon can easily be followed by a rapid decrease.
- For more information please see our eBook: *Soil carbon in the Monaro region* (https://itunes.apple.com/au/book/id1035198100 or http://tinyurl.com/zrr9mht).

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Introduction

This project identified and demonstrated farm management practices that could increase soil organic carbon (C) in the Monaro region in southern New South Wales. Members of the Monaro Farming Systems group identified the management practices to be monitored, including:

- liming
- nutrient management
- introduced perennial pastures
- minimum disturbance cropping.

A group of technical specialists identified 19 sites on commercial farms eligible for the project, based on the land-system comparison, parent material, vegetation and management class, as well as landholder cooperation and agreement. All sites were sampled to a depth of 50 cm in late spring in 2012 and 2014. Analysis included soil C (total organic carbon and organic carbon fractions: POC, ROC and HUM) and major soil chemical properties. This report presents the C stock (t C/ha) data for 2012 and 2014.

Site details and treatments

The Monaro region is located 800 m above sea level with an average annual rainfall of 645 mm. Nineteen sites were sampled as paired or triplet study sites where the desired comparison site was within 500 m and where the site had an existing history of the management practice. Paired sites had the same parent material (granite, sedimentary or basalt) and similar soil and landscape attributes. Site comparisons were selected by the Monaro Farming Systems landholder group to demonstrate the influence of management practices on soil C (Table 1). Management practices compared were:

- Cropping vs native perennial pasture
- Low fertiliser input vs high fertiliser input – native perennial pasture
- Northerly aspect vs easterly aspect – introduced perennial pasture
- Crop vs old introduced perennial pasture vs pine plantation
- Crop vs native perennial pasture vs new introduced perennial pasture
- Unlimed vs limed – introduced perennial pasture
- Old introduced vs new introduced perennial pasture
- Crop vs native perennial pasture vs new introduced perennial pasture.

Sites with native perennial pastures (NPP) had never been cultivated and were typically wallaby grasses (*Rytidosperma* spp.), speargrasses (*Austrostipa* spp.) and snowgrass (*Poa sieberiana*). Introduced perennial pastures (IPP) were typically phalaris (*Phalaris aquatica* L.) and cocksfoot (*Dactylis glomerata* L.). Both native and introduced perennial pastures included exotic annual species such as subterranean clover (*Trifolium subterraneum*).

Table 1. Summary of the comparison with parent material class (IPP: introduced perennial pasture, NPP: native perennial pasture). All pasture paddocks were grazed.

Comparison	Treatment
Basalt	
Crop vs NPP	Short-term cropping (since 2012, previously NPP) paddock (barley in 2012) compared with a native perennial pasture.
Low fertiliser vs high fertiliser	Low compared with high Phosphorus, Sulfur input (since 2005) on a native perennial pasture.
Low grade metamorphics	
IPP: Aspect north vs east	Northerly aspect compared with easterly aspect within the same paddock under an introduced perennial pasture (sown 1989).
Crop vs >35-year-old IPP vs pine plantation	Long-term cropping (since 1998) paddock (oats 2012) compared with an old introduced perennial pasture (sown 1960) and commercial pine plantation (established 2002).
Crop vs NPP vs <5 yr old IPP	Short-term cropping (since 2009, previously native perennial pasture) paddock (wheat 2012) compared with a native perennial pasture and a new introduced perennial pasture (sown 2010, previously crop since 2004).
Granite	
IPP: Unlimed vs limed	Unlimed compared with limed paddock (2.5 t/ha lime broadcast in 2002) under introduced perennial pasture (sown 1970).
IPP: >35 yr old vs <10 yr old	Old (sown 1974) compared with new (sown 2003) introduced perennial pasture.
Crop vs NPP vs <5 yr old IPP	Short-term cropping (since 2011, previously introduced perennial pasture) paddock (wheat 2012) compared with a native perennial pasture and new introduced perennial pasture (sown 2012, previously crop since 2009).

Sites were sampled within a 25 × 25 m quadrat according to the Soil Carbon and Research Project protocols (Sanderman et al. 2011). Soil samples for total organic carbon (TOC) were oven-dried at 40 °C, passed through a 2 mm sieve and analysed on a LECO combustion furnace (LECO 1995) (Rayment & Lyons 2011; Method 6B2b). Results were reported as TOC g/100g on an oven-dry basis. Bulk density was determined on each core with samples dried at 105 °C (Dane & Topp 2002). Results were calculated as bulk density (BD) in g/cm^3 on an oven-dry basis.

Carbon stock was calculated using the equivalent soil mass (ESM) method within a specified soil layer. Carbon stock was calculated in 10 cm increments to 30 cm or 50 cm. For each site, the C stock was first calculated to a depth standard (DS) as; DS C stock ($g/100\ cm^2$) = C concentration (g/100 g) × BD (g/cm^3) × depth (cm) × gravel correction factor (1 − proportion gravel >2 mm), where C stock ($g/100\ cm^2$) = C stock (t C/ha). Carbon stock using the ESM was then calculated. For changes within a site between 2012 and 2014, the 2012 soil mass was used as the reference soil mass. So in 2012, C stocks were calculated to a depth standard (as a starting reference soil mass) and 2014 C stocks for the same site were calculated based on a soil mass equivalent to 2012. Carbon stock in the ESM of the soil layer (e.g. 0–30 cm) t C/ha = DS C stock (to 20 cm) + (DS C stock 20–30 cm × (ESM for the total soil layer/actual soil mass for the total soil layer)).

Summary

Overall, C stocks were influenced by landscape attributes, including:

- parent material
- soil depth
- clay content
- aspect
- topography and relief
- soil nutrients such as nitrogen, phosphorus and sulfur.

The soil C stocks for each treatment comparison and sampling time are summarised in Table 2.

Liming

There were no consistent results indicating an increase or decline in C stocks with liming an introduced perennial pasture. In 2012, there was 1.4 t C/ha/30 cm more under the limed treatment, while in 2014, there was 4.9 t C/ha/30 cm less under the limed treatment.

Correcting soil acidity with lime can have both an immediate and long-term influence on soil C stocks. If soil pH was limiting plant growth, then liming to increase soil pH (and thereby reducing aluminium toxicity) can increase pasture growth and organic matter (OM) supply. However, liming can also increase microbial activity and, therefore, there may be a short-term decrease in C stocks associated with increased decomposition of labile OM. Liming can also influence the pasture composition, in particular the leguminous component of the pasture, which supplies N to the grass component, and again can be responsible for increasing biomass production and OM supply to the soil. Based on the 2012 and 2014 soil survey, there are several sites in this study that have soil pH values at or below the critical value of 4.6. These sites might achieve increases in soil C stocks with liming if responsive plant species are present.

Pasture composition

It is hypothesised that newly established pastures will increase soil C rapidly in the first five to 10 years and then plateau with steady increases in soil C continuing for up to 30 years. The new pasture in this study was sown in 2003, and had a greater existing stock of C potentially representing this rapid increase. However, this increase is surprisingly high given that the Monaro region experienced drought conditions for the first six years following pasture establishment. Based on these soil survey results, from 2012 to 2014 there was a 10 t C/ha/30 cm decrease in C stock. If this is a true representation of what occurred during this period, a possible explanation could be an increase in the rate of decomposition, or a decrease in pasture production associated with soil nutrient limitations under the new introduced pasture. However, given the magnitude of the decrease, it would seem this is more likely due to spatial variability in soil C within the sampling quadrat and not solely due to management effects.

Table 2. Carbon stocks (t C/ha) for each treatment and sampling time (2012 and 2014) comparison. The 2012 C stocks are calculated to a depth standard and the 2014 C stocks were calculated based on an equivalent soil mass (with the 2012 soil as the reference soil mass).

	2012	2014	Difference	2012	2014	Difference
Basalt derived soil						
Crop	46.39	50.12	3.74	71.72	77.09	5.37
Native pasture	59.98	64.94	4.97	80.80	87.10	6.30
Δ Native pasture – crop	13.59	14.82	1.23	9.08	10.01	0.93
Low fertiliser	61.38	77.10	15.72	75.87	101.45	25.58
High fertiliser	78.82	73.48	-5.34	108.65	101.11	-7.54
Δ High – low	17.44	-3.62	-21.06	32.78	-0.34	-33.12
Low grade metamorphics						
Northerly aspect IPP	46.97	49.38	2.41	55.69	58.09	2.40
Easterly aspect IPP	42.37	48.09	5.72	52.29	69.96	17.67
Δ North–east aspect	4.60	1.29	-3.31	3.40	-11.87	-15.27
Crop	47.65	45.36	-2.29	55.69	52.43	-3.26
Native pasture	45.15	55.91	10.76	56.76	70.34	13.59
New IPP	68.96	69.91	0.95	84.76	86.73	1.97
Δ Native pasture – new IPP	-23.81	-13.99	9.81	-28.00	-16.38	11.62
Δ Native pasture – crop	-2.50	10.55	13.05	1.07	17.91	16.84
Pine	66.83	93.87	27.04	85.06	125.14	40.07
Crop	42.37	46.53	4.16	53.82	57.72	3.90
Old intro. pasture	44.93	43.63	-1.30	59.33	55.80	-3.53
Δ Old IPP – crop	2.56	-2.90	-5.46	5.51	-1.92	-7.43
Δ Old IPP – pine	-21.90	-50.24	-28.34	-25.73	-69.34	-43.61
Granite derived soil						
Unlimed IPP	45.87	52.29	6.42	58.85	67.43	8.57
Lime IPP	47.30	47.43	0.13	60.04	63.61	3.57
Δ Lime – unlimed IPP	1.43	-4.86	-6.29	1.19	-3.82	-5.00
Crop	40.21	53.19	12.98	54.92	67.26	12.34
Native pasture	39.94	46.80	6.86	54.88	62.45	7.57
New IPP	36.66	42.79	6.13	47.64	54.69	7.05
Δ Native pasture – new IPP	3.28	4.01	0.73	7.23	7.76	0.52
Δ Native pasture – crop	-0.27	-6.39	-6.12	-0.04	-4.81	-4.77
Old IPP	46.66	44.99	-1.67	66.27	61.29	-4.98
New IPP	50.80	40.79	-10.02	65.91	54.62	-11.29
Δ Old IPP – new IPP	-4.15	4.20	8.35	0.35	6.67	6.31

Cropping

The cropping comparisons in this field study highlighted opportunities for cropping in this region on a range of soil types to at least maintain C stocks that are comparable with introduced pastures. We suggest that soil nutrient management programs associated with cropping and favourable climate years immediately before, and during this project, would have contributed to comparable C stocks. Under drier conditions, the C stocks could decline more under the crop compared with a perennial pasture.

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Acknowledgements

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Managing wheat stubble to effectively sequester soil carbon in a semi-arid environment: spatial modelling

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Key findings

- Soil organic carbon (SOC) losses of up to 200 kg/ha/year with 100% stubble removal and SOC increases of up to 200 kg/ha/year with 100% stubble incorporation in the current climate.
- SOC losses of 135 ± 15 kg/ha/year with 100% stubble removal and SOC increases of 80 ± 23 kg/ha/year with 100% stubble incorporation under the projected climate (2049–2098).

Introduction

This project models changes in SOC from stubble management under current and future climates. More attention is being paid to farm management practices that enhance SOC stocks because of SOC's importance to soil fertility, crop production and the global carbon cycle. Sequestering atmospheric carbon dioxide (CO_2) as SOC has potential feedback for climate change.

Site details

In the Liverpool Plains and the southern slopes of NSW, SOC in the top 30 cm layer is in a higher range of 40–50 t/ha, while from the south-west plains to the northern plains and extending to the New England tablelands, SOC is in a lower range of 25–35 t/ha. SOC in the central slopes is also in the lower range of 25–35 t/ha. Modelling incorporated daily weather data comprising solar radiation, maximum and minimum temperatures and rainfall for 509 sites in the NSW wheat belt, and 169 soil data sets from the APSoil database in the NSW wheat belt is taking place.

Treatments

The Agricultural Production Systems Simulator (APSIM) was used to evaluate the effect of management options under current and future climates on the SOC dynamics across New South Wales. APSIM consists of climate, soil, plant and farming management modules. The model was validated against a long-term (1979–2004) experiment and showed a moderate accuracy in predicting SOC turnover.

Results

Current climate

There was a large simulated range of SOC when 100% of stubble was removed (0–200 kg/ha/year) and also when 100% of stubble was incorporated (0–200 kg/ha/year) under the current climate.

With 100% wheat stubble removal, the average SOC is decreased by 126 ± 40 kg/ha/year. With 100% incorporation, the averaged SOC is increased by 100 ± 34 kg/ha/year.

To maintain the current level of SOC in the south-western wheat growing region (lower rainfall) of the state, 20–40% wheat stubble is required to be incorporated into soil. In the north-eastern area (high rainfall), 40–60% wheat stubble is required.

Future climate

SOC change patterns are similar under a projected future climate, but as future temperatures rise, less SOC will be sequestered.

Averaged SOC levels will decrease by 135 ± 15 kg/ha/year with 100% stubble removal under the projected climate (2049–2098), and increase 80 ± 23 kg/ha/year with 100% incorporation.

Emissions

There is a clear trend to theoretically decrease CO_2 emissions with increasing wheat stubble incorporation.

Across the actual wheat growing area in NSW, 100% incorporation of all wheat stubble reduces emissions by 3.29 ± 1.11 Mt CO_2/year under the current climate, or by 2.68 ± 0.77 Mt CO_2/year under the projected climate.

Complete (100%) wheat stubble removal results in 3.90 ± 1.23 Mt CO_2 emissions/year under the current climate and 4.06 ± 0.50 Mt CO_2/year under the future climate.

Summary

Modelling changes in SOC in NSW's wheat growing areas shows:

- SOC losses of up to 200 kg/ha/year with 100% stubble removal and SOC increases of up to 200 kg/ha/year with 100% stubble incorporation in the current climate.
- SOC losses of 135 ± 15 kg/ha/year with 100% stubble removal and SOC increases of 80 ± 23 kg/ha/year with 100% stubble incorporation under the projected climate (2049–2098).

Acknowledgements

This study was completed as part of the project 'Increasing soil carbon in eastern Australian farming systems: linking management, nitrogen and productivity', 01203.013, 2012–15, jointly funded by NSW DPI, Department of Agriculture and Water Resources (Australian Government), Department of Economic Development, Jobs, Transport and Resources (Victoria), Department of Science, Information Technology and Innovation (Queensland) and the University of New England. Rebecca Lines-Kelly collated the key messages from Liu, DL, Anwar, MR, O'Leary, G & Conyers, M 2014, 'Managing wheat stubble as an effective approach to sequester soil carbon in a semi-arid environment: Spatial modelling', *Geoderma*, vol. 214–215, pp. 50–61.

Can we achieve carbon sequestration to depth (1 m) under phase farming systems in NSW? Results from the EverCrop® Carbon Plus project

Susan Orgill, **Richard Hayes**, **Dr Mark Conyers**, **Albert Oates**, **Binbin Xu**, **Graeme Poile**, **Vince van der Rijt** and **Yan Jia** NSW DPI, Wagga Wagga; **Stephen Morris** NSW DPI, Wollongbar

Key findings

- Perennial pastures play an important role in phase farming systems; however, these results indicate that in the short-term, increasing carbon (C) stocks might not be one of them.
- Increases in C stock achieved with the perennial pasture phase were short-term and not sustained through the following cropping phase.
- There was no decline in C stock with the continuously cropped treatment.

Introduction

Perennial pasture phases in cropping systems can offer the opportunity to increase soil nitrogen (N) for the following cropping phase, improve soil aggregation and increase soil carbon (C) compared with continuous cropping. From a farming and profitability perspective, this could decrease the amount of mineral N that needs to be applied in the cropping phase. From a climate change mitigation perspective, this could decrease the amount of nitrogenous fertiliser applied to the crop, and therefore nitrous oxide emissions, and sequester in soil C that could otherwise be warming the atmosphere.

The purpose of this study was to determine whether including deep-rooted perennial pastures into cropping systems could maintain or increase soil C relative to annual-based cropping systems. The perennial-based farming systems included temperate herbaceous perennials (species such as lucerne, *Medicago sativa*) commonly grown in phases with winter crops in south-eastern Australia. The two experiment sites used in this study were existing EverCrop® sites located at Wagga Wagga and Yerong Creek, in southern NSW. At site 1 (Wagga Wagga), C stocks under annual and perennial pastures were compared to a depth of 1.0 m. At site 2 (Yerong Creek), C stocks under continuous cropping and perennial pasture phases were compared to a depth of 1.2 m. These sites were used to investigate changes in soil C during a perennial pasture phase and assess any changes in soil C when the cropping phase started.

Site details

Two EverCrop® trial sites of approximately 0.5 ha and located on red kandosols in southern NSW were examined in this project. Site 1 was located at Wagga Wagga on the Graham Centre research site (35.032628°S, 147.359144°E) at Charles Sturt University. Site 2 was located on a commercial farm at Yerong Creek (35.38796°S, 146.930745°E), approximately 80 km south-west of site 1.

Treatments

Site 1 (Wagga Wagga) was sown in late autumn 2012 to one of four pasture treatments; subterranean clover (*Trifolium subterraneum*) monoculture (the annual pasture control), lucerne/subterranean clover mix, phalaris (*Phalaris aquatica*)/subterranean clover mix, or a mix of all three species (lucerne/phalaris/subterranean clover). Each treatment was replicated three times.

Site 2 (Yerong Creek) was sown in autumn 2008 to one of four perennial-based pasture mixtures; lucerne/subterranean clover mix, phalaris/subterranean clover mix, cocksfoot (*Dactylis glomerata*)/subterranean clover mix, or chicory (*Cichorium intybus*)/subterranean clover mix, and a continuous crop (control) treatment. Each treatment was replicated three times. This experiment was repeated in 2009 and 2010 immediately adjacent to the previous trial (therefore three sowing years; 2008, 2009 and 2010). Pasture phases were in for three years before returning to the cropping phase.

Soil sampling, analysis and calculations

At site 1 (Wagga Wagga), soil samples were collected in late spring (after sowing in late autumn) in 2012, 2013 and 2014. At site 2 (Yerong Creek), soil samples were collected in early autumn 2013 and 2014. Intact cores were collected using a tractor-mounted hydraulic corer with a 44 mm core diameter and cut into depth increments of 0–5 cm, 5–10 cm (0–10 cm at site 2), 10–20 cm, 20–30 cm, 30–40 cm, 40–60 cm, 60–80 cm, 80–100 cm, 100–120 cm and 120–150 cm.

Soil samples for total organic carbon and total nitrogen were oven-dried at 40 °C, passed through a 2 mm sieve and analysed on a LECO combustion furnace (LECO 1995) (Rayment & Lyons, 2011; Method 6B2b). Bulk density was determined on each core with samples dried at 105 °C (Dane & Topp, 2002). Results were calculated as bulk density (BD) in g/cm^3 on an oven-dry basis.

Carbon stock was calculated using an equivalent mass of soil (ESM) within a specified soil layer. For each core, gravel was broken to <2 mm by a jaw crusher or mortar and pestle and retained in the sample. Initially, C stock was calculated to a depth standard (DS); DS C stock (g/100 cm^2) = C concentration (g/100 g) × BD (g/cm^3) × depth (cm), where C stock (g/100 cm^2) = C stock (t C/ha). Carbon stock using the equivalent mass of soil (ESM) was then calculated. Here, the ESM was calculated as the 10th percentile of all values of soil mass for the given soil layer (as no other suitable undisturbed reference soil was available). Carbon stock in the ESM of the soil layer (e.g. 0 to 30 cm) t C/ha = DS C stock (to 20 cm) + (DS C stock 20–30 cm × (ESM for the total soil layer/actual soil mass for the total soil layer)).

Results

At site 1 (Wagga Wagga), there was no difference in C stock in the 0–30 cm, 30–100 cm or 0–100 cm soil layers with pasture type or pasture type × year interaction (Table 1). While there were observed differences in mean C stock for all soil layers between the control (annual pasture) and pasture types, these were not significant for any year. However, there was a significant increase in C stock with year for the 0–30 cm, 30–100 cm and 0–100 cm soil layers (Table 1). There was also a significant increase in C stock within the year for all soil layers with phalaris and for the 0–30 cm and 0–100 cm soil layers for lucerne.

At site 2 (Yerong Creek) there was no difference in C stock for any soil layer with pasture type or between perennial pasture and continuous cropping; and no difference in C stock with sowing year in the 0–30 cm soil layer (Figure 1). However, there was a significant difference with sowing year in the 30–120 cm ($P < 0.001$) and 0–120 cm soil layer ($P = 0.02$). Within each sowing year there were occasional high C stocks attributed to pasture treatment, however, these were not consistent in the two sampling years, and observed data revealed significant ($P < 0.05$) plot effects (Figure 1).

Table 1. Site 1 (Wagga Wagga) mean carbon stock (t C/ha) classed by pasture type, year and depth (cm), with standard error of the means (se), least significant difference (5% critical value) for comparison of year for a given treatment (l.s.d. year) and treatments between year (l.s.d. treatment) and null hypothesis significance test probabilities for treatment (p.trt), year (p.year) and the interaction (p.trt.year).

Treatment	Year	C stock (t C/ha)		
		0–30 cm	30–100 cm	0–100 cm
Control	2012	34.86	22.46	57.45
	2013	36.33	23.92	59.33
	2014	36.17	24.38	60.64
Lucerne	2012	35.98	24.27	60.29
	2013	37.34	26.50	63.35
	2014	38.22	25.83	64.04
Phalaris	2012	35.03	21.56	56.80
	2013	36.49	25.17	60.86
	2014	37.43	25.11	62.54
Lucerne+phalaris	2012	38.05	24.13	62.42
	2013	36.33	25.92	61.98
	2014	37.61	25.31	62.76
se		0.97	1.12	1.88
l.s.d..year		1.76	2.63	3.65
l.s.d..treatment		3.34	3.87	6.51
p.trt		0.56	0.40	0.41
p.year		0.01	0.00	0.01
p.trt.year		0.09	0.81	0.45

Summary

There was little evidence in this study to suggest that including perennial pastures used in typical rotations with crops would increase soil C stocks compared with an annual-based system. Any increase in C stock achieved with the perennial pasture phase was only short-term, and was not sustained through the following cropping phase. Importantly, there was no decline in C stock with the continuously cropped treatment. There are a few likely reasons to explain comparable C stocks under annual pastures and crops relative to perennial pastures. Firstly, the studies included in this paper only represent three years of perennial pasture (site 1), or one 3-year perennial pasture phase (site 2). Under dryland conditions, three years might not be long enough to increase organic matter (OM) inputs, therefore C stocks, relative to the annual comparison. Secondly, at site 2, the primary purpose of a pasture phase was to supply N for the following cropping phase. The continuously cropped treatment at site 2 had N applied and it is conceivable that the crop supplied a similar amount of OM to the soil as the perennial pasture treatments, as is theorised for the annual pasture control treatment at site 1.

Perennial pastures undeniably play an important role in phase farming systems; however, our results indicate that in the short term, increasing C stocks might not be one of them.

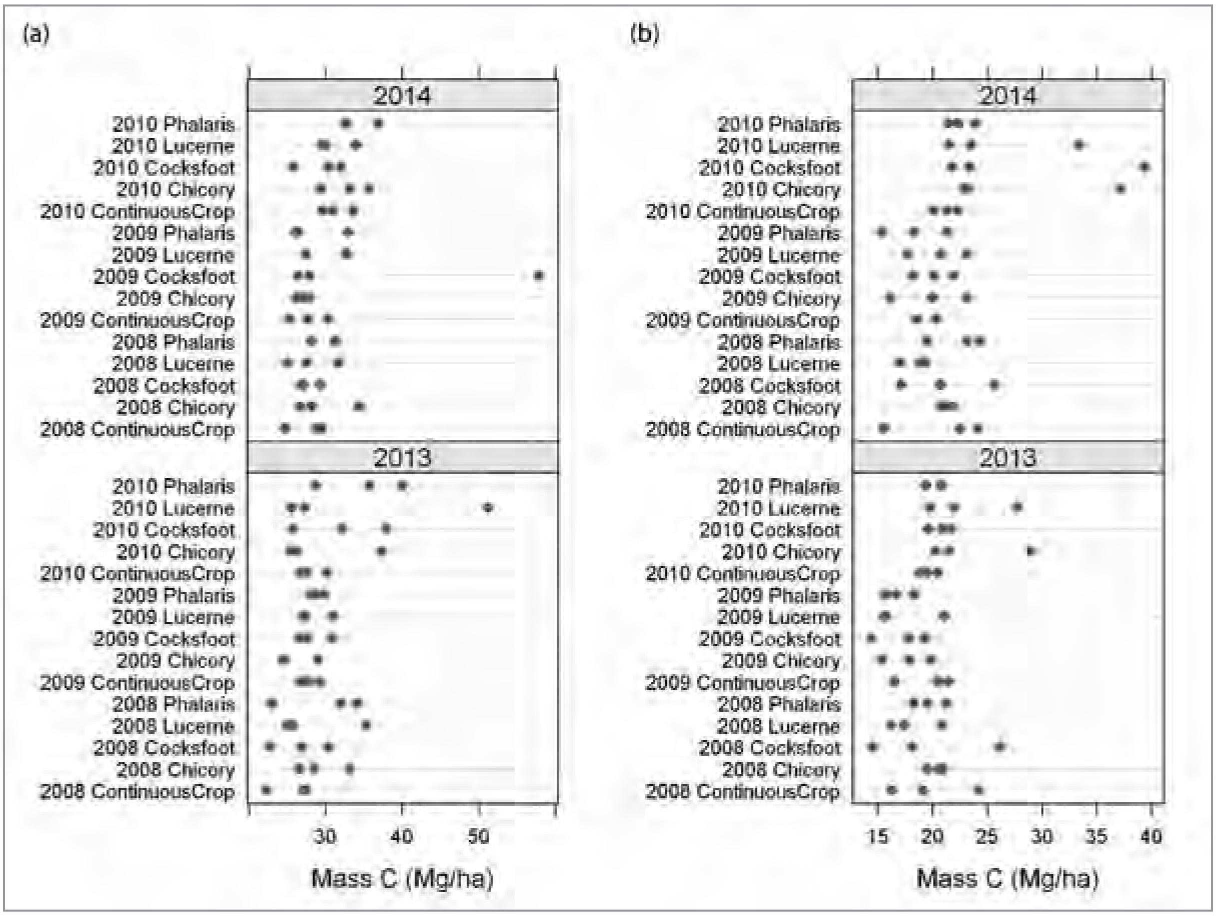

Figure 1. Site 2 (Yerong Creek) observed carbon stock (Mg C/ha = t C/ha) in the 0–30 cm (a: left graph) and 30–120 cm soil layer (b: right graph) based on an equivalent mass of soil for the 2013 and 2014 samplings. Plot replicates indicated by closed circles.

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Acknowledgements

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Septoria tritici blotch experiments – southern NSW 2015

Dr Andrew Milgate and **Michael McCaig** NSW DPI, Wagga Wagga

Key findings

» Fungicide application reduced disease levels in all varieties and had a large effect on yield.

» Observed differences in disease levels were broadly in agreement with published variety resistance ratings.

» Infected stubble increased the disease progression through the canopy, but yield results between stubble treatments were similar.

» Sowing a variety with a high septoria tritici blotch (STB) resistance will increase yields under high disease pressure.

Introduction

This experiment aimed to develop disease response curves indicating potential yield losses for five varieties that represent various resistance categories for septoria tritici blotch (STB). Yields were measured against five different treatments within southern NSW.

Site details

Wagga Wagga was selected for the experiment as it represents the medium–high rainfall zone in southern NSW winter cropping region. This site also has an overhead irrigation system available to promote disease in experiments.

Varieties

Five locally relevant varieties with a range of resistance to STB were used (Table 1).

Table 1. Varieties included in the STB experiment 2015.

Variety	STB rating #
Sentinel3R⊕	Moderately resistant–moderately susceptible (MR–MS)
Sunvex⊕	Moderately resistant–moderately susceptible (MR–MS)
Bolac⊕	Moderately susceptible (MS)
Forrest⊕	Moderately susceptible–susceptible (MS–S)
Axe⊕	Susceptible–very susceptible (S–VS)

As published in the NSW DPI Winter crop variety sowing guide 2015.

Treatments

Before sowing, the experiment was inoculated with STB-infected stubble collected the previous year. The stubble was applied to plots before plant emergence to simulate the disease under paddock conditions.

The crop was sown on 27 April and fungicide was applied to the protected treatment only on 7 July, 30 July and 19 August (full control every three weeks).

Supplementary spray irrigations were applied to promote the disease. The timing and rate varied in response to seasonal factors between August and November to ensure a conducive disease environment.

There were five treatments ranging from protected to high disease pressure (Table 2).

Results

Disease severity

Disease progress was monitored and recorded weekly. Results indicated that the amount of infected stubble applied to varieties produced different levels of disease. The disease progress on resistant varieties also significantly changed with the interaction of stubble load (Figure 1). The percentage of leaf area damage varied between varieties and with stubble loads. For example, the 2.5 t/ha treatment caused leaf area losses of: Axe 80%, Bolac 50%, Forrest 75%, Sentinel3R 20% and Sunvex 20%. Signs of the epidemic started to show in early July due to favourable conditions. The experiment also received daily irrigation from August which, when combined with the infected stubble loads, provided high disease pressure on all varieties.

Table 2. The five STB treatments applied in the experiment.

Treatment	Stubble application	Fungicide application
High disease pressure	2,500 kg/ha infected stubble added to plots	No foliar fungicide applications
Medium disease pressure	500 kg/ha infected stubble added to plots	No foliar fungicide applications
Low disease pressure	100 kg/ha infected stubble added to plots	No foliar fungicide applications
Very low disease pressure	No stubble treatments	No foliar fungicide applications
Protected #	No stubble treatments Seed treated with Jockey® (fluquinconazole 167 g/L) at 4.5 L/tonne of seed	Received multiple applications of Bumper® (propiconazole 250 g/L) at 500 mL/ha

Disclaimer: The protected treatments used do not constitute a recommendation for grower practice. Growers must follow label guidelines to ensure minimum residue levels are not exceeded.

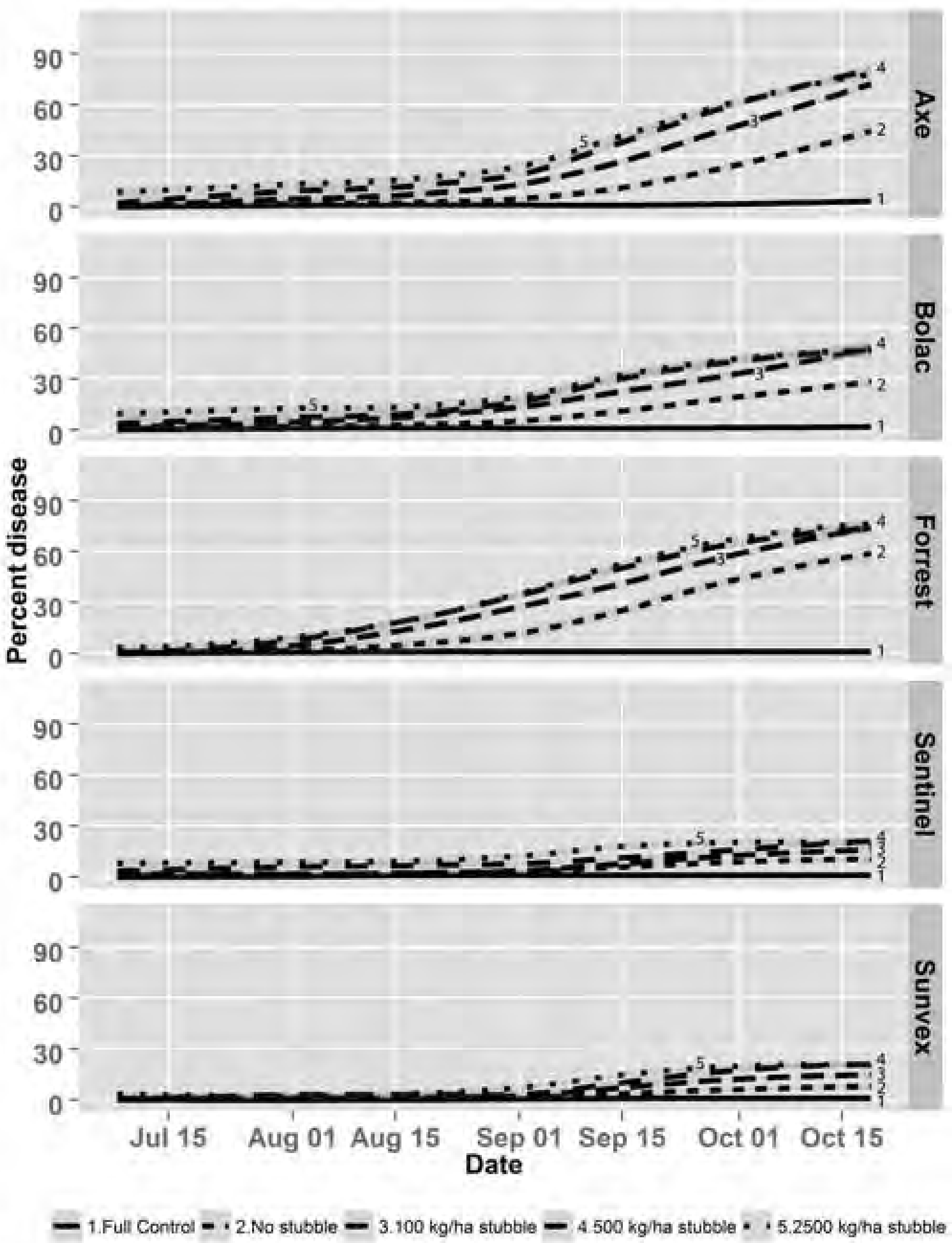

Figure 1. Disease progress in the irrigated STB experiment at Wagga Wagga, 2015.

crop protection

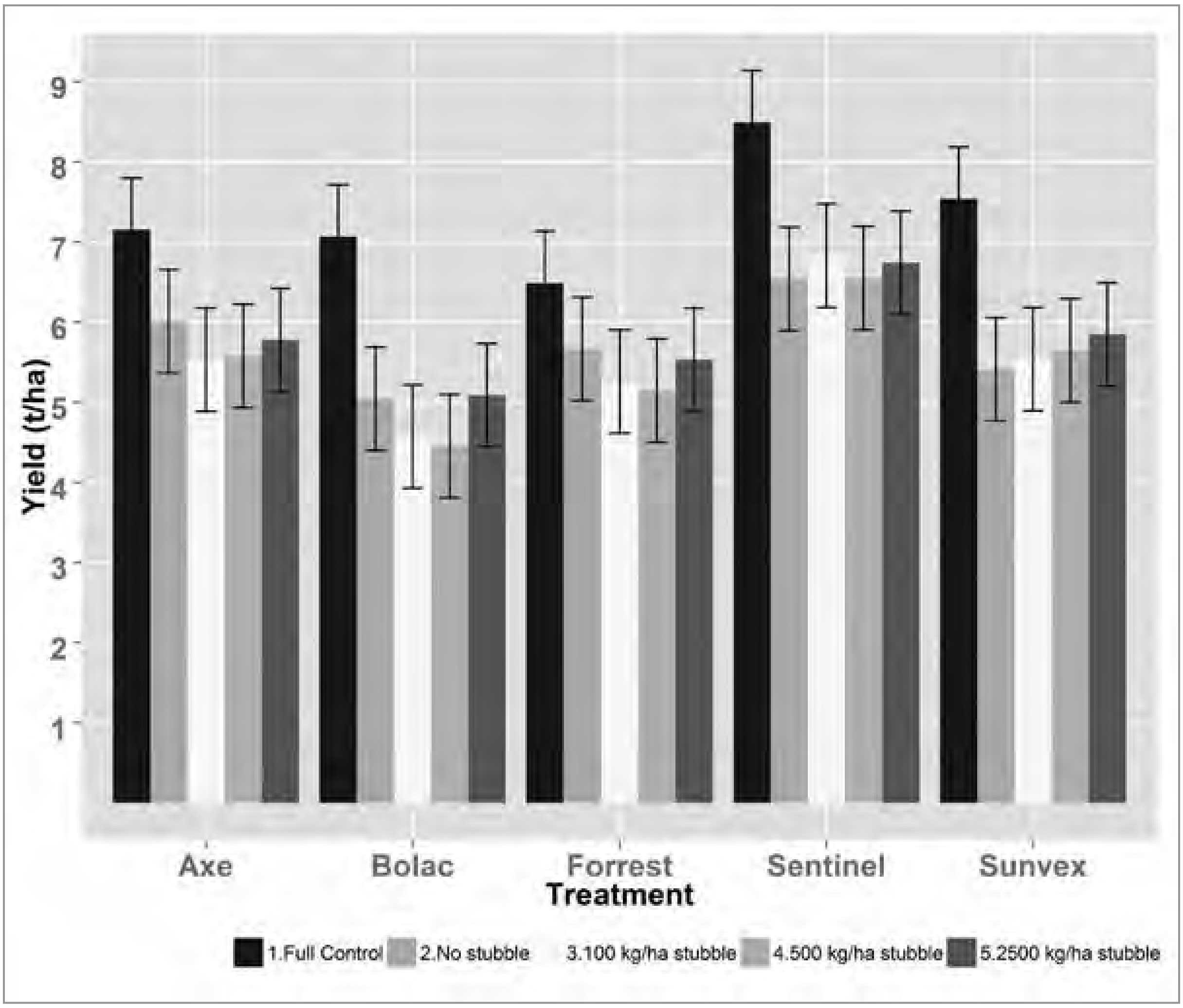

Figure 2. Yield of five wheat varieties in the irrigated STB experiment at Wagga Wagga, 2015. Standard error bars indicate a significant difference between treatments where they do not overlap.

Yield

The protected treatment developed no disease and was the highest yielding in all varieties. All treatments that developed disease had a reduced yield (Figure 2). The extent of yield loss was similar for each treatment in each variety, which was unexpected and does not follow trends observed in other diseases. Further investigation is required.

Summary

This experiment confirms that managing infected stubble is important for controlling STB. Results also show that variety resistance has a large effect on disease development within a season. Yield responses of varieties to disease in this experiment appear complex; they are from a single experiment and, as such, should be viewed in conjunction with other guidelines for controlling STB. This experiment will be repeated in 2016 to confirm results.

Note: This is an industry summary provided pre-publication. Further information and analysis will be published in due course.

Acknowledgements

This experiment is part of the 'Improving Grower Surveillance, Management, Epidemiology Knowledge and Tools to Manage Crop Disease in southern NSW project', DAN00177, 2013–18, jointly funded by GRDC and NSW DPI.

Thank you to Tony Goldthorpe, Brad Baxter and Michael McCaig for technical support.

Yellow leaf spot yield loss experiment – southern NSW 2015

Dr Andrew Milgate and **Tony Goldthorpe** NSW DPI, Wagga Wagga

Key findings

- Fungicide reduced disease levels in all varieties, but failed to eliminate the disease completely.
- Observed differences in disease levels were broadly in agreement with published variety resistance ratings.
- Yield losses were observed in the more susceptible varieties due to early disease development.
- Low disease levels from an early stage can cause yield losses.
- Variety selection will always play an important role in managing disease in high risk areas.

Introduction

This experiment examined the effect of yellow leaf spot (YLS) on yield in three wheat varieties of differing resistance in southern NSW.

Site details

Wagga Wagga was selected for the experiment as it represents the medium–high rainfall winter cropping regions of southern NSW.

Varieties

Three locally relevant varieties ranging in resistance to YLS were used (Table 1). Varieties with adequate stripe rust resistance were selected to reduce confounding effects from this disease.

Yellow leaf spot treatment

The experiment (disease plots) was inoculated with YLS-infected stubble on 19 May 2015 at 250 g/m^2, which is equivalent to 2.5 t/ha. Control plots also had non-infected stubble applied at the same rates. The experimental crop was sown on 15 May 2015.

Supplementary spray irrigations were applied to promote disease in the experiment; timing and rate varied in response to seasonal factors between August and November to ensure a conducive disease environment.

Table 1. Varieties included in YLS experiments 2015.

Variety	YLS rating [#]
Phantom[PBR]	Susceptible–very susceptible (S–VS)
EGA_Gregory[PBR]	Susceptible (S)
Strzelecki[PBR]	Moderately susceptible (MS)

[#] As published in the NSW DPI Winter crop variety sowing guide 2015.

The experiment was sown on 15 May and there were four fungicide treatments applied in the experiment (tables 2 and 3).

Table 2. The four YLS treatments applied in the experiment.

Treatment	Stubble application	Fungicide application
Full control#	Non-infected stubble added 2.5 t/ha	Multiple applications of Bumper® (propiconazole 250 g/L) at 500 mL/ha
Fungicide at 5-leaf stage	Infected stubble added 2.5 t/ha	Bumper® (propiconazole 250 g/L) at 500 mL/ha
Fungicide at GS31+GS39	Infected stubble added 2.5 t/ha	Bumper® (propiconazole 250 g/L) at 500 mL/ha applied at growth stage 31 and growth stage 39
No fungicide	Infected stubble added 2.5 t/ha	No foliar fungicide applications

All plots were sown with Jubilee® (flutriafol 250 g/L) treated fertiliser at 800 mL/ha for stripe rust control.

#Disclaimer: The full control treatment used in this experiment does not constitute a recommendation for grower practice. Growers must follow label guidelines to ensure minimum residue levels are not exceeded.

Table 3. Fungicide application dates.

Growth stage	Fungicide application dates
Full control	30 July, 1 September, 1 October (approximately every 3–4 weeks)
5-leaf stage	30 July
GS31	1 September
GS39	1 October

Results

Disease severity

Disease development was expressed early at the 5-leaf stage in all varieties and treatments. This was due to heavy disease pressure from the stubble collected from a susceptible variety infected with YLS the previous year.

Disease development did not conform to the disease progress curves observed in many other crop diseases. There was no extended lag period when the disease was at a low level relative to the amount of green leaf area in the canopy. Disease symptoms were expressed continuously throughout the season, which illustrates that conditions conducive to YLS can result in disease symptoms keeping pace with new leaf production as the plants grow.

Fungicide applications throughout the growing period separated the treatments to some extent, but they did not give complete control of the disease. This is more noticeable in the S–VS variety Phantom than in the S variety EGA_Gregory or the MS variety Strzelecki (Figure 1).

Yield

Yield loss due to treatment effects were observed in all varieties. However, it was most evident in the S–VS variety Phantom with a yield loss of 26% between the full control and no fungicide treatments (Figure 2). The benefit of higher varietal resistance was observed with EGA_Gregory and Strzelecki having yield losses of only 17% and 12% respectively.

Fungicide applied at the 5-leaf stage improved yield, but it was not significantly different to the no fungicide treatment. Phantom and EGA_Gregory had significant higher yields when fungicides were applied at GS31 and GS39, but this effect was not observed for Strzelecki.

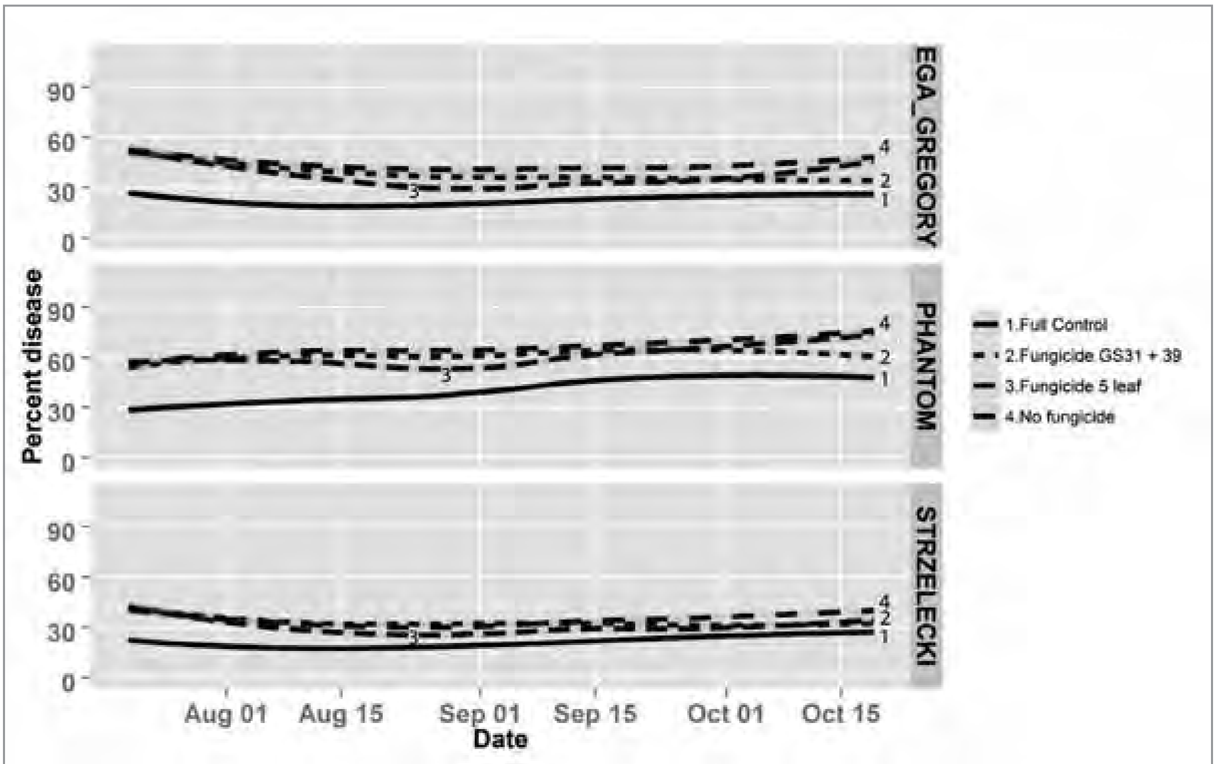

Figure 1. Disease progress in the YLS experiment at Wagga Wagga, 2015.

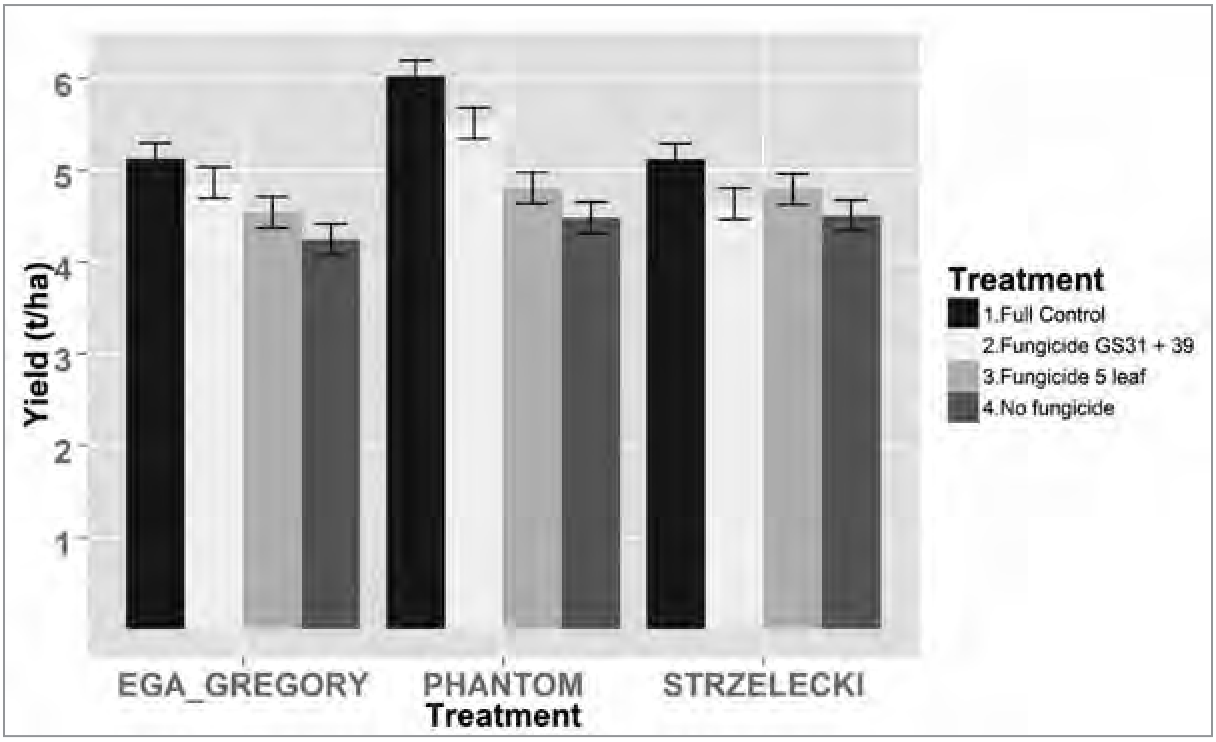

Figure 2. Yellow leaf spot yield experiment at Wagga Wagga, 2015. Where standard error bars do not overlap indicates a significant difference between treatments.

Summary

This experiment confirms the susceptibility of Phantom to YLS relative to EGA_Gregory and Strzelecki. High levels of disease can result in a significant yield loss in susceptible varieties such as Phantom. Variety selection needs more consideration in high YLS risk areas.

Low levels of disease can result in significant yield losses in higher yielding situations as was observed in the susceptible-rated variety EGA_Gregory. However, infection timing plays an important role in determining if there will be an effect on yield.

Complete control of YLS with fungicides was not achieved in the susceptible varieties, even with regular applications throughout the growing season.

Note: This is an industry summary provided pre-publication. Further information and analysis will be published in due course.

Acknowledgements

This experiment is part of the 'Improving Grower Surveillance, Management, Epidemiology Knowledge and Tools to Manage Crop Disease in southern NSW project', DAN00177, 2013–18, jointly funded by GRDC and NSW DPI.

Thank you to Michael McCaig, Tony Goldthorpe and Brad Baxter for technical support.

Southern NSW root and crown disease paddock survey – 2014 and 2015

Dr Andrew Milgate and **Brad Baxter** NSW DPI, Wagga Wagga

Key findings

- 55% of paddocks tested in 2014 and 80% of paddocks in 2015 had crown rot.
- 90% of paddocks tested in 2014 and 2015 had take all.
- The previous crop grown in the paddock can greatly influence the pre-sowing levels of crown rot and take all in the following year, particularly in a cereal on cereal rotation.
- Most paddocks with pre-sowing levels of crown rot and take all had increased inoculum levels throughout the growing season.
- Crop rotation and duration, and stubble management can reduce crown rot and take all infection risk.

Introduction

A total of 87 paddocks were surveyed as a part of a longitudinal study of soil- and stubble-borne diseases in southern NSW (sNSW) farming systems. Particular emphasis has been placed on the soil-borne disease, crown rot.

Crown rot is caused by the pathogens *Fusarium pseudograminearum* (Fp) and *Fusarium culmorum* (Fc). Crown rot restricts the flow of nutrients and water up the stem resulting in pinched or empty grain heads. Previous experiments have shown that grain yield can be reduced by 40% or more in susceptible cereal cultivars.

Other relevant observations identified from the survey data include take all's ability to rapidly increase inoculum levels during the growing season. Take all is caused by the pathogens *Gaeumannomyces graminis* var. *tritici* (Ggt) and *Gaeumannomyces graminis* var. *avenae* (Gga).

Site and method

The 87 paddocks were selected to reflect medium to high rainfall cropping systems in sNSW. Samples were collected at permanent GPS locations in a spiral pattern working from the centre moving outwards. Ten soil cores and 10 pieces of stubble were collected at 10 points along the spiral. The samples were bulked, homogenised and a sub sample taken for analysis. The sub sample was comprised of 500 g of soil and 30 random pieces of stubble 4–5 cm long, ensuring the crown was present on the stubble.

The soil and stubble sample was subjected to DNA analysis using PreDicta B to measure selected pathogen levels.

Results

Crown rot

Crown rot was present in 55% of paddocks surveyed in 2014 and 80% of paddocks in 2015. Most paddocks that had crown rot before sowing resulted in the pathogen building up considerably throughout the growing season (Figure 1).

Cereal–cereal–canola–cereal–cereal rotations such as in paddock number 6 (Figure 1) clearly show the rapid buildup of crown rot over the two-year period. This particular paddock went from a low crown rot risk before sowing in 2014 to high risk after one season. The inoculum survived over the 2014–15 summer, which then provided a high risk starting level for the 2015 wheat crop.

A paddock within the data set was sown to peas in 2013 and canola in 2014. The pre-sowing and postharvest PreDicta B samples gathered in 2015 showed no crown rot. This underlies the importance of crop rotation and duration in breaking down and maintaining low levels of crown rot inoculum.

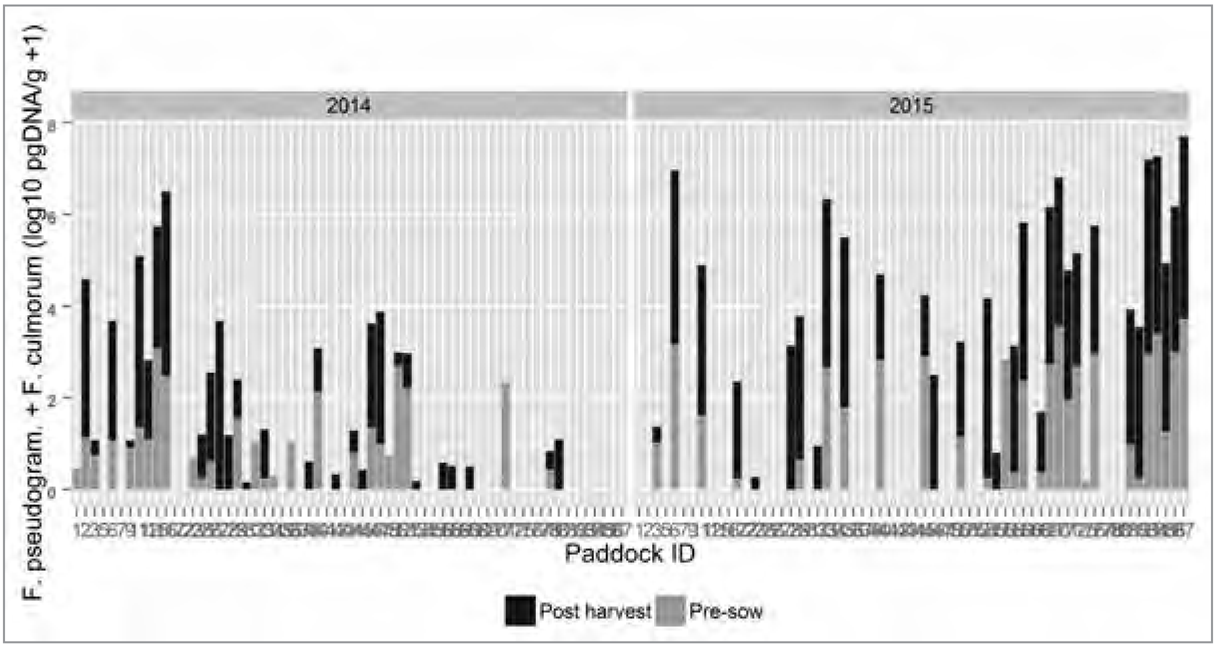

Figure 1. Increase in the levels of crown rot (Fp + Fc) during the growing season from pre-sowing to postharvest in 2014 and 2015. Log risk levels: Below detection = <0.6. Low = 0.6–<2.0. Medium = 2.0–<2.5. High = ≥2.5 for bread wheats in southern NSW.

Take all

Take all was present in 90% of paddocks surveyed in 2014 and 2015. Take all has the ability to rapidly increase under suitable climatic conditions, which were present during the 2015 growing season. Most paddocks had starting levels of inoculum in the below detection or low risk category before sowing and resulted in a medium–high risk postharvest (Figure 2).

The inoculum carryover from 2014 to 2015 varied from paddock to paddock. Some paddocks that had medium–high levels postharvest in 2014 carried those levels into 2015. Inoculum in other paddocks spiked postharvest in 2014 and then declined over summer and into the 2015 season. This variation in inoculum levels could be explained by variable rainfall received over summer. Each rainfall event of >25 mm over summer can reduce inoculum levels by 30% (SARDI 2015).

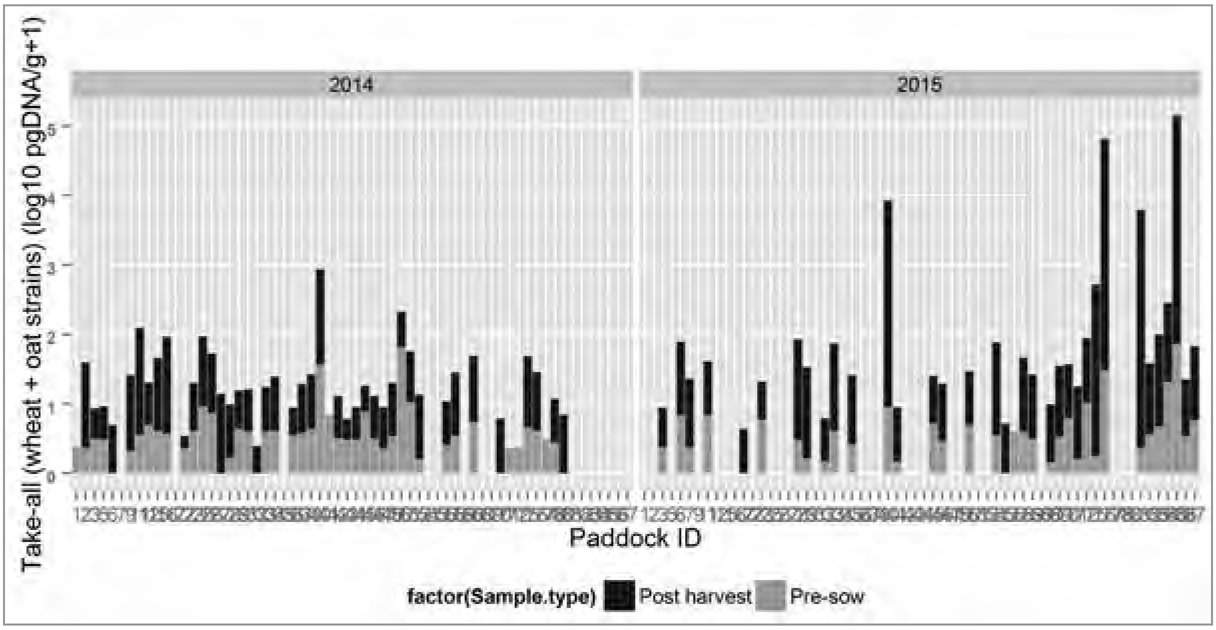

Figure 2. Increase in the levels of Take all (Ggt + Gga) during the growing season from pre-sowing to postharvest in 2014 and 2015. Log risk levels: Below detection = <0.8. Low = 0.8–<1.1. Medium = 1.1–<2.0. High = ≥2.0.

Previous crop effects

The crop grown in the previous year has a significant effect on the pre-sowing levels of crown rot and take all (figures 3 and 4). Host crops such as wheat allow inoculum levels to build up and carryover through summer.

Approximately half of the paddocks surveyed pre-sowing were in the medium and high risk categories for crown rot following a cereal crop (Figure 3). This translates to a potential yield loss of 5–60% before the crop is sown (SARDI 2015). Take all levels following a cereal crop are not as substantial as crown rot. Most of the paddocks fell in the below detectable–low risk category. This translates to 10–30% of paddocks expecting a 1–10% yield loss (SARDI 2015). Even low levels of take all are concerning due to the pathogen's ability to rapidly increase and cause yield loss (Figure 2).

A one-year canola break crop reduced inoculum build-up compared with a previous cereal crop. However, considerable levels of both crown rot and take all inoculum can be carried over summer. The majority of paddocks fell in the below detection–low risk categories for crown rot relating to a 0–10% yield loss (SARDI 2015). A number of paddocks fell into the medium–high risk category, which could result in a 5–60% yield loss (SARDI 2015). Take all levels were less responsive following a single canola break when compared with crown rot levels. At the beginning of 2015, the majority of the paddocks fell into the below detection–low risk category.

Summary

The 2014 and 2015 climatic conditions were conducive for high levels of crown rot and take all disease to develop. Cool wet winters followed by a relatively dry spring (in many instances) allowed low levels of crown rot and take all to develop to medium–high risk in paddocks. Many of the paddocks observed have disease complexes that can exacerbate yield losses in the presence of one, two or more significant pathogen levels.

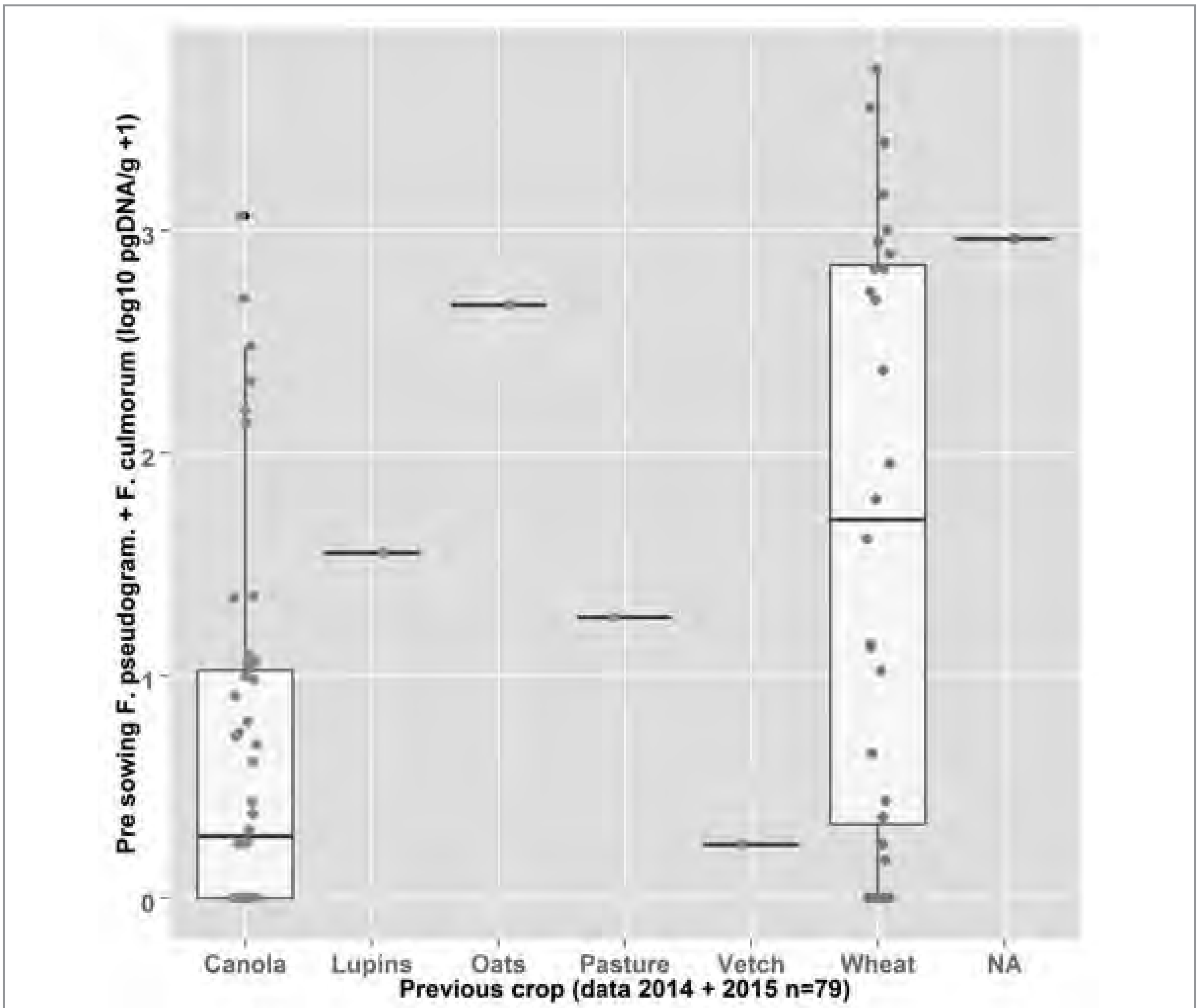

Figure 3. Previous crop effects on the background levels of crown rot (Fp + Fc) before sowing in 2014 and 2015. Log risk levels: Below detection = <0.6. Low = 0.6–<2.0. Medium = 2.0–<2.5. High = ≥2.5 for bread wheats in southern NSW.

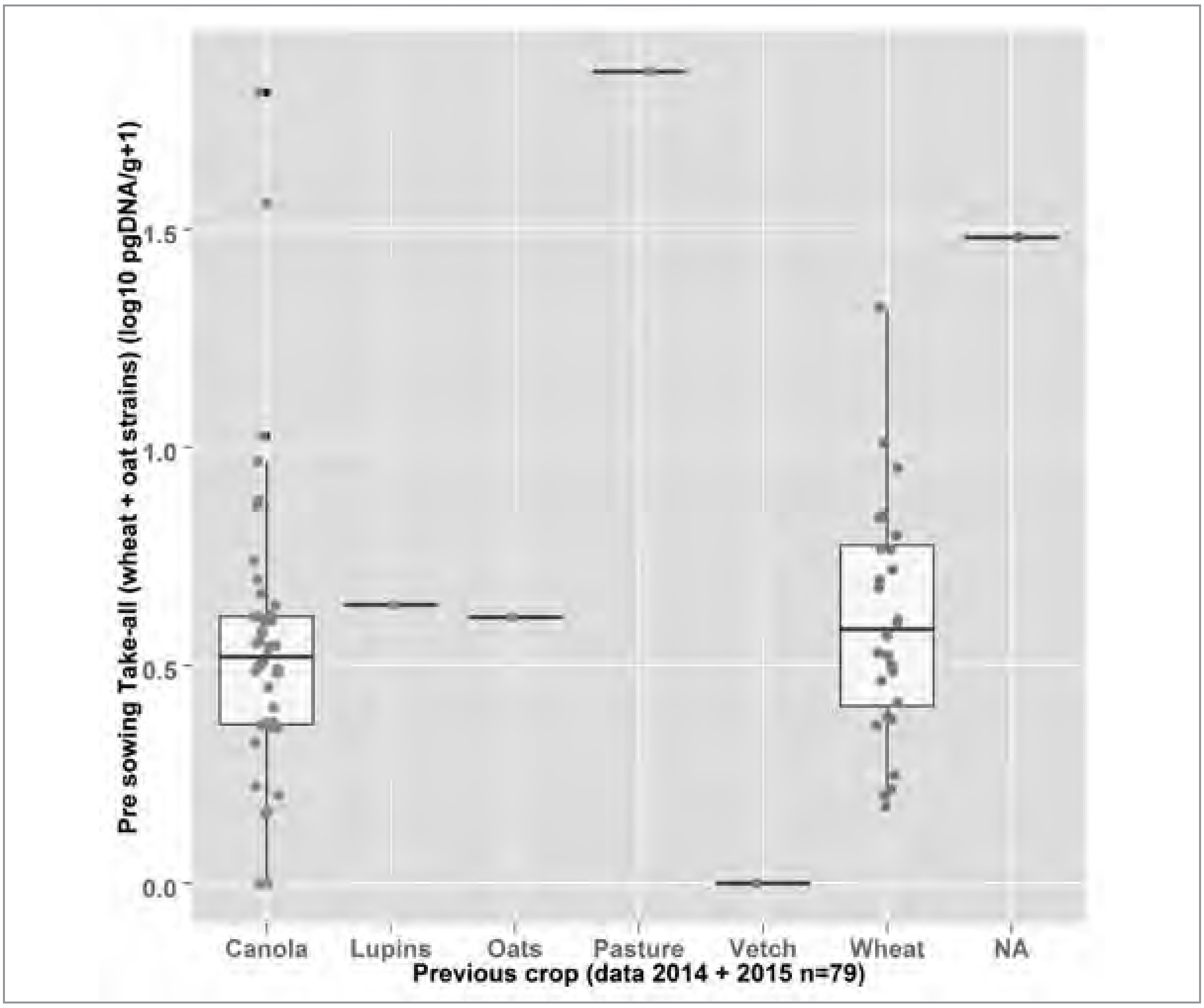

Figure 4. Previous crop effect on the background levels of Take all (Ggt + Gga) prior to sowing in 2014 and 2015. Log risk levels: Below detection= <0.8. Low= 0.8-<1.1. Medium= 1.1-<2.0. High= ≥2.0.

The previous year's crop has a significant effect on the starting levels of crown rot and take all disease. Cereal on cereal rotations increased the pre-sowing levels of both crown rot and take all when compared with canola as the previous crop. Other non-host crops such as lupins, field pea and vetch do not have enough data associated with each crop to make relevant conclusions at this stage.

The current recommendation to growers, where there are high levels of crown rot or take all, is to remove cereals from the paddock rotation. Sow a pulse or oilseed crop to allow inoculum to break down for more than one season if possible. If a cereal must be grown, consider sowing barley. Because barley matures earlier it can potentially negate the effects of crown rot during the grain fill stage. However, barley is susceptible to both crown rot and take all and it will not reduce the inoculum build-up during the growing season.

Note: This is an industry summary provided pre-publication. Further information and analysis will be published in due course.

Acknowledgements

This survey is part of the 'National crown rot program', DAN00175, 2013–18; and 'Improving Grower Surveillance, Management Epidemiology Knowledge and Tools to Manage Crop Disease in southern NSW, DAN00177, 2013–18; jointly funded by GRDC and NSW DPI.

Thank you to the growers who allowed access to their paddocks for survey data to be collected and the agronomists for arranging access.

Thank you to Tony Goldthorpe and Brad Baxter (NSW DPI), Chris Minehan (Rural Management Strategies), James Whiteley (previously Riverina Co-op), Tim Tarlington (Riverina Co-op) and Will Haines (Landmark) for technical assistance.

Reference

South Australian Research and Development Institute 2015, *Broadacre soilborne disease manual: PreDicta B DNA soilborne disease DNA tests*.

Crown rot variety trials – southern NSW 2015

Dr Andrew Milgate and **Brad Baxter** NSW DPI, Wagga Wagga

Key findings

» Yield losses of up to 20% due to crown rot were observed in 2015.

» Losses ranged from 2%–11% in bread wheat and 1.5%–3% for barley.

» Crown rot has a significant effect on gross margins when comparing grain quality and yields between crown rot treated and untreated plots.

» Select the highest yielding varieties rather than those with enhanced crown rot tolerance to minimise losses.

» Reduce the risk of crown rot infection by using crop rotation as well as stubble management.

Introduction

The aim of the experiment was to examine the effect of crown rot on yield in 12 bread wheats, one durum wheat and five barley varieties of differing tolerance levels in southern NSW (sNSW).

Crown rot is caused by the pathogens *Fusarium pseudograminearum* and *Fusarium culmorum*. Crown rot restricts the flow of nutrients and water up the stem resulting in pinched or empty grain heads.

Site details

Wagga Wagga was the site selected for 2015 as it represents the medium–high rainfall cropping region of southern NSW. The experiment was sown on 2 June 2015.

Treatments

Eighteen locally relevant varieties with a range of tolerance levels to crown rot were used (Table 1). Trials were inoculated with a mixture of isolates collected from southern NSW .

There were two treatments:

1. Crown rot added (Plus CR): 72 g of crown rot infected non-viable seed sown per plot with the viable seed.
2. Control/no crown rot added (Minus CR): no crown rot inoculum sown in plots.

A foliar spray of Bumper® at 0.5 L/ha was applied on 14 September for foliar disease control. The herbicides Precept 150® at 1.5 L/ha, Axial® at 0.2 L/ha and Adigor® at 0.5 L/ha were applied on 9 September to ensure good weed control.

Table 1. Barley and wheat varieties included in the 2015 crown rot trial.

Variety	Cr rating [#]
Buloke⌽	S–VS [P]
Commander⌽	MS–S
Compass⌽	S
GrangeR⌽	S
Hindmarsh⌽	S
Waagan⌽	S
Elmore CL Plus⌽	MS–S [P]
Emu Rock⌽	MS–S
EGA_Gregory⌽	S
Impala⌽	MS–S
Lancer⌽	MS–S
Merlin⌽	MS
Phantom⌽	MS–S
Sunguard⌽	MS
Suntop⌽	MS–S
Trojan⌽	MS
EGA_Wedgetail⌽	MS–S
EGA_Bellaroi⌽	VS

[#] Crown rot rating from NSW DPI Winter crop variety sowing guide 2015.

[P] Provisional rating.

Results

Yield

Adding crown rot inoculated seed resulted in a yield loss in all varieties in the experiment with the exception of Suntop (Figure 1), but not all these differences were statistically significant. The greatest yield loss comparing the crown rot treated and untreated plots was in the VS durum wheat variety EGA_Bellaroi (20%).

Where there was crown rot, Trojan performed well, yielding higher than 9 of the10 other bread wheats that had no crown rot. Yield losses

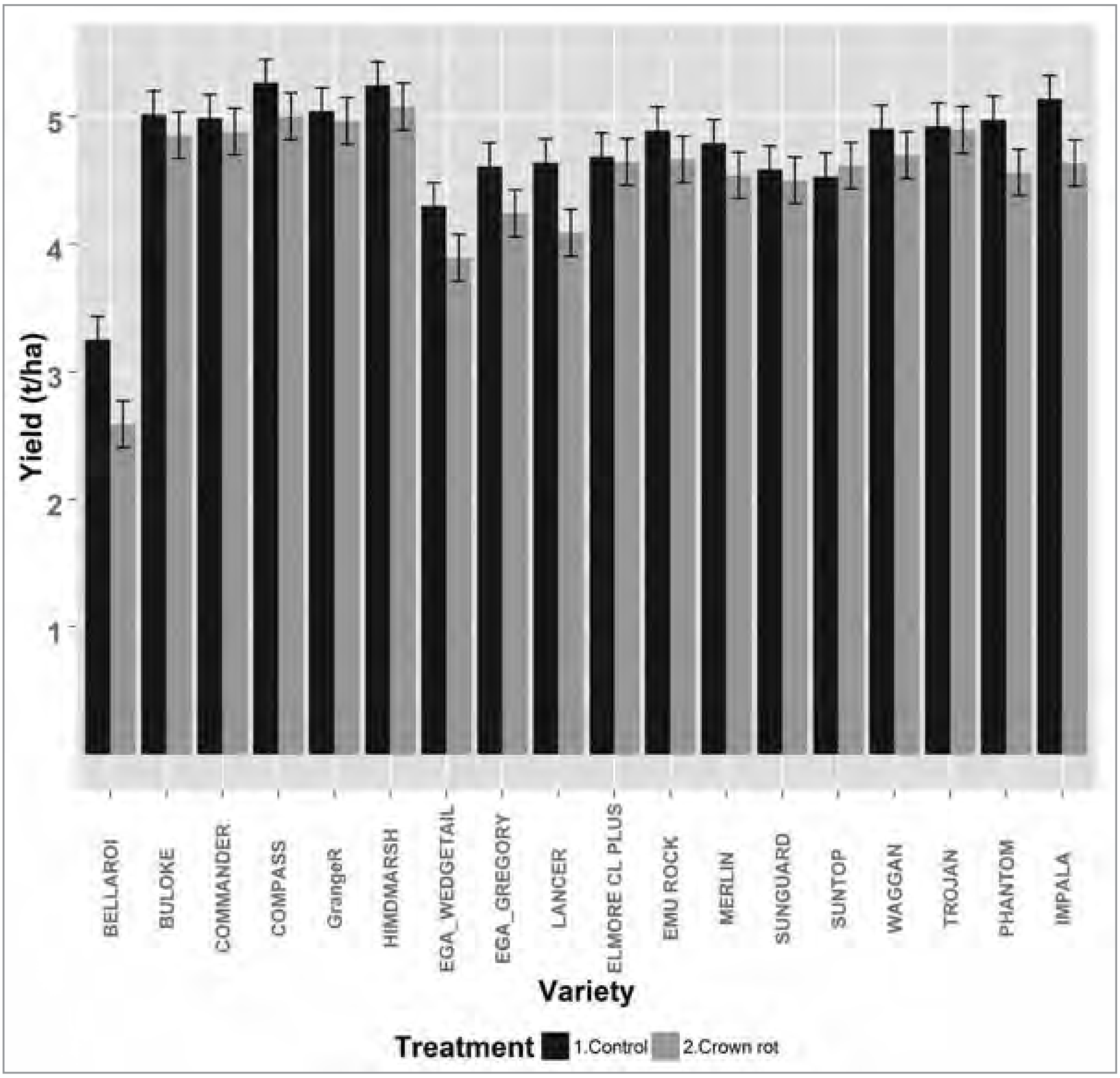

Figure 1. Crown rot yield trial Wagga Wagga, 2015. The effect of crown rot on yield in treated and untreated plots. Standard error bars indicate a significant difference between treatments where they do not overlap.

associated with crown rot varied from 2–11% in the remaining bread and biscuit wheats. Elmore CL PLUS, Sunguard, Suntop and Trojan displayed minimal losses between treated and untreated plots. EGA_Bellaroi was the worst performing variety. The later maturing lines such as EGA_Wedgetail were lower yielding due to the late sowing time.

Compass and Hindmarsh were the best performing barley varieties where there was crown rot. However, Compass showed the greatest yield loss (5%) between treated and untreated plots. There were minimal differences between the other three varieties in the trial with 1.5–3% yield losses.

Gross margins

The effects of crown rot on yield are shown in Figure 1. Crown rot can also affect the gross margin through increased screenings, test weight reductions, retention reductions and variation in grain protein content. These factors combine to downgrade grain quality and pricing, adding a multiplier effect to any reduced yield.

Table 1 shows the variation in yield, quality grades and effect on gross margin between crown rot treated and untreated plots for the 18 varieties selected.

The figure ($) lost per hectare varied between varieties depending on yield, tolerance and grain quality downgrades. On average across the 18 varieties, $78.51 per hectare was lost due to yield reduction and grain quality downgrades. In particular, crown rot caused the barley cultivar Commander to be downgraded from malt to feed quality due to reduced test weight. This resulted in a drop in per hectare price from $232 to $178, or $54/tonne penalty. The flow on effect resulted in a $288.60 net loss per hectare when comparing crown rot treated and untreated plots.

Table 1. Crown rot effects on gross margin, grain quality and yield.

Variety	Treatment	Grade potential (a)	Grade potential price ($/t) (b) (d) (e)	Actual grade (c)	Actual grade price ($/t) (b) (d) (e)	Loss in downgrades ($/t)	Mean yield (t/ha)	Gross margin ($/ha)	Loss (minus CR versus Plus CR) ($/ha)
Buloke	Minus CR	BU1	229.00	BU1	229.00	0.00	5.02	1149.34	
Buloke	Plus CR	BU1	229.00	BU1	229.00	0.00	4.85	1111.73	-37.61
Commander (d)	Minus CR	CO1	232.00	CO1	232.00	0.00	4.99	1157.90	
Commander (d)	Plus CR	CO1	232.00	F1	178.00	-54.00	4.88	869.30	-288.60
Compass	Minus CR	F1	178.00	F1	178.00	0.00	5.26	937.14	
Compass	Plus CR	F1	178.00	F1	178.00	0.00	5.00	890.65	-46.49
GrangeR	Minus CR	GN1	229.00	GN1	229.00	0.00	5.04	1155.07	
GrangeR	Plus CR	GN1	229.00	GN1	229.00	0.00	4.97	1137.45	-17.62
Hindmarsh	Minus CR	HIND	202.00	HIND	202.00	0.00	5.25	1059.79	
Hindmarsh	Plus CR	HIND	202.00	HIND	202.00	0.00	5.08	1025.73	-34.06
EGA_Bellaroi (E)	Minus CR	DR1	340.00	DR3	270.00	-70.00	3.25	877.70	
EGA_Bellaroi (E)	Plus CR	DR1	340.00	DR3	270.00	-70.00	2.59	698.95	-178.76
EGA_Gregory	Minus CR	AH	231.50	ASW1	211.50	-20.00	4.61	975.55	
EGA_Gregory	Plus CR	AH	231.50	AGP1	210.50	-21.00	4.24	892.31	-83.24
EGA_Wedgetail	Minus CR	APH	246.50	ASW1	212.50	-34.00	4.30	913.28	
EGA_Wedgetail	Plus CR	APH	246.50	ASW1	212.50	-34.00	3.89	827.09	-86.19
Elmore CL Plus	Minus CR	AH	231.50	HPS1	213.50	-18.00	4.69	1001.12	
Elmore CL Plus	Plus CR	AH	231.50	AGP1	210.50	-21.00	4.64	977.43	-23.69
Emu Rock	Minus CR	AH	231.50	AUH2	220.50	-11.00	4.89	1078.64	
Emu Rock	Plus CR	AH	231.50	AGP1	210.50	-21.00	4.66	981.65	-96.99
Impala (E)	Minus CR	ASF1	330.00	ASF1	330.00	0.00	5.14	1695.84	
Impala (E)	Plus CR	ASF1	330.00	ASF1	330.00	0.00	4.64	1529.77	-166.07
Lancer	Minus CR	APH	246.50	AGP1	210.50	-36.00	4.64	977.06	
Lancer	Plus CR	APH	246.50	AGP1	210.50	-36.00	4.09	860.60	-116.46
Merlin	Minus CR	AH	231.50	ASW1	212.50	-19.00	4.79	1018.90	
Merlin	Plus CR	AH	231.50	ASW1	212.50	-19.00	4.54	964.41	-54.49
Phantom	Minus CR	APW	217.50	APW1	217.50	0.00	4.98	1082.52	
Phantom	Plus CR	APW	217.50	AGP1	210.50	-7.00	4.56	960.39	-122.14
Sunguard	Minus CR	AH	231.50	AGP1	210.50	-21.00	4.59	965.71	
Sunguard	Plus CR	AH	231.50	AGP1	210.50	-21.00	4.50	947.12	-18.59
Suntop	Minus CR	APH	246.50	AGP1	210.50	-36.00	4.53	954.08	
Suntop	Plus CR	APH	246.50	AGP1	210.50	-36.00	4.62	971.61	17.53
Trojan	Minus CR	APW	217.50	AGP1	210.50	-7.00	4.92	1036.69	
Trojan	Plus CR	APW	217.50	AGP1	210.50	-7.00	4.90	1030.54	-6.15
Waagan	Minus CR	ASW	212.50	ASW1	212.50	0.00	4.90	1042.30	
Waagan	Plus CR	ASW	212.50	AGP1	210.50	-2.00	4.70	989.00	-53.31

(a) NSW DPI Winter crop variety sowing guide 2015
(b) GrainCorp prices at Grong Grong at 23 February 2015
(c) GrainCorp 2015–16 grain specifications
(d) GrainCorp prices at Coolamon at 23 February 2016
(e) Grain Link specifications and price at 23 February 2016

Not all varieties were as severely penalised as Commander. The majority of wheat and barley in the experiment lost significantly less per hectare (in the vicinity of $20–$80). This is still a considerable loss when multiplied out on a paddock scale. Suntop was not consistent with the rest of the data as it increased yield even though crown rot was present. However, this yield increase was not significant.

Summary

The dry spring conditions (September and October 2015) were conducive to the expression of crown rot in sNSW. The combination of high infection rates and warm conditions resulted in the observed yield losses. However, yield losses were less than expected, possibly due to adequate winter rainfall providing sub soil moisture at depth, reducing stress during the grain fill stage.

A few varieties of both wheat and barley were able to maintain yield in the presence of crown rot. Elmore CL Plus, Sunguard, Buloke and Hindmarsh performed well in the 2014 and 2015 experiments, whilst Trojan, Suntop, GrangeR and Commander performed well in the 2015 experiment. More varieties will be assessed during the coming year.

Crown rot has the ability to severely affect gross margins. It not only reduces yield, but can also increase screenings, affect test weight and grain protein resulting in quality downgrades. Downgraded grain quality and yield can cost the grower a considerable income. Quality losses can occur even when yield is not affected.

The current recommendation remains that growers should remove cereals from their rotations under high levels of crown rot. Sow a pulse or oilseed break crop and for more than one season if possible. If a cereal must be grown then select wheat varieties for the best yield in the area, or consider barley.

Growers should note that this is a single site summary and should not be relied on soley when selecting varieties.

Note: This is an industry summary provided pre-publication. Further information and analysis will be published in due course.

Acknowledgements

This trial is part of the 'National crown rot program', DAN00175, 2014–18, jointly funded by GRDC and NSW DPI. Thank you to Tony Goldthorpe, Michael McCaig, Joel Gray and Brad Baxter for their technical assistance.

Yellow leaf spot epidemiology trial – southern NSW 2015

Dr Andrew Milgate and **Tony Goldthorpe** NSW DPI, Wagga Wagga

Key findings

» Fungicide reduced disease levels in all varieties, but failed to eliminate disease completely.

» Observed differences in disease levels agreed with published variety resistance ratings.

» Early infection of yellow leaf spot (YLS) caused high yield losses in the more susceptible varieties.

» Variety selection will always play an important role in high risk areas.

» Crop rotation and best practice methods are required to maximise the benefits of correct variety selection.

Introduction

The aim of this experiment was to develop disease response curves indicating potential yield losses for a selection of varieties that represent various resistance categories for YLS.

Site details

Wagga Wagga was selected for the experiment as it represents the medium–high rainfall winter cropping regions of southern NSW. The site has an overhead irrigation system available to promote disease in trials. The experimental crop was sown on 15 May 2015.

Varieties

Five locally relevant varieties of similar maturity and with a range of YLS resistance ratings were used (Table 1). Varieties with adequate stripe rust resistance were selected to reduce confounding effects from this disease.

Treatments

YLS-infected stubble was collected locally and applied to disease plots on 19 May 2015 to simulate stubble retained from the previous year's crop. The treatments ranged from full control to high disease pressure (Table 2). All plots were sown with Jubilee® (flutriafol 250 g/L) treated fertiliser at 800 mL/ha for stripe rust control. Supplementary spray irrigations were applied to promote disease in the experiment. The timing and rate of these varied in response to seasonal factors between August and November to ensure a conducive disease environment.

Table 1. Yellow leaf spot (YLS) and stripe rust (Yr) ratings for varieties included in the YLS trial, 2015.

Variety	YLS rating #	YR rating #
Emu Rock⁽ᴰ⁾	Moderately resistant–moderately susceptible (MR–MS)	Moderately resistant–moderately susceptible (MR–MS)
Espada⁽ᴰ⁾	Moderately susceptible (MS)	Moderately resistant–moderately susceptible (MR–MS)
Lincoln⁽ᴰ⁾	Moderately susceptible–susceptible (MS–S)	Resistant–moderately resistant (R–MR)
EGA_Gregory⁽ᴰ⁾	Susceptible (S)	Moderately resistant (MR)
Phantom⁽ᴰ⁾	Susceptible–very susceptible (S–VS)	Moderately resistant (MR)

As published in the NSW DPI Winter crop variety sowing guide 2015.

Table 2. Treatments applied in the experiment.

Treatment	Stubble and fungicide application
Full control #	Five applications of Bumper® (propiconazole 250 g/L) at 500 mL/ha (30 July, 19 August, 1 September, 1 October and 27 October)
High disease pressure	Infected stubble applied at 2.5 t/ha
Medium disease pressure	Infected stubble applied at 0.5 t/ha
Low disease pressure	Infected stubble applied at 0.1 t/ha
Very low disease pressure	Natural infection only (no stubble applied)

Disclaimer: The full control treatments used in this experiment do not constitute a recommendation for grower practice. Growers must follow label guidelines to ensure minimum residue levels are not exceeded.

Results

Disease severity

Disease development was expressed early in all varieties, with spores released from the stubble inoculum as soon as the seedlings emerged. With the ability to maintain an extended leaf wetness period throughout the day and the mild temperatures, conditions for disease development were ideal. Disease progression differed in the treatments for most of the growth cycle indicating the amount of infected stubble present in a paddock affects the epidemic development. This was more noticeable in the S–VS variety Phantom and the S variety EGA_Gregory (Figure 1).

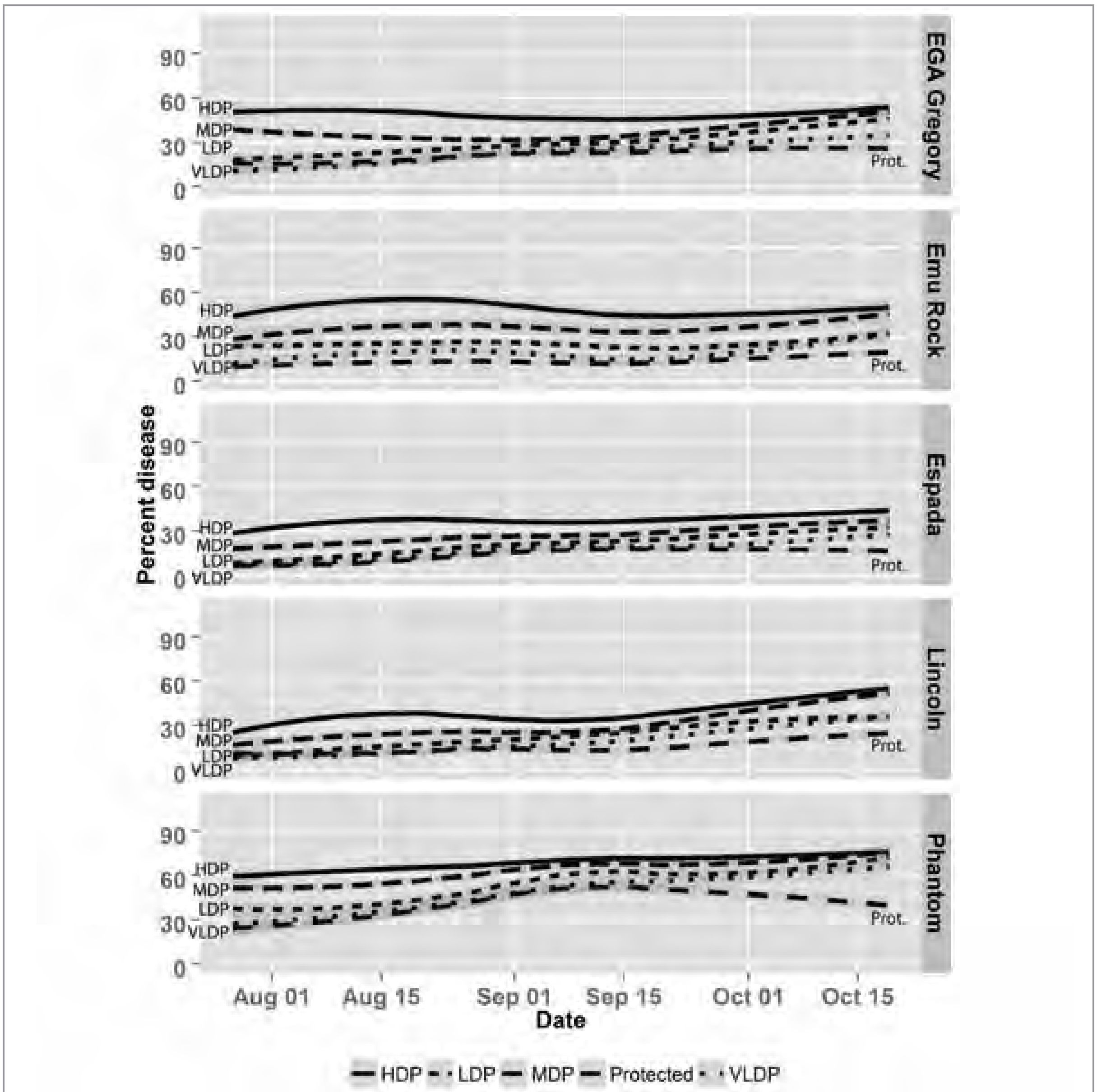

Figure 1. Disease progress in the YLS epidemiology trial at Wagga Wagga, 2015.

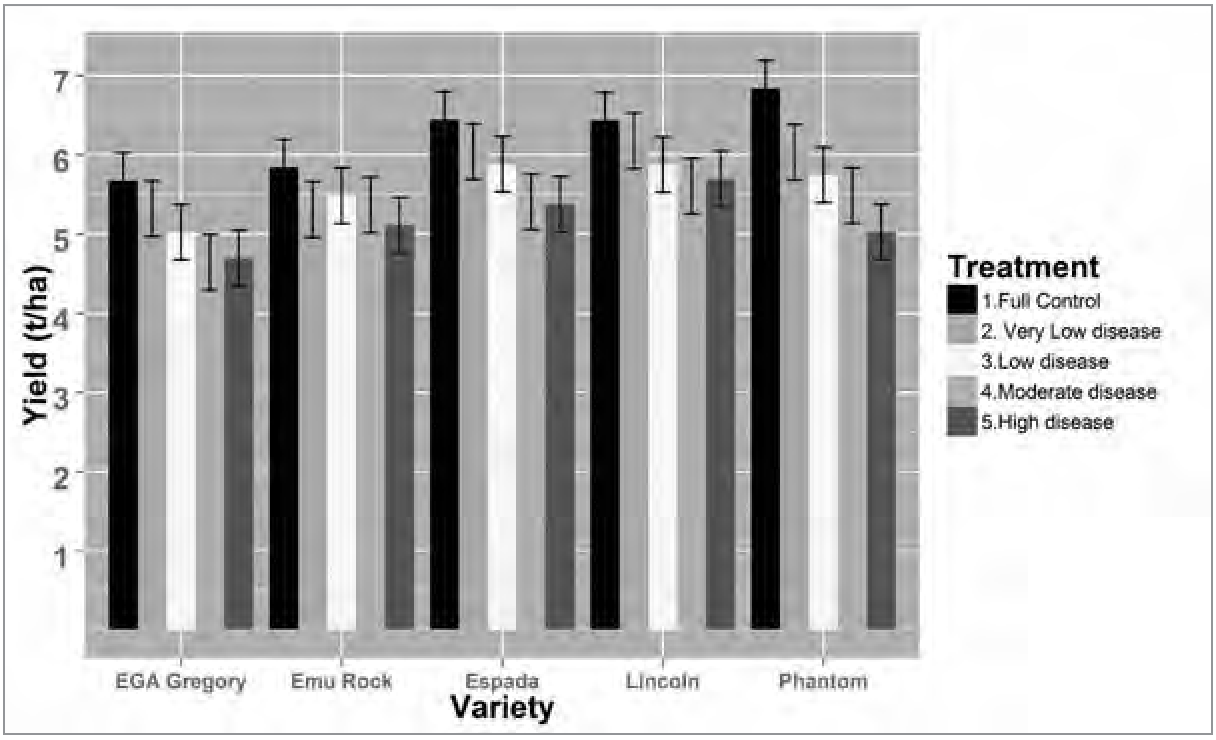

Figure 2. Yield of five varieties in the YLS epidemiology trial at Wagga Wagga, 2015. Standard error bars indicate a significant difference between treatments where they do not overlap.

The final expression of disease varied between 40%–75% on the S–VS variety Phantom. Although there was little difference between the plots that had no fungicide applied, the level of disease ranged from 60% to 75% of total leaf area diseased, with the more resistant varieties able to limit the amount of leaf area infected. The disease progress observed in this experiment shows no lag phase where the disease is low then progressively gets higher through the season. This could be due to the short life cycle of the YLS pathogen, *Pyrenophora tritici-ripentis*, which allows for rapid spore production and re-infection of newly emerged leaves.

Yield

The different rates of infected stubble applied to the plots affected yield, with the biggest differences in the S–VS variety Phantom (Figure 2).

Differences between treatments with no fungicide applied were not significant in the MR–MS variety Emu Rock, but total yield loss was still 13% compared with the full control treatment. Early YLS infection clearly had a larger impact on the S–VS variety Phantom (with a total yield loss of 26% and leaf necrosis up to 75%) and S variety EGA_Gregory (with a total yield loss of 18% and leaf necrosis up to 55%). The MS variety Espada had a total yield loss of 17%, which was higher than that of the MS–S variety Lincoln, which had a total yield loss of 13%.

Summary

These results confirm the susceptibility of Phantom and EGA_Gregory to early YLS infection. In high risk areas, disease resistance should be considered when selecting a suitable variety for your region confirmed by the MR–MS varieties that reduce yield losses under high disease pressure. Full control of YLS was not achieved by the fungicides used, but the infection rate was slowed and disease restricted to the lower canopy of the plant, achieving higher yields in the control plots.

Note: This is an industry summary provided pre-publication. Further information and analysis will be published in due course.

Acknowledgements

This experiment is part of the 'Improving Grower Surveillance, Management, Epidemiology Knowledge and Tools to Manage Crop Disease in southern NSW project', DAN00177, 2013–18, jointly funded by GRDC and NSW DPI.

Thank you to Michael McCaig, Tony Goldthorpe and Brad Baxter for technical support.

Grain yield performance of new wheat germplasm with resistance to Karnal bunt

Dr Livinus Emebiri, **Shane Hildebrand** and **Kerry Taylor** NSW DPI, Wagga Wagga

Key findings

» There was no detectable yield penalty associated with Karnal bunt resistance when new wheat lines were compared with commercial varieties.

» Three of the new wheat lines had yields comparable to Mace$^{\phi}$, Scout$^{\phi}$ and Suntop$^{\phi}$, the highest yielding commercial varieties.

» Half of the new wheat germplasm with resistance to Karnal bunt had grain yields above the experiment's average.

Introduction

Karnal bunt, a disease of wheat caused by the fungus *Tilletia indica*, has the potential to seriously damage the Australian wheat industry because it is a quarantine barrier to international trade (Beattie & Biggerstaff 1999). It is not present in Australia, but carries a significant biosecurity risk. Developing resistant varieties is the most economical, sustainable and environmentally friendly approach to managing disease risk (Murray & Brennan 1998).

Genetic resistance to plant disease is an active process that requires investment by the plant which, in the absence of the parasite, might result in a yield penalty (Oliver et al. 2014). An international research collaboration with CIMMYT (International Maize and Wheat Improvement Center, Mexico) has developed new wheat germplasm carrying Karnal bunt resistance genes. These will be made available to Australian breeders for variety development. As a prerequisite, this study was carried out to determine what penalties could affect yield or its components due to incorporating Karnal bunt resistance.

Treatments

The experiment was conducted at the Wagga Wagga Agricultural Institute in the 2015 winter cropping season. Six varieties known to be susceptible to Karnal bunt were chosen to represent the Australian-adapted cultivars. In comparison, 12 new wheat germplasm with resistance to Karnal bunt (Table 1), including a newly released cultivar (Super172) from the CIMMYT breeding program, were used for the study. The experiment design was a p-rep with two replicates. Data on grain yield was spatially analysed to account for field heterogeneity by using spatial information of the plot layouts (rows and columns) (Cullis & Gleeson 1991).

Table 1. New wheat germplasm with resistance to Karnal bunt.

Wheat germplasm	Pedigree
ZVS13_312	CHIBIA//PRLII/CM65531/3/SKAUZ/BAV92/4/MUNAL1
ZVS13¬_385	TAM200/PASTOR/TOBA97/3/HEILO
ZVS13_406	CHUANMAI 43*2/3/ATTILA/3*BCN*2//BAV92
ZWB10_44	ROLF07/7/CAL/NH//H567.71/3/SERI/4/CAL/NH/H567.71/5/2*KAUZ/6/PASTOR
ZWB11_172	WAXWING/4/BL 1496/MILAN/3/CROC_1/AE.SQUARROSA (205)//KAUZ/5/FRNCLN
ZWB11_95	MUNAL#1/FRANCOLIN#1
ZWB12_14	KIRITATI//ATTILA*2PASTOR/3/AKURI
ZWB12_187	FRANCOLIN#1BECARD//FRNCLN
ZWB12_30	BAJ#1/3/KIRITATI//ATTILA*2/PASTOR
ZWB12_31	BAJ#1/3/KIRITATI//ATTILA*2/PASTOR
ZWB12_4	CHIBIA//PRLII/CM65531/3/SKAUZ/BAV92/4/MUNAL#1
ZWB12_62	KLEIN DON ENRIQUE*2/3/FRET2/WBLL1//TACUPETO F2001

Results

The experiment was managed to achieve maximum yield potential. It was irrigated to the optimal level and top-dressed with nitrogen. The resulting grain yield was 4.7–8.0 t/ha (Figure 1). Grain yield variability was higher in the new wheat germplasm than in the commercial cultivars, probably indicating the difference in adaptation. Nevertheless, variance analysis indicated that there was no significant ($P = 0.19$) difference in grain yield amongst the genotypes. Super172, the newly released Karnal bunt resistant variety from CIMMYT, did not perform well in the experiment. Mace, Scout and Suntop were the highest yielding of the commercial varieties (Figure 1), but some of the Karnal bunt resistant lines also had comparable yields of ≥7.0 t/ha and six of the 12 lines had grain yields above the experiment's average.

Summary

This study used a field experiment to examine the yield performance of new wheat germplasm selected for resistance to Karnal bunt. There was no significant difference in yield between the new wheat lines and adapted, commercial varieties, indicating no evidence of yield penalty. On the contrary, three of the new lines yielded over 7 t/ha that compared favourably with the highest yielding of the commercial varieties.

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Acknowledgements

This work was part of the project 'Managing on-farm biosecurity risk in wheat through preemptive breeding', DAN00174, 2013–18, and jointly funded by NSW DPI and GRDC. Collaborative support and germplasm provided by Pawan Singh and RP Singh (CIMMYT) are also gratefully acknowledged.

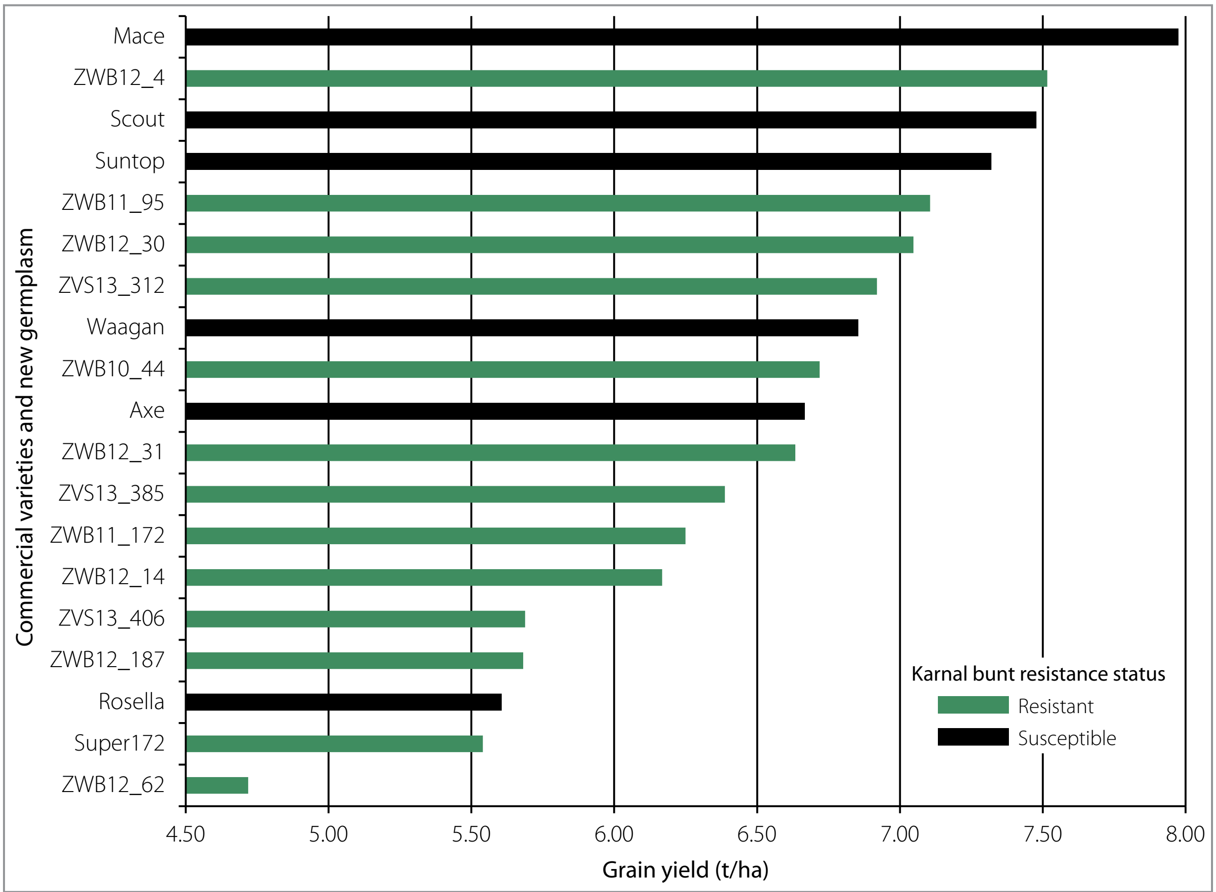


Figure 1. Yield performance of novel wheat germplasm with Karnal bunt resistance and current commercial varieties.

Reaction of Australian barley varieties to scald from southern NSW 2015

Dr Dante Adorada and **Dr Andrew Milgate** NSW DPI, Wagga Wagga

Key findings

» There are large differences in virulence at the seedling stage in southern NSW (sNSW).

» The variety grown in a region influences time-based changes in virulence.

» Strategic variety choice can affect the existence of virulent pathotypes.

Introduction

Successful disease management requires an in-depth understanding of the pathogens present in a region. Barley scald is a highly variable disease. Changes in virulence have been observed in a number of varieties at the adult stage in recent years, therefore a better understanding of the virulence profile present in sNSW is required. This experiment is beginning to characterise the reaction of Australian barley varieties at the seedling stage to scald isolates collected from southern NSW. It complements the adult plant screening process.

Site details

The trial was conducted in a glasshouse at the Wagga Wagga Agricultural Institute.

Treatments

Varieties

Thirty-five commercially available varieties with a range of adult plant resistance to scald were used (Table 1).

Scald inoculum

The varieties were inoculated at seedling stage under glasshouse conditions with isolates collected from barley growing areas in southern NSW. A total of 39 isolates (15 from 2013, 11 from 2014 and 13 from 2015) were used in the study (Figure 1).

Table 1. Australian barley varieties (AusBar) used in glasshouse trials and their adult plant reaction to scald.

Cultivar	Scald rating 2014*	Scald rating 2015*
Barque	nd**	nd
Bassɸ	MR-MS	S-VS
Baudinɸ	S	S-VS
Bulokeɸ	VS	S-VS
Capstanɸ	S	S-VS
Chargerɸ	S-VS	VS
Commanderɸ	S	VS
Compassɸ	S-VS	S-VS
Fairviewɸ	VS	VS
Fathomɸ	MR	MR
Finnissɸ	nd	nd
Fitzroyɸ	S	S-VS
Flagshipɸ	MS-S	S-VS
Fleetɸ	MS-S	S-VS
Flindersɸ	S	S-VS
Franklinɸ	nd	nd
Gairdnerɸ	S-VS	S-VS
GrangeRɸ	S	S-VS
Hindmarshɸ	VS	VS
La Trobeɸ	VS	VS
Litmusɸ	VS	nd
Navigatorɸ	S-VS	S-VS
Oxfordɸ	S-VS	S-VS
Schooner	S	S
Scopeɸ	S	S-VS
Shepherdɸ	VS	S-VS
Skiff	nd	nd
Skipperɸ	S-VS	VS
SY Rattlerɸ	MS	S-VS
Tantangara	nd	nd
Tilga	S	S
Tullaɸ	S	S
Urambieɸ	MR	MR
Westminsterɸ	MR	S
Wimmeraɸ	S-VS	S-VS

*Adult plant reaction to scald as published in the NSW DPI Winter crop variety sowing guide 2014 and 2015.
**No data.

Results

Differential reactions were observed among barley varieties from the different scald isolates (Table 2). For example, a 2013 isolate collected from Franklin, a barley cultivar identified to have adult plant resistance (APR), caused a susceptible (S) seedling reaction to Franklin and the majority of the varieties tested. It also caused moderately susceptible (MS) reaction to Buloke, previously identified to have seedling resistance to the disease. Some isolates also displayed lower levels of virulence such as 2013 isolate collected from Keel and a barley breeding line (BL no.1). In the 2015 collection, more virulent isolates were observed, which were able to infect most of the varieties tested. These results highlight the variable nature of scald.

The results appear to show differences in cultivar reactions to scald isolates influenced by where and when the isolates were collected. However, many more isolates will need to be tested before these apparent patterns can be verified. At this early stage of data collection, it is apparent that the scald pathogen is highly variable and that the changes in adult plant reaction recently observed are also present at the seedling stage. In addition, these virulences have been collected from growers' paddocks and, as such, represent a more broad potential risk for infection in the region. The absence of any virulent isolates detected on Tantangara in these tests appears promising; however, further isolates are required to determine if this resistance is effective in the whole region.

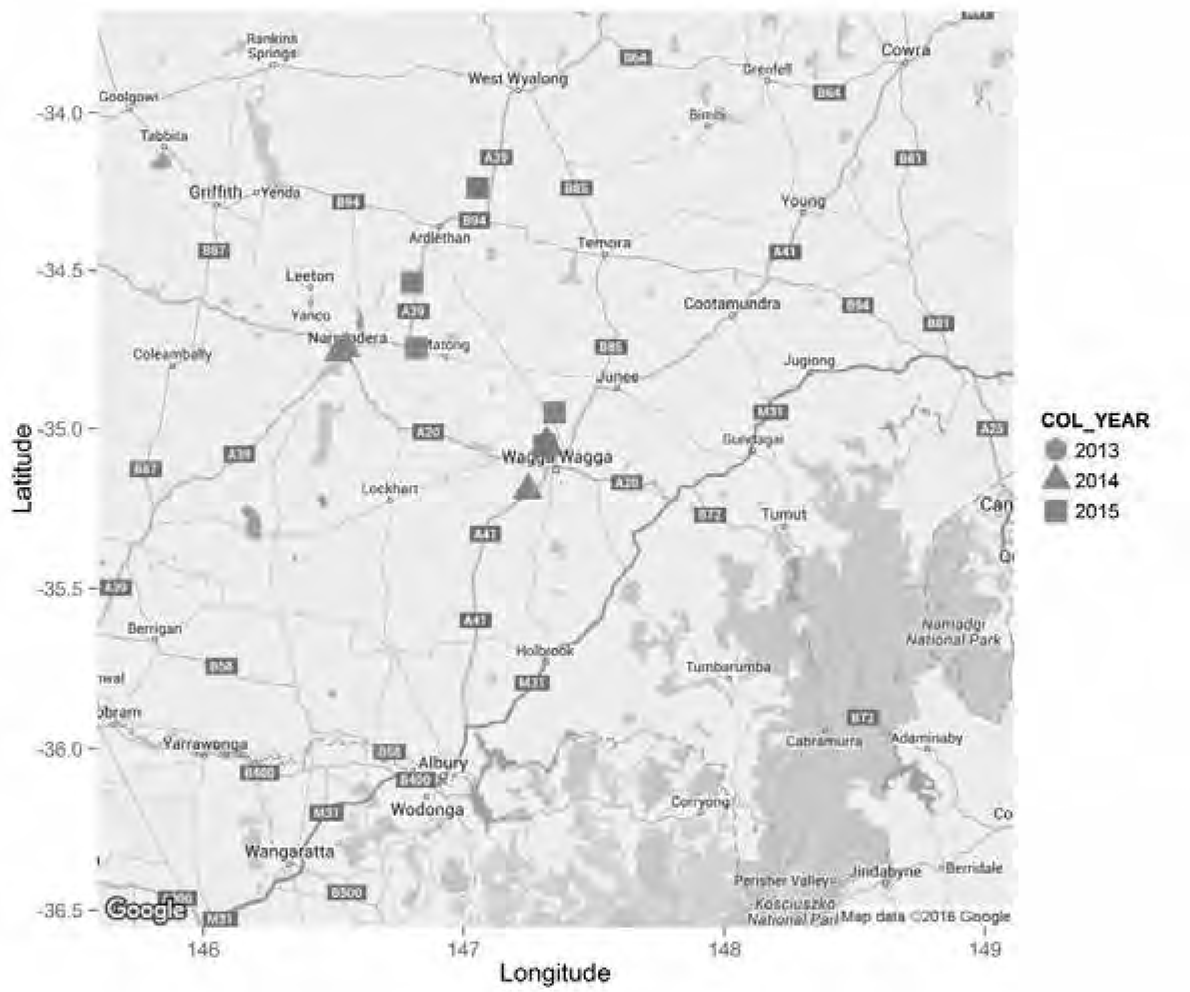


Figure 1. Locations of barley scald isolates collection in southern NSW 2013–2015.

Table 2. Reaction of AusBar to selected scald isolates representing the 39 scald isolates collected from barley growing areas of southern NSW 2013–2015 *.

AusBar	Year of collection, location and cultivar source of isolates																	
	2013				2014						2015							
	Wagga Wagga, Franklin **	Wagga Wagga, Hindmarsh	Wagga Wagga, Keel	Wagga Wagga, BL no. 1	Wagga Wagga, Franklin **	Wagga Wagga, Tilga**	Wagga Wagga, Keel	Wagga Wagga, Fathom	Narrandera, n/a ***	Uranquinty, Hindmarsh	Wagga Wagga, Skiff **	Wagga Wagga, Hindmarsh	Downside, n/a	Grong Grong, n/a	Derriwong, Hindmarsh	Bogan Gate, Buloke	Garema, n/a	Mirrool, n/a
Barque**	MR	MR	MR	R	R	MR	R	MR	R	R	S	R	R	R	R	R	R	S
Bass	MS	MS	MR	R	R	R	R	R	MR	R	S	R	R	R	MS	S	MR	S
Baudin**	S	MS	MS	MR	S	MS	MS	R	MS	R	MR	R	R	R	MR	S	R	R
Buloke** #	MS	MS	MS	R	MR	S	MR	MR	MR	R	S	R	S	S	S	S	MS	S
Capstan	MS	MR	MR	R	R	R	R	R	R	R	MR	R	MR	MR	R	R	MS	R
Charger	S	S	MS	MR	MS	S	MR	MR	MS	R	S	R	S	S	S	S	MS	S
Commander**	S	MR	MS	R	MS	MR	MR	R	MR	R	MR	R	R	MR	R	S	MR	S
Compass	MS	MR	MR	R	R	MS	MR	R	MR	R	S	R	R	R	MR	S	MR	S
Fairview	MS	MS	MS	R	MS	S	R	MR	MR	R	S	MR	R	MS	MR	S	R	S
Fathom	S	MR	MR	R	MR	MR	R	R	R	R	MR	R	R	R	MS	R	R	S
Finniss**	MR	R	MR	R	MS	R	R	R	MR	R	S	R	S	S	S	R	S	R
Fitzroy	MR	MR	R	R	R	MR	MR	R	MR	R	S	R	R	R	R	R	R	S
Flagship**	S	MS	MR	R	MR	MR	R	MR	R	R	S	MR	R	R	S	n/a	MR	S
Fleet**	MR	MS	MR	R	MR	MR	R	R	R	R	MR	R	S	MS	R	R	MR	S
Flinders	MS	MS	MR	MR	MS	MS	R	R	MR	R	S	R	MR	MS	MS	S	MR	S
Franklin**	S	MR	MS	MR	MS	MS	MR	R	MR	R	MR	R	R	MR	MR	S	MR	S
Gairdner**	S	MR	MS	R	MR	R	R	R	MS	R	R	MR	R	R	R	S	R	S
Granger	S	MS	MR	MR	MR	MS	R	MR	R	R	S	R	MS	S	MS	S	MR	S
Hindmarsh	MR	R	R	R	R	R	R	R	R	R	S	R	R	R	R	R	R	S
LaTrobe	R	S	R	R	R	R	R	R	R	R	MS	R	S	S	S	R	S	R
Litmus	S	S	MS	MR	S	S	MR	MR	MS	R	S	R	S	S	S	S	MS	S
Navigator	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	S
Oxford	MS	MS	MR	R	MR	MS	R	MR	MR	R	S	R	MS	MS	MR	S	MS	S
Schooner	S	S	MS	MR	MR	S	MR	MR	MS	R	S	R	S	S	S	S	MS	S
Scope	MS	MS	MR	MR	S	S	R	MR	MR	R	S	R	MR	S	S	S	MS	S
Shepherd	MS	MS	MR	MR	MS	S	MR	MR	MR	R	S	R	S	S	S	S	MS	S
Skiff**	MR	MS	R	R	MR	MR	MR	MR	MR	R	S	R	R	R	R	R	R	S
Skipper	MS	S	MR	R	MS	MS	R	MR	R	R	S	R	MS	MR	S	S	MR	S
SyRattler	MR	R	MR	R	R	R	R	R	R	R	R	R	R	R	R	MS	R	MR
Tantangara**	MR	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Tilga**	MR	MS	MR	R	MR	MS	R	R	MR	R	S	R	MR	S	S	R	MS	S
Tulla**	MR	S	R	R	R	R	R	R	R	R	S	MR	R	S	R	R	R	S
Urambie	R	MS	R	R	R	R	R	R	R	R	MS	R	MR	S	S	R	R	R
Westminster	MS	MR	MR	R	MR	R	R	R	R	R	S	MR	R	R	MS	MS	R	MS
Wimmera	MS	S	MR	R	MR	MS	MR	R	MS	R	S	MR	MS	S	S	S	S	S

* R = Resistant, MR = Moderately resistant, MS = Moderately susceptible and S = Susceptible

** With identified adult plant resistance to scald

*** n/a – no cultivar information available

With identified seedling resistance

crop protection

Summary

Changes in scale virulence can significantly affect both crop losses and control costs, especially for regularly grown commercial varieties. The variety's genetic composition influences changes in scald virulence, which leads to increased prevalence of virulent pathotypes against a variety. This has implications for variety selection by growers. Strategically choosing varieties with resistance levels of MS or better will have an effect on reducing the overall pathogen population size and help protect resistant genes.

It is important to also remember the results presented here are seedling reactions and that these do not always agree with results at the adult plant stage. The seedling results will be used to improve the understanding of the pathogen's dynamic nature. The NSW DPI Winter crop variety sowing guide is the recommended source of information for variety resistance ratings.

Surveying and collecting scald isolates in sNSW and testing against barley varieties is continuing to provide guidance to growers and agronomists in their variety selection and disease management strategies.

Note: This is an industry summary provided pre-publication. Further information and analysis will bepublished in due course.

Acknowledgements

This trial is part of 'The National Barley Foliar Pathogen Variety Improvement Program (NBFPVIP)', DAQ187, 2013–17, jointly funded by GRDC and NSW DPI.

Thank you to Joel Gray, Encarnacion Adorada and Sujeewa Rathnayake for technical assistance.

Tapping into ancient sources of disease resistance to protect our modern barley cultivars – barley scald 2015

Dr Dante Adorada and **Dr Andrew Milgate** NSW DPI, Wagga Wagga

Key findings

» Ancient barley germplasm from Ethiopia harbours resistance to scald and other diseases.

» Twenty-eight out of 355 Ethiopian lines were moderately resistant to scald.

» Careful selection for disease-resistant lines is important to retain other desirable traits.

Introduction

The aim of this work is to increase the sources of multi-disease resistant germplasm available for barley variety improvement in Australia. This is being achieved by screening and identifying possible sources of resistance to barley scald and other diseases from the centres of origin of barley cultivation.

Site details

The trial was conducted at the Wagga Wagga Agricultural Institute, which represents the medium rainfall winter cropping regions of southern NSW. This material is also being evaluated for other diseases in a number of other locations around Australia.

Varieties

A total of 335 Ethiopian lines were screened under field conditions as part of the National Barley Foliar Pathogen Varietal Improvement Program (NBFPVIP). This program contains diverse barley germplasm from ancient landraces to material more adapted to modern agricultural practices.

Treatments

Scald-infected barley stubble from the previous season was spread on the buffer rows to promote an epidemic. Regular overhead sprinkler irrigation was conducted to spread the disease and ensure the epidemic developed to high levels.

Results

The decline in the number of Australian barley varieties resistant to scald in the past two years, as reported in the NSW DPI Winter crop variety sowing guide 2015, prompted plant pathologists and breeders to find alternative sources of resistance to the disease. Of the 335 diverse set of Ethiopian lines evaluated against scald under field conditions, 28 were found to have a moderately resistant (MR) reaction to scald (Figure 1). These can now be investigated further as possible new sources of scald resistance that can be incorporated into research and breeding programs.

The material will require further development through crossing to elite Australian varieties to ensure it is adapted to Australian conditions. This is because there are often associated traits that are not desirable for modern agriculture. The Ethiopian germplasm were used because Ethiopia is proposed as the centre of origin of barley (Badr & El-Shazly 2012) and is thought to harbour desirable traits such as resistance to diseases. Careful selection is imperative to recover the best these lines have to offer, as a variety with acceptable resistance against one pathogen could lack resistance against others (Table 1).

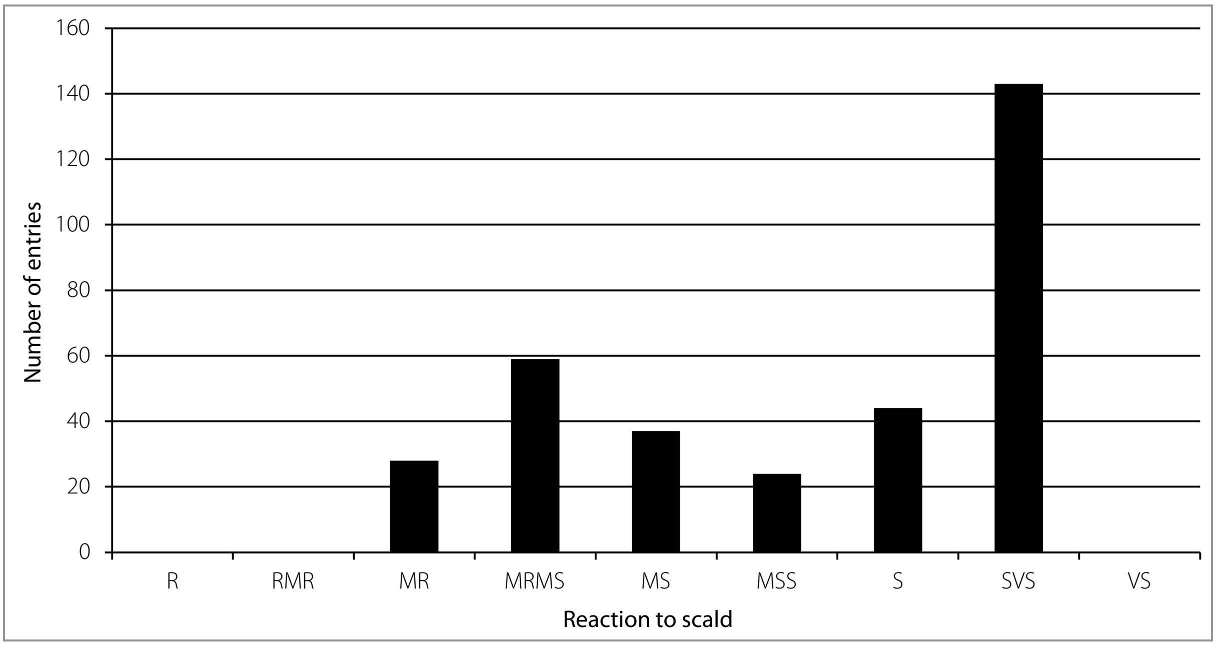


Figure 1. Frequency distribution of the 335 Ethiopian lines' reaction to scald under field conditions, 2015.
NB: R = resistant; R–MR = resistant–moderately resistant; MR = moderately resistant;
MR–MS = moderately resistant–moderately susceptible; MS = moderately susceptible;
MS–S = moderately susceptible–susceptible; S = susceptible; S–VS = musceptible–very susceptible; VS = very susceptible.

Table 1. Example list of Ethiopian lines that are possible sources of resistance (MR) to barley scald, spot form of net blotch (SFNB), net form of net blotch (NFNB) and leaf rust (LR), plus some other attributes.*

Name	Grain colour	Row No.	Scald	SFNB	NFNB	LR
AUS400105	White	6	MR	S	R	VS
AUS400107	White	6	MR	MS	R	R
AUS400110	White	6	MR	MS	R	MS
AUS400112	White	4	MR	MS	R	MS
AUS400115	White	6	MR	S	R	S
AUS400210	White	6	MR	VS	R	MS
AUS400213	Blue	6	MR	MS	R	MS
AUS400216	Blue	6	MR	VS	R	VS
AUS400217	White	2	MR	VS	R	R
AUS400411	White	6	MR	MS	R	R
AUS402784	White	6	MR	MR–MS	R	VS
AUS403034	Blue	4	MR	MR	R	MS
AUS403071	Black	6	MR	MS	R	MS
AUS403223	Black	6	MR	VS	R	R
AUS403839	White	2	MR	VS	R	R
AUS403850	White	6	MR	MR–MS	R	R
AUS403864	Pink-Blue	6	MR	S	R	R
AUS403884	White	2	MR	MS	R	MS
AUS403888	Black	6	MR	S	R	R
AUS403896	Pink (Brown)	4	MR	MR–MS	R	MS
AUS403920	White	6	MR	S	R	R
AUS403932	White	6	MR	VS	R	R
AUS403946	White	6	MR	MR–MS	R	R
AUS405821	White	6	MR	S	R	MS
AUS407177	White	6	MR	MR	R	S–VS
AUS407337	White	6 & 2	MR	S	R	R
AUS408654	Blue	4	MR	S	R	R
AUS409392	Brown	6	MR	VS	R	VS

*Attributes and reaction to barley diseases provided by Ryan Fowler, Department of Agriculture and Fisheries Queensland.

Summary

Screening for sources of barley scald and other disease resistances plays a vital role in improving the performance of barley varieties for NSW. Identified sources of resistance are provided to breeders for incorporation in their breeding program to develop improved varieties with resistance to scald. By tapping into ancient germplasm collections from where the crop originated, researchers hope to discover resistance that will provide protection to the barley industry into the future.

Note: This is an industry summary provided pre-publication. Further information and analysis will be published in due course.

Acknowledgements

This experiment is part of 'The National Barley Foliar Pathogen Variety Improvement Program (NBFPVIP)', DAQ187, 2013–17, jointly funded by GRDC and NSW DPI.

Thank you to Joel Gray, Michael McCaig and Sujeewa Rathnayake for technical assistance.

Reference

Badr, A & El-Shazly, H 2012, 'Molecular approaches to origin, ancestry and domestication history of crop plants: Barley and clover as examples', *Journal of Genetic Engineering and Biotechnology*, vol. 10, no. 1, pp. 1–12.

A petal survey for Sclerotinia in canola across NSW and northern Victoria

Audrey Leo, **Fleur Muller**, **Gerard O'Connor** and **Dr Kurt Lindbeck** NSW DPI, Wagga Wagga

Key findings

- » Sites in the Riverina, Cootamundra, Cowra and Grenfell developed high levels of Sclerotinia-infested petals during the flowering period in 2015.
- » No correlation was found between individual districts and petal infestation levels.
- » The amount of rainfall during flowering was positively correlated to the level of inoculum.
- » Rainfall during flowering is not the only factor that determines the level of petal infestation. Other factors such as initial inoculum level (from sclerotia), crop height, crop-canopy density and paddock history play a significant role.

Introduction

Petal testing, used as one of the Sclerotinia disease forecasting tools, can provide information on the presence and levels of Sclerotinia inoculum, which can lead to the stem rot developing in canola. Ascospores are released from apothecia (the fruiting structures of the Sclerotinia fungus) in winter and early spring and colonise canola petals when conditions are favourable. The infected canola petals fall into the canola crop canopy and can become lodged against a stem (main stem or branch). If environmental conditions are favourable, a stem lesion and stem rot can subsequently develop, causing yield loss.

Some districts in NSW and Victoria are known to frequently develop Sclerotinia stem rot. The purpose of conducting the petal survey was to identify if there are significant differences in the level of petal infestation between districts where the disease develops frequently, compared with those districts where the disease develops once every few years. This information will indicate what influences disease development, background inoculum levels or environmental conditions, or both.

Site details

Weekly petal samples were collected from commercial crops. Locations in NSW were divided into three meteorological districts: Riverina; South West Slopes; and Central West Slopes and Plains. Sites within the Riverina included Lockhart, Alma Park, Morven and Howlong. Sites within the South West Slopes included Mirrool, Pucawan, Coolamon, Junee, Harden and Cootamundra. Sites within the Central West Slopes and Plains included Condobolin, Forbes, Parkes, Manildra, Cowra and Grenfell. All petal samples from Victoria were collected from four commercial crops located at Dookie. Details on the paddock, time of sowing, time of fungicide application, date of sample collection, bloom stage, variety, nearest town location, the presence of apothecia and stem lesions (weekly) were recorded.

Sample collection and analysis

Flower heads were collected weekly from each site during the flowering period and were sampled from areas within the crop where no foliar fungicide had been applied. Collected samples were then sent to NSW DPI at Wagga Wagga for analysis. Random petals from the flower heads were plated onto agar plates and analysed after seven days. Counts were then taken for the number of Sclerotinia colonies present on a plate. Daily rainfall from Bureau of Meteorology (BOM) weather stations nearest to each site or location was used.

There are limitations with the testing procedure. The test cannot differentiate whether the Sclerotinia colony grew from an ungerminated resting Sclerotinia ascospore, or from an infected and colonised petal. However the result does give an indication of inoculum potential. Hence the term 'infested' is used rather than 'infected' to describe the level of inoculum present.

Results and discussion

The overall petal test survey showed that all sites in the Riverina had high levels of infestation throughout most of the flowering period (Table 1). Pucawan and Cootamundra had the highest levels of petal infestation in the South West Slopes compared with other sites within the district, which had moderate levels of petal infestation (Table 2). Only two sites in the Central West Slopes and Plains, Cowra and Grenfell, had high levels of petal infestation, while other sites within the district had low to moderate levels of infestation (Table 3). Two paddocks in Dookie had high levels of petal infestation while the other two sites showed moderate levels of infestation (Table 4).

Out of all the sites tested, only sites within the Riverina were shown to have the same pattern of infestation levels throughout the flowering period. The rest of the NSW and Victorian sites did not congregate according to their meteorological districts ($P > 0.05$). This is most likely due to the different amounts of rainfall and other factors that contribute to the level of inoculum released in the individual site within a district.

Positive correlation was detected between the level of petal infestation and the amount of total rainfall during flowering ($P < 0.05$). This was particularly apparent in the South West Slopes and the Central West Slopes and Plains, where an increase in rainfall during the flowering period coincided with an increase in the level of petal infestation. This pattern is clearly observed at Condobolin (Figure 1), where the percentage of infestation peaked in late August and early September, due to the increasing amount of rainfall. However, at some high rainfall sites only moderate levels of petal infestation were recorded. In this instance, paddock history is significant in determining the level of inoculum. The results from the four crops sampled at Dookie highlight the sporadic nature of Sclerotinia development, despite being located in close proximity. Factors such as variety, crop height, growth stage, canopy density and paddock history can all have an effect.

Table 1. Percentage of Sclerotinia infested petals and total rainfall during flowering at the Riverina sites.

Date	Week	% Petal infestation – Riverina				
		Lockhart	Alma Park 1	Alma Park 2	Howlong	Morven
27/07/15–02/08/15	1		100			100
03/08/15–09/08/15	2		100	94		100
10/08/15–16/08/15	3		100	98		100
17/08/15–23/08/15	4	100	100	100		100
24/08/15–30/08/15	5	100	100	100	100	90
31/08/15–06/09/15	6	96	100	100	100	100
07/09/15–13/09/15	7	98	98	100	100	100
14/09/15–20/09/15	8	100	100	100	100	100
21/09/15–27/09/15	9	100	100	100	96	98
28/09/15–04/10/15	10	94	96	100	100	100
05/10/15–11/10/15	11	18	23	33	64	28
12/10/15–18/10/15	12					
Total rainfall during flowering (mm)		99	111	111	107	131

Table 2. Percentage of Sclerotinia infested petals and total rainfall during flowering at the South West Slopes sites.

Date	Week	% Petal infestation – South West Slopes						
		Mirrool	Pucawan	Coolamon	Junee	Cootamundra 1	Cootamundra 2	Harden
27/07/15–02/08/15	1							
03/08/15–09/08/15	2					100	100	
10/08/15–16/08/15	3			36		100	100	
17/08/15–23/08/15	4			60		100	100	
24/08/15–30/08/15	5		62	40		94	96	46
31/08/15–06/09/15	6	46	94	54	96	100	100	80
07/09/15–13/09/15	7	76	98		88	90	100	36
14/09/15–20/09/15	8	50	82	68	58	100	100	48
21/09/15–27/09/15	9	38	96					58
28/09/15–04/10/15	10	48		42	78	100	100	78
05/10/15–11/10/15	11				12	30	18	10
12/10/15–18/10/15	12						8	
Total rainfall during flowering (mm)		90	90	131	92	112	112	97

Table 3. Percentage of Sclerotinia infested petals and total rainfall during flowering at the Central West Slopes and Plains sites.

Date	Week	% Petal infestation – Central West Slopes and Plains							
		Condobolin 1	Condobolin 2	Forbes	Parkes 1	Parkes 2	Manildra	Cowra	Grenfell
27/07/15–02/08/15	1								
03/08/15–09/08/15	2	4							
10/08/15–16/08/15	3	4			90				
17/08/15–23/08/15	4	6			82	58	50	100	
24/08/15–30/08/15	5	15				30	68	100	
31/08/15–06/09/15	6	20	20	22	48		62	96	92
07/09/15–13/09/15	7		14	46		18	64		94
14/09/15–20/09/15	8	4	8	62	58		30	76	100
21/09/15–27/09/15	9	10	22	18	10		20	94	94
28/09/15–04/10/15	10		26	4	8	6			4
05/10/15–11/10/15	11								
12/10/15–18/10/15	12								
Total rainfall during flowering (mm)		54	54	57	83	83	51	127	219

Table 4. Percentage of Sclerotinia infested petals and total rainfall during flowering at the Dookie sites.

Date	Week	% Petal infestation – Dookie			
		Dookie 1	Dookie 2	Dookie 3	Dookie 4
27/07/15–02/08/15	1				
03/08/15–09/08/15	2	60	48		
10/08/15–16/08/15	3	58	96		
17/08/15–23/08/15	4	96	100	54	98
24/08/15–30/08/15	5	98	100	42	92
31/08/15–06/09/15	6	72	98	84	100
07/09/15–13/09/15	7	26	30	28	78
14/09/15–20/09/15	8	46	92	26	88
21/09/15–27/09/15	9				
28/09/15–04/10/15	10	4		34	4
05/10/15–11/10/15	11				
12/10/15–18/10/15	12				
Total rainfall during flowering (mm)		47	50	56	57

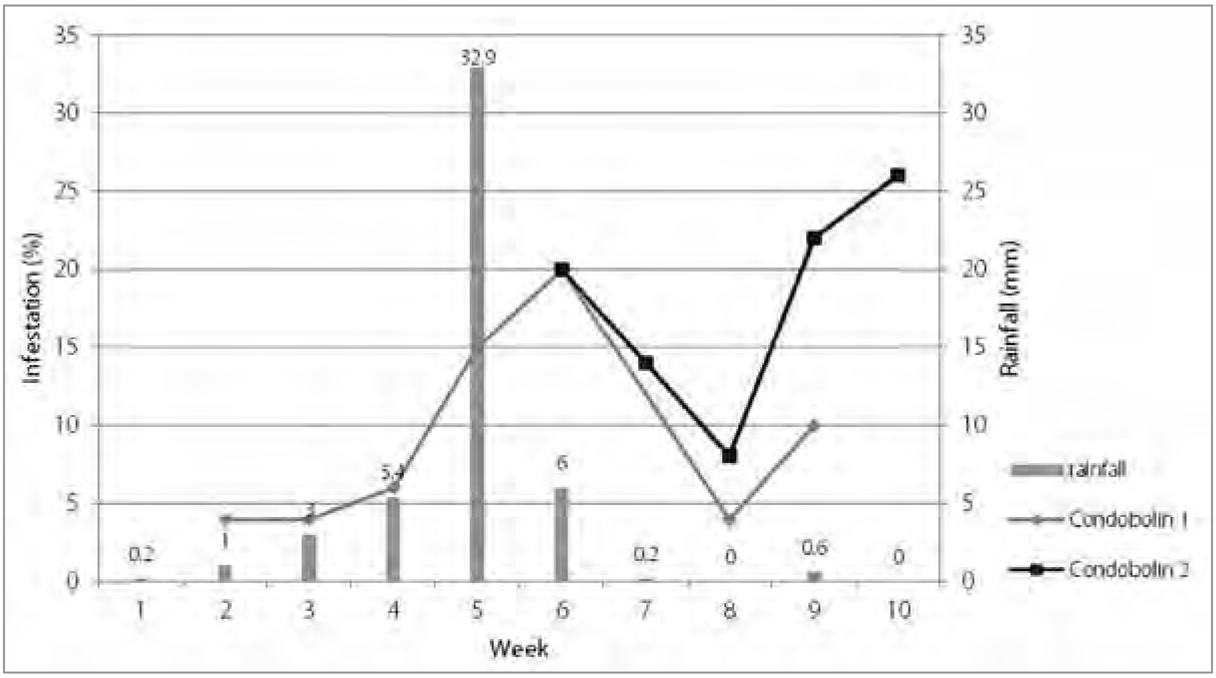


Figure 1. Percentage of petal infestation and weekly rainfall events at Condobolin 1 and Condobolin 2 during the flowering period.

Summary

All sites in this study were found to have varying levels of infestation. The level of petal infestation within each site did not cluster according to the meteorological districts, but it was positively correlated to the total amount of rainfall at an individual site during the flowering period.

High rainfall sites, for example at Cowra, Grenfell, Cootamundra and five of the Riverina sites, were found to have high levels of petal infestation from early until late bloom. At some of these sites such as Alma Park, large numbers of apothecia were seen developing within the crop before stem elongation. This shows that the level of inoculum is not a limiting factor and there is a high disease potential for these sites to develop a significant level of stem rot if the environmental conditions permit. It should be noted that the incidence of stem rot depends not only on the initial level of inoculum, but the frequency and amount of rainfall as well. Other factors such as crop-canopy density, variety and paddock history should be considered as these will have a major impact in creating a favourable micro-environmental climate for the apothecia to grow and produce ascospores leading to a high disease incidence.

Acknowledgements

This study is part of the 'National Canola Pathology project', UM0051, 2013–18, jointly funded by GRDC and NSW DPI.

Monitoring Sclerotinia stem rot development in commercial canola crops in southern NSW

Dr Kurt Lindbeck, **Audrey Leo** and **Gerard O'Connor** NSW DPI, Wagga Wagga

Key findings

- Sclerotinia stem rot is a very sporadic disease in southern NSW. Variations in the level of disease can occur between districts, between years and between paddocks.
- The best indicators of a high Sclerotinia risk district are a high intensity of canola production, frequent development of Sclerotinia stem rot (e.g. every year) and reliable spring rainfall during flowering.
- Results indicate that prolonged (at least 48 hours) durations of relative humidity above 95% can trigger Sclerotinia stem rot development.
- A high level of petal infestation with Sclerotinia ascospores does not guarantee that stem rot will develop.

Introduction

In 2015 commercial canola crops in southern NSW were closely monitored to increase our knowledge of Sclerotinia stem rot epidemiology. Six commercial crops in districts where the disease is known to frequently occur were specifically chosen to identify the trigger points that lead to Sclerotinia stem rot outbreaks. This is the third season of this study.

The outcome of this work is to improve our understanding of the interaction between the pathogen life cycle, the host crop and environmental conditions with the view to developing a disease prediction model for industry to use.

Sites and monitoring

Six commercial canola crops were chosen and located in districts with a high Sclerotinia risk. These districts feature high yield potential with reliable spring rainfall, extended flowering periods for canola and a high frequency of canola in the district (meaning ample inoculum availability). The crops were located at Howlong, Alma Park (south-west of Henty), Morven (east of Culcairn) and two crops located east of Cootamundra.

Each crop had half hourly recordings of relative humidity (RH) and temperature using electronic data loggers located within the crop canopy. The nearest Bureau of Meteorology (BOM) weather station was used to access rainfall records. Weekly observations were taken within each crop from early stem elongation to maturity. These included scouting for apothecia development, sampling petals for levels of ascospore infestation and counting the level of plant infection within the crop. The type of infection (leaf, lateral branch or main stem) was recorded.

Results

Of the six commercial crops monitored, all developed varying levels of Sclerotinia stem rot in spring (Table 1).

Table 1. Date of first observed stem lesion and highest level of stem infection recorded in six commercial canola crops in southern NSW

Site	Date of 1st stem lesion – 2015	Highest level of stem infection
Howlong	13 October	13.6%
Alma Park 1	14 September	21%
Alma Park 2	21 September	7%
Morven	14 September	3.6%
Cootamundra 1	07 October	10%
Cootamundra 2	14 October	3%

Apothecia were observed in all crops from the start of flowering. Petal testing showed high levels (over 90%) of petal infestation by Sclerotinia ascospores for virtually all of the flowering period until the first week of October (see report 'A petal survey for Sclerotinia in canola across NSW and northern Victoria').

Using a similar approach to previous years, RH, rainfall and temperature data were plotted against plant infection observations made during the growing season to identify infection events.

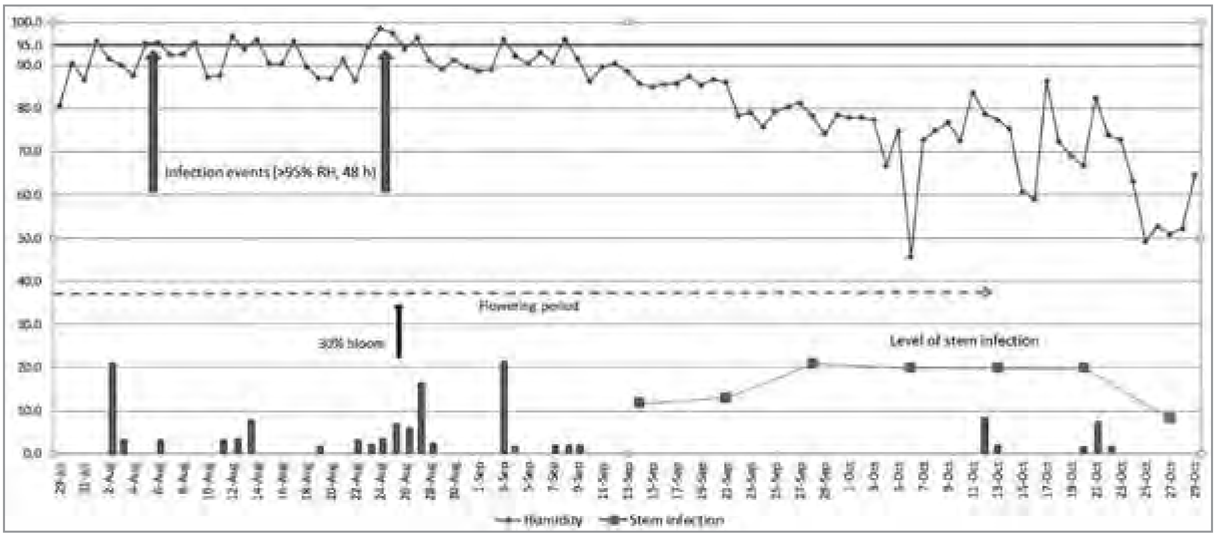


Figure 1. Relationship between relative humidity (diamond line) and level of Sclerotinia stem rot at Alma Park in 2015. The square line represents the level of main stem and branch infection from Sclerotinia stem rot. Flowering period is represented by the dashed line, with 30% bloom indicated. The solid line at the top represents 95% relative humidity (RH), it is assumed above this level there is free water within the crop canopy. Infection events (>95% RH, 48 h) are indicated by the two large arrows. Rainfall events (mm) are represented by the pale columns along the bottom line of the graph.

Figure 1 shows the typical Sclerotinia stem rot development pattern within a canola crop, which was observed at an Alma Park site in 2015. Infection events have been defined as durations of RH above 95% for 48 hours or more. When RH is above 95% it is likely that free water is present within the crop canopy and this time allows Sclerotinia ascospores to germinate and infect. These events occurred twice, 5–6 August and 24–26 August. The second infection event also occurred as the crop was reaching 30% bloom. At this point, significant numbers of petals are developing, but also senescing into the crop canopy, allowing infection to spread from petals onto canola stems. Hence, the first signs of stem rot symptoms were expressed about 14 days later on 14 September, which is typical. Dry conditions in September and October prevented the formation of a wet crop canopy and any further stem rot symptoms from developing.

Summary

Results from previous years validate the strong relationship between the duration of high RH (at least 95% for 48 hours), rainfall events, and stem rot symptom development. Petal testing in past years and in 2015 indicated that the presence of fungal inoculum (as viable ascospores) was not limiting in those crops monitored, with petal infestation levels above 90% for most of the flowering period. This implies that there was a high potential for Sclerotinia stem rot to develop in those crops. However, the presence of infested petals is only one part of the Sclerotinia equation, with the development of stem rot symptoms also reliant on favourable conditions within the crop canopy.

Results from this study are indicating that prolonged (48 hours) durations of high RH and rainfall during flowering (particularly after the 30% bloom stage) are the major influences in the Sclerotinia stem rot development in southern NSW. Symptom development relies on events to provide sufficient leaf wetness periods for ascospores to germinate and the infection of petals and leaves. The crop observations indicate that only one infection event is required to trigger significant levels of the disease to develop in the crop, with follow up rainfall events promoting further symptom development.

Results collated from the past three years of observations further reinforce the reputation of Sclerotinia stem rot as a sporadic disease, varying in incidence and severity between regions and years. Rainfall event at the critical crop development stage largely determines the severity of yield loss in any year.

Note: This is an industry summary provided pre-publication. Further information and analysis will be published at a later date.

Acknowledgements

This study is part of the 'National canola pathology project', UM0051, 2013–18; the 'National pathogen modelling project' DAW00228, 2013–18; and the 'Improving grower surveillance, management, epidemiology knowledge and tools to manage crop disease in southern NSW project', DAN00177, 2013–18. These projects are jointly funded by GRDC and NSW DPI.

Powdery mildew control in soybeans – southern NSW 2014–15

Mark Richards and **Luke Gaynor** NSW DPI, Wagga Wagga; **Mathew Dunn** and **Alan Boulton** NSW DPI, Yanco

Key findings

- Djakal has powdery mildew resistance.
- Other varieties are susceptible to powdery mildew.
- New chemistries are effective in powdery mildew control.
- Split fungicide application can have excellent results.
- Bidgee⁽ᐩ⁾ and Djakal grain yields were not affected by powdery mildew.
- Snowy⁽ᐩ⁾ and N005A-80 grain yields were reduced by powdery mildew.

Introduction

Powdery mildew is a disease in soybeans caused by the fungal pathogen *Erisyphe diffusa* (*Microsphera diffusa syn*.) It thrives in both dry (no rainfall) and humid conditions and causes major production losses in the tropical and subtropical soybean production areas of Australia. It first appeared in the Riverina (NSW), in 2011–12 and has caused significant infection in susceptible varieties.

In 2014–15, this experiment was conducted at the NSW DPI Leeton Field Station to investigate the potential impact of naturally occurring powdery mildew (PM) and four fungicide treatments on the grain yield of three commercial soybean varieties and an unreleased line (N005A-80).

Site details

Sowing date	4 December 2014
Soil type	Self-mulching, medium clay soil
Target sowing density	35 plants/m^2
Inoculation	Water injected peat slurry Group H
Fertiliser	125 kg/ha legume starter
Herbicides pre-emergent	Glyphosate 450 g/L at 2 L/ha Pendimethalin 330 g/L at 2.5 L/ha
Insecticides	Abamectin @ 300 mL/ha on 30 December 2014 Lamdacyhalothrin @ 80 mL/ha on 11 March 2015
In-crop rainfall	113 mm
Irrigation layout	1.83 m raised bed irrigation layout
Irrigations	8 ML/ha (approximately) The beds where pre-irrigated before the soybeans were sown
Harvest date	29 April 2015

Treatments

Varieties	Djakal, Bidgee⁽ᐩ⁾, Snowy⁽ᐩ⁾, NOO5A-80 (unreleased breeding line)
Fungicides (PM control)	Control = no fungicide applied Tebuconazole 430 g/L: full rate at full flower Tebuconazole 430 g/L: 80% rate at full flower, 80% approximately three weeks later Product A: full rate at full flower Product A: split application 50% rate at full flower, 50% approximately three weeks later
Fungicide applications	Control, no fungicide applied Tebuconazole: at full flower applied at 240 mL/ha on 3 February 2015 Tebuconazole: at full flower applied at 200 mL/ha on 3 February 2015 and at 200 mL/ha on 19 February 2015 Product A: at full flower applied at 400 mL/ha + 1% Hasten® on 3 February 2015 Product A: at full flower applied at 200 mL/ha + 1% Hasten® on 3 February 2015 and at 200 mL/ha + 1% Hasten® on 19 February 2015

Results

Powdery mildew infection

While both Tebuconazole and Product A were effective against powdery mildew, Tebuconazole was most effective when applied in a split application, and product A was most effective as a single application

(Figure 1). When Product A was applied as a split application, each application was only half rate, which could have reduced its effectiveness. The single application of a full rate of Product A at flowering was the most effective treatment in this experiment.

Bidgee, Snowy and N005A-80 all encountered similar levels of powdery mildew infection for each treatment. Djakal demonstrated its known resistance to powdery mildew with very low levels of infection detected in these plants.

Grain yield

The yield from Snowy was significantly increased by all fungicide treatments, due to its high susceptibility to powdery mildew. It is also likely that the variety's dense canopy structure reduced airflow and leaf drying favouring powdery mildew infection.

There were no significant differences in grain yield between the control and all fungicide treatments for the Bidgee and Djakal varieties. However, N005A-80 was only significantly higher yielding than the control with the single Tebuconazole application at full flower (Figure 2).

Tebuconazole has a permit for use (PER14645) in soybeans to control powdery mildew. Product A is not currently permitted in Australia for use in soybeans. Product A is also expensive, which will deter its use in the southern soybean-growing regions. However, it may be an option in the northern growing region where powdery mildew pressure is stronger.

The powdery mildew infection that occurred during the 2014–15 season had no significant impact on protein and oil levels. However, the severity of powdery mildew infection in this region is considered low compared with the northern growing regions where powdery mildew can cause total leaf desiccation.

The results confirm that Djakal has a strong level of resistance to powdery mildew. However, the white hilum varieties Snowy, Bidgee and the unreleased line N005A-80 are the preferred human consumption varieties to produce high quality soymilk and tofu products. As a result, producers aiming to supply these markets might need to consider fungicide use in high pressure seasons to prevent potential seed quality losses due to powdery mildew infection.

Summary

Powdery mildew is a major disease affecting soybeans in the tropical and subtropical regions of northern Australia. In the past four seasons, this disease has appeared in the Riverina. This experiment to evaluate variety susceptibility and fungicide efficacy found that:

» Djakal has powdery mildew resistance
» other varieties are susceptible to powdery mildew
» new chemistries are effective in powdery mildew control
» split fungicide application can have excellent results
» Bidgee and Djakal grain yields were not affected by powdery mildew
» Snowy and N005A-80 grain yields were reduced by powdery mildew.

NSW DPI will continue to research new breeding lines with powdery mildew resistance.

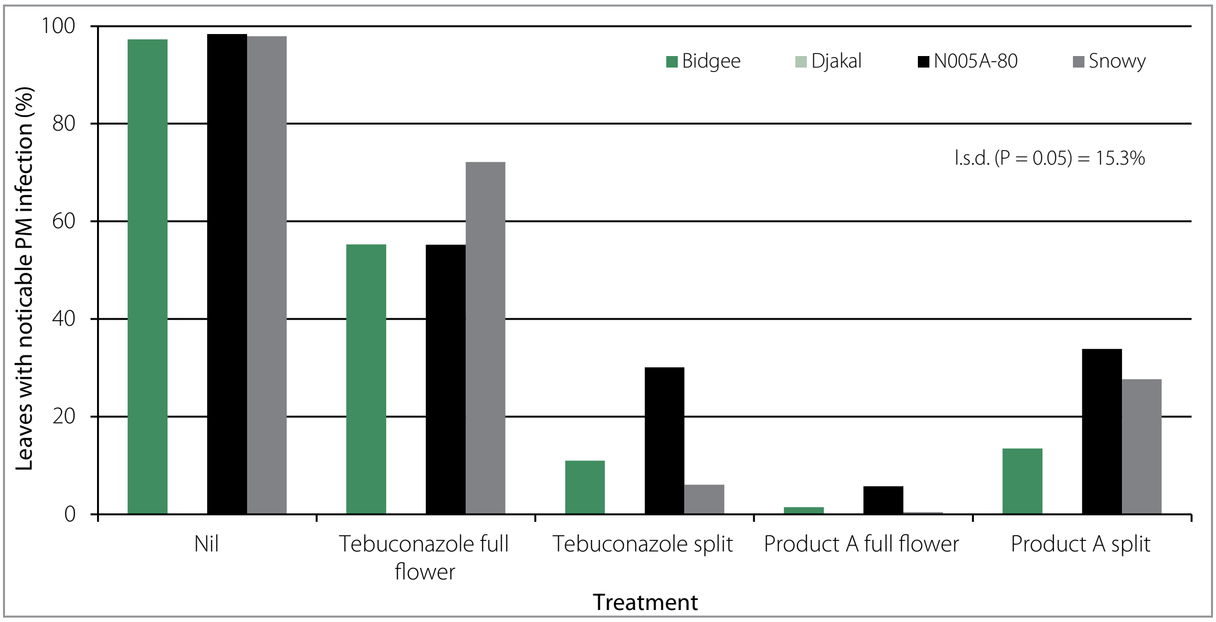


Figure 1. Fungicide efficacy on powdery mildew (PM) on four soybean varieties.

crop protection

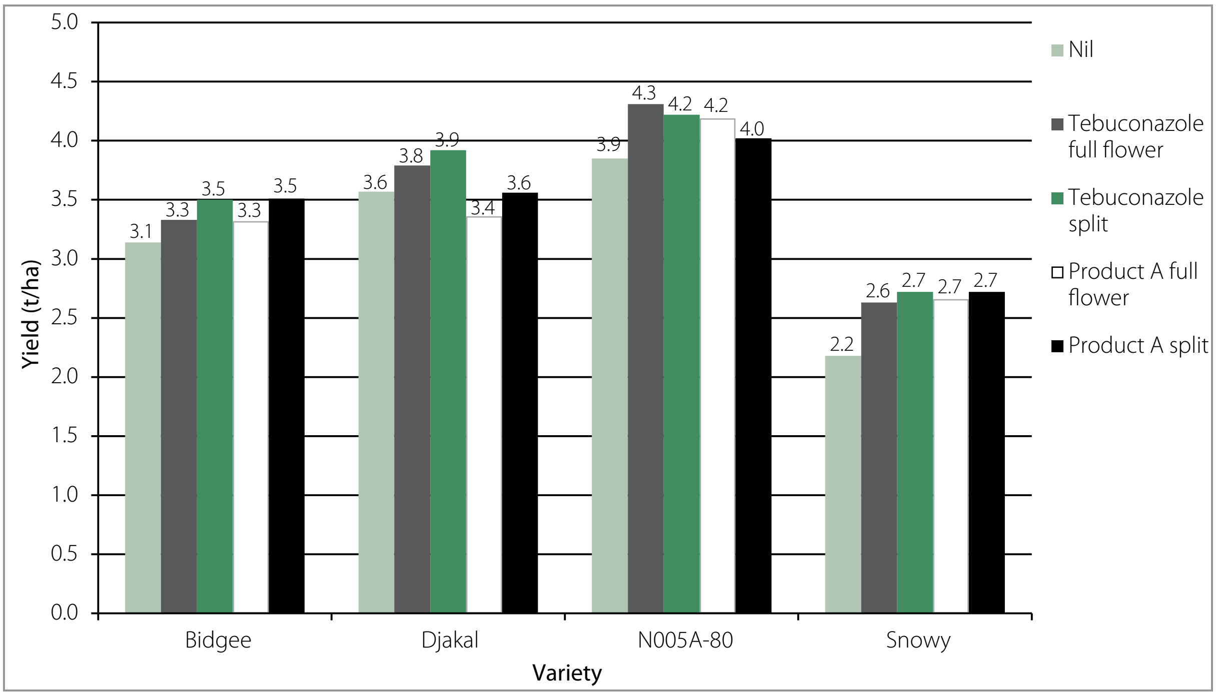


Figure 2. Soybean grain yield for variety and fungicide treatment interaction on four soybean varieties.

Acknowledgements

The experiment is part of the 'Southern NSW Soybean Agronomy project', DAN00192, 2014–18, which is jointly funded by GRDC and NSW DPI. Technical assistance was provided by John Dando and Paul Morris.

Southern cotton seedling thrips species composition

Dr Jianhua Mo, **Scott Munro**, **Dr Sandra McDougall**, **Sarah Beaumont** and **Dr Mark Stevens** NSW DPI, Yanco

Key findings

» Onion thrips were the dominant thrips species observed during monitoring.

» Western flower thrips constituted less than 5% of thrips monitored.

» During early cotton establishment there were more tomato thrips larvae than onion thrips larvae. By December, onion thrips larval numbers exceeded tomato thrips larval numbers.

Introduction

Thrips are common seedling pests of cotton in most growing districts. They feed on growing terminals causing leaf distortion and sometimes death of the terminals. Heavy infestation can result in yield loss and delayed maturity. Most insecticides applied in the southern cotton production region are targeted against thrips. The cotton industry thrips spray threshold of 10 thrips per plant and >80% leaf area loss from seedling to 6-leaf stage has been developed and validated in many research experiments in the northern production areas (see Cotton Pest Management Guide 2015–16). The southern production areas have a shorter season and early crop establishment has been strongly linked with high yields.

Western flower thrips (WFT), *Frankliniella occidentalis*, is a widespread thrips pest in horticultural production in the Riverina and was anticipated to be relatively more important in southern cotton production areas compared with the northern production areas. WFT is a species that is highly resistant to most registered thrips insecticides. Therefore, understanding thrips species composition during cotton establishment in the southern cotton production region is important in accessing the validity of the cotton industry thrips spray thresholds and recommendations.

Site details

Site 1	Coleambally Demonstration Farm (CDF) [145.95 E; -34.74 S]; planted and 1st water 8 October 2014; cooperators: Matt Toscan and Ben Witham
Site 2	Huddersfield (H), Darlington Point [145.91 E; -34.60 S]; planted and 1st water 8 October 2014
Site 3	Irrigation Research and Extension Committee (IREC) demonstration site, Whitton [145.92 E; -34.65 S]; planted and 1st water 1 October 2014; cooperators: Matt Stott (lessee of IREC demonstration site); James Hill (agronomist for Matt) and farm operations staff
Site 4	Point Farms (PF), Darlington Point [145.91 E; -34.65 S]; planted 10 October 2014 and 1st water 14 October 2014; cooperators: Matt Stott (lessee of IREC demonstration site); James Hill (agronomist) and farm operations staff

Treatments

Variety	Bt cotton: Sicot 74BRF D2; conventional cotton: Sicot 71 RRF D2
Seed treatment	D2= Dynasty® - azoxystrobin+ metalaxyl-M+ fludioxonil
Irrigation	Drip (IREC); furrow (PF, CDF & H)
Monitoring dates	CDF: 28 October, 3 November, 10 November, 17 November, 27 November, and 5 December 2014 Huddersfield: 28 October, 11 November, 17 November, 25 November, and 1 December 2014 IREC: 21 October; 27 October, 3 November, 13 November, 20 November, and 1 December 2014 PF: 27 October, 3 November, 10 November, 17 November, 25 November and 4 December 2014
Sample unit	10 whole random plants from untreated Bt and conventional cotton plots
Monitored	Thrips adults, nymphs and species composition
Analysis	Permutational Multivariate Analysis of Variance (MANOVA), significant treatment effects were detected (P<0.05)

crop protection

Results and discussion

Thrips pressure was relatively low in October, ranging from 0.55 to 2.20 per plant for adult thrips and 0.60 to 2.33 per plant for larval thrips (Figure 1). The pressure built up quickly in the next two months, reaching >40 per plant in November for adult thrips and >190 per plant for larval thrips. The IREC site recorded the highest thrips pressure for both adult and larval thrips, with peak thrips density over twice as many than that at the other three sites.

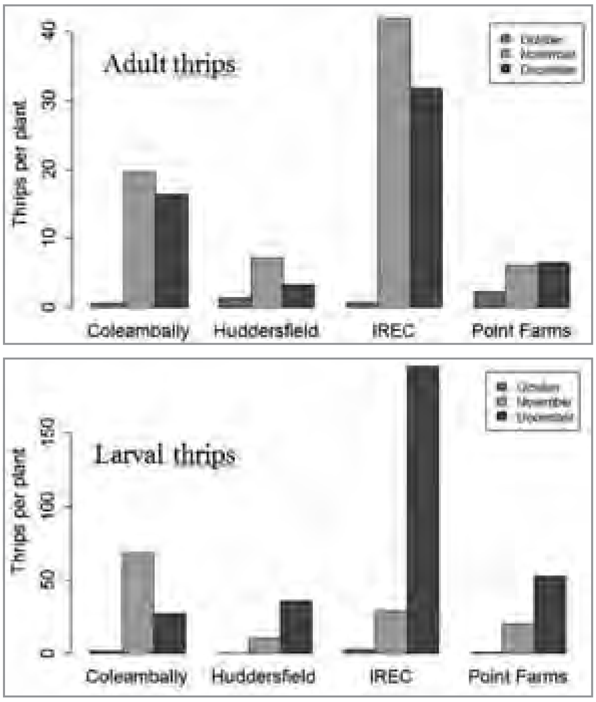


Figure 1. Density of adult (top) and larval thrips (bottom) during October–December 2014 at the monitoring sites in Coleambally, Huddersfield, IREC and Point Farms.

Four thrips species were regularly identified from the foliage samples and a number of other species were occasionally identified and are grouped as 'other thrips':

1. onion thrips (*Thrips tabaci*)
2. tomato thrips (*Frankliniella schultzei*)
3. western flower thrips (*Frankliniella occidentalis*)
4. plague thrips (*Thrips imaginis*)
5. 'other thrips' including: *Haplothrips* sp., *Australothrips bicolor*, *Tenothrips frici*, *Desmothrips* sp., *Anophothrips* sp., and *Andrewarthaia kellyana*.

Overall, onion thrips is the most dominant adult thrips species (71–83%), followed by tomato thrips (9–22%) (Figure 2). Adults of the other thrips species were only found in very small numbers (<5%). Onion thrips and tomato thrips also dominated in larval thrips, accounting for 29–69% and 19–50%, respectively. It is worth noting that tomato thrips was much more abundant in larval samples than in adult samples. Larval tomato thrips even outnumbered larval onion thrips in some samples.

From month to month, there were noticeable changes in the relative abundance of onion thrips, tomato thrips, and WFT. Relative abundance of tomato thrips decreased steadily from October to December in both adults and larvae (Figure 2). In larval thrips, the gradual decrease of tomato thrips was accompanied by a gradual increase of onion thrips (Figure 2).

In particular, the abundance of tomato thrips larvae was twice as high as onion thrips larvae in October, but dropped to less than one third of onion thrips larvae in December. There is also a noticeable increase in WFT larvae abundance from October (1%) to December (9%).

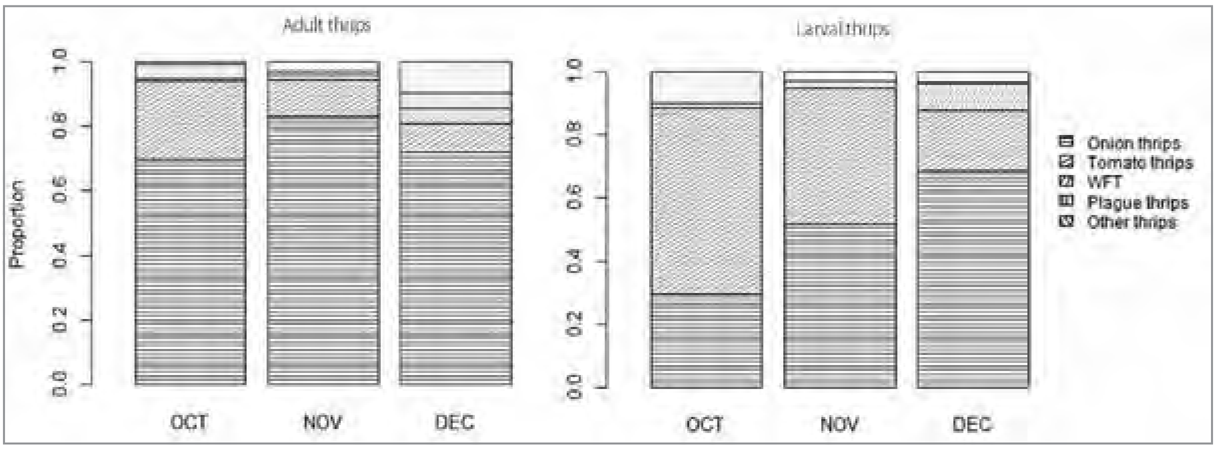


Figure 2. Monthly changes in overall compositions of adult and larval thrips species across four sites. Coloured areas indicate the relative proportions of the thrips species.

Relative abundance of different adult thrips species was similar across the four sites (Figure 3) and between Bt and non-Bt crops (Figure 4). However, tomato thrips larvae were noticeably more abundant at Point Farms (55%) than at the other three sites (26–30%) (Figure 3) and there were slightly more onion thrips larvae and slightly less tomato thrips larvae in non-Bt crops than in Bt crops (Figure 4).

Analyses of permutational MANOVA or multivariate analysis of variance showed significant effects of site and month on the compositions of both adult and larval thrips species (P <0.05) (tables 1 and 2). On the other hand, variety (Bt or non-Bt) had no significant effects on the species compositions.

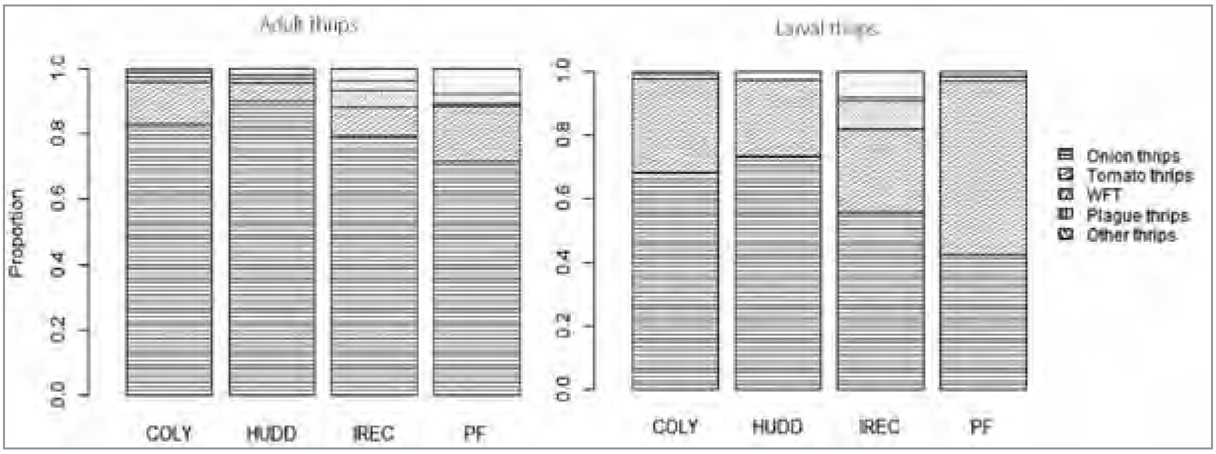


Figure 3. Overall compositions of adult and larval thrips species at individual sites. Coloured areas indicate the relative proportions of the thrips species.

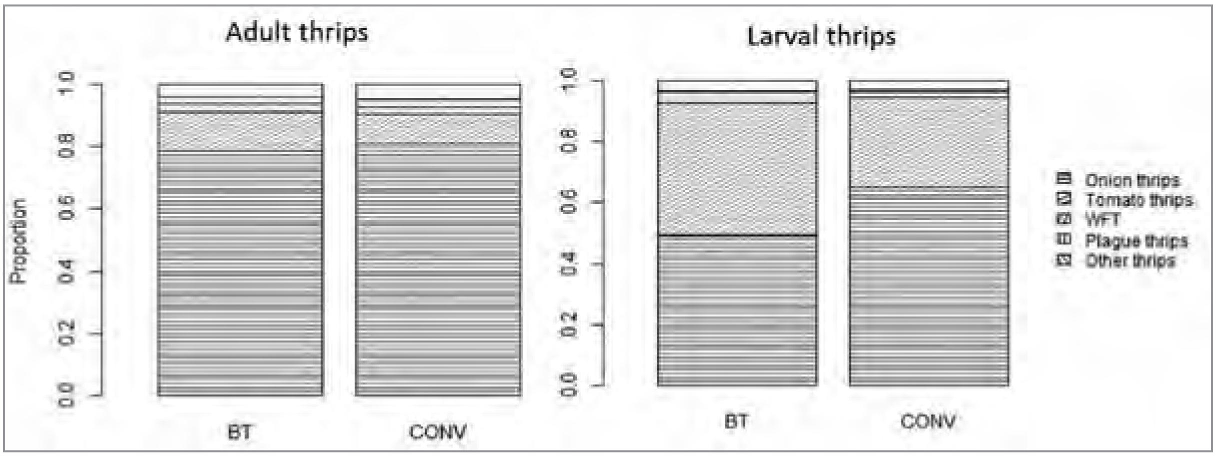


Figure 4. Comparing the compositions of adult and larval thrips species between Bt and conventional cotton crops. Coloured areas indicate the relative proportions of the thrips species

Table 1. Effects of site, month, and variety on the composition of adult thrips species as estimated by permutational MANOVA using distance matrices.

	DF	SS	MS	F	R^2	P (>F)
Site	3	1.1978	0.3993	6.0408	0.1669	< 0.0001
Month	2	1.4709	0.7355	11.1272	0.2049	< 0.0001
Variety	1	0.1475	0.1475	2.2321	0.0206	0.0818
Residual	66	4.3623	0.0661			
Total	72	7.1785				

crop protection

Table 2. Effects of site, month, and variety on the composition of larval thrips species as estimated by permutational MANOVA using distance matrices.

	DF	SS	MS	F	R^2	P (>F)
Site	3	1.2558	0.4186	5.5696	0.1807	0.0002
Month	2	0.9419	0.4710	6.2664	0.1356	0.0006
Variety	1	0.1664	0.1664	2.2138	0.0239	0.0993
Residual	61	4.5846	0.0752			
Total	67	6.9488				

Summary

Thrips populations in cotton seedlings in the Riverina were dominated by onion thrips and tomato thrips. Onion thrips was the single most dominant species in adult populations across the four sites and three monitoring months. Thrips larval numbers were initially dominated by tomato thrips and only at the end of the seedling period did onion thrips dominate. The results suggest that tomato thrips prefer to breed in cotton and probably only migrated into the crop early in cotton establishment, whereas onion thrips continually migrated into the cotton as adults and either didn't breed in the cotton until late spring, or were less successful in their breeding. WFT appeared to have been occasional visitors to cotton seedlings in the Riverina. Although it also established breeding populations in cotton, WFT did not appear to have colonised the study sites in significant numbers, resulting in its overall low numbers during the study period. The significant effect of the site on thrips composition could have been due to different vegetation at the four sites, with some sites having more alternative hosts to some thrips species than others. Bt toxin presence or absence in cotton crops did not appear to have made them more or less attractive to, or suitable for, some thrips species than others.

Given the dominance of onion thrips and relative absence of WFT, recommendations on thrips to the cotton industry are relevant to the southern cotton production areas. Pesticide management and thrips spray threshold validation is the subject of other experiments.

Acknowledgements

This project has been jointly funded by NSW DPI and the CRDC 'Establishing Southern Cotton - IPM project', DAN1501, 2014–17. We greatly appreciate the Coleambally Demonstration Farm committee's cooperation, Apex Coleambally and the grower cooperators: Matt Toscan and Ben Witham. Thanks to Ross Askins at Huddersfield and the IREC demonstration farm committee, the Stott family and farm staff, James Hill, and Matt Watson. Thanks to Jorian Millyard (Cotton Seed Distributors) for supplying seed.

Reference

CottonInfo 2015, *Cotton Pest Management Guide 2015–16*: www.crdc.com.au/publications/cotton-pest-management-guide-2015–16, viewed 28 April 2016.

Seed or planting treatments impact on thrips – commercial-scale trials

Dr Sandra McDougall, **Dr Jianhua Mo**, **Scott Munro**, **Liz Munn** and **Sarah Beaumont**
NSW DPI, Yanco

Key findings

- 60 thrips per plant four weeks after cotton emergence.
- Cruiser® seed treatment reduced thrips larvae numbers at one week after cotton emergence.
- Thimet® in-furrow treatment reduced thrips larvae numbers at one and three weeks after cotton emergence.
- Hand-harvest yields indicated the Thimet® treatment increased yields over no Thimet®-treated plots.
- Machine harvest yields were not significantly different between treatments.

Introduction

Thrips are common seedling pests of cotton in most growing districts. They feed on growing terminals causing leaf distortion and sometimes death of the terminals. Heavy infestation can result in yield loss and delayed maturity. Most insecticides applied in the southern cotton production region are targeted against thrips. Thiamethoxam (Cruiser®) seed treatment is aimed at controlling early season sucking pests. Phorate (Thimet®) is applied in-furrow at planting targeting wireworm, but also is likely to reduce invertebrate pest establishment.

Site details

Location	Coleambally Demonstration Farm
Cooperators	Matt Toscan and Ben Witham
Sowing date & 1st Water	8 October 2014
Variety	Sicot 74BRF
Seed treatment	Dynasty® - azoxystrobin+ metalaxyl-M+ fludioxonil
Irrigation	Furrow
Establishment	10 plants/m^2
Harvest date	14 May 2015

Treatments

T1	Cruiser + Thimet – Dynasty® and Cruiser® (thimethoxam) seed treatment + Thimet® (phorate)
T2	Thimet only – Dynasty® seed treatment + Thimet®
T3	Cruiser only – Dynasty® and Cruiser® seed treatment
T4	Untreated Control: Dynasty® fungicide seed treatment only

	Dynasty® + Cruiser® seed treatment (+C)	Dynasty® seed treatment (–C)
Thimet® in-furrow spray (+T)	T1: D2C+T	T2: D2+T
No in-furrow spray (–T)	T3: D2C	T4: D2

Replicate 1				Replicate 2				Replicate 3				Replicate 4			
T3	T4	T2	T1	T1	T2	T4	T3	T1	T4	T2	T3	T3	T2	T4	T1

Figure 1. Coleambally Demonstration Farm trial field plan: four treatments replicated four times (plot = 6 rows × 900 m).

Experiment details

Design	Randomised block-plot
Plot size	6 rows × 0.9 m beds × 900 m = 0.486 ha
Replicates	4
Area per treatment	1.94 ha
Trial area	7.76 ha
Monitoring dates	28 October, 11 November, 17 November, 25 November and 1 December 2014
Sample unit	10 whole random plants
Monitored	Thrips adults, nymphs and species composition
Analysis	Analysis of Variance (ANOVA), significant treatment effects were detected (P <0.05), treatment means were separated by Fisher's l.s.d.

Results

Each week, 20 whole plants were sampled with both adult and larval thrips counted. Adult thrips are mobile and hence are not useful for showing treatment effects, whereas the larvae don't normally move from plant to plant so their abundance provides an excellent indicator of the treatment effects. Figure 2 shows the larval thrips numbers on each monitoring occasion. On 28 October or eight days after cotton emergence (DAE), plots treated only with fungicide seed treatment had a statistically significantly higher number of larval thrips per plant than the other plots (P <0.05). On 11 November, the two Thimet® (phorate) treatments had lower larval thrips numbers than the Cruiser® (thiomethoxam) or the fungicide only treatment. All subsequent monitoring periods showed no statistical difference of thrips numbers between treatments (P >0.05).

Onion thrips (*Thrips tabaci*) was the dominant thrips species observed at Coleambally Demonstration Farm (Figure 3) and at the other project monitoring sites in Whitton and Darlington Point. Such dominance is consistent with what was found in other cotton production areas (Lewis Wilson *pers. com*). Tomato thrips (*Frankliniella schultzei*) was the next most dominant thrips species. Its proportions were even higher among larval thrips, suggesting it was more residential than onion thrips in cotton. The insecticide-resistant Western flower thrips (WFT) (*Frankliniella occidentalis*), plague thrips (*Thrips imaginis*) and a number of predatory thrips species, were observed in very small numbers during cotton establishment.

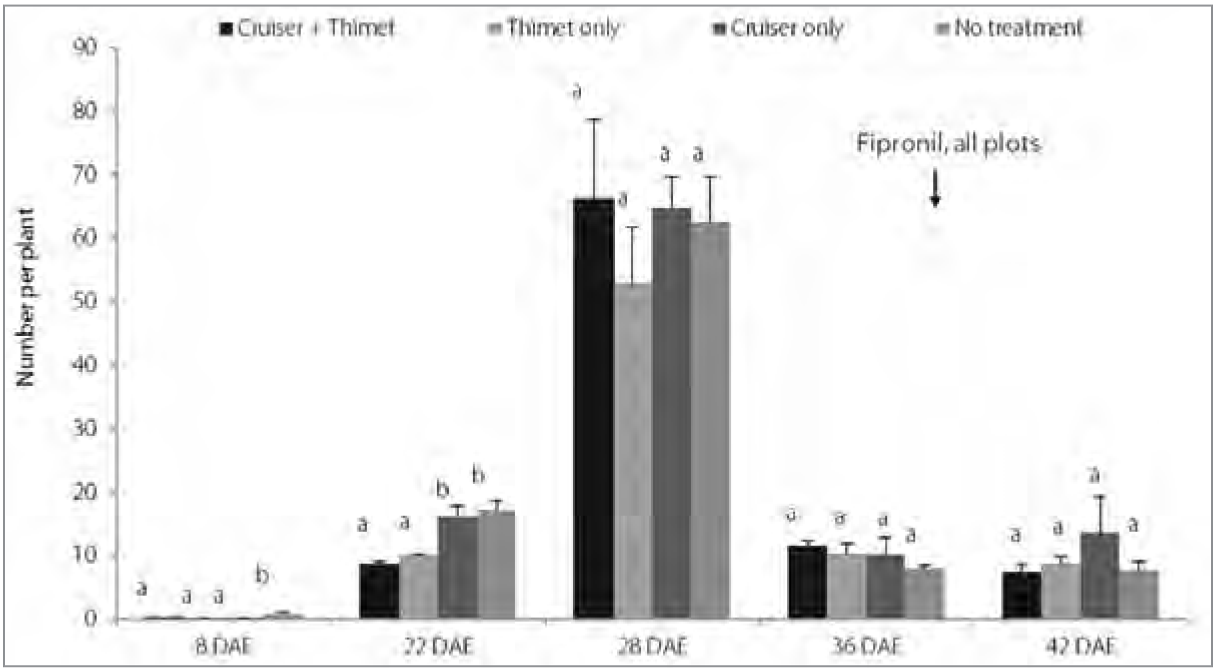


Figure 2. Larval thrips per plant during early establishment from 8–42 days after emergence (DAE). At 8 DAE the cotton was at the cotyledon stage, at 22 DAE it was at 1.5–2-leaf stage, at 28 DAE was 5-leaf stage, at 36 DAE 6–8-leaf stage and at 42 DAE was at 14-leaf stage. Error bars show the standard errors. At eight DAE, the three treatments with Thimet® and Cruiser® reduced thrips larval numbers compared with the untreated control. At 22 DAE, only the two Thimet treatments had significantly reduced numbers of thrips larvae. From 28 DAE on, the differences between treatments were no longer significantly at P = 0.05. A foliar application of the insecticide fipronil was applied across all plots after the 36 DAE assessment.

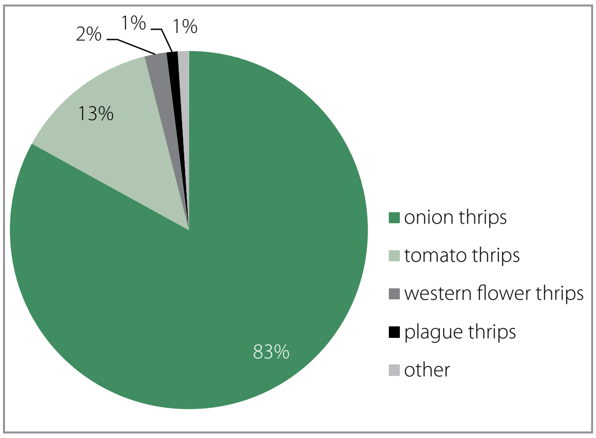
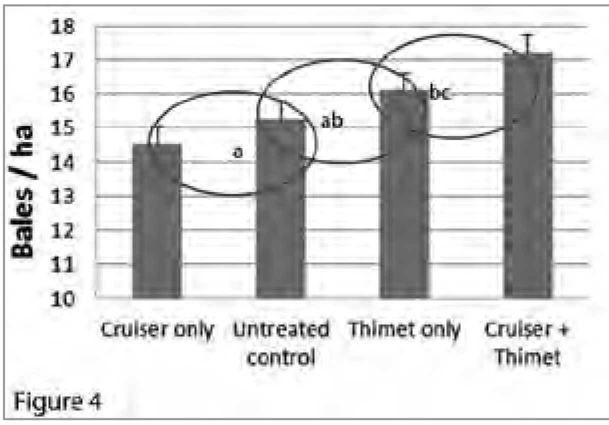


Figure 3. Adult thrips species found at Coleambally Demonstration Farm during cotton establishment (8–42 days after emergence).

Cotton yields were assessed by a 2 × 1 m hand harvest and with a commercial cotton machine harvester. Hand harvest data was converted to bales per hectare based on plot areas and areas needed to generate a single module/round from the machine harvest. Each machine harvested module/round was weighed on Cotton Seed Distributors' (CSD) trailer scales and the turnout was calculated from the hand-ginned results (CSIRO Narrabri) from the hand-harvested samples. Statistical analysis showed a lower yield in the non-Thimet® treatments (Figure 4), however, no such difference was detected by machine harvest (Figure 5).

Summary

A commercial scale cotton trial was conducted at the Coleambally Demonstration Farm in the 2014–15 season comparing Cruiser® (thiamethoxam) seed treatment with and without in-furrow Thimet® (phorate) treatment. Cruiser® with and without Thimet®, and Thimet®-only treatments reduced thrips larvae numbers a week after cotton emergence when compared with un-treated plots. However, only the Thimet® treatments reduced thrips larvae numbers at three weeks after emergence. There were no significant treatment differences on subsequent monitoring occasions. Larval thrips numbers peaked at approximately 60 per plant, or about four weeks after cotton emergence, before declining. Yields calculated from hand harvest samples indicated the Thimet®-treated plots had higher yields, but yields calculated from the machine harvest data were not significantly different.



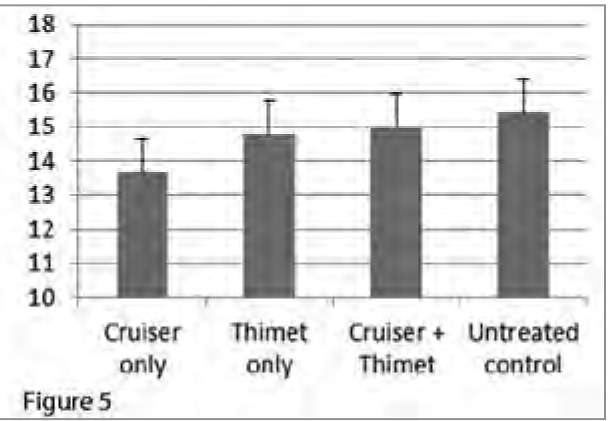


Figure 4. Hand harvest treatment yields were calculated from 2 × 1 m hand harvests and hand-gin turnout figures. Bars in the same group labelled with different letters are significantly different at P = 0.05 by Fisher's l.s.d. following the detection of a significant overall treatment effect.

Figure 5. Machine harvest treatment yields were calculated on the area it took to harvest a single round per plot, the round's weight and hand-gin turnout figures from the plot hand harvest samples. The treatment differences are not significantly different.

Acknowledgements

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We greatly appreciate the cooperation of the Coleambally Demonstration Farm committee, Apex Coleambally and the grower cooperators: Matt Toscan and Ben Witham. Thanks to Dupont, Dow AgroSciences and UPL Australia Limited for supplying insecticides for the trial and Cotton Seed Distributors for supplying seed.

Thrips threshold validation – commercial-scale experiments

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Key findings

- Thrips pressure reached the positive control threshold of one thrips per plant in late October while plants were at the cotyledon to 1-leaf stage.
- Thrips pressure reached the industry threshold of 10 thrips per plant in mid-November when plants were at the 4–5-leaf stage.
- Onion thrips were the dominant thrips species observed during monitoring.
- Western flower thrips (WFT) constituted less than 5% of thrips monitored.
- There was no yield difference between sprayed and unsprayed plots.

Introduction

Thrips are common seedling pests of cotton in most growing districts. They feed on growing terminals causing leaf distortion and sometimes death of the terminals. Heavy infestation can result in yield loss and delayed maturity. Most insecticides applied in the southern cotton production region are targeted against thrips. The cotton industry thrips spray threshold of 10 thrips per plant and >80% leaf area loss from seedling to 6-leaf stage was developed and validated in many research experiments in the northern production areas (Wilson and Room 1983; Sadras and Wilson 1998; Wilson 1999, 2002, 2005; Wilson et al. 2003; Lei and Wilson 2004; Cotton Info 2015). The southern production areas have a shorter season than the northern production areas and early crop establishment has been strongly linked to high yields.

These experiments were conducted to evaluate whether thrips controls applied at the thrips threshold led to higher or lower yields when compared with treatments at a lower threshold (one thrips per plant) and a non-spray treatment. The local cotton industry supported commercial-scale experiments over small plot experiments.

WFT (*Frankliniella occidentalis*) is a widespread thrips pest in horticultural production in the Riverina and was anticipated to be relatively more important in southern cotton than the northern production areas. WFT is a species that is highly resistant to most registered thrips insecticides, hence the treatment options needed to include insecticides that were expected to be efficacious against WFT.

Dimethoate and omethoate are two thrips insecticides permitted or registered in cotton that are relatively ineffective against WFT. Fipronil is another foliar insecticide registered for thrips in cotton, which is effective against WFT, however it is highly toxic to bees and both our commercial scale experiment areas were near horticultural crops, so it was initially agreed to avoid it as a treatment. Sulfoxaflor is newly registered in cotton for aphid control. Baseline insecticide resistance testing in the Dr Grant Herron's laboratory (Biosecurity NSW) based at Elizabeth Macarthur Agricultural Institute, found that it had good activity against WFT, hence its use as the positive control. Similarly, another newly registered cotton insecticide, Cyantraniliprole, showed laboratory activity against WFT and was used in a second threshold treatment in the larger of the two commercial threshold experiments. A petroleum spray oil was used as a third threshold treatment, also in the larger commercial threshold experiment.

Site details

Location	**Smaller experiment**: Irrigation Research and Extension Committee (IREC) demonstration site, Whitton [145.92 E; -34.65 S] **Larger experiment**: Point Farms (PF), Darlington Point [145.91 E; -34.65 S]
Cooperators	Matt Stott (owner PF and current lessee of IREC demonstration site); James Hill (agronomist) and farm operations staff
Sowing date	1 October 2014 (IREC); 10 October 2014 (PF)

1st Water	1 October 2014 (IREC); 14 October 2014 (PF)
Variety	Sicot 74BRF
Seed treatment	Dynasty® – azoxystrobin+ metalaxyl-M+ fludioxonil
Irrigation	Drip (IREC); furrow (PF)
Establishment	6 plants/m^2 (IREC); 9.6 plants/m^2 (PF)
Hand harvest date	7 May 2015 (IREC); 14 May 2015 (PF)
Machine harvest date	26 May 2015 (IREC); 23 May 2015 (PF)

Treatments

T1: Unsprayed	Dynasty® fungicide seed treatment only
T2: Trans 1	Dynasty® and Cruiser® seed treatment + Transform® at one thrips per plant
T3: Trans 10	Dynasty® + Transform® at 10 thrips per plant
T4: Exirel 10	Dynasty® + Exirel® at 10 thrips per plant
T5: Oil 10	Dynasty® + Canopy Oil® at 10 thrips per plant
T1-3	IREC site
T1-5	PF
T1	negative control
T2	positive control
Transform®	sulfoxaflor 240 g/L Group 4C; rate: 300 mL/ha + Agral
Exirel®	cyantraniliprole 100 g/L Group 28: rate: 600 mL/ha + Hasten
Canopy oil®	paraffinic oil C27 792 g/L 2%v/v
Regent®	fipronil 800 g/L WG Group 2B; rate 125 mL/ha

Experiment details

Trial design	Randomised block-plot
Plot size	IREC: 12 beds (2 rows to a bed) × 1.8 m beds × 750 m = 1.62 ha PF: 12 beds (2 rows to a bed) × 1.8 m beds × 420 m = 0.91 ha
Replicates	4
Monitoring dates	IREC: 21 October, 27 October, 3 November, 13 November, 20 November, and 1 December 2014 PF: 27 October, 3 November, 10 November, 17 November, 25 November and 4 December 2014
Sample unit	10 whole random plants
Monitored	Thrips adults, nymphs and species composition
Analysis	Analysis of Variance (ANOVA), significant treatment effects were detected (P <0.05), treatment means were separated by Fisher's l.s.d.

Results

IREC

Thrips pressure was similar in all plots before the first spray (Figure 1). Onion thrips (*Thrips tabaci*) was the dominant thrips species with 80% of all adult thrips monitored from seedling to 17-leaf stage (Figure 2). Other thrips species observed were: tomato thrips (*Frankliniella schultzei*), western flower thrips (*F. occidentalis*), plague thrips (*Thrips imaginis*) and some predatory thrips species.

crop protection

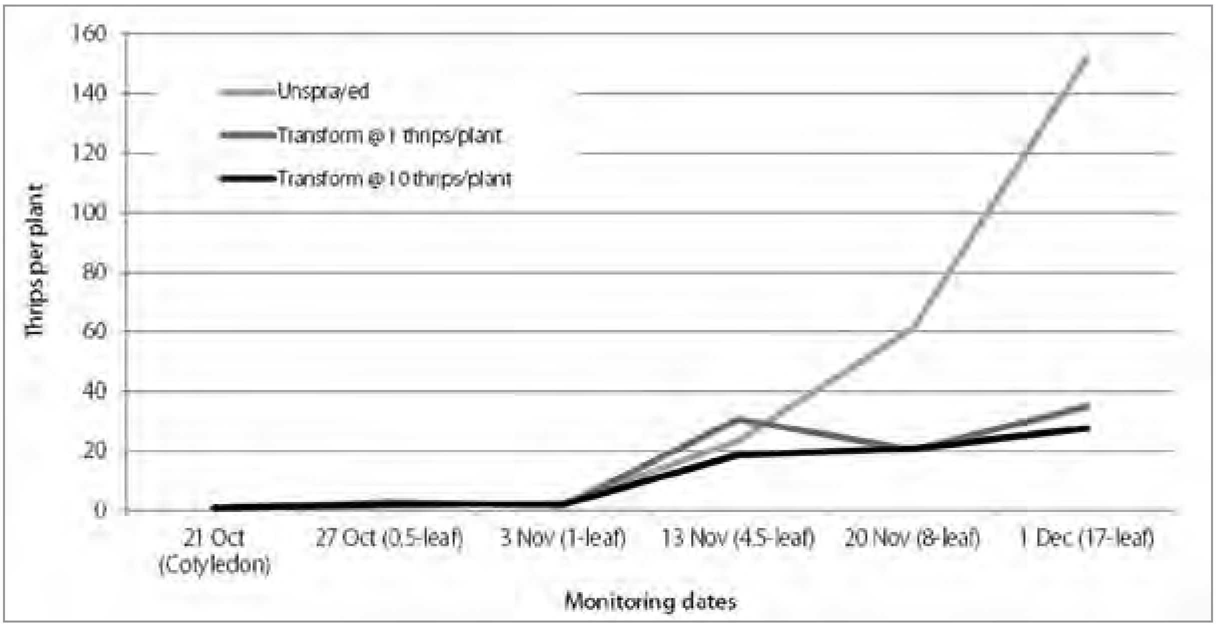

Figure 1. Total numbers of thrips per plant at each monitoring date from 20 whole plant washes from each plot–IREC.

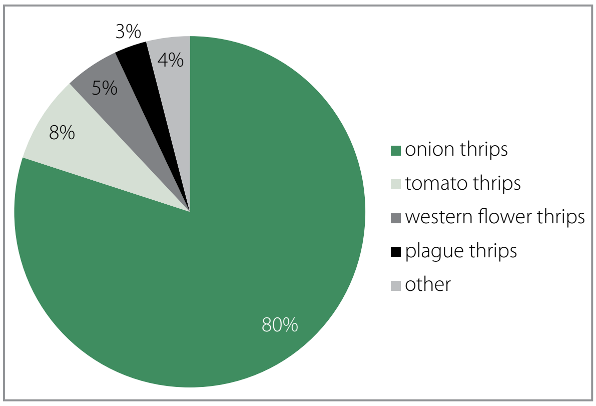

Figure 2. Breakdown of total adult thrips by species collected between 21 October and 1 December 2014 from the IREC experiment site.

The low threshold was reached in late October and the high threshold in mid-November. Two sprays of Transform® were applied before the high-threshold sprays were triggered. Neither showed any effects in thrips control (P >0.05) (Figure 3). In fact, larval thrips numbers had continued to increase despite the two sprays. In an effort to bring down thrips numbers in the positive control plots, Fipronil was applied in lieu of Transform® in these plots at the time when the first high-threshold sprays were triggered.

Following this round of sprays, larval thrips numbers in both Fipronil-treated plots (positive control plots) and plots receiving the high-threshold Transform® sprays were significantly reduced compared with the negative control plots (P <0.05). The significant effects persisted at the last assessment following a further round of high-threshold sprays (P <0.05). It is worth noting that although thrips pressure remained relatively high in the two spray treatments (>10 thrips per plant), the density was less than a quarter of that in the negative control plots.

There were no significant differences in lint yield (kg/ha) among the threshold treatments in the hand harvest data (P >0.05) (Figure 4) at the IREC site. Machine harvest data are yet to be finalised.

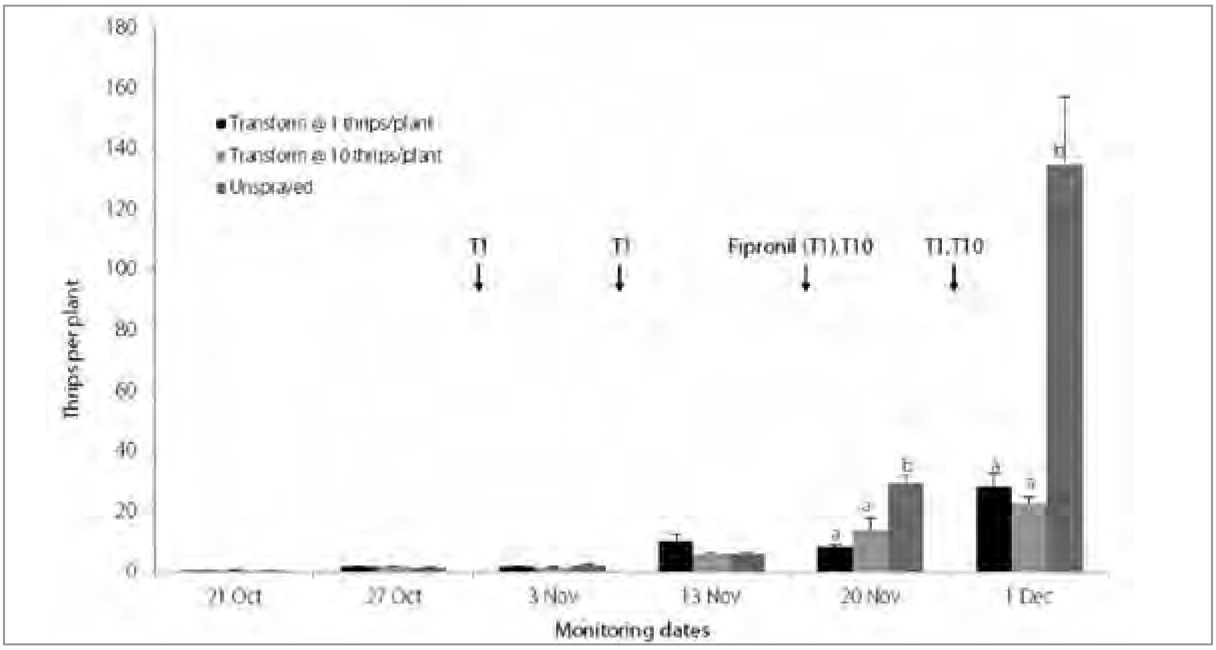

Figure 3. Comparing average numbers of larval thrips in different threshold treatments at IREC. Trans 1 – Transform applied at one thrips per plant, Trans 10 – Transform applied at 10 thrips per plant. Bars in the same group labelled with different letters were significantly different at P = 0.05 by Fisher's l.s.d. tests after detecting significant overall treatment effects by ANOVA. Error bars show the standard errors. Arrows indicate spray timings.

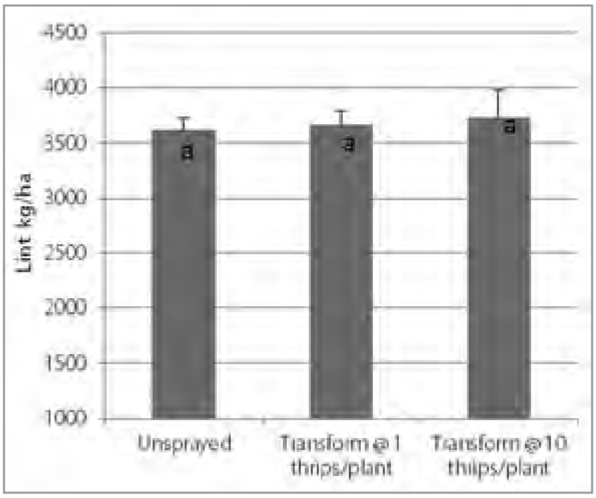

Figure 4. Effects of threshold treatments on lint yield (kg/ha) in the hand harvest data at the IREC site. Bars sharing the same letters were not significantly different at P = 0.05 by Fisher's l.s.d. tests after detecting significant overall treatment effects by ANOVA. Error bars show the standard error.

Point Farms

Thrips pressure was similar in all plots before the first spray (Figure 5).

Similarly to the IREC site at Point Farms, onion thrips (*Thrips tabaci*) was the dominant thrips species with 71% of all adult thrips monitored from seedling to 17-leaf stage (Figure 6). Other thrips species observed were: tomato thrips (*Frankliniella schultzei*), western flower thrips (*F. occidentalis*), plague thrips (*Thrips imaginis*) and some predatory thrips species.

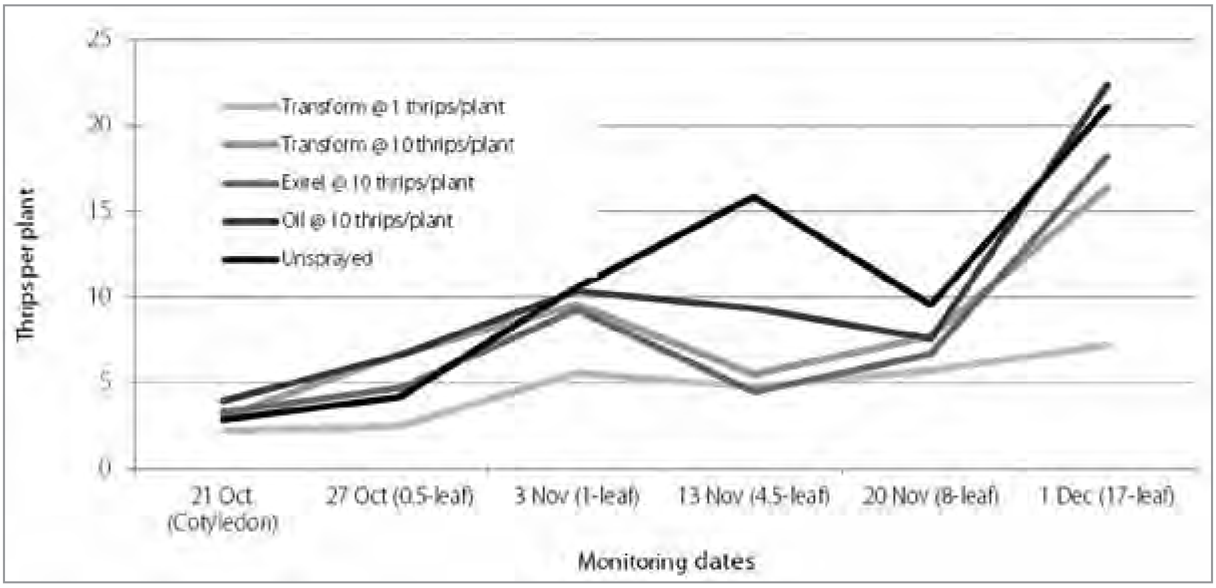

Figure 5. Total numbers of thrips per plant at each monitoring date from 20 whole plant washes from each plot.

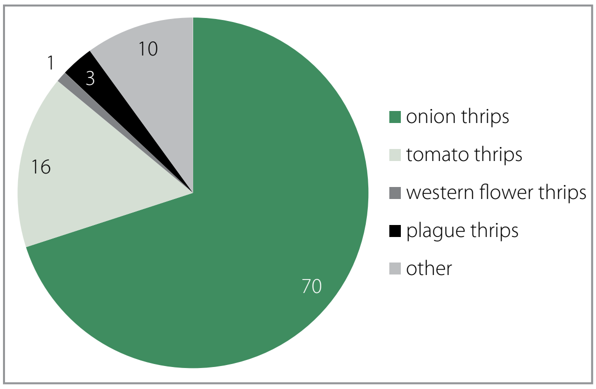

Figure 6. Breakdown of total adult thrips by species collected between 27 October and 4 December 2014 from the Point Farms experiment site.

The low threshold was reached in late October and the high threshold in mid-November. Five sprays of Transform® were applied at the low threshold, one spray each of Transform® and Exirel® at the high threshold, and two sprays of oil at the high threshold. The first two low-threshold sprays of Transform® were applied before any of the high-threshold sprays were triggered. Both sprays reduced the numbers of larval thrips in the positive control plots to about half of that in the un-sprayed plots (negative control plots and plots assigned for the three high-threshold treatments) (Figure 7).

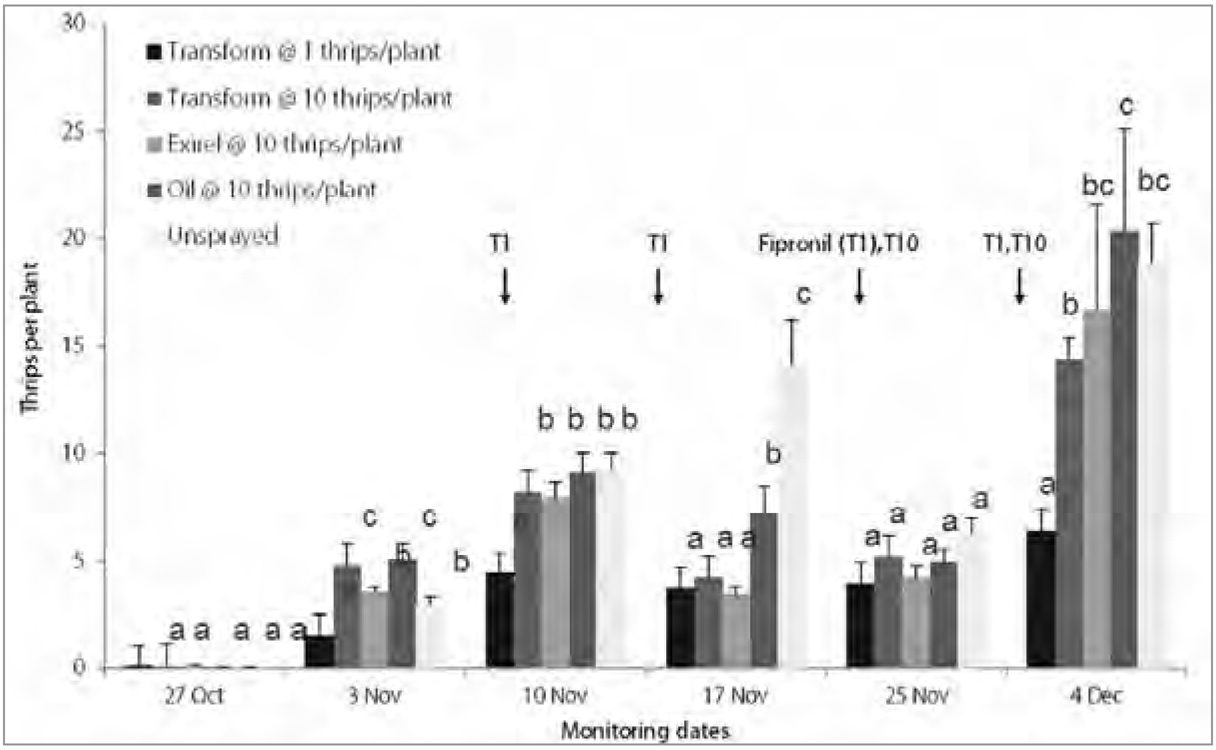

Figure 7. Comparing average numbers of larval thrips in different threshold treatments at Point Farms. Trans 1 – Transform applied at one thrips per plant, Trans 10 – Transform applied at 10 thrips per plant, Exirel® 10 – Exirel® applied at 10 thrips per plant, Oil 10 – Canopy oil® applied at 10 thrips per plant. Bars in the same group labelled with different letters were significantly different at P = 0.05 by Fisher's l.s.d. tests following detection of significant overall treatment effects by ANOVA. Error bars show the standard errors. Arrows indicate spray timings.

In mid-November, a single spray of Transform® and Exirel® at the high threshold also significantly reduced larval thrips numbers (P <0.05), bringing down the population to a similar level to those in the positive control plots, which had already been sprayed twice before with Transform®. The first oil spray at the high threshold also significantly reduced larval thrips compared with the negative control plots (P <0.05), however, the reduction was significantly less than the other two high-threshold treatments. Oil was applied again at the high threshold in the following week, but failed to show significant effects of thrips control (P >0.05). At the last assessment, only the positive control plots maintained significantly lower numbers of larval thrips than the negative control plots (P <0.05).

There were no significant differences in lint yield among the threshold treatments in either the hand harvest data or the machine harvest data at the Point Farms site (P >0.05) (Figure 8).

Summary

No yield differences were observed in plots where thrips were uncontrolled versus plots where thrips were sprayed with insecticides at either one thrips per plant (positive control) or at the cotton industry threshold of 10 thrips per plant at either of two commercial-scale experiments. Thrips pressure reached the 10 thrips per plant threshold by mid- November when plants were at about the 4 to 4.5-leaf stage at both sites. Eighty-three per cent of the adult thrips monitored up to the 15-leaf stage were onion thrips. Tomato thrips constituted 13% of the thrips population and other species made up no more than 2% each. The positive control plots received four and five foliar insecticide sprays at the Whitton and Darlington Point sites respectively; the industry threshold treatment plots received two foliar insecticide sprays. The experiments are part of a project to validate whether the Australian cotton industry thrips threshold applies in southern NSW cotton production areas. The treatment plots were 1.62 ha (Whitton) and 0.9 ha (Darlington Point) and replicated four times.

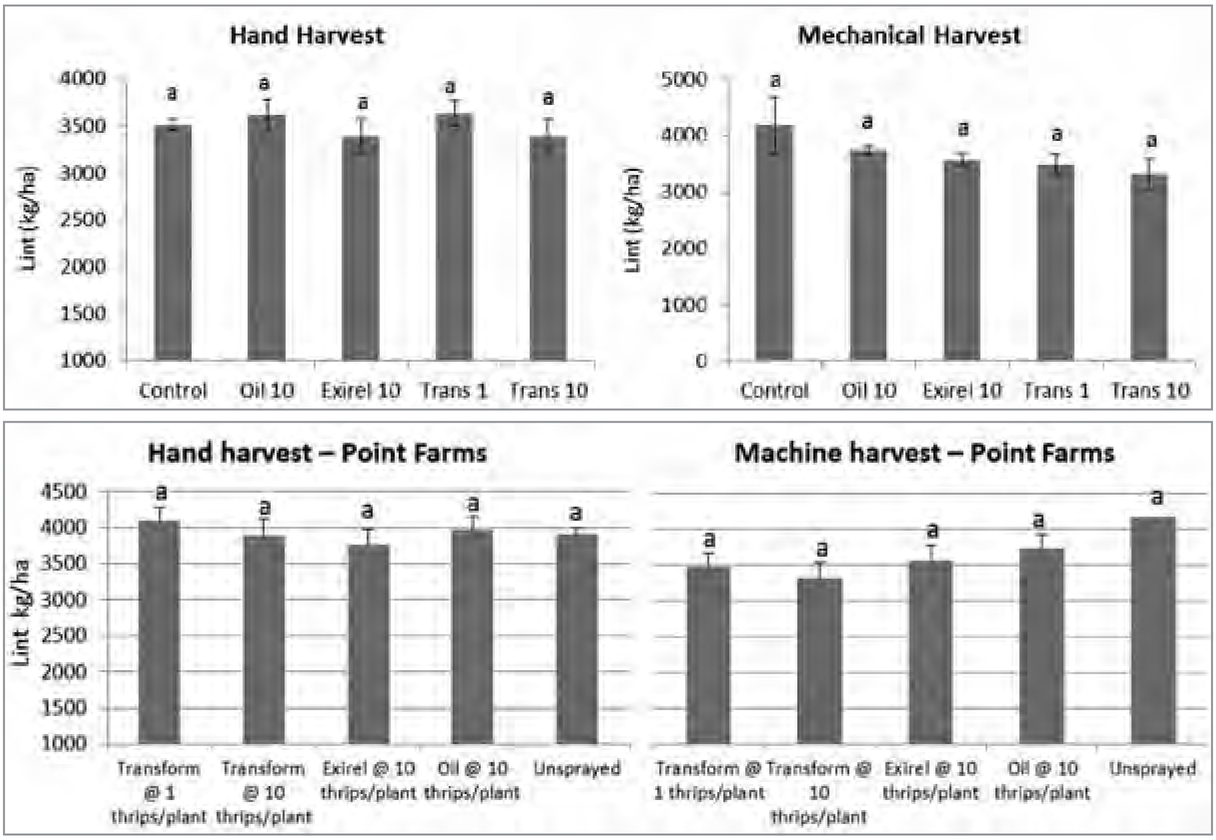

Figure 8. Effects of threshold treatments on lint yield (kg/ha) in the hand harvest data (left) and the machine harvest data (right) at the Point Farms site. Bars sharing the same letters were not significantly different at P = 0.05 by Fisher's l.s.d. tests after detecting significant overall treatment effects by ANOVA. Error bars show the standard error.

Foliar insecticide sprays were applied using a ground rig and yields assessed from both hand harvest samples and at least one commercially harvested round module per plot. Turn-out was determined from hand-ginned samples from the hand harvest.

Acknowledgements

This project was jointly funded by the CRDC 'Establishing Southern Cotton -IPM project', DAN1501, 2014–17, and NSW DPI.

We greatly appreciate the cooperation of the IREC demonstration farm committee, the Stott family and farm staff, James Hill, and Matt Watson. Thanks to Dupont, Dow AgroSciences and Caltex for supplying insecticides for the experiment. Thanks to Jorian Millyard (Cotton Seed Distributors) for supplying seed and trailer scales for weighing modules. Thanks to Lewis Wilson (CSIRO) for advice. Thanks to Warrick Stillard (CSIRO) and team for hand ginning our cotton samples.

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Summer herbicide trials on prickly lettuce 2015–16

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Key findings

- After stem elongation, mature prickly lettuce plants are difficult to control.
- Controlling mature prickly lettuce plants early achieves better results.
- No single treatments, except paraquat, achieved 100% control of mature prickly lettuce plants that emerged after a wheat crop was harvested. The paraquat, either used alone or as a follow-up application, was the only outstanding treatment, achieving 100% control.

Introduction

Prickly lettuce (*Lactuca serriola*) has recently become an increasing problem in southern NSW, mostly in cereals and lucerne pastures. It can grow up to two metres tall and is therefore highly competitive with crops or pastures. If left uncontrolled, it uses soil moisture and nutrients during summer. The seed has a white pappus that could be easily spread by wind and through surface water run-off. Prickly lettuce forms a rosette of leaves after emergence and develops a strong taproot. Plants are difficult to control with herbicides once the plants start to elongate. The weed was reported to have evolved resistance to Group B herbicides in both Australia and the United States, to Group I herbicides in the USA in 2007 and, most recently, to glyphosate in Australia in 2015.

Little is known about its emergence patterns in southern NSW. Elongated plants are often cut during harvest operations and regrow with competitive branches after harvest. Limited control options are available for the mature plants.

These two experiments aimed to evaluate a range of herbicides with different modes of action on prickly lettuce control, and to evaluate if a 'double-knockdown' technique is needed to effectively control mature prickly lettuce.

Treatments

Two experiments were established on two properties (one at Lake Cowal and one at Temora), after the wheat harvest in December 2015. Average prickly lettuce density was 9.5 plants/m^2 at Lake Cowal and 10 plants/m^2 at Temora.

A randomised complete block design with three replicates was used, with plot size 2 m × 16 m. A total of 17 and 20 treatments were imposed respectively at Lake Cowal and Temora, including an untreated control. After the initial application, each plot was equally divided with half the plot receiving an additional application of paraquat as a double knockdown.

Herbicides were applied using a hand-held boom sprayer, calibrated to deliver 100 L/ha at 2 bar pressure. The first application was applied at the Lake Cowal and Temora sites on 10 and 15 December 2015 respectively, and the double-knockdown paraquat application at the Lake Cowal and Temora sites on 16 and 21 December 2015, respectively. At the time of application, the prickly lettuce plants were at the elongating/re-branching stage (after being cut during wheat-crop harvest) and were not under moisture stress.

Visual rating (% of control) was conducted on 8 January 2016. The number of prickly lettuce plants was recorded in a 1 × 6 m strip within each plot on 2 February 2016.

Results

At the Lake Cowal site, the single-knock application differed significantly in controlling prickly lettuce (Table 1). Five treatments, Amicide® Advance 700 + Weedmaster® Argo, Weedmaster® Argo, Ally® + Weedmaster® Argo, Basta® and Starane™ Advanced had a control rating of more than 90%, while the remaining 11 treatments only controlled prickly lettuce from 30% to 87%.

The single knock herbicide application at the Temora site was generally less effective than at the Lake Cowal site. Only four treatments had control efficacy slightly over 80%, including Amicide®

Advance 700 + Weedmaster® Argo, Tordon™ 75-D + Weedmaster® Argo, Basta® and Amitrole T. The other 15 treatments had poor control of prickly lettuce from 7% to 72% (Table 2).

At both trial sites, it was very encouraging to find that the follow-up treatment with paraquat provided 100% control of prickly lettuce, even in the untreated plots that did not have the first knock of herbicide applications.

In general, no single treatments except paraquat achieved 100% control of mature prickly lettuce plants after crop harvest. Many plants, even though severely damaged, managed to survive and re-branch. The paraquat application was the only outstanding treatment, achieving complete control of the mature prickly lettuce plants. The distinct difference with and without the follow-up paraquat is shown in Figure 1.

Figure 1. Contrasting the difference between the single knockdown (without a follow-up paraquat application, left) and the double knockdown (with a follow-up paraquat application, right) at the Lake Cowal trial site.

Table 1. Herbicide control efficacy on mature prickly lettuce plants at the Lake Cowal trial site.

Treatment	Herbicide	Group	Active	Rate (mL or g/ha)	Adjuvant	Visual rating (%) [a]	Density (plants/m²)	
							Single [b]	Double-knock [c]
1	Amicide® Advance 700	I	700 g/L 2,4-D amine	1150 mL	Liase at 2%	30.0	3.7	0.0
2	Amicide® Advance 700 + Weedmaster® Argo	I, M	700 g/L 2,4-D amine + 540 g/L glyphosate	515 mL + 1300 mL	LI 700® at 0.3%	93.3	0.6	0.0
3	Weedmaster® Argo	M	540 g/L glyphosate	1300 mL	LI 700® at 0.3%	90.0	2.0	0.0
4	Starane™ Advance	I	333 g/L fluroxypyr	600 mL	Uptake™ at 0.5%	95.0	0.8	0.0
5	Starane™ Advance + Weedmaster® Argo	I, M	333 g/L fluroxypyr + 540 g/L glyphosate	600 mL + 1300 mL	–	88.3	2.4	0.0
6	Ally® + Weedmaster® Argo	B,I	600 g/kg metsulfuron-methyl + 540 g/L glyphosate	7 g + 1300 mL	–	95.0	1.6	0.0
7	Goal™ + Weedmaster® Argo	G, M	240 g/L oxyfluorfen + 540 g/L glyphosate	75 mL + 1300 mL	BS1000 at 1%	86.7	2.1	0.0
8	Kamba® 500 + Weedmaster® Argo	I, M	500 g/L dicamba + 540 g/L glyphosate	240 mL + 1300 mL	–	85.0	4.5	0.0
9	Basta®	N	200 g/L glufosinate ammonium	4000 mL	–	91.7	1.8	0.0
10	Amitrole T	Q	250 g/L amitrole + 220 g/L ammonium thiocyanate	5600 mL	LI 700® at 0.3%	85.0	1.6	0.0
11	Tordon™ 75-D	I	300 g/L 2,4-D amine + 75 g/L picloram	700 mL	–	53.3	3.9	0.0
12	Tigrex®	F, I	250 g/L MCPA and 25 g/L diflufenican	1000 mL	–	81.7	3.7	0.0
13	Affinity Force + Agritone® 750	G, I	240 g/L carfentrazone-ethyl + 750 g/L MCPA amine	100 mL + 333 mL	–	76.7	2.5	0.0
14	Lontrel™ + L.V.E. Agritone®	I	300 g/L clopyralid + 570 g/L LVE MCPA	150 mL +1000 mL	–	63.3	2.4	0.0
15	L.V.E. Agritone®	I	570 g/L LVE MCPA	1000 mL	–	40.0	4.3	0.0
16	Hotshot™ + L.V.E. Agritone®	I	10 g/L aminopyralid and 140 g/L fluroxypyr + 570 g/L LVE MCPA	750 mL + 1000 mL	–	86.7	3.5	0.0
17	Control	–	–	–	–	0.0	6.2	0.0
	l.s.d. (P = 0.05)					17.93	1.89	NA

[a] Visual rating was conducted on 8/01/2016 in the single treatments (no double knock) and plant counts on 4/02/2016.
[b] Single application of the respective herbicide on 10/12/2015.
[c] Paraquat at 2.4 L/ha was used as a second knock and applied across all treatments on 16/12/2015.

Table 2. Herbicide control efficacy on mature prickly lettuce plants at the Temora trial site.

Treatment	Herbicide	Group	Active	Rate (mL or g/ha)	Adjuvant	Visual rating (%) [a]	Density (plants/m^2)	
							Single [b]	Double-knock [c]
1	Amicide® Advance 700	I	700 g/L 2,4-D amine	1150 mL	Liase at 2%	51.7	4.6	0.0
2	Amicide® Advance 700 + Weedmaster® Argo	I, M	700 g/L 2,4-D amine + 540 g/L glyphosate	515 mL + 1300 mL	LI 700® at 0.3%	80.0	1.2	0.1
3	Weedmaster® Argo	M	540 g/L glyphosate	1300 mL	LI 700® at 0.3%	78.3	4.2	0.0
4	Ally® + Weedmaster® Argo	B, I	600 g/kg metsulfuron-methyl + 540 g/L glyphosate	7 g + 1300 mL	–	28.3	5.5	0.0
5	Goal™ + Weedmaster® Argo	G, M	240 g/L OXYFLUORFEN + 540 g/L glyphosate	75 mL + 1300 mL	BS1000 at 1%	60.0	8.7	0.0
6	Kamba® 500 + Weedmaster® Argo	I, M	500 g/L dicamba + 540 g/L glyphosate	240 mL+ 1300 mL	–	71.7	2.6	0.0
7	Starane™ Advance	I	333 g/L fluroxypyr	600 mL	Uptake™ at 0.5%	53.3	6.8	0.1
8	Starane™ Advance + Weedmaster® argo	I, M	333 g/L fluroxypyr + 540 g/L glyphosate	600 mL + 1300 mL	–	63.3	5.7	0.1
9	Tordon 75D + Weedmaster® Argo	I, M	300 g/L 2,4-D amine and 75 g/L picloram + 540 g/L glyphosate	700 mL + 1300 mL	–	81.7	2.6	0.1
10	Garlon™ 600 + Weedmaster® Argo	I, M	600 g/L triclopyr + 540 g/L glyphosate	700 mL + 1300 mL	Uptake™ 0.5%	53.3	5.8	0.1
11	Sharpen® WG + Weedmaster® Argo	G, M	700 g/kg saflufenacil + 540 g/L glyphosate	34 g + 1300 mL	Bonza® at 1%	53.3	5.0	0.1
12	GF-2688	I, M	fluroxypyr + arylex	400 mL	Uptake™ at 0.5%	55.0	6.3	0.6
13	Basta®	N	200 g/L Glufosinate ammonium	4000 mL		83.3	1.3	0.1
14	Amitrole T	Q	250 g/L amitrole 220 g/L ammonium thiocyanate	5600 mL	LI 700® at 0.3%	81.7	4.9	0.1
15	Tordon™ 75-D	I	300 g/L 2,4-D amine and 75 g/L picloram	700 mL	–	30.0	6.1	0.1
16	Affinity Force + Agritone® 750	G, I	240 g/L carfentrazone-ethyl + 750 MCPA amine	100 mL + 333 mL	–	6.7	5.4	0.1
17	Lontrel™ + L.V.E. Agritone®	I	300 g/L clopyralid + 570 g/L LVE MCPA	150 mL + 1000 mL	Uptake™ at 0.5%	30.0	6.3	0.0
18	L.V.E. Agritone®	I	570 g/L LVE MCPA	1000 mL	–	28.3	5.7	0.0
19	Hotshot™ + L.V.E. Agritone®	I	10 g/L aminopyralid and 140 g/L fluroxypyr +570 g/L LVE MCPA	750 mL + 1000 m	–	58.3	5.8	0.0
20	Control	–	–	–	–	0.0	7.4	0.0
	l.s.d. 0.05	21.6	3.9	0.3				

a: Visual rating was conducted on 8/01/2016 in the single treatments (no double knock) and plant counts on 4/02/2016.
b: Single application of the respective herbicide on 10/12/2015.
c: Paraquat at 2.4 L/ha was used as a second knock and applied across all the treatments on 16/12/2015.

Acknowledgements

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Nationwide field survey for herbicide residues in soil

Dr Mick Rose and **Dr Lukas Van Zwieten** NSW DPI, Wollongbar

Key findings

» Growers need to be aware that glyphosate, trifluralin and diflufenican residues, plus the glyphosate metabolite AMPA, can accumulate to agronomically significant levels in certain soils.

» These findings suggest that the current risk of damage to crops in NSW is minor compared with some sites in WA that have lower rainfall and sandy soils with low organic matter.

» The risk to soil biological processes is generally minor when herbicides are used at label rates and given sufficient time to dissipate before re-application.

» However, given the frequency of glyphosate application and the persistence of trifluralin and diflufenican, further research is needed to define site-specific critical thresholds for these chemicals to avoid potential negative effects on soil function and crop production.

Introduction

Due to the high cost of herbicide residue analysis, information about herbicide residue levels in Australian grain cropping soils is scarce. This report presents the results of a national field survey of herbicide residues in 40 cropping soils before sowing and pre-emergent herbicide application in 2015. It looks at the relevance of these residues to soil biological processes and crop health with a focus on those herbicides most frequently detected.

Site details

A total of 40 paddocks were surveyed including 12 from Western Australia, 15 from South Australia, 10 from New South Wales and three from Queensland. Eight of these sites were located in southern NSW between Wagga Wagga, Young and Ardlethan. Two sites in northern NSW were located in the Coonamble area.

The topsoil (0–10 cm) pH (H_2O) ranged from 5.4 to 7.5 in southern NSW and 7.3–8.2 in northern NSW. The subsoil (10–30 cm) pH (H_2O) ranged from 5.4 to 7.0 in southern NSW and 8.8–8.9 in northern NSW.

Treatments/sampling

Soil sampling was undertaken to provide a representative snapshot of herbicide residue levels in cropping soils at the beginning of the 2015 growing season (April/May) before applying pre-emergent herbicides. Composite samples (12 subsamples) were taken from a randomly chosen 50 × 50 m grid in each paddock at two depths (0–10 cm and 10–30 cm). Samples were analysed for 15 commonly used herbicides using advanced analytical techniques developed and validated by the project team.

Results

Which herbicides are remaining in soil?

The soil survey of 40 different paddocks from around Australia detected residues of 11 chemicals out of the 15 analysed (Figure 1). Glyphosate and its primary break-down product (metabolite) aminomethylphosphonic acid (AMPA) were the most commonly detected residues, with AMPA residues present in every topsoil sample taken.

Trifluralin residues were also detected in over 75% of the paddocks surveyed, both in topsoil and in the 10–30 cm soil layer, indicating some vertical movement, despite the strong tendency of trifluralin to remain close to the application site. This is possibly due to cultivation, however, leaching or movement of particle-bound trifluralin can also occur on lighter textured soils that have low organic matter content.

Diflufenican and diuron residues were frequently detected in samples from WA paddocks, but less so in NSW, Qld and SA.

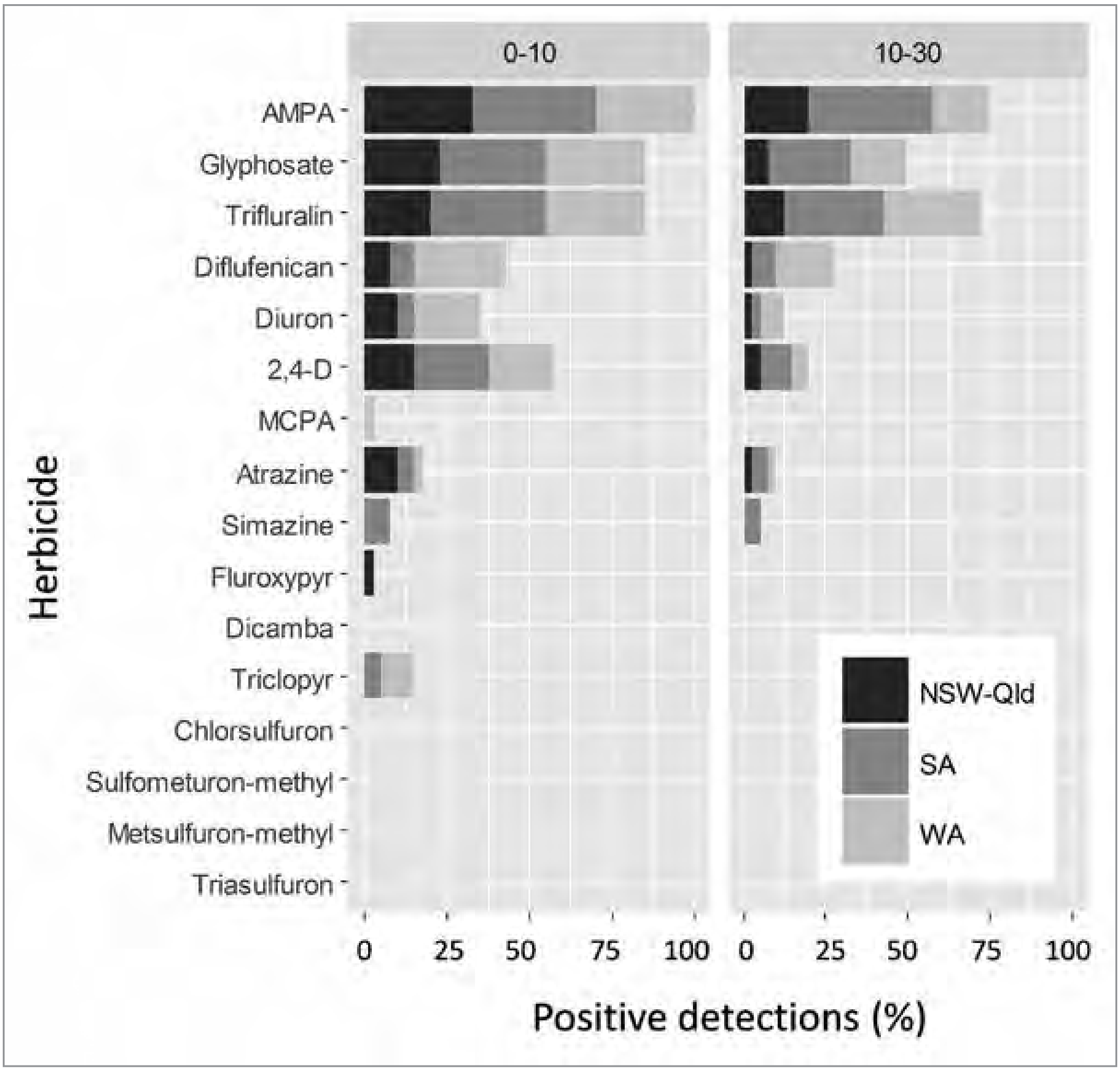

Figure 1. Number of positive detections of herbicides and the glyphosate metabolite AMPA in soil samples from 40 grain cropping paddocks around Australia.

Interestingly, despite known application of triasulfuron and metsulfuron-methyl in many of the surveyed paddocks, neither of these residual herbicides were detected in any of the samples tested. This is probably a reflection of low application rates, close to the limit of analytical detection. It should be noted that sulfonylurea (SU) herbicides might still have some residual activity at levels below the limit of (currently available) analytical detection. By contrast, the lack of positive detections of frequently applied MCPA reflects its relatively short persistence.

By multiplying herbicide concentrations (mg/kg) by soil bulk density (kg/dm [dry matter]) and area, the estimated total load of herbicide in the 0–30 cm soil profile for each paddock was calculated (Table 1). The average and maximum estimated loads of glyphosate, trifluralin, diflufenican and diuron were all significantly higher in paddocks in WA compared with those in SA, NSW and Qld. This probably reflects the lighter soil types, lower organic matter, dry summers and cool winters, which contribute to lower microbial activity and constrained herbicide breakdown. The higher load of atrazine in SA paddocks is probably due to the higher persistence of s-triazine herbicides in alkaline soils. The higher values for 2,4-D in the NSW and Qld soil profiles was due to a high value in a single paddock that had recently been sprayed.

Notably, in a number of paddocks (especially in WA but also in other states), there was a higher load of glyphosate than was applied in the previous spray, demonstrating glyphosate accumulation and its metabolite AMPA over time. Although the half-life of glyphosate is relatively low (10–40 days), a significant portion of the glyphosate (and AMPA) is bound to the soil and is much less accessible for continued degradation. This, combined with the high frequency of glyphosate use, can lead to a build-up of glyphosate and AMPA in soil. An accumulation of trifluralin was also apparent in a number of paddocks in WA. It should be reiterated that these levels represent the total loads, rather than the bio-available fraction. Residues aging in the soil results in stronger binding over time, and a reduction in bioavailability, so any biological effect can be difficult to predict.

How do soil functions respond to herbicide residues?

A literature review of over 300 published studies identified common themes for herbicide impacts on soil function (Rose et al. 2016). Most papers had reports of negligible impacts from herbicides on beneficial soil functions when applied at recommended rates. Even in the cases where negative effects were observed, they were usually minor and only lasted for less than one month.

However, some exceptions were apparent, especially regarding the effects from repeated herbicide application. For example, there is evidence that the accumulation of some sulfonylurea (SU) herbicides after repeat application can reduce plant-available nitrogen (N) by slowing down the processes involved in N-cycling. Persistence of SUs in soil has also been linked with increased incidences of rhizoctonia diseases in cereals and legumes. These effects are more likely to occur in alkaline soils, where SU herbicides are significantly more persistent. There are also cases in which other herbicides (e.g. glyphosate) can increase the incidence of disease, but these interactions appear to be site-specific and often occur under stressful growing conditions.

Based on this information and the herbicide residues detected in the soil survey, it is unlikely that SU residues are having ongoing negative effects on soil functions in the paddocks surveyed. However, the high residue loads of glyphosate, its metabolite AMPA and trifluralin could be altering some soil functions or plant-pathogen interactions. The localised nature of interactions with glyphosate, and the lack of specific data on trifluralin, means that firm conclusions cannot yet be made with respect to the residues detected.

How do crops respond to herbicide residues?

Because the potential for each herbicide to damage crops varies according to soil, agroclimate and crop, comprehensive damage thresholds (given as soil residue concentrations) for assessing plant-back risk are not readily available. However, there is the potential for glyphosate (+AMPA) or trifluralin residues to cause seedling damage given their high frequency of application and subsequent detection in the residue survey.

Table 1. Residue loads (average and maximum) of herbicide active ingredients (a.i.) in the 0–30 cm soil profile of paddocks by region.

Herbicide	Estimated average load across all sites (kg a.i./ha)*			Estimated maximum load detected (kg a.i./ha)*		
	NSW/Qld	SA	WA	NSW/Qld	SA	WA
AMPA	0.91	0.95	0.92	1.92	1.97	2.21
Glyphosate	0.56	0.48	0.79	2.05	1.05	1.75
Trifluralin	0.08	0.11	0.53	0.14	0.26	1.34
Diflufenican	0.01	0.03	0.04	0.02	0.05	0.09
Diuron	0.14	0.05	0.17	0.16	0.05	0.29
2,4-D	0.20	0.02	0.01	1.00	0.05	0.02
MCPA	0	0	0	0	0	0
Atrazine	0.02	0.03	0.02	0.03	0.05	0.02
Simazine	0	0.04	0	0.00	0.05	0
Fluroxypyr	0.03	0	0	0.03	0	0
Dicamba	0	0	0	0	0	0
Triclopyr	0	0.04	0.01	0	0.07	0.01
Chlorsulfuron	0	0	0	0	0	0
Sulfometuron-methyl	0	0	0	0	0	0
Metsulfuron-methyl	0	0	0	0	0	0
Triasulfuron	0	0	0	0	0	0

*Calculated by multiplying mass concentration (mg/kg) detected by area and average bulk density (derived from soilquality.org) for each soil layer.

It is generally accepted that glyphosate is deactivated when it reaches the soil and poses little risk to crops. However, recent research has shown that under certain circumstances glyphosate can be remobilised and become plant bioavailable, including:

» in the event of phosphorus (P) fertilisation, which can compete with glyphosate for binding sites on soil and remobilise bound glyphosate residues
» in the event of glyphosate applied to a high weed density shortly before sowing, such that dying weeds translocate glyphosate into the soil and act as a more soluble pool of glyphosate to the germinating crop.

A sandy, low organic matter soil from Wongan Hills, WA, was used to construct dose-response curves for wheat and lupin encountering glyphosate residues applied one month before sowing. To demonstrate circumstance, half the test plots received a one-off application of 20 kg/ha P fertiliser (as soluble potassium phosphate) at sowing.

In the soil not receiving P fertiliser, wheat was not affected by levels of glyphosate in soil resulting from a 27 kg/ha application rate, whilst lupin biomass was only significantly reduced at rates above 12 kg/ha (when upper 95% confidence level falls below 100% biomass) (Figure 2). When P fertiliser was added at 20 kg P/ha, both wheat and lupin showed signs of damage at a lower glyphosate concentration – for lupin this occurred at levels of glyphosate >3.5 kg/ha and for wheat >12.5 kg/ha (Figure 2). Previous research has shown that increasing levels of P fertiliser application will continue to lower the toxicity threshold to glyphosate/AMPA residues in soil. The soil samples from this experiment are currently being analysed to determine the residue level of both glyphosate and AMPA in soil. This will provide a more accurate understanding of whether the residues found in the field survey are likely to affect crop growth following P fertilisation.

For trifluralin, plant-back damage thresholds for oats vary from 0.1 to 0.2 mg/kg, and wheat from 0.2 to 0.4 mg/kg depending on the soil type (Hager & Refsell 2008). Table 2 shows the number of paddocks in which the topsoil trifluralin residue concentration exceeds the lower threshold for oats and wheat, respectively. Again, it must be stressed that the residues detected in our field survey constitute 'aged' residues, which are likely to be less bioavailable and hence less of a threat to crop growth. Nevertheless, considering that some of these paddocks will receive a pre-emergent application of trifluralin in 2016, the risk of some plant-back damage is tangible.

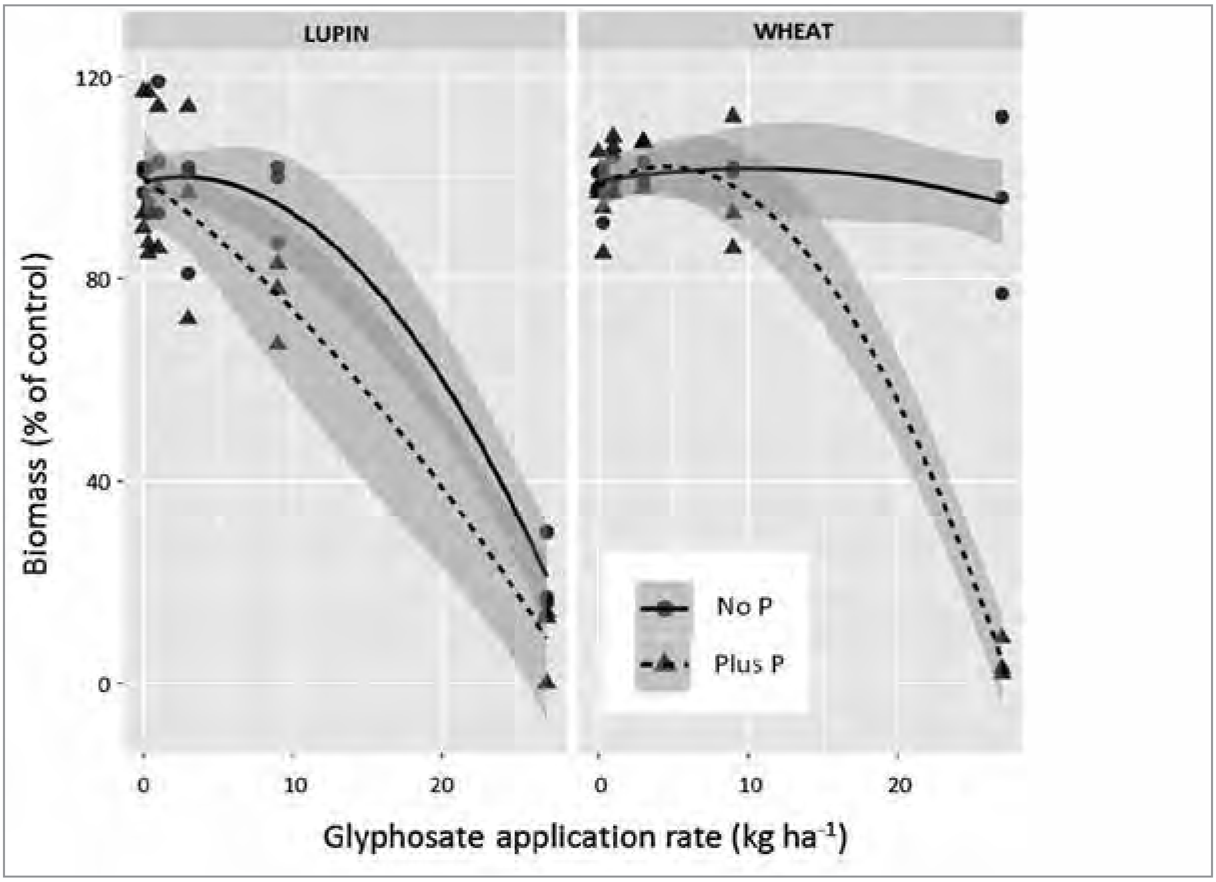

Figure 2. Growth response of lupin and wheat to glyphosate applied to soil one month before sowing with and without P fertiliser (20 kg/ha) added at sowing.

Table 2. Number of paddocks exceeding trifluralin lower phytotoxicity thresholds for oats (0.1 mg/kg) and wheat (0.2 mg/kg) in topsoil (0–10 cm).

Region	Trifluralin >0.1 mg/kg	Trifluralin >0.2 mg/kg	Number of paddocks surveyed
WA	10	5	12
SA	2	0	15
NSW–Qld	0	0	13

Acknowledgements

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We acknowledge the generosity of all growers participating in this survey for support, access and information regarding on-farm herbicide use. Special thanks to Cindy Cassidy, Tony Pratt and Kellie Jones from Farmlink, NSW; Greg Butler from SANTFA, SA; Clare Johnston and Elly Wainwright from Liebe Group, WA; Sarah Hyde and Georgia Oliver from Facey Group, WA; and Ashley Webb, Annabelle McPherson, Clarence Mercer and Helen Burns, NSW DPI, for their invaluable assistance with soil sampling and liaison. Thank you also to Ken Lisha and Scott Petty, NSW DPI who provided excellent support in processing soil samples.

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Crop sequencing for irrigated double cropping

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Key findings

- » The single cropping phase of cotton achieved the highest returns for both $/ha and $/ML.
- » The double cropping treatment of canola and maize achieved the highest returns for $/ha.
- » All double cropping treatments achieved similar returns for $/ML.

Introduction

The project aims to overcome some of the difficulties with double cropping systems (growing a winter and summer crop following one another) and to provide the opportunity for growers to capitalise on their investment in irrigated agriculture. This project considers the issues of herbicide residues; irrigation layouts and management; stubble management; and quantifying achievable crop yield and profitability.

The project has two core sites, one located in Boort (northern Victoria) and the other at the Leeton Field Station (southern NSW). The Victorian site is focusing on herbicide and stubble management. This report is a summary of the first year's results from the southern NSW experiment where the focus is on evaluating the different crop sequences to quantify achievable crop yield and profitability.

Site details

The experimental site was established at the Leeton Field Station in a field with a history of irrigated lucerne. The paddock was formed into 1.83 m-wide beds suitable for furrow irrigated cropping. The crop sequencing started in early 2014 with a winter cropping or fallow phase. The project will run for two years (four cropping seasons) ending in mid-2016 with the harvest of the second summer cropping phase.

Treatments

The experiment includes both single cropping (one crop per year) and double cropping (three or four crops in two years) treatments. The experiment has seven treatments with four replications of each treatment (Table 1). Each plot includes three beds 1.83 m wide by 120 m long, giving a total plot area of 660 m^2 and a treatment area of 0.26 ha. There is a fallow buffer area of one bed between each plot (Figure 1).

Figure 1. Irrigated double cropping experiment located at the Leeton Field Station.

Table 1. Summary of the seven treatments evaluated in the experiment.

Season/Year	Treatment						
	1	2	3	4	5	6	7
Winter 2014	Fallow	Fallow	Fallow	Wheat	Wheat	Barley	Canola
Summer 2014–15	Soybean	Soybean	Cotton	Soybean	Fallow	Soybean	Maize
Winter 2015	Fallow	Fallow	Faba bean	Wheat	Wheat	Barley	Faba bean
Summer 2015–16	Maize	Soybean	Fallow	Soybean	Fallow	Soybean	Fallow

Yield results of first two seasons

Treatments one and two – winter fallow followed by summer soybeans

The first winter phase was left as fallow. The summer crop was pre-irrigated and sown with Djakal soybeans on 20 November 2014. Both treatments were irrigated 14 times, using a total of 8 ML/ha of water for each treatment. Both crops were harvested on 5 May 2015 and achieved an average yield of 3.09 t/ha and 3.36 t/ha respectively. Both treatments were left as fallow during the 2015 winter phase.

Treatment three – winter fallow followed by summer cotton

The first winter phase was left as fallow. Sitcot 71 cotton was sown on 1 October 2014 and irrigated up. The cotton was irrigated 16 times requiring a total of 10 ML/ha of water. The crop was harvested on 29 April 2015 and achieved an average yield of 13.95 bales/ha. The plots were then cultivated and prepared for the faba bean phase to be sown on 22 May 2015.

Treatment four – winter wheat followed by summer soybeans

The first winter crop was sown to Dart⁽ᐅ⁾ wheat on 23 May 2014, but due to poor establishment, the crop was re-sown on 20 June 2014. The wheat crop was irrigated four times requiring a total of 3.5 ML/ha of water. The wheat crop was harvested on 11 December and achieved an average yield of 5.25 t/ha. The crop stubble was burned and Djakal soybeans were direct seeded on 16 December 2014 (five days after harvesting the wheat). The soybeans were irrigated 12 times requiring a total of 7 ML/ha of water. The crop was harvested on 21 April 2015 and achieved an average yield of 2.79 t/ha. The plots were then prepared for the winter wheat phase to be sown on 16 May 2015.

Treatment five – winter wheat followed by summer fallow

The first winter crop was sown to Dart⁽ᐅ⁾ wheat on 23 May 2014, but due to poor establishment, the crop was re-sown on 20 June 2014. The wheat crop was irrigated four times requiring a total of 3.5 ML/ha of water. The wheat crop was harvested on 12 December and achieved an average yield of 5.17 t/ha. The 2014–15 summer phase was left fallow.

Treatment six – winter barley followed by summer soybeans

The first winter crop was sown to Scope CL⁽ᐅ⁾ barley on 23 May 2014. The barley crop was irrigated four times requiring a total of 3.5 ML/ha of water. The barley crop was harvested on 29 November and achieved an average yield of 4.19 t/ha. The crop stubble was burnt and Djakal soybeans were direct seeded on 2 December 2014 (three days after harvesting the barley). The soybeans were irrigated 13 times requiring a total of 7.5 ML/ha of water. The crop was harvested on 21 April 2015 and achieved an average yield of 2.79 t/ha. The plots were then prepared for the winter barley phase to be sown on 18 May 2015.

Treatment seven – winter canola followed by summer maize

The first winter crop was sown to Hyola® 50 canola on 16 May 2014. The canola crop was irrigated four times requiring a total of 3 ML/ha of water. The canola crop was harvested on 13 November and achieved an average yield of 3.44 t/ha. The crop stubble was mulched and Pioneer P0012 maize was direct seeded on 21 November 2014 (eight days after harvesting the canola). The maize was irrigated 14 times requiring a total of 9 ML/ha of water. The maize crop was harvested on 21 April 2015 and achieved an average yield of 9.75 t/ha. The plots were then prepared for the winter faba bean phase to be sown on 22 May 2015.

Profitability results of first two seasons

Treatment three demonstrated the highest profit per hectare with a gross margin return of $4766/ha, which was significantly higher than all other treatments. Treatment seven had the second highest profit per hectare with $1840/ha, which was significantly higher than the remaining five treatments. Treatment five had the lowest profit per hectare with a gross margin of $461/ha, which was significantly lower than all other treatments (Figure 2).

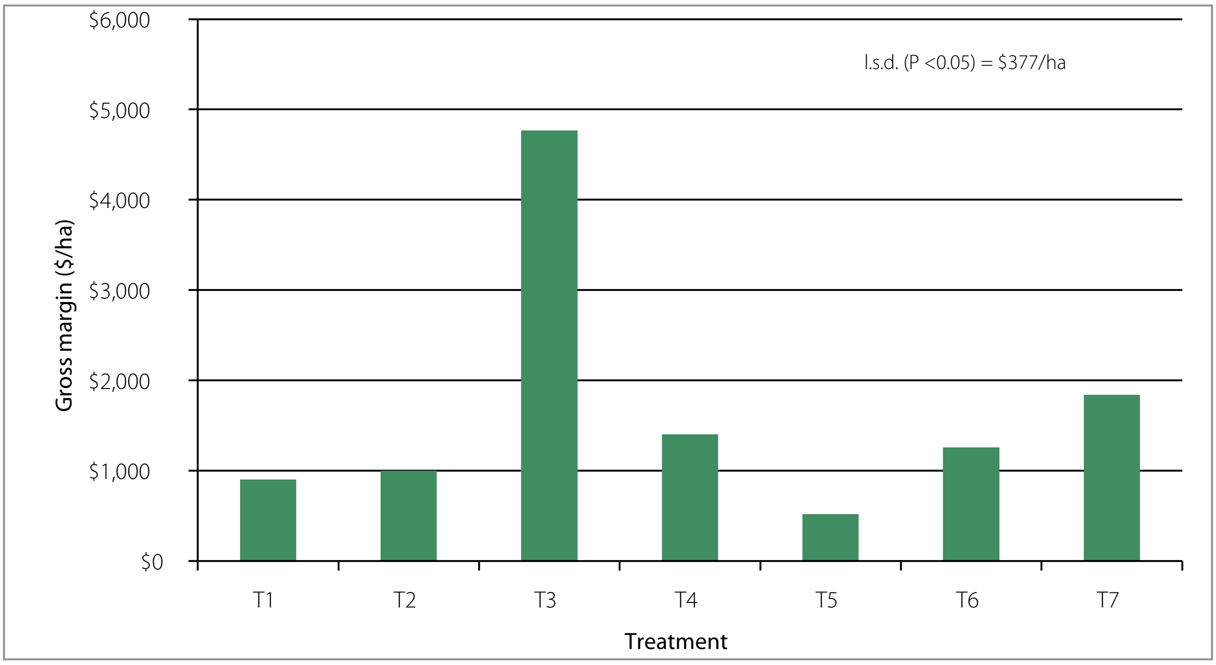

Figure 2. Gross margin ($/ha) return for the irrigated double cropping experiment at Leeton from April 2014 to April 2015.

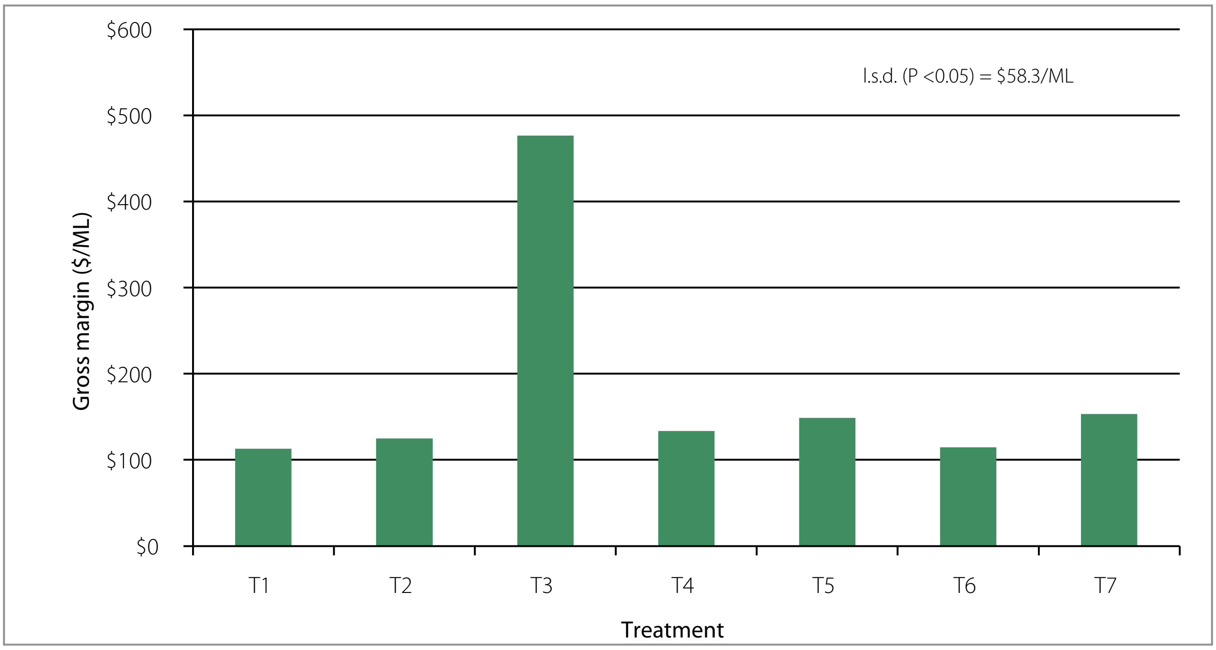

Figure 3. Gross margin ($/ML) return for the irrigated double cropping experiment at Leeton from April 2014 to April 2015.

Treatment three achieved the highest profit per megalitre with a gross margin return of $477/ML, which was significantly higher than all other treatments. Treatment seven had the second highest profit per megalitre with $153/ML, which was statistically similar to the remaining five treatments (Figure 3).

Summary

The first two season's results clearly demonstrate that the single cropping phase of cotton produced a significantly higher return for both $/ha and $/ML than any other single or double cropping treatment. Treatment seven achieved the highest return per hectare for the treatments with a cropping phase over both winter and summer. All double cropping treatments achieved statistically similar returns for $/ML.

Acknowledgements

The research is part of the 'Correct crop sequencing for irrigated double cropping project', VIC00010, 2014–16, jointly funded by NSW DPI and GRDC, and ICC are the Project Leaders. The support of Alan Boulton, Glenn Morris and Paul Morris is gratefully acknowledged.

The effect of variety, plant population and nitrogen rate on high-yielding irrigated wheat production – 2015

Tony Napier NSW DPI, Yanco; **Luke Gaynor**, **Deb Slinger** and **Cynthia Podmore** NSW DPI, Wagga Wagga; **Dr Neroli Graham** NSW DPI, Tamworth

Key findings

» Varietal selection again proved to be the major factor in achieving higher wheat yields in the second year of experiments in irrigated wheat production at Leeton.

» Cobra[⊕] was the highest yielding variety in this experiment but Corack[⊕], Suntop[⊕] and the durum breeding line 280913 also performed very well.

» Correct nitrogen timing significantly increased grain yield, grain protein and significantly reduced lodging.

» Managing plant population also significantly reduced lodging.

Introduction

The effect of variety, plant density and nitrogen management on grain yield was evaluated for a second year at the NSW DPI Leeton Field Station (LFS). Varietal selection again proved to be the major influence on irrigated wheat yields. Correct nitrogen timing significantly increased grain yield, grain protein and reduced lodging. Managing plant population can also significantly reduce lodging.

Site details

Location	Leeton Field Station, Leeton NSW
Experiment period	Winter crop growing season 2015
Soil type	Self-mulching medium clay
Previous crop	Barley
Sowing date	8 May 2015
Harvest date	3 December
Irrigation	One pre-sowing and two spring irrigations (total irrigation water applied 4.2 ML/ha) (Figure 1)

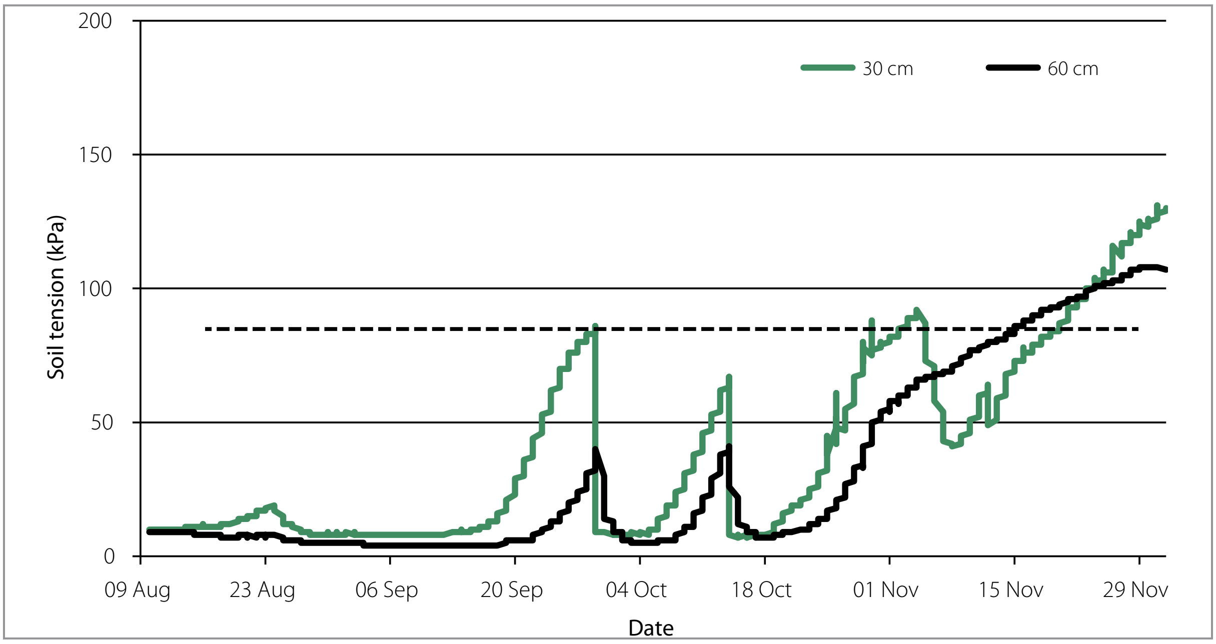

Figure 1. Soil moisture tension (kPa) at 30 cm and 60 cm deep for the 2015 LFS irrigated wheat experiments with a dashed line depicting the irrigation trigger point.

irrigation & climate

Treatments

Fourteen wheat varieties were evaluated over two plant densities and two nitrogen timings (tables 1 and 2). The plant density treatments were 'high density' (average 163 plants/m^2) and low density (average 117 plants/m^2). Both nitrogen timing treatments had a total of 245 kg N/ha applied throughout the growing season. The early nitrogen treatment had the majority of nitrogen applied at sowing while the late nitrogen treatment had the majority of the nitrogen applied later in the season.

Table 1. Wheat varieties evaluated in the 2015 Leeton Field Station irrigated wheat experiment.

Variety		
280913 (durum breeding line)	Kioraᶲ	Wallupᶲ
EGA_Bellaroiᶲ	Lancerᶲ	EGA_Gregoryᶲ
Charaᶲ	Maceᶲ	Trojanᶲ
Cobraᶲ	Merindaᶲ	Impalaᶲ
Corackᶲ	Suntopᶲ	

Table 2. Nitrogen timing treatments evaluated in the 2015 Leeton Field Station irrigated wheat experiment.

Treatment	Early nitrogen	Late nitrogen
Base (kg N/ha)	135	65
First node (kg N/ha)	80	80
Booting (kg N/ha)	30	100
Total (kg N/ha)	245	245

The experiment was sown with six rows per plot and a row spacing of 250 mm. There were three replicates of 56 treatments (168 plots) in a randomised block design. Each plot was 1.5 m wide and 10.5 m long. The experiment was both hand harvested (2 m^2 cuts) and machine harvested (the remaining 12 m^2) for yield. The hand-harvested cuts were taken from the middle four rows so there was no outside-row effect. The machine harvest was taken from the whole six rows. The machine harvested yields have been used in this report as there was much less variation between the mean yields for each treatment. The machine harvest yields were on average 14% higher than the hand harvested yields; including the outside rows that are higher yielding due to no competition for light and nutrients.

Results

Grain yield averaged 9.60 t/ha across all variety, density and nitrogen treatments (machine harvest yields). Cobra was the highest yielding variety at 11.03 t/ha, significantly higher than all other varieties. Corack, Suntop and 280913 (durum breeding line) also achieved very high grain yields exceeding 10 t/ha. Merinda, Impala and EGA_Gregory were the lowest yielding varieties (Figure 2).

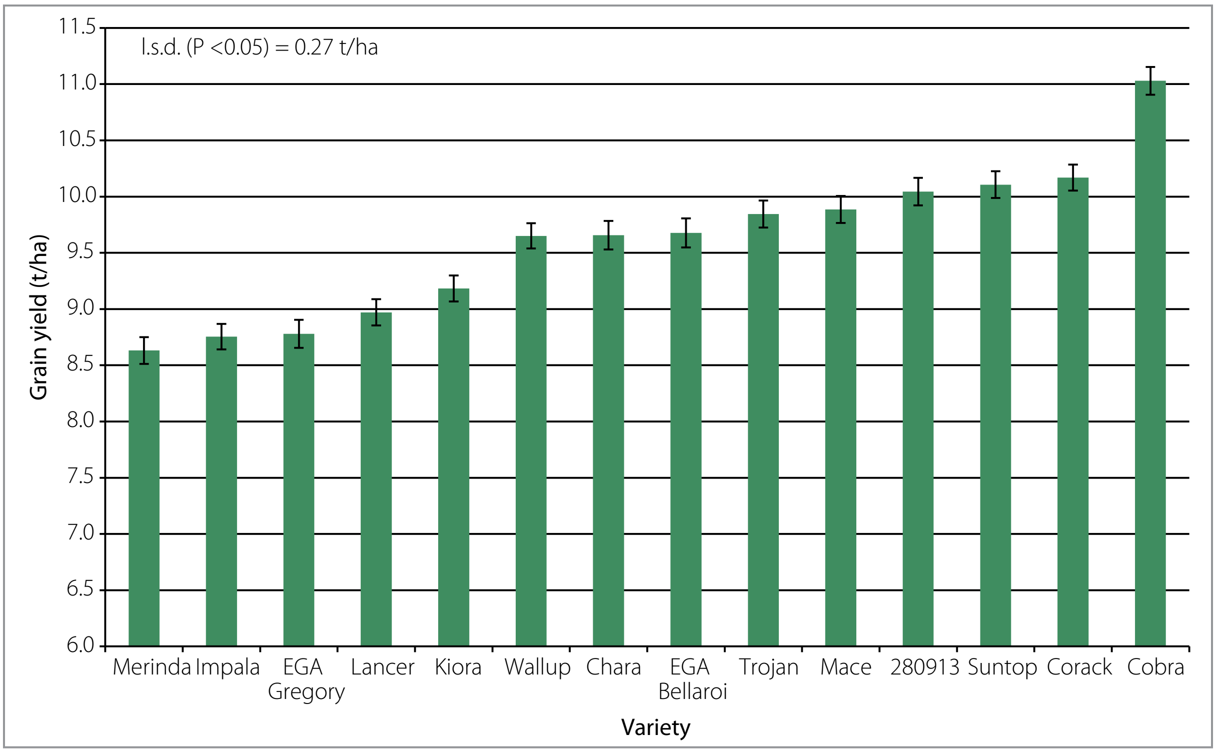

Figure 2. Machine harvested grain yield for the 2015 Leeton Field Station irrigated wheat experiment.

The experiment also demonstrated the significant effect that nitrogen application timing has on wheat grain yield. Applying the majority (73%) of nitrogen at or after the first node stage significantly increased grain yield compared with over half (55%) of the nitrogen applied pre-sowing. The late nitrogen treatments yielded an average of 9.71 t/ha, which was statistically higher than the early nitrogen treatments that averaged 9.49 t/ha (l.s.d. ($P < 0.05$) = 0.10 t/ha).

Plant density did not significantly affect wheat grain yield. The high density treatment (163 plants/m^2) yielded 9.57 t/ha and the low density (117 plants/m^2) treatment yielded 9.63 t/ha.

Lancer had the highest grain protein content of 13.1%, which was similar to the breeding line 280913 with 13.1%. Impala had the lowest grain protein content of 11.5%, which was similar to Suntop with 11.7%. Nitrogen timing also affected grain protein. The late nitrogen treatments had the highest average grain protein content of 12.5%, which was significantly higher than the early nitrogen treatments, which averaged 12.3%. Plant density had no effect on grain protein content.

Corack had the highest test weight of 85.4 kg/hL, which was statistically similar to Wallup, Lancer, Impala, EGA_Gregory, Trojan and Suntop. EGA_Bellaroi had the lowest test weight – 82.8 kg/hL, which was statistically similar to Merinda, 280913, Mace and Cobra. Neither nitrogen timing nor plant density had an effect on test weight.

The durum breeding line 280913 had the lowest screenings (1.2%) and was significantly lower than all other varieties. Merinda had the highest screenings (6.3%) and was statistically similar to Kiora (6.0%). Both nitrogen timing and plant density had a significant effect on screenings. The late nitrogen treatments had significantly lower screenings than the early nitrogen treatments. The low density treatments also had significantly lower screenings than the high density treatments.

Corack had the least lodging with a score of 1.8 and had significantly less lodging than all other varieties. EGA_Bellaroi had the most lodging with a score of 8.1 and had significantly more lodging than all other varieties. Plant population had a significant effect on lodging with the low density treatments having significantly less lodging than the high density treatments. Nitrogen application timing had no effect on lodging (Table 3).

Table 3. Grain quality and lodging averaged across density and nitrogen treatments for the 2015 Leeton Field Station irrigated wheat experiment.

Variety	Grain protein (%)	Test weight (kg/hL)	Screenings (% < 2 mm)	Lodging score (0 to 9)
Lancer	13.1 *	85.0 *	3.0	4.0
280913	13.1 *	83.1 #	1.2 *	7.4
EGA_Bellaroi	12.8	82.8 #	3.3	8.1 *
Wallup	12.7	85.0*	3.1	4.3
Merinda	12.6	82.8 #	6.3 #	5.7
Chara	12.6	84.0	4.5	4.6
Cobra	12.4	83.3 #	2.7	5.0
Kiora	12.3	84.0	6.0 #	4.9
EGA_Gregory	12.2	84.7 *	3.8	4.7
Corack	12.1	85.4 *	2.3	1.8 #
Trojan	12.1	84.6 *	4.3	5.0
Mace	12.0	83.3 #	3.2	3.5
Suntop	11.7 #	84.3 *	4.0	4.4
Impala	11.5 #	84.8 *	4.8	7.0
l.s.d. (P<0.05)	0.3	0.9	0.7	0.7

Statistically in the lowest grouping
* Statistically in the highest grouping
Lodging score: 0=no lodging; 9=completely lodged

Summary

The 2015 irrigated wheat experiment at Leeton Field Station demonstrated that varietal selection and irrigation management have the most influence for achieving maximum yields. The experiments averaged 9.60 t/ha across all varieties and treatments (machine harvested samples including edge rows). These yields are about 14% higher than plots with the outside rows removed. Cobra was the highest yielding variety with an average machine harvest yield of 11.0 t/ha. Without the edge row effect, Cobra yielded 9.5 t/ha. Other high yielding varieties included Corack, Suntop and the durum breeding line 280913.

Irrigation management also had a significant effect on grain yield in this experiment. Soil moisture was monitored throughout the season and the plots were irrigated before any moisture stress occurred. The experiment was pre-irrigated and received two spring irrigations. In total, 4.2 ML/ha of irrigation water was applied.

Nitrogen timing and plant density also influenced the results. Applying the majority of nitrogen (73%) at or after the first node stage (late nitrogen treatment) significantly increased both grain yield and grain protein. The late nitrogen treatment also significantly reduced screenings. The low density treatment significantly reduced screenings and lodging.

Acknowledgements

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The support of Daniel Johnston, Glenn Morris, Gabby Napier and Michael Hately for assistance with experiment management, field assessments and data collection is gratefully acknowledged.

The effect of irrigation management on wheat grain yield, grain quality and water use efficiency

Brian Dunn, **Tina Dunn**, **Craig Hodges** and **Chris Dawe** NSW DPI, Yanco

Key findings

» In 2015, two spring irrigations produced the highest wheat grain yield (7.61 t/ha), but one irrigation provided the highest water use efficiency (1.7 t/ML).

» Ponding irrigation water for 48 hours to induce waterlogging did not reduce grain yield in this experiment, but increased water use and reduced water use efficiency by 25%.

» If the number of spring irrigations is limited, it is important to find a balance between irrigating before significant moisture stress occurs and ensuring adequate moisture is available during flowering.

Introduction

This experiment investigated the irrigation water requirements of a wheat crop and the impact of irrigation intensity and water ponding on grain yield, grain quality, water use and water use efficiency.

Site details

Location	Leeton
Soil type	Self-mulching heavy clay
Previous crop	Canola
Field preparation	Canola stubble burnt – no cultivation
Sowing	18 May (disc drill at 18 cm row spacing)
Establishment rainfall/ irrigation	19 May – 8 mm rain 2 June – 11 mm sprinkle irrigation
Variety and seeding rate	Corack and Suntop wheat @ 85 kg/ha seed
Sowing fertiliser	Diammonium phosphate (DAP) @ 175 kg/ha sown with seed
Establishment	Corack – 89 plants/m^2 Suntop – 110 plants/m^2
Herbicides	Axial @ 300 mL/ha; Precept @ 1 L/ha
Topdressed nitrogen	21 July (Z30) – before 10 mm rain
Irrigation dates	1 irrigation treatment – 2 October 2 irrigation treatments – 29 September and 14 October
Spring rainfall	64 mm between 31 October and 6 November

Treatments

Irrigation management treatments

There were four irrigation treatments and four replicates in each treatment:

T1: no irrigation (rainfall only)

T2: one spring irrigation – five hours ponding before draining

T3: two spring irrigations – five hours ponding before draining

T4: waterlogged – two spring irrigations with water ponded for 48 hours before draining.

Each of the above mentioned treatments were in small separate bays (Figure 1) to allow water use to be accurately measured. Irrigation timing was determined using a combination of evapotranspiration data, crop factors and rainfall, while considering the necessity for wheat to have adequate available soil moisture during flowering.

Figure 1. Aerial photo of experiment (1 November 2015).

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Wheat varieties

The irrigation treatments were applied to two wheat varieties, Corack and Suntop.

Nitrogen treatments

Four nitrogen treatments (0, 130, 260 and 390 kg/ha of urea) were applied to each irrigation/variety treatment at the beginning of stem elongation (Z30) and before 10 mm of rainfall.

Results

Grain yield

The T3 irrigation treatment (two-irrigations) produced the highest grain yield when averaged across variety and nitrogen treatments with 7.6 t/ha. T4 (waterlogged with two-irrigation) yielded 7.3 t/ha and T2 (one-irrigation) yielded 6.8 t/ha. The lowest yield 4.9 t/ha was obtained from T1 (zero irrigation) as expected. Overall, Corack achieved a significantly higher grain yield (7.0 t/ha) than Suntop (6.4 t/ha) (Figure 2).

Very little rainfall was received between 3 September and 31 October. As a result, the zero irrigation treatment was very moisture-stressed before 64 mm of rain was received at the end of October and in early November. This stress was the major cause of lower grain yields in the zero irrigation treatment compared with the other treatments that received irrigations during this period.

Despite the extended period of ponding, the waterlogged treatment achieved a high grain yield, which can be attributed to the very good structure and internal drainage of the soil at the experiment site.

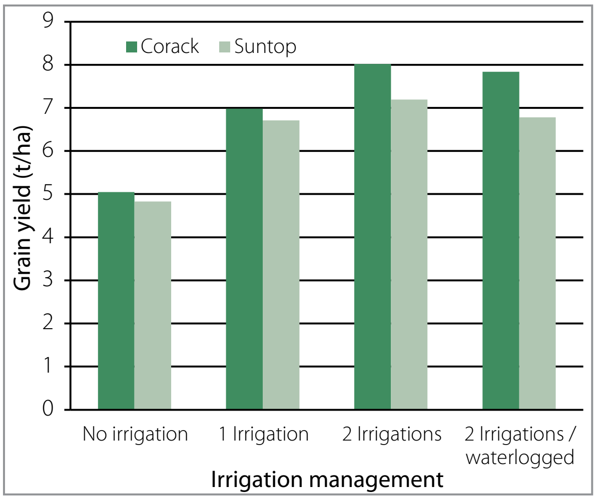

Figure 2. Grain yield (t/ha) for irrigation by variety interaction, averaged across nitrogen treatments (l.s.d. (P <0.05) = 0.40).

Grain quality

The zero irrigation treatment (T1) produced grain with a significantly higher protein content than the other three irrigation treatments (Figure 3). Increasing the rate of topdressed nitrogen increased grain protein levels in all irrigation treatments (Table 1). Corack (12.0%) produced significantly higher grain protein levels than Suntop (11.7%) when averaged across all treatments.

Suntop had a significantly higher level of screenings than Corack at 9.6% and 7.1% respectively (when averaged across all treatments). Screenings were highest in the zero irrigation treatment (T1) for both varieties with no significant difference between the other irrigation treatments.

Grain test weight averaged 79 kg/hL, with all treatments above the 76 kg/hL minimum limit for many wheat grades.

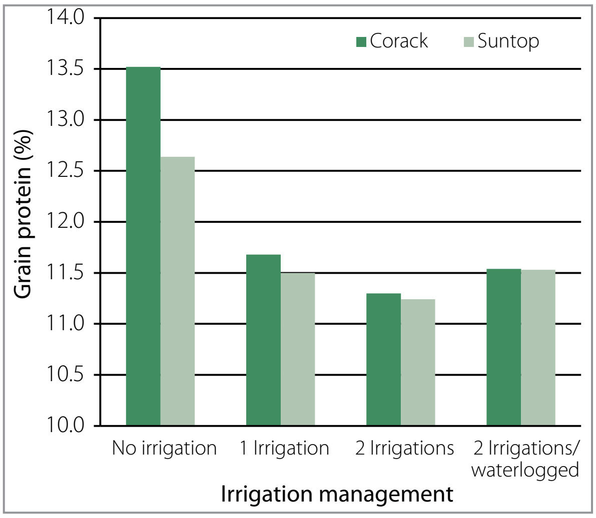

Figure 3. Grain protein (%) for irrigation by variety interaction, averaged across nitrogen treatments (l.s.d. (P <0.05) = 1.6).

Water use and water use efficiency

The zero irrigation treatment (T1) received 3.1 ML/ha as rainfall during the crop growing period. The one (T2), two (T3) and waterlogged (T4) irrigation treatments received 4.1, 4.9 and 6.1 ML/ha total water respectively consisting of rainfall and irrigation water (Table 1). Increasing the ponding period from five hours to 48 hours for the waterlogging treatment, as can often occur in commercial fields with flatter slopes, slow supply or poor drainage, significantly increased water use.

Table 1. Wheat grain yield, water use and productivity, grain quality and wheat grade (average of varieties).

Treatment Irrigation management	Topdressed nitrogen (kg urea/ha)	Grain yield (t/ha)	Water use rain+irrigation (ML/ha)	Water use efficiency (t/ML)	Grain protein (%)	Test weight (kg/hL)	Screenings <2 mm* (%)	Wheat grade
Zero	0	5.8	3.1	1.9	9.7	82	7.9	AGP1
	130	5.1		1.6	12.9	78	11.4	HPS1
	260	4.5		1.5	14.3	76	15.9	HPS1
	390	4.4		1.4	15.1	76	17.5	HPS1
1 irrigation	0	6.9	4.1	1.7	9.6	82	6.1	AGP1
	130	7.2		1.7	11.5	81	6.8	AUH2
	260	6.8		1.6	12.5	79	7.5	AUH2
	390	6.6		1.6	12.9	78	8.1	AUH2
2 irrigations	0	7.2	4.9	1.5	9.6	81	6.0	AGP1
	130	7.9		1.6	11.2	80	6.4	AGP1
	260	7.7		1.6	12.0	80	6.5	AUH2
	390	7.5		1.5	12.4	78	6.8	AUH2
2 irrigations waterlogged	0	7.2	6.1	1.2	10.2	79	6.2	AGP1
	130	7.6		1.3	11.4	79	6.1	AGP1
	260	7.3		1.2	12.1	78	6.8	AUH2
	390	7.1		1.2	12.4	77	7.7	AUH2
l.s.d. (P <0.05)		0.37	0.2	0.10	0.46	2.6	1.6	

* Screenings could be higher than expected due to harvesting with a plot harvester compared with a commercial harvester, but the trend is consistent with previous results.

The one irrigation treatment (T2) had the highest water productivity with 1.7 t/ML followed by the zero (T1) and two irrigation (T3) treatments both with 1.6 t/ML and the waterlogged treatment (T4) with 1.2 t/ML. Even though the grain yield of the waterlogged (T4) and two-irrigation (T3) treatments were similar, the extra water use associated with waterlogging created a 25% reduction in water use efficiency with this treatment (Table 1).

Summary

Even though it was a wet winter and considerable rainfall was received during grain fill, the very dry period during September and October caused a large reduction in grain yield and adversely affected grain quality in the zero irrigation treatment. The one-irrigation treatment received the irrigation during this dry period, resulting in only slight moisture stress before the rainfall event during grain fill.

It is important that adequate soil moisture is available to a wheat crop during flowering. If the number of spring irrigations applied to a wheat crop is limited, it is important to find a balance between irrigating before significant moisture stress occurs, while also ensuring adequate moisture is available during flowering.

This research highlights the importance of irrigation management. The 25% reduction in water use efficiency due to poor irrigation management (i.e. 48 hour ponding) clearly demonstrates the importance that effective layouts and irrigation management play in maximising returns from the very valuable water resource.

Acknowledgements

This research is a part of the 'Southern irrigated cereal and canola varieties achieving target yields project', DAN00198, 2014–17, jointly funded by NSW DPI and GRDC.

The effect of variety, time of sowing and plant population on high-yielding irrigated canola – 2015

Tony Napier NSW DPI, Yanco; **Luke Gaynor**, **Deb Slinger** and **Cynthia Podmore** NSW DPI, Wagga Wagga; **Dr Neroli Graham** NSW DPI, Tamworth

Key findings

» Varietal selection again proved to be the strongest determinant of irrigated canola grain yield in the second year of experiments at Leeton.

» The three highest yielding varieties were Nuseed® Diamond, Hyola® 50 and Nuseed® GT-50.

» Sowing time and variety interaction affected lodging, grain yield and harvest index (HI).

» Plant population alone only affected lodging but the variety interaction affected lodging and the harvest index.

Introduction

The second year of irrigated canola experiments as part of the Southern irrigated cereal and canola varieties achieving target yields project were conducted in 2015. The experiment at Leeton evaluated the effect of variety, time of sowing, plant population and their interactions on canola grain yield, grain quality (oil content) and crop growth (lodging and harvest index).

The experiments reinforced the key messages from year one: varietal selection is the major driver of high yielding irrigated canola production, but other agronomic management such as plant population and time of sowing also affect yield and grain quality.

Site details

Location	Leeton Field Station, Leeton NSW
Experiment period	Winter crop growing season 2015
Soil type	Self-mulching medium clay
Previous crop	Barley
Sowing dates	3 April and 27 April 2015
Harvest date	13 November and 16 November 2015
Irrigation	One pre-sowing and two spring irrigations (total irrigation water applied 3.8 ML/ha).
Nitrogen budget	Total 318 kg N/ha (68 kg N/ha starting soil level; 100 kg N/ha pre-sowing; 100 kg N/ha topdressed; approximately 50 kg N/ha mineralised during growing season)

Treatments

Variety

Canola varieties (14)	
ATR Bonito⁽ᵈ⁾	Hyola® 577CL
ATR Gem⁽ᵈ⁾	Hyola® 600RR
AV Garnet⁽ᵈ⁾	Nuseed Diamond
Hyola® 50	Nuseed GT-50
Hyola® 559TT	Pioneer® 44Y84 (CL)
Hyola® 750TT	Pioneer 45Y88 (CL)
Hyola® 575CL	Victory® V3002

Plant population

The target population treatments were 25 plants/m^2 (low density) and 50 plants/m^2 (high density).

Time of sowing

The two sowing dates evaluated were 3 April 2015 (TOS 1) and 27 April 2015 (TOS 2).

Results

There was a significant difference between the yields of varieties evaluated with a 1.55 t/ha difference between the highest and lowest yielding varieties. Nuseed® Diamond (4.59 t/ha) yielded significantly higher than all other varieties and 34% higher than the lowest yielding variety Pioneer® 44Y84 (CL) (3.04 t/ha). The next five varieties (Hyola 50®, Nuseed® GT-50, Pioneer® 45Y88 (CL), AV Garnet, Hyola® 575CL) did not have significantly different yields (Figure 1).

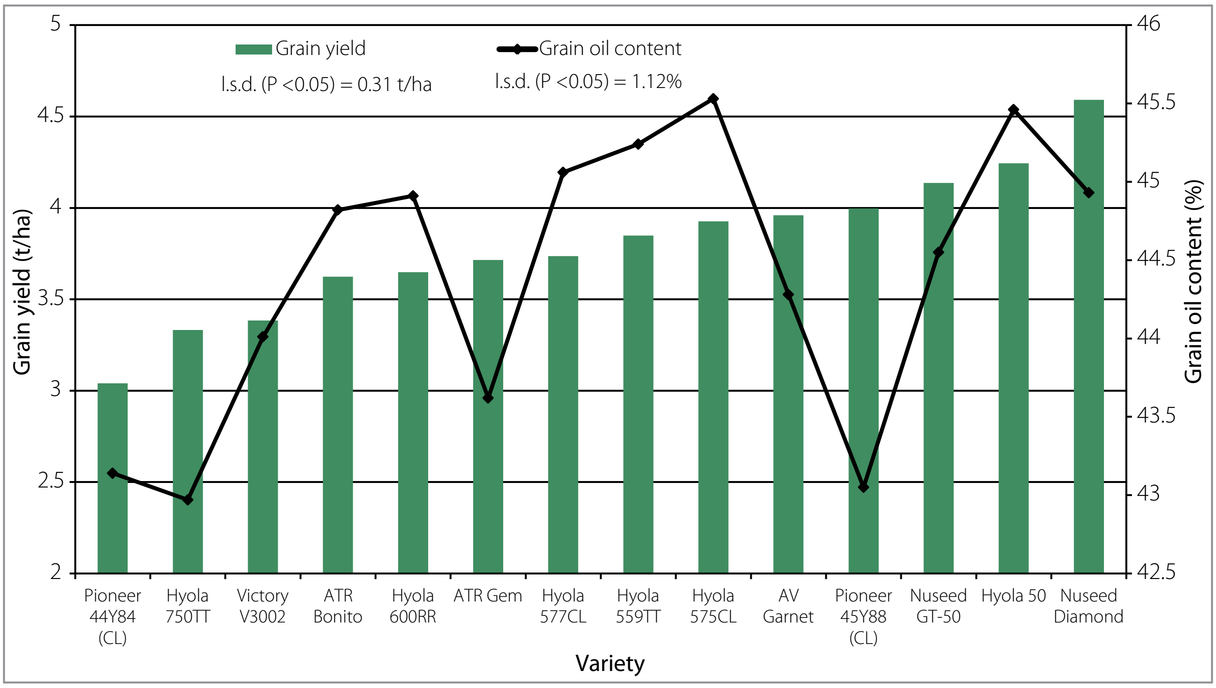

Figure 1. Grain yield and oil content of 14 canola varieties, Leeton 2015.

The varieties produced significantly different oil contents however there was no correlation between oil content and grain yield. Hyola® 575CL had the highest oil content (45.5%) and was the sixth highest grain yield followed by Hyola® 50 (45.5%), which yielded second highest and Hyola® 559TT (45.2%), which yielded seventh highest (Table 1).

The HI ranged from 0.20 for Pioneer® 44Y84 (CL) to 0.30 for ATR Bonito. Again, there was no correlation between HI and grain yield.

There was a significant difference in lodging between the varieties evaluated, but this did not have an overall correlation with grain yield. The variety Pioneer® 45Y88 (CL) had the lowest lodging score (0.1) followed by Hyola® 577CL (0.2) and Hyola® 575CL (0.3). These variety yield rankings were 4th, 8th and 6th respectively. The varieties Pioneer® 44Y84 (CL) and Hyola® 750TT had the highest lodging scores of 3.7 and 2.8 respectively and the lowest yields (3.04 t/ha and 3.33 t/ha respectively). It was observed at harvest that lodging probably affected yield in these two varieties.

Table 1. Grain yield, grain quality and crop growth measurements for canola varieties and ranking.

Variety	Grain yield (t/ha)	Oil content (%)	Harvest index	Lodging score [A]
Pioneer 44Y84 (CL)	3.04	43.1	0.20	3.7
Hyola 750TT	3.33	43.0	0.23	2.8
Victory V3002	3.38	44.0	0.24	1.5
ATR Bonito	3.62	44.8	0.30 [1]	2.3
Hyola 600RR	3.65	44.9	0.21	1.6
ATR Gem	3.72	43.6	0.29 [2]	0.8 [5]
Hyola 577CL	3.74	45.1 [4]	0.23	0.2 [2]
Hyola 559TT	3.85	45.2 [3]	0.28 [4]	1.6
Hyola 575CL	3.93	45.5 [1]	0.24	0.3 [3]
AV Garnet	4.00 [5]	44.3	0.26	1.5
Pioneer 45Y88 (CL)	4.00 [4]	43.1	0.26	0.1 [1]
Nuseed GT-50	4.14 [3]	44.6	0.27 [5]	1.4
Hyola 50	4.24 [2]	45.5 [2]	0.26	0.5 [4]
Nuseed Diamond	4.59 [1]	44.9 [5]	0.29 [2]	1.7
Experiment mean	3.80	44.4	0.25	1.4
l.s.d.(P <0.05)	0.31	1.1	0.01	0.8

[A] lodging score: 0=no lodging; 9=complete lodging

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Plant population did not affect grain yield or oil content. High plant density resulted in a higher lodging score (2.0) than low plant density (0.8), but both were relatively low lodging scores. There was also a significant difference between varieties and plant populations on lodging and HI (Table 2).

Time of sowing, when averaged over all treatments, did not affect grain yield, grain quality or crop growth. However, the varieties differed significantly in their response to the time of sowing (variety × time of sowing interaction) on grain yield, lodging score and HI (Table 3).

Of the 14 varieties evaluated, eight yielded higher at the first time of sowing and six at the second time of sowing. The general trend was for the longer-maturing varieties to have a higher grain yield from the first time of sowing (3 April) and the shorter-maturing varieties to have a higher grain yield from the second time of sowing (27 April).

Despite having no overall effect, only four varieties had a higher lodging score at the later time of sowing (Pioneer® 44Y84 (CL), ATR Bonito, Nuseed® Diamond and Hyola® 750TT) and only two varieties had a higher HI at the early time of sowing (Hyola® 575CL and Hyola® 577CL).

Table 2. The effect of the variety and plant population interaction on lodging and harvest index.

Variety	Lodging score [A]		Harvest index	
	Low plant density	High plant density	Low plant density	High plant density
Pioneer 44Y84 (CL)	2.9	4.5	0.21	0.20
Pioneer 45Y88 (CL)	0.2	0.0	0.26	0.25
ATR Bonito	1.1	3.4	0.31	0.28
Nuseed Diamond	0.8	2.6	0.30	0.29
AV Garnet	0.7	2.2	0.27	0.26
ATR Gem	0.5	1.2	0.30	0.27
Nuseed GT-50	1.1	1.7	0.28	0.27
Hyola 50	0.1	0.9	0.25	0.27
Hyola 575CL	0.1	0.5	0.23	0.25
Hyola 600 RR	0.7	2.4	0.21	0.21
Hyola 750TT	0.6	5.0	0.25	0.21
Hyola 559TT	1.5	1.7	0.28	0.28
Hyola 577CL	0.3	0.2	0.23	0.22
Victory V3002	1.4	1.5	0.24	0.24
Experiment mean	0.8	2.0	0.26	0.25
l.s.d.(P <0.05)	1.1	0.02		
[A] Lodging score: 0 = no lodging; 9 = complete lodging				

Table 3. The effect of the variety and time of sowing interaction on grain yield and crop growth.

Variety	Grain yield (t/ha)		Lodging score [A]		Harvest index	
	TOS 1	TOS 2	TOS 1	TOS 2	TOS 1	TOS 2
Pioneer 44Y84 (CL)	2.94	3.14	2.9	4.5	0.20	0.20
Pioneer 45Y88 (CL)	3.92	4.07	0.2	0.0	0.25	0.27
ATR Bonito	3.68	3.56	1.6	2.9	0.28	0.31
Nuseed Diamond	4.67	4.51	1.2	2.2	0.29	0.30
AV Garnet	4.05	3.87	1.6	1.3	0.26	0.27
ATR Gem	4.00	3.43	0.9	0.8	0.28	0.30
Nuseed GT-50	4.04	4.23	1.8	1.1	0.27	0.28
Hyola 50	4.11	4.38	0.7	0.2	0.26	0.26
Hyola 575 CL	4.23	3.62	0.3	0.3	0.26	0.23
Hyola 600 RR	3.42	3.87	1.9	1.2	0.19	0.23
Hyola 750TT	3.31	3.35	1.8	3.9	0.23	0.24
Hyola 559TT	3.68	4.02	1.7	1.6	0.28	0.29
Hyola 577	4.01	3.46	0.6	0.0	0.24	0.22
Victory 3002	3.23	3.54	1.8	1.1	0.22	0.25
Experiment mean	3.81	3.79	1.3	1.5	0.25	0.26
l.s.d. (P <0.05)	0.45		1.23		0.02	
[A] 0 = no lodging; 9 = complete lodging						

Summary

This experiment demonstrated that high irrigated canola yields can be achieved if the correct varieties are selected and best practice agronomic management applied. Five of the 14 varieties evaluated yielded over 4 t/ha and nine yielded over 3.5 t/ha. The overall experiment mean yield was 3.8 t/ha.

Plant population did not affect grain yield. However, the higher plant population resulted in increased lodging overall and a lower HI for most varieties (11 of the 14 varieties).

The time of sowing did not affect average grain yield, grain quality or crop growth, but there were varietal differences. Also, most varieties had a higher lodging score from the time of sowing one (11 of 14 varieties) and a higher HI from the time of sowing two (12 of 14 varieties).

The third and final year of experiments will be conducted in 2016.

Acknowledgements

GRDC and NSW DPI jointly funded this research which is part of the 'Southern irrigated cereal and canola varieties achieving target yields project', DAN00198, 2014–17.

The support of Daniel Johnston, Glenn Morris, Gabby Napier and Michael Hately for assistance with experiment management, field assessments and data collection is gratefully acknowledged.

Time of sowing soybeans – southern NSW 2014–15

Mark Richards and **Luke Gaynor** NSW DPI, Wagga Wagga; **Mathew Dunn** and **Alan Boulton** NSW DPI, Yanco

Key findings

- The ideal sowing time for soybeans in southern NSW is from mid-November to early December.
- Delaying sowing until late December can result in reduced grain yield.

Introduction

This soybean experiment was conducted at the NSW DPI Leeton Field Station to test the response of three commercial varieties and five unreleased lines to three sowing times. The three sowing times represent an early (20 November), mid (5 December) and late (22 December) sowing time for this region.

Site details

Soil type	Self-mulching, medium clay
Previous crop	Chemical fallow
Sowing date	5 December 2014
Establishment irrigation	Pre-watered
Irrigation layout	1.83 m raised beds with furrow irrigation
Row spacing	2 rows/bed (91.5 cm)
Sowing density	35 plants/m^2
Inoculation	Water injected peat slurry Group H
Fertiliser	125 kg/ha legume starter
Herbicides pre-emergent	Glyphosate (450 g/L) at 2 L/ha plus pendimethalin (330 g/L) at 2.5 L/ha
Insecticides	Abamectin at 300 mL/ha on 30 December 2014 Lamdacyhalothrin at 80 mL/ha on 11 March 2015
In-crop rainfall	84 mm
Irrigations	8 ML/ha (approximately)
Harvest date	16 April 2015

Treatments

Varieties (8)	Bidgee⊕ Djakal Snowy⊕ N005A-80	N116C-3 P176-1 P176-14 P176-2
Sowing dates (3)	20 November 2014 5 December 2014 22 December 2014	

Results

Grain yield was significantly affected by both sowing time (P <0.01) and variety (P <0.01). The interaction between sowing time and variety was not significant (P = 0.31).

Averaged across varieties, grain yield and plant dry matter results were higher for the 20 November and 5 December sowing times than the 22 December sowing time (Figure 1).

All varieties individually achieved higher grain yields at the 20 November and 5 December sowing times than the 22 December sowing date. The highest yielding varieties were Djakal and the unreleased line P176-2 (Figure 2).

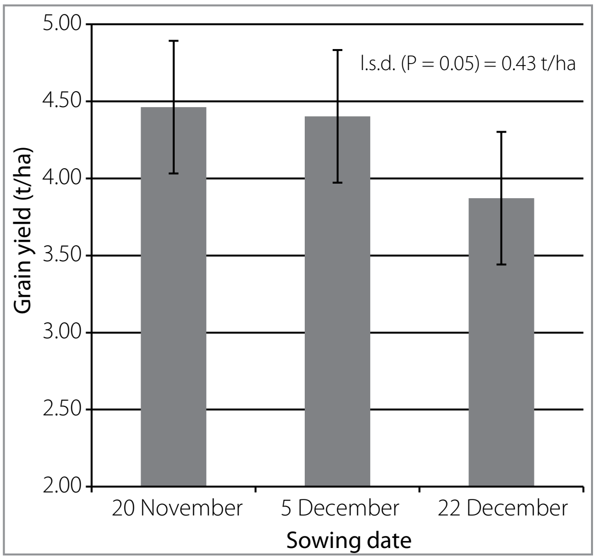

Figure 1: Soybean grain yield by sowing date averaged across varieties.

Summary

The evaluation of eight soybean varieties at three sowing times in this experiment found that:the ideal sowing time for soybeans in Southern NSW is from mid-November to early December

- delaying sowing until late December can result in reduced grain yield.

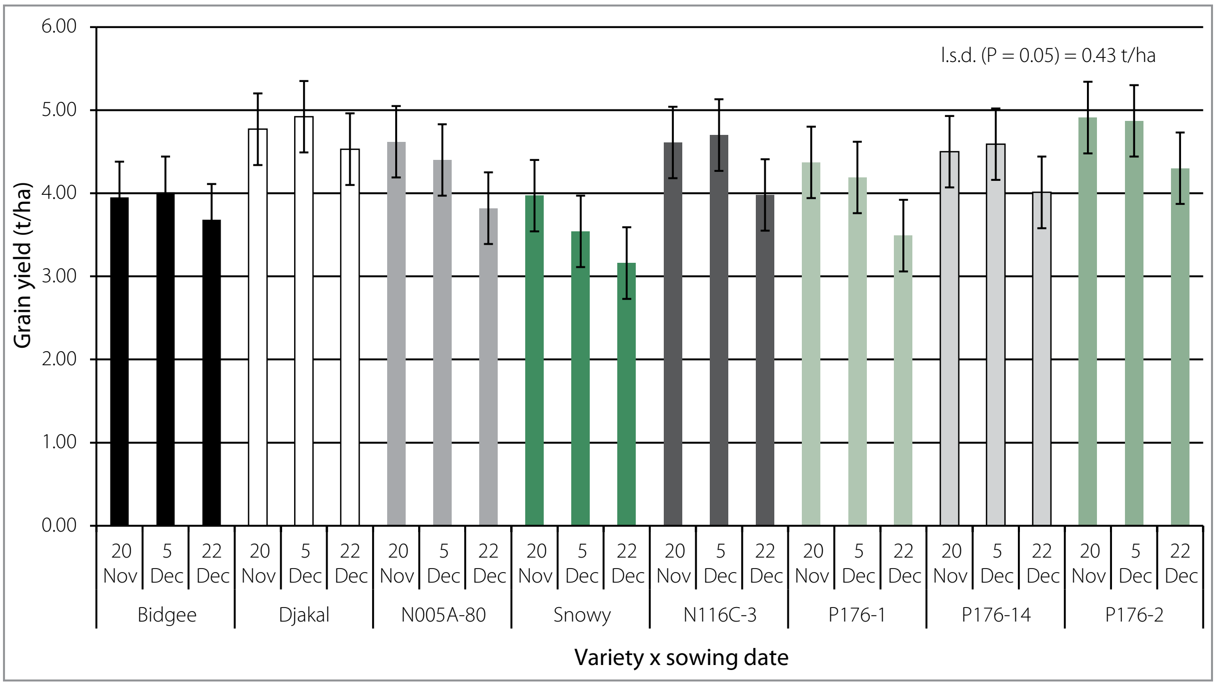

Figure 2: Soybean grain yield for variety and sowing date interaction. Statistical significance detected when comparing varieties mean within sowing dates.

Acknowledgements

This experiment is part of the project 'Southern NSW soybean agronomy', DAN00192, 2014–18, which is jointly funded by GRDC and NSW DPI.

Thank you to John Dando, Paul Morris and the NSW DPI farm staff at the Leeton Field Station for their assistance in managing the site. Also thankyou to Dr Neil Coombes from NSW DPI for undertaking the biometrical tasks associated with this project.

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Advanced soybean breeding line evaluations across time of sowing – southern NSW 2014–15

Mark Richards and **Luke Gaynor** NSW DPI, Wagga Wagga; **Mathew Dunn** and **Alan Boulton** NSW DPI, Yanco

Key points

- Average grain yields are maximised by sowing mid-November to early December in southern NSW.
- In northern Victoria, sowing should begin earlier from 1 November until late November.

Introduction

This soybean experiment, conducted at the NSW DPI Leeton Field Station, tested the response of 26 advanced-stage lines and four commercial varieties at two sowing times. The first time of sowing (TOS) was 26 November followed by the second TOS (26 days later) on 22 December. These two sowing times represented the ideal sowing period (26 November) and a later than ideal sowing time for this region (22 December).

The experiment discussed is part of the National Soybean Breeding Program funded by GRDC, NSW DPI and CSIRO. The breeding objectives of that program are to produce soybean varieties for human consumption markets that are high yielding, early maturing, and have high disease tolerance. Recent varietal releases include Bidgee, Snowy and Djakal.

Site details

Soil type	Self-mulching medium clay
Previous crop	Chemical fallow
Establishment irrigation	Pre-watered
Irrigation layout	1.83 m raised beds with furrow irrigation
Row spacing	2 rows/bed (91.5 cm)
Sowing density	35 plants/m^2
Inoculation	Water injected peat slurry Group H
Fertiliser	125 kg/ha legume starter
Herbicides pre-emergent	glyphosate 450 g/L at 2 L/ha Pendimethalin 330 g/L at 2.5 L/ha
Insecticides	Abamectin at 300 mL/ha on 30 December 2014, lamdacyhalothrin at 80 mL/ha on 11 March 2015
In-crop rainfall	113 mm (TOS 1), 104 mm (TOS 2)
Irrigations	8 ML/ha (approximately)
Harvest date	TOS 1: 16/04/2015 TOS 2: 23/04/2015

Results

The 2014–15 season was favourable for growing soybeans with no environmental extremes. Warmer than average temperatures were recorded, with a total of 2,172 growing degree days [(max. temp. + min. temp.)/2) - 5 °C] compared with the long-term average of 1,983.

In Figure 1, grain yield of the 26 advanced-stage breeding lines sown in mid-November (TOS 1) can be seen with the commercial checks of Djakal, Bidgee$^{\phi}$, Snowy$^{\phi}$ and Bowyer varieties.

The standout breeding lines included P176-2, P126-37, P213-41, P168-11 and P176-23. These lines will be evaluated further for potential release in the future.

The dashed lines in Figure 1 indicate a significant yield difference from the benchmark variety Djakal, with a least significant difference (l.s.d.) of 0.3 t/ha. N005A-80 is currently under commercial seed increase and evaluation for commercial release.

In comparison, the later than ideal sowing date (TOS 2: 22 December) grain yield results are in line with what we would expect from this TOS (Figure 2). Across all varieties, grain yield from the later sowing date were 0.8 t/ha lower than TOS 1 (26 November).

At the later sowing date, several of the standout breeding lines included P176-30, N005A-80, P176-2, P168-11, P167-14 and P176-23.

Further seed quality analyses showed that all lines met the minimum requirements of protein content on a dry matter basis. Djakal has the lowest acceptable level of protein to meet human consumption standards.

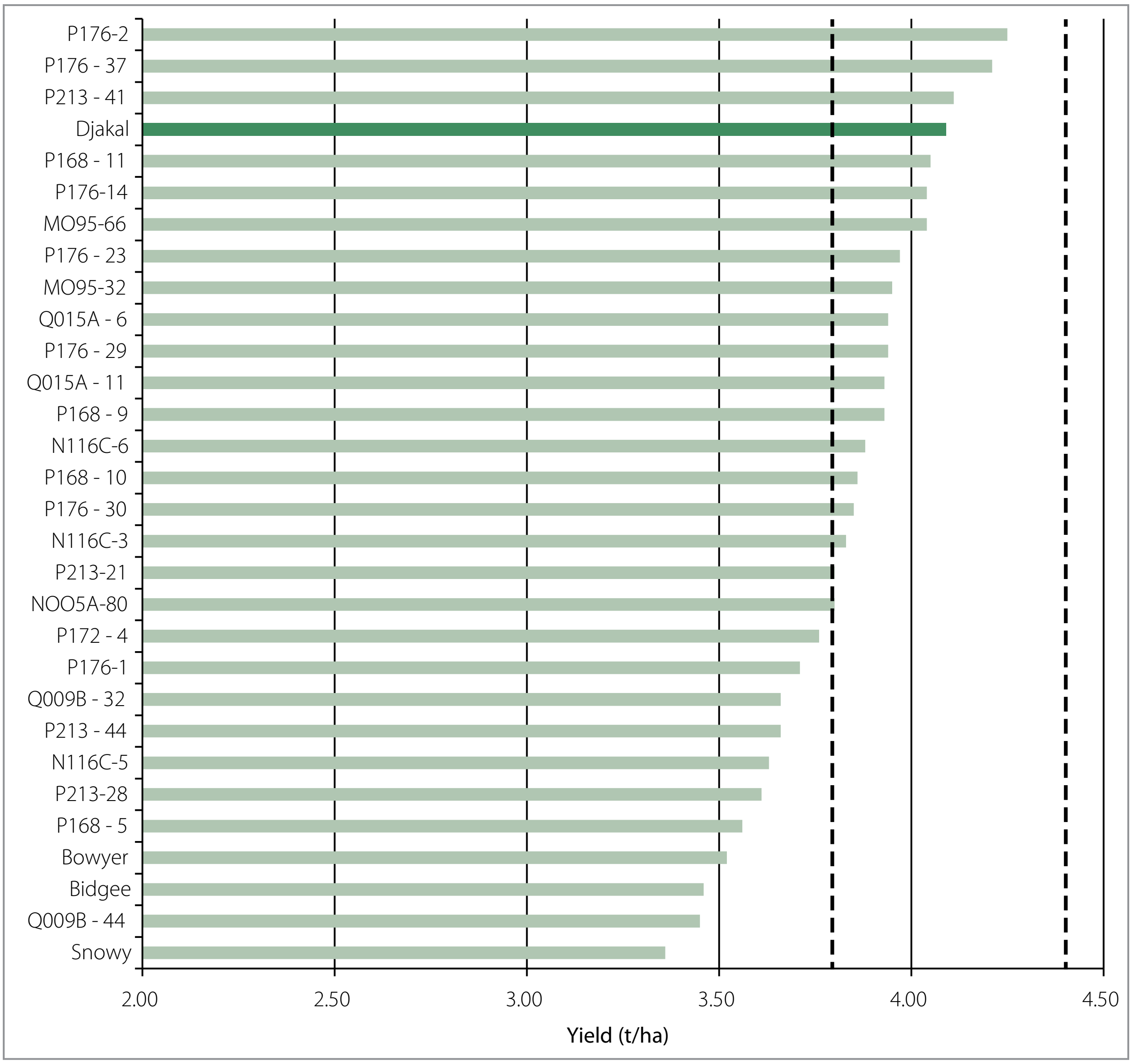

Figure 1: Grain yield of soybean varieties in the core variety trial at Yanco 2014–15, TOS 1 sown on 26 November 2014.

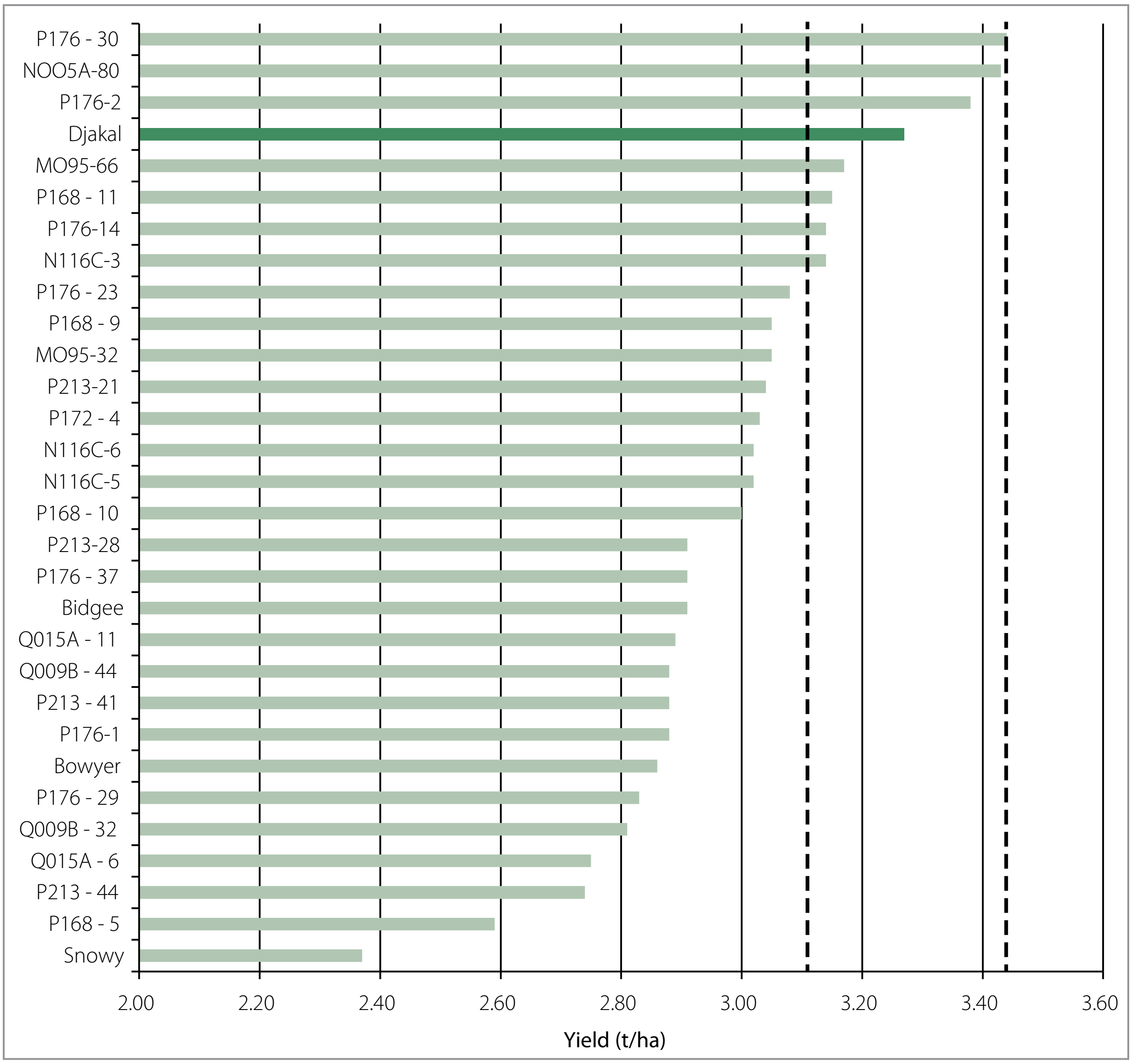

Figure 2: Grain yield of soybean varieties in the core variety trial at Yanco 2014–15, TOS 2 sown on 22 December 2014.

Summary

This year's results, combined with long-term experiments, clearly show that sowing in mid-November to early December maximises average grain yield in southern NSW. Further south into northern Victoria, sowing should begin earlier from 1 November until late November.

Grain yields from the late December sowing date were still acceptable, which indicates that current varieties can effectively fit into double-cropping systems where a later sowing window is often required.

A number of breeding lines are showing potential with many standout characteristics. These lines will be evaluated and tested into the future for potential release.

Acknowledgements

The experiment is part of the project 'Southern NSW soybean agronomy', DAN00192, 2014–18, which is jointly funded by GRDC and NSW DPI.

Thank you to John Dando, Paul Morris and the NSW DPI farm staff at the Leeton Field Station for their assistance in managing the site. Also thank you to Dr Neil Coombes from NSW DPI for undertaking the biometrical tasks associated with this project.

Plant population density soybeans – southern NSW 2014–15

Mark Richards and **Luke Gaynor** NSW DPI, Wagga Wagga; **Mathew Dunn** and **Alan Boulton** NSW DPI, Yanco

Key findings

- Bidgee⁽ᵈ⁾ and Djakal performed best at 45 plants/m^2.
- N005A-80 and Snowy⁽ᵈ⁾ performed best at 30 plants/m^2.
- Severe lodging occurred in all varieties at the 60 plants/m^2 sowing density.
- Snowy⁽ᵈ⁾ has poor resistance to lodging, which was exacerbated at higher sowing densities.

Introduction

This experiment was conducted at the NSW DPI Leeton Field Station to test the grain yield and lodging response of three commercial varieties and an unreleased line (N005A-80) to four targeted sowing densities.

Site details

Soil type	Self-mulching medium clay
Previous crop	Chemical fallow
Sowing date	12 December 2014
Establishment irrigation	Pre-watered
Irrigation layout	1.83 m raised beds with furrow irrigation
Row spacing	2 rows/bed (91.5 cm)
Inoculation	Water injected peat slurry Group H
Fertiliser	125 kg/ha legume starter
Herbicides pre-emergent	Glyphosate 450 g/L at 2 L/ha Pendimethalin 330 g/L at 2.5 L/ha
Insecticides	Abamectin @ 300 mL/ha on 30 December 2014, lamdacyhalothrin @ 80 mL/ha on 11 March 2015
In-crop rainfall	104 mm
Irrigations	8 ML/ha (approximately)
Harvest date	23 April

Treatments

Varieties (4)	Bidgee⁽ᵈ⁾ Djakal Snowy⁽ᵈ⁾ N005A-80
Targeted plant densities (4)	15, 30, 45, 60 plants/m^2

Results

Lodging

Lodging in soybeans can cause reduced yield and problems with harvest. In this experiment, higher plant densities resulted in increased lodging with all four varieties exhibiting severe lodging at the 60 plants/m^2 sowing density (Figure 1). The poor lodging resistance of Snowy was evident, with severe lodging occurring at the 30, 45 and 60 plants/m^2 sowing densities. Bidgee, with its lower height and biomass responded well with little lodging occurring up to 45 plants/m^2. Above 45 plants/m^2, Bidgee was also prone to lodging.

Grain yield

Grain yield was significantly affected by both plant density ($P < 0.01$) and variety ($P < 0.01$). The interaction between plant density and variety was not significant ($P = 0.46$).

Grain yields were reduced at both the 15 plants/m^2 and 60 plants/m^2 sowing densities for all four varieties (Figure 2). Bidgee and Djakal achieved their highest yield at the 45 plants/m^2 sowing density. N005A-80 and Snowy achieved their highest yield at the 30 plants/m^2 sowing density.

Averaged across all sowing densities, Djakal and N005A-80 yielded significantly higher than Bidgee and Snowy at 4.2 t/ha, 4.1 t/ha, 3.6 t/ha and 3.2 t/ha respectively.

Summary

Through the evaluation of four soybean varieties at four targeted sowing densities, this experiment found that:

- Bidgee and Djakal performed best at 45 plants/m^2

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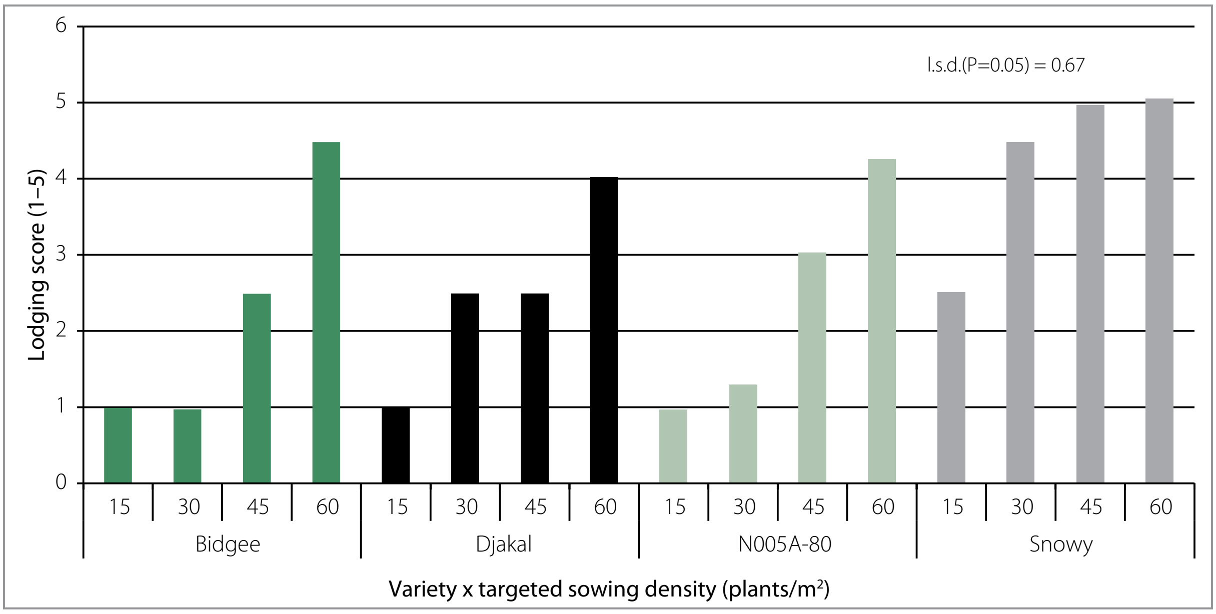

Figure 1. Soybean lodging score for variety and targeted sowing density interaction. (1 = minimal lodging, 5 = severe lodging).

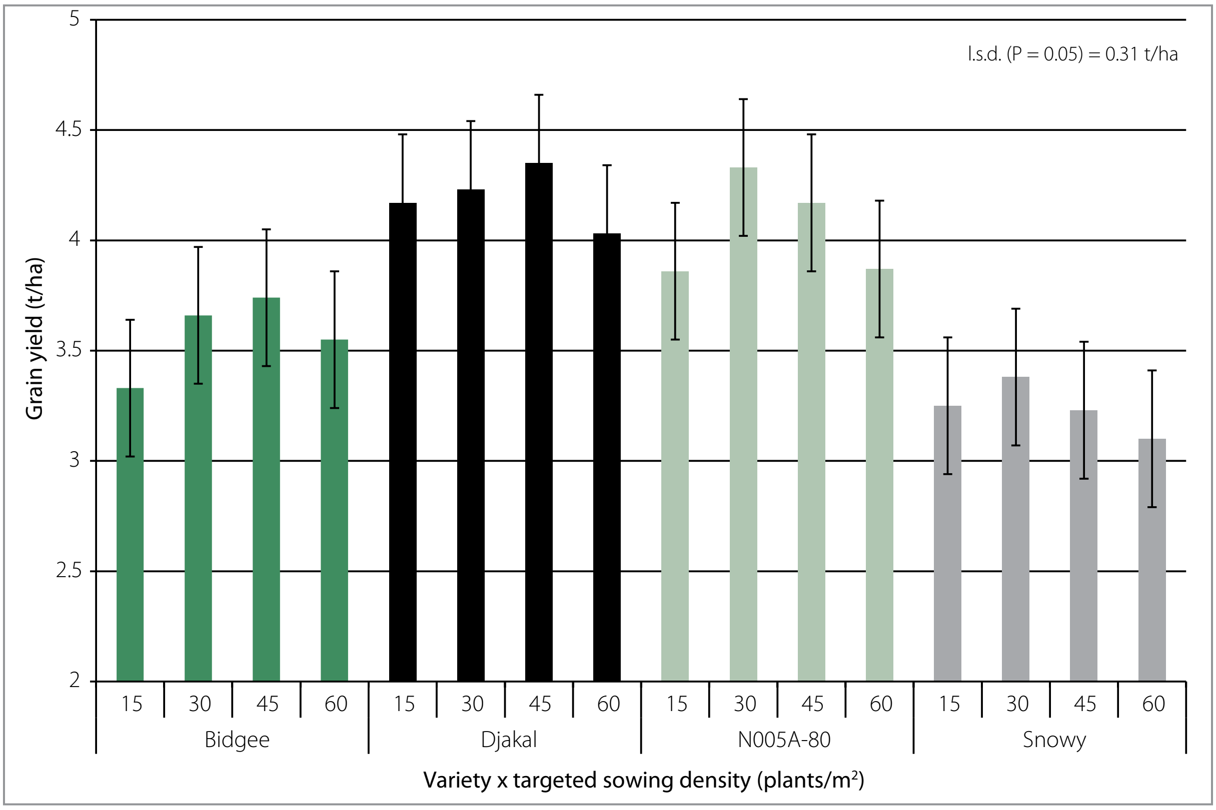

Figure 2. Soybean grain yield for variety and targeted sowing density interaction.

- N005A-80 and Snowy performed best at 30 plants/m^2
- all varieties suffered severe lodging at the 60 plants/m^2 sowing density
- Snowy has poor resistance to lodging, which is exacerbated at higher sowing densities.

Acknowledgements

The experiment is part of the project 'Southern NSW soybean agronomy', DAN00192, 2014–18, which is jointly funded by GRDC and NSW DPI.

Thank you to John Dando, Paul Morris and the NSW DPI farm staff at the Leeton Field Station for their assistance in managing the site. Also thankyou to Dr Neil Coombes from NSW DPI for undertaking the biometrical tasks associated with this project.

Overhead irrigation of soybeans – southern NSW 2014–15

Mark Richards and **Luke Gaynor** NSW DPI Wagga Wagga; **Mathew Dunn** and **Alan Boulton** NSW DPI, Yanco

Key findings

» High soybean grain yields can be achieved on a flat layout under overhead irrigation.

» Djakal and N005A-80 varieties yielded the highest across all densities and row spacings.

» The 40 plants/m^2 targeted plant density yielded the highest across all varieties and row spacings.

» At targeted plant densities of 40 plants/m^2, the highest yields were achieved with 30 cm row spacing.

Introduction

Soybeans in southern NSW are preferably grown on raised-bed layouts with furrow irrigation. An alternative for flat to undulating ground is to use overhead irrigation.

This experiment was conducted over the 2014–15 season with overhead irrigation on a relatively flat site in the Finley area of southern NSW. The purpose of the experiment was to test the response of one new breeding line and two commercial varieties of soybeans at three row spacings and two plant densities to examine the effect of these treatments on dry matter production, harvest index, grain yield and grain protein.

Warmer than average temperatures were recorded during the 2014–15 season with a total of 2,172 growing-degree days [(max. temp. + min. temp.)/2) -5 °C] compared with the long-term average of 1,983 day degree units.

Site details

Location	'Cooinda' Closes Rd, Finley, NSW
Experiment period	Summer growing season 2014–15
Soil type	Red-brown, fine, sandy-clay loam over light clay
Previous crop	Wheat (stubble baled)
Establishment irrigation	Rainfall and post-sowing irrigation
Irrigation method	Overhead irrigation
Sowing date	20 November 2014
Inoculation	Water injected peat slurry Group H
Fertiliser	125 kg/ha legume starter
Herbicides pre-emergent	Roundup 450 @ 1.5 L/ha + trifluralin @1.6 L/ha
Insecticides	Indoxacarb 150 g/L @ 400 mL/ha by air
In-crop rainfall	179 mm plus irrigation as required
Irrigations	7.83 ML/ha
Harvest date	15–16 April 2015

Treatments

Varieties	Djakal Bidgee$^{\text{(}\!\text{b}\text{)}}$ N005A-80 (unreleased breeding line)
Row spacing	2 rows/plot (90 cm) 3 rows/plot (60 cm) 6 rows/plot (30 cm)
Targeted plant density	25 plants/m^2 40 plants/m^2

Results

Variety

When averaged across all row spacings and targeted plant densities, the Djakal and N005A-80 grain yield was significantly higher than Bidgee. The highest yielding variety treatments were Djakal and N005A-80 at 40 plants/m^2 on 30 cm row spacings (Figure 1).

There was a significant interaction between variety and row spacing for peak dry matter production (Figure 2). Both Djakal and N005A-80 achieved their highest dry matter yield at the 60 cm row spacing; however, there was no statistical difference between 30 and 60 cm in dry matter production

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for these varieties. Bidgee dry matter declined linearly as row spacing widened, with dry matter yield at the 90 cm row spacing significantly lower than at the 30 and 60 cm row spacing (Figure 2).

Row spacing

When averaged across all varieties and targeted plant densities, the grain yield from the 30 cm row spacing was significantly higher than either the 60 and 90 cm row spacings, which yielded 4.1 t/ha, 3.6 t/ha and 3.3 t/ha respectively.

Total dry matter averaged across all varieties and targeted plant densities was significantly higher for the 30 and 60 cm row spacings than the 90 cm row spacing, producing 10.0 t/ha, 10.4 t/ha and 8.5 t/ha respectively. This higher dry matter in part explains how the narrower row spacing was higher yielding than the 90 cm row spacing. In general terms, grain yield is correlated with total dry matter production.

Targeted plant density

The actual plant densities achieved for the 25 plants/m^2 and 40 plants/m^2 density targets were an average of 21 plants/m^2 and 31 plants/m^2 respectively. Across all varieties and row spacings, the 40 plants/m^2 plant density was significantly higher yielding than 25 plants/m^2, yielding 3.9 t/ha and 3.4 t/ha respectively.

There was a significant interaction between targeted plant density and row spacing (Figure 3). At the higher plant density (40 plants/m^2), the narrower row spacing (30 cm) yielded higher than the wider row spacings (60 and 90 cm) for all three varieties. However, at the lower plant density (25 plants/m^2) there was no statistical effect of row spacing on grain yield for Bidgee or Djakal, with the only exception being N005A-80 at the 90 cm row spacing. From this data, it is apparent that plant density has a greater influence on grain yield than row spacing.

Summary

This experiment demonstrated that under overhead irrigation on a relatively flat layout, soybean grain yield above 4.5 t/ha is achievable. Variety selection, row spacing and plant density are all key agronomic factors for achieving high yields under this irrigation method and paddock layout. In summary, in this experiment:

- Djakal and N005A-80 varieties yielded higher than Bidgee
- under overhead irrigation, 30 cm row spacing was found to be the optimum, especially at higher plant densities
- the optimum plant density, especially at narrow row spacings was 31 plants/m^2
- maintaining a population at or above this level is critical to maximising yield potential.

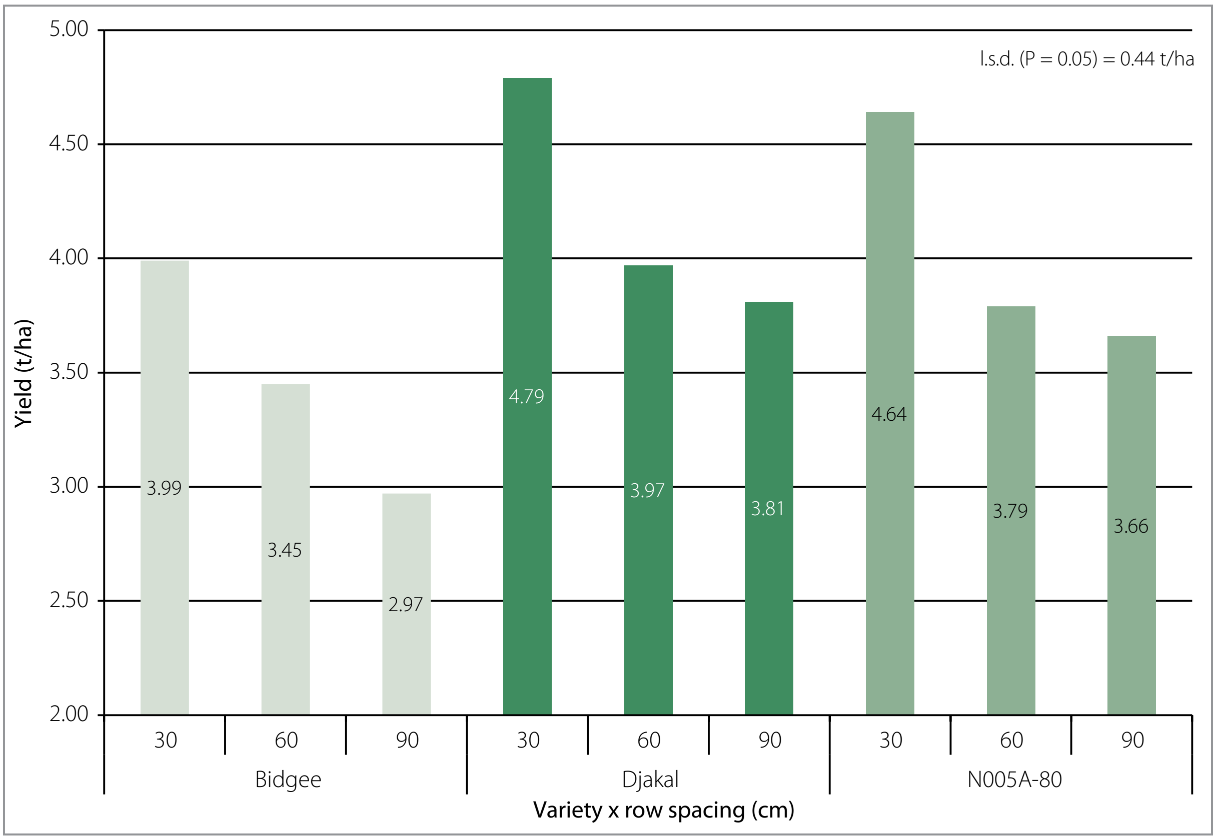

Figure 1. Soybean grain yield for variety and row spacing at the 40 plants/m^2 plant density.

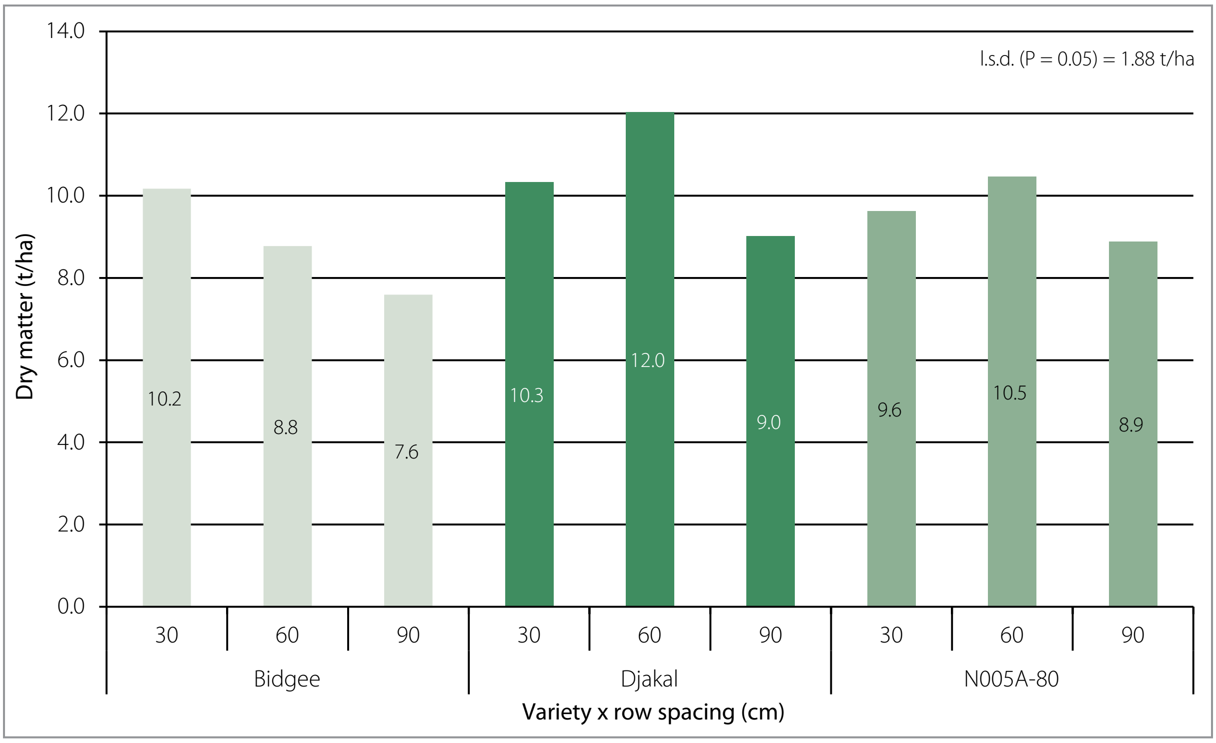

Figure 2. Soybean dry matter for variety and row spacing interaction at the 40 plants/m² plant density.

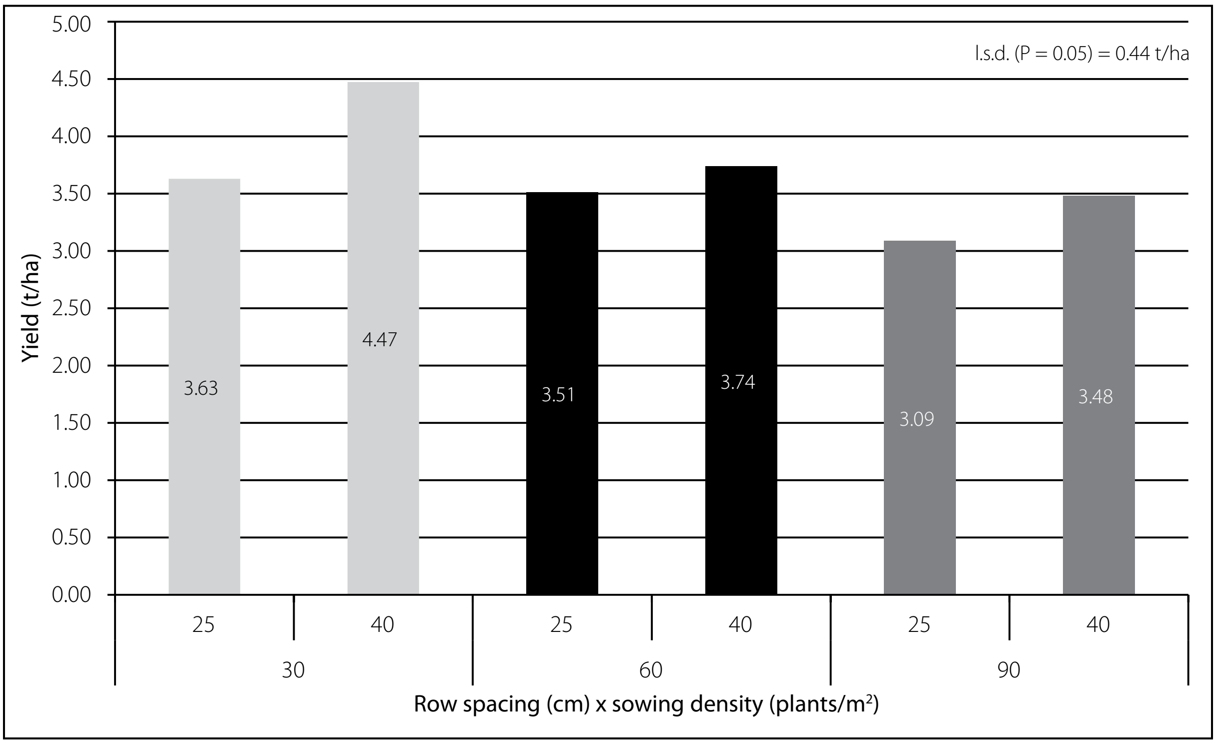

Figure 3. Soybean grain yield for row spacing and plant density averaged across varieties.

Acknowledgements

This experiment is part of the project 'Southern NSW soybean agronomy', DAN00192, 2014–18, which is jointly funded by GRDC and NSW DPI. Technical assistance was provided by John Dando and Paul Morris.

Using remote sensing to predict PI nitrogen uptake in rice

Brian Dunn and **Tina Dunn** NSW DPI, Yanco; **Dr Iain Hume** and **Beverly Orchard** NSW DPI, Wagga Wagga; **Dr Remy Dehaan** Charles Sturt University, Wagga Wagga; **Dr Andrew Robson** University of New England, Armidale

Key findings

» Remote sensing can confidently be used to map a rice crop's panicle initiation (PI) nitrogen (N) uptake.

» A remotely sensed image of nitrogen uptake at PI can identify variability in the uptake and enable variable rate nitrogen topdressing to maximise grain yield with reduced risk.

» Remotely sensed data has been collected using field spectroradiometer (SVC HR1024), multispectral cameras including the MicaSense RedEdge, Tetracam MCA and Headwall Hyperspectral Imager, and Worldview 3 satellite data.

Introduction

Applying nitrogen to a rice crop at panicle initiation to increase yield is efficient and reliable. The NIR (Near Infra-red Reflectance) tissue test has been the industry standard for measuring crop growth and nitrogen at panicle initiation since the mid 1980s. However, many growers and agronomists do not take advantage of this technology and instead rely on estimating the rice crop's nitrogen requirements. One of the main reasons growers do not use the test is difficulty in sampling the rice crop in the water.

Researchers have been investigating using remote sensing to predict PI nitrogen uptake with very encouraging results. Remote sensing derived PIN (panicle initiation nitrogen) uptake maps would reduce the need to physically sample the crop and would also provide a greater understanding of within-crop spatial variability. Four years of research have been conducted to determine if rice PIN uptake can be predicted using remote sensing from drones, aircraft and satellites as part of an ongoing Rural Industries Research & Development Corporation (RIRDC) research project.

Method

Each year a series of experiments were set up using several commercial rice varieties. Across the varieties, a range of nitrogen rates were applied to create plots with a large range in PIN uptake levels. These plots were measured at PI using several remote sensing instruments, physical samples were also collected. The relationship between the remotely sensed data and the physically measured rice crop PIN uptake were investigated. Over the four years of the project, 885 plots were imaged and PIN uptake physically measured.

In the first three years of the project, plots were measured with a field portable hyperspectral radiometer (SVC 1024) mounted on a four-wheel motor bike (Figure 1). This instrument uses the same wavelengths (400–2400 nm) as the laboratory NIR instrument, which is very accurate at determining rice tissue nitrogen content at PI. We were then able to determine how accurately PIN uptake could be measured using the best possible instrument and conditions, and also determine the optimal wavelengths to achieve the greatest correlation with PIN uptake. This information has provided confidence that remote sensing can determine rice PIN uptake (Figure 2).

Figure 1. Collecting rice canopy spectra using a hyperspectral scanner mounted on a four-wheel motor bike.

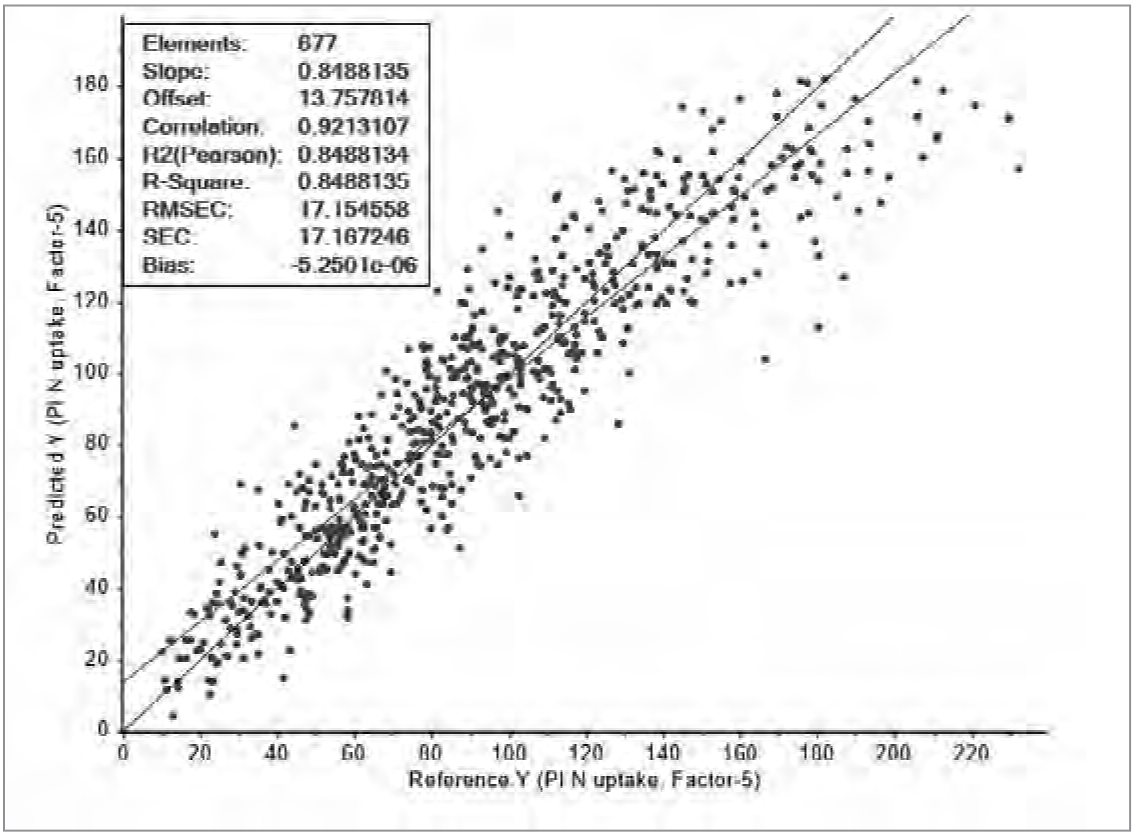

Figure 2. Measured vs predicted PIN uptake (kg N/ha) from 677 plots scanned over three seasons with a hyperspectral scanner mounted on a four-wheel motor bike.

Data from a minimum of 100 plots (including two seasons and several rice varieties) are required before a realistic evaluation of each instrument is possible. Multi-season correlations have been developed between the data and measured crop PIN uptake for several multispectral and hyperspectral systems (Table 1).

Results

All instruments can create a normalised difference vegetation index (NDVI) from the canopy reflectance measured and produced similar correlations between NDVI and PIN uptake. At low PIN uptake levels (below 100 kg N/ha) NDVI showed a reasonable relationship with PIN uptake. At higher levels (above 100 kg N/ha) the relationship between NDVI and plant nitrogen uptake plateaued, with the NDVI unable to detect, and therefore predict, changes in PIN uptake.

Alternatively, very high resolution satellite imagery might prove to be an accurate and affordable option. The first season of the Worldview 3 satellite data has shown considerable potential and when the second season's data (current season) is analysed, a better understanding of its potential can be determined. A satellite-based remote sensing system with automated processing and delivery systems that could generate near real-time management decisions to industry and growers could be an option.

Table 1.The range of instruments used to collect remotely sensed data from the rice variety and nitrogen experiments.

Remote sensing instrument	Collection method	Bands	Data collected
SVC 1024	Ground	Hyperspectral (330–2500 nm)	3 seasons
Greenseeker	Ground	NDVI	2 seasons
Aerial NDVI	Aerial	6 bands (490–900 nm)	3 seasons
micaSense	Aerial	4 bands with red edge	1 season
HyVista Hymap	Aerial	Hyperspectral (430–2450 nm)	1 season
Worldview 3	Satellite	8 bands (400–1040 nm)	2 seasons

The three years of hyperspectral and multispectral data have identified the wavelengths that best predict PIN uptake. This provides an opportunity to develop a relatively inexpensive camera with filters to measure those wavelengths that predict PIN uptake. This camera could be mounted in an aircraft to measure rice fields across the industry. This option has the added benefit of making data collection timing more flexible, thus reducing the risk of clouds interrupting the process.

Summary

Data analysis from the current season will enable identification of sensing technology that predicts PIN uptake most accurately and affordably. The project team will then start to develop a semi-commercial system for determining rice PIN uptake. It is expected that this will be trialled in the 2016–17 rice season. It might be a few years before growers can obtain a PIN uptake map of their rice fields using this method, but it appears to be a reality in the near future.

Acknowledgements

This research was jointly funded by NSW DPI and RIRDC. Technical support from Chris Dawe and Craig Hodges has contributed significantly to this project and is gratefully acknowledged.

Systems to control the air–water interface to reduce evaporation from water storages

Dr Harnam Gill NSW DPI, Yanco

Key findings

» Applying a monolayer of ethylene glycol monooctadecyl ether polymer reduced evaporation by 50%–60% under small scale, controlled environmental conditions.

» Under field situations its efficacy is significantly reduced and produces inconsistent results with evaporation savings of less than 10%.

» Windy conditions and/or a decrease in the polymer's longevity on the water surface under field situations probably cause this reduced effectiveness.

Introduction

On- and off-farm storages are an integral part of Australian agriculture and the environment. Evaporation and seepage are known to significantly reduce the efficiency of water storage systems. Until now, seepage had been considered important; however, evaporative loss has not been given due scientific attention as it has been considered inevitable in the natural hydrologic cycle.

The impacts of frequent drought and related increased prices of dwindling water supplies for domestic and agricultural uses have led to investigations into methods of saving water lost through stored water evaporation. This is a national problem currently causing potential reducible losses of more than 23,000 GL/year, or 120% of all water used in Australia (18,767 GL/year). This is comprised of 22,123 GL/year from larger storages (>1000 ML storage capacity) and 1,320 GL/year from farm dams.

Relatively expensive mechanical structures such as floating covers and suspended shade cloths are deemed unsuitable for commercial or large sized storages (>10 ha) due to the high initial capital investment and maintenance costs. Using mono- and micro-layers of certain chemicals, in spite of their variable performance, for larger storages is promising. These products, which self-spread across the water surface to provide a thin layer (often called a monolayer due to its thickness of one molecule) that lowers water vapour transfer into the air, are potentially cost effective and practical. Monolayers applied to water bodies with a surface area greater than 1 km^2 have reportedly reduced evaporation by 8%–37%.

More than 95% of water storages are currently uncovered and untreated. There is an urgent need to develop new chemical-film technology, including new environmentally benign and biodegradable products with monitoring capabilities. Research reported here highlights results from a series of experiments that evaluated polymer-based evaporation control systems under various environmental scales.

Site details

Evaluating common evaporation mitigation (EM) products started several years ago at the Yanco Agricultural Research Institute. Early experiments used a polymethyl silicone solution, a mixture of cetyl (hexadeconol) and stearyl (octadecanol) alcohols, and two polymer-based products (E10 and E100) under the following controlled environments (figures 1 and 2):

(i) temperature-controlled glass chambers
(ii) exterior fly-screen house
(iii) lined shallow concrete tanks
(iv) two 20 m long lined channel storages with 110 m^2 water surface area when filled to maximum capacity.

Figure 1. Set-up for evaporation experiments conducted in temperature-controlled glass house (left); exterior fly-screen house (centre); and lined, shallow, concrete tanks (right).

In all experiments, available untreated irrigation water was used. A series of experiments were conducted for evaluating EM products for their application rates and frequency of application on reducing evaporation. A field experiment was also undertaken to evaluate polymethyl silicone solution, and a mixture of the two alcohols.

A commercial irrigation channel was used to prepare five lined channel storages in 2010 for the field scale evaluations of polymer based evaporation mitigation products. Each of the five storage channels had a water surface area 42 m long and 5 m wide when full. Researchers from the University of Melbourne and Cooperative Research Centre for Polymers collaborated in the experiment. This site is maintained for conducting experiments during the summer season, including pre-season testing and post-season care. Since then trials of 3–5 weeks duration have been conducted annually to evaluate different polymer formulations, their application rates, forms (solutions, suspensions and solid powders) and application frequencies. Available water from the irrigation canal used in these experiments was analysed for pH, electrical conductivity (EC), dissolved oxygen, turbidity and ionic chemistry before and after each experiment. Evaporation was measured using pressure sensors linked to an automated data logger and a weather station. Odyssey capacitance meters were also used to measure water levels in the lined channel storages for measuring evaporative water losses.

Results

Glass house

Experimental results showed significant reduction and variation in evaporation due to different temperatures, application rates and re-application frequencies of the alcohol mixture, polymethyl silicone, and the two experimental polymers. Comparison of water savings indicate superiority of polymers X and Y (Table 1).

Table 1. Impact of applying evaporation mitigation products on reducing evaporative losses of water.

Product and application rate	Application frequency	Evaporation reduction (%) at 20 °C	Evaporation reduction (%) at 30 °C	Evaporation reduction (%) at 40 °C
Polymer X @12 monolayer concentration	2-day intervals	40–61	39–47	36–43
Polymer Y @12 monolayer concentration	2-day intervals	42–58	38–48	35–45
Polymethyl silicone solution at 12–18 L/ha	10-day intervals	28–34	24–29	18–26
Cetyl and stearyl alcohols mixture applied at 1500–3000 g/ha	Alternate days	18–26	14–21	12–18

Exterior fly-screen house

Using polymers showed significantly improved efficacy by almost halving evaporative losses. Polymer application of 12 monolayer concentration at two- or four-day intervals reduced evaporation by 40%–60%. Results also showed that application at a 36 monolayer concentration at two-day intervals was significantly superior to the 12 monolayer concentration. Application frequencies of two- or four-day intervals were mostly on par, but significantly better than application at seven-day intervals.

Shallow concrete tanks in the open

Results indicated water savings of 3.1% by applying the alcohol mixture (1000 g/ha on alternate days) whereas polymethyl silicon (6.0 L/ha at 10-day intervals) saved just 7.1%. Application of polymer E10 and E100 at a 12 monolayer concentration at four-day intervals reduced evaporation by 12.1% and 10.3% respectively. Water savings were found to increase to 12.5%, 20.5%, 30.3% and 27.2% with a three-fold increase in application rates of the alcohol mixture, polymethyl silicone, polymers E10 and E100. Relatively lower savings in the open environment highlight the probable role of solar radiation and/or wind in reducing the effectiveness of EM products.

Field evaluation

Results from experiments conducted in the lined storages under field situations indicated the significant role climatic variability plays, especially wind. Results have been variable so far, notwithstanding their satisfactory efficacy under controlled environmental conditions. Visual observations indicate that a wind velocity of more than 6–8 km/hour pushes the applied monolayer to the end of storage channels.

Figure 2. Field setup of lined storages on a commercial irrigation channel.

Polymer scientists at Melbourne University are working to improve polymer compound effectiveness by changing from a monolayer to a duo-layer approach to enhance bonding at the water surface for increased resistance to movement of monolayer by wind. It has also been noted that wind tends to pick up its flow velocity at noon, probably due to the convective flow of energy. Considering this, appropriately timing polymer compound applications are also being reviewed and evaluated.

Summary

Research into use of EM products (especially polymers) is of significant interest to the Australian agricultural industry. A monolayer polymer called ethylene glycol monooctadecyl ether (C18E1) has been developed. It reduces evaporation consistently by 50%–60% under controlled conditions. However, research is still in progress to improve its desired effectiveness under field situations.

Acknowledgments

Thanks to the Cooperative Research Centre for Polymers CEO Dr Ian Dagly for financial assistance and motivation in this research project, 'System for controlling the air-water interface and reducing evaporation from water storages' CRC-P Project 2.2.

Informing investment in irrigated grains R&D in southern NSW

Sam North and **Don Griffin** NSW DPI, Deniliquin; **Peta Neale** Precision Agriculture, Toowoomba; **Dr John Hornbuckle** Deakin University, Griffith; **Rob Fisher** Irrigated Cropping Council, Kerang

Key findings

» Analysis of wheat crops sown after rice harvest in the Murray Irrigation Ltd districts (MIL) found that increasing yields required different management depending on soil type and irrigation layout.

» Four management factors that limit winter crop yields were identified: waterlogging, late season water stress, under-fertilisation and low soil pH.

» In the MIL districts alone, increasing wheat yields after rice from the current median to the 80th percentile would result in an additional 20,000–30,000 tonnes per annum ($4–6 million at $200/t).

» If all rice areas were sown to wheat after harvest every year and 80th percentile yields achieved, an additional 128,000–138,000 tonnes of wheat would be produced ($26–$28 million at $200/t).

Introduction

Toohey and Chaffey (2006) examined the potential of irrigated grain production in the southern Murray–Darling Basin. The study had three key findings:

1. There is a need to lift irrigated grain productivity and profitability and to achieve higher efficiencies from using irrigation water because of cut-backs in water entitlements.
2. Irrigated wheat water use efficiency is low. In 2006, average wheat yields of 3.0 t/ha achieved 10 kg/mm/ha. There is the potential for improvement to 22 kg/mm/ha with yields of 10.4 t/ha – a figure being achieved in variety trials and by some growers.
3. Farm gate value for all crops studied was $176 million in 2006. If yields rose to best trial levels, farm gate value would nearly double to $347.7 million (at 2006 values).

Despite efforts since 2006 (e.g. the identification and development of cereal varieties for irrigation in the 'High yielding genotypes of winter cereals for irrigated regions of south east Australia project'), this situation is largely unchanged.

A new project being conducted by the Irrigated Cropping Council, NSW DPI, Deakin University, Murray Local Land Service and Precision Agriculture, with financial support from GRDC, started in July 2014. The long-term objective is to 'increase grain production and profitability from surface irrigated soils in the GRDC Southern Region by improving the understanding of the interaction between crops, soils, and irrigation and their effects on crop production'.

The first question that will be answered is 'What increase in grain production can we realistically expect from irrigated grains in the GRDC Southern Region if major constraints can be overcome?'

Grower survey of yield expectations

An online survey (2014) of irrigation areas in northern Victoria and southern NSW asked irrigated growers what their average and expected yields, and best ever yields were. The rationale behind this was if a best yield can be achieved once, then it should be possible to achieve it again. Our goal is to establish why it isn't achieved regularly and see if we can overcome the barriers. One hundred responses to the survey were received from irrigators with a wide range of farming systems. The results (Table 1) support the contention that there is significant potential to increase yields in all crops across the region: 2.0 t/ha for cereals and 0.8 t/ha for oilseeds.

Table 1. Expected and best ever yields of a range of crops grown in the irrigation areas of the southern Murray–Darling Basin based on a grower survey.

	Rice (t/ha)	Cotton (bales/ha)	Soy (t/ha)	Wheat (t/ha)	Barley (t/ha)	Canola (t/ha)	Faba bean (t/ha)	Chickpea (t/ha)
Expected yield (t/ha)	10.1	10.1	3.1	4.7	4.0	2.3	3.9	2.5
Best ever yield (t/ha)	12.1	12.8	3.9	6.6	5.9	3.1	4.6	3.4
Yield gap (t/ha)	2.0	2.6	0.9	1.9	1.8	0.7	0.8	0.9
Total no. responses	46	9	16	78	47	53	14	3

Table 2. Potential yield (median and 80th percentile) and yield gap for estimated areas of the Murray Irrigation Ltd area planted to wheat in rice layouts in 2013 and 2014.

Year	Surface drainage	Bay	Bay	Bay	Contour	Contour	Contour
	Internal soil drainage	*Fair*	*Poor*	*Very poor*	*Fair*	*Poor*	*Very poor*
2013	Median yield	3.5	3.5	3.2	2.9	2.3	2.8
	80th percentile yield	5.8	5.5	4.2	4.1	3.1	3.8
	Yield gap	2.2	1.9	1.1	1.1	0.8	1.1
2014	Median yield	3.6	3.6	2.4	2.3	2.1	2.2
	80th percentile yield	7.0	7.0	3.2	2.9	2.5	2.8
	Yield gap	3.4	3.4	0.9	0.6	0.4	0.6

Using GIS and satellite imagery to inform and prioritise R&D investment

Big data from GIS and satellite imagery were used to determine if yield increases are realistically achievable, to examine factors behind lower than expected yields, and to identify priority areas for R&D investment. Only the MIL districts were examined because digitised soil maps of the MIA are not currently available (work to include the MIA in this analysis is currently underway).

There are 145,500 ha of basin (contour) irrigation systems in the MIL districts. The area was categorised based on surface drainage and internal soil drainage. Using Landsat normalised difference vegetation index (NDVI) imagery taken in late August–early September we estimated the mid-season biomass of wheat sown after rice in these layouts in 2013 and 2014 and compared the NDVI readings with header grain yield from paddocks that had not been water-stressed in spring. This enabled an estimate of potential (non-water limited) yield of wheat sown after rice across the MIL districts categorised according to surface drainage and soil type.

Median and 80th percentile yields were obtained from the frequency distributions of the estimated yields in each drainage category. Table 2 shows the 80th percentile yields that were assumed to be achievable through better crop management. These can be summarised as follows:

1. On soils with better internal drainage (i.e. red–brown earths, transitional red–brown earths and self-mulching clays):
    - landforming to improve surface drainage will lift wheat yields by around 1.2 t/ha
    - better crop management can increase wheat yields by 2–3 t/ha in landformed bays
    - improving crop management in combination with landforming produces the greatest yield increases (3–5 t/ha).
2. On soils with very poor internal drainage (i.e. non self-mulching clays):
    - landforming to improve surface drainage will lift wheat yields by only 0.4 t/ha
    - better crop management only results in significantly better yields if paddocks are not subjected to waterlogging (e.g. 0.5 t/ha in 2014 when the autumn was wet compared with 1.0 t/ha in 2013 when the autumn was dry).

If yields from wheat sown immediately after rice can be lifted from the current median to the 80th percentile (Table 2), then there is the potential to increase wheat production in the MIL districts by 20,000–30,000 tonnes per annum ($4–6 million p.a. at $200/t).

If all the area under rice in the MIL districts was sown to wheat immediately after rice, and 80th percentile yields were achieved, then an additional 128,000–138,000 tonnes of wheat would be produced ($26–28 million p.a. at $200/t).

Caution is needed as these figures are based on potential yields estimated from NDVI and do not take into account the rice area sown to wheat after a fallow. It also omits border check and sprinkler systems and doesn't include the irrigated cropping areas of northern Victoria and the Murrumbidgee Valley. Despite this, it is the first time that wheat crop production has been estimated across an irrigation district using objective data. This has allowed RD&E areas to be identified and prioritised, potential returns from that investment to be estimated, and provided a method by which we might monitor our progress.

Acknowledgements

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Reference

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Maximising on-farm irrigation profitability project

John Smith NSW DPI, Yanco; **Peter Regan** NSW DPI, Orange

Key findings

- Significant water allocation cuts have forced irrigators to optimise production with the amount of water available.
- The project has an agronomy component and a hydrology component.
- Experiments are located in Whitton, Kerang and Finley.

Introduction

'Maximising on-farm irrigation profitability' is a new project that had its first season of field experiments in the ground during the 2015–16 summer. The project is a component of a joint Rural Industries Research and Development Corporation (RIRDC) project titled 'Smarter irrigation for profit'.

Reductions in water availability in the southern Murray–Darling Basin of around 30% have caused irrigators to place much greater emphasis on optimising production with less water. The project's overall objective is to develop sustainable broadacre irrigation systems that increase the profitability and flexibility of farming systems in the region.

The project has two components: an agronomy component that will assess the impact of varying surface irrigation management strategies (scheduling and frequency) on nitrogen use efficiency, water use efficiency and overall system profitability; and a hydrology component that will develop irrigation design criteria that will allow precise application of water in basin irrigation layouts, such as bankless channel systems, allowing flexible management to match recommendations from the project's agronomy component.

The project uses the research experience from both NSW DPI and Deakin University and has been established in conjunction with three grower groups across the region. Each grower group hosts field experiment sites for the project. These are key sites for sharing project findings between sites as well as with advisory organisations such as Local Land Services, CottonInfo and Rice Extension.

Site details

Irrigation Research and Extension Committee (IREC) – Whitton

Given the recent rapid growth of cotton production in southern NSW, IREC members considered it important to gain further understanding on the relationship between nitrogen (N) and irrigation management for this relatively new crop. This site focuses on the interaction between nitrogen use efficiency and irrigation management in cotton (Figure 1).

In the 2015–16 summer season there were five N rates (0, 80, 100, 150 and 250 kg N/ha). All treatments were applied pre-planting and received two irrigation frequency treatments.

Figure 1. Planting the upfront N treatments for the cotton field experiment at the IREC field station, Whitton, which is investigating the interaction between N and irrigation management.

irrigation & climate

Southern Growers (SG) – Finley

A particular interest for SG is improving profitability in the rice farming system. This research is investigating if it is possible to continuously double crop (producing two grain crops within a 12-month period) using a short-season rice variety and a short-season barley variety. Beds were incorporated into the bay layouts to determine what role they could have in reducing the turnaround time between crops and if they have any effect on the soil chemistry which often provides unfavourable conditions for winter crops that immediately follow rice.

The site's focus is to improve the performance of the winter crop component of the rice farming system as a means of improving the overall system profitability. To do this, an emphasis is being placed on further understanding the soil chemistry that could limit winter crop production immediately after the rice crop.

The rice was established using a standard drill sowing technique and the winter crop will not be irrigated, forcing it to use the residual moisture from the rice crop (Figure 2).

Irrigated Cropping Council (ICC) – Kerang

Growers within the ICC growing region were interested in investigating the interaction between N management and irrigation management as technologies such as automated delivery increase the flexibility of their systems.

The site was established at Numurkah with fully automated border check surface irrigation with maize as the crop sown. The budgeted N requirement (218 kg N/ha) for the target yield of the crop was varied through differing N strategies: 75% upfront and 25% in-crop; and 40% upfront and 60% in-crop. There were also two irrigation frequency treatments using approximately five- and seven-day intervals.

An additional area was also sown as an initial investigation into the role that enhanced efficiency fertilisers might have in the system. This work is expected to increase throughout the project (Figure 3).

Figure 2. Establishing the short-season rice variety YRM70 on beds at Rice Research Australia Pty Ltd.

Hydrology component

There are no criteria currently available to design basin irrigation systems, including bankless channels. The hydrology component of the project will focus on developing design criteria to ensure that new layouts are able to achieve suitable watering times (target of water on and off in 10 hours) given the intended design characteristics and infrastructure. This is intended to deliver irrigation layouts that are more water productive, flexible and profitable.

Acknowledgements

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NSW DPI and Deakin University's Centre for Rural and Regional Futures (CeRRF) are also significant funding contributors to the project.

Stott Farming, Rice Research Australia Pty Ltd and the Irrigated Cropping Council managed each field site. The Irrigated Cropping Council's technical assistance is also gratefully acknowledged.

Figure 3. Inspection of the Irrigated Cropping Council maize N and irrigation management field experiment by the research team and members of the project Steering Committee in February 2016 (Carlos Ballester Lurbe).

Application of life cycle assessment of grain cropping

Dr Sally Muir, **Dr Pip Brock** and **Dr Aaron Simmons** NSW DPI, Orange;
Prof. David Herridge PIIC University of New England, Armidale

Key findings

» Nitrogen fertilisers significantly contribute to on-farm emissions.

» Emissions vary depending on fertiliser type, yields, previous crop and region.

Introduction

This work estimates greenhouse gas (GHG) emissions from grain production systems for different regions of NSW. Data used for analysis was based on DPI gross margins and validated at grower forums in Wagga Wagga and Harden in the southern region.

Treatments

The analysis considered greenhouse gas emissions from:

» agricultural production

» on-farm lime, MAP and urea use

» crop residues and farm operations

» chemical and diesel manufacture and transport.

Life cycle assessment (LCA) methodology was used to determine the cradle-to-farm gate GHG emissions for rain-fed wheat grown in monoculture (wheat–wheat) or in sequence with the break crops canola and field pea; and for canola and field pea produced in the south-eastern grains region of Australia.

Results

Results showed that greenhouse gas emissions from producing and using nitrogen fertilisers are the primary contribution to the wheat carbon footprint in south-eastern NSW (Figure 1). Lime also makes a considerable contribution.

On-farm emissions associated with nitrogen fertiliser use include direct losses of:

» nitrous oxide (N_2O) through nitrification and denitrification processes

» carbon dioxide (CO_2) from hydrolysis of urea when used

» CO_2 from the dissolution of lime where used.

Other research supports the key finding that nitrogen fertilisers make considerable contributions to the overall carbon footprint of crops (Barton et al. 2014; Wang and Dalal 2015).

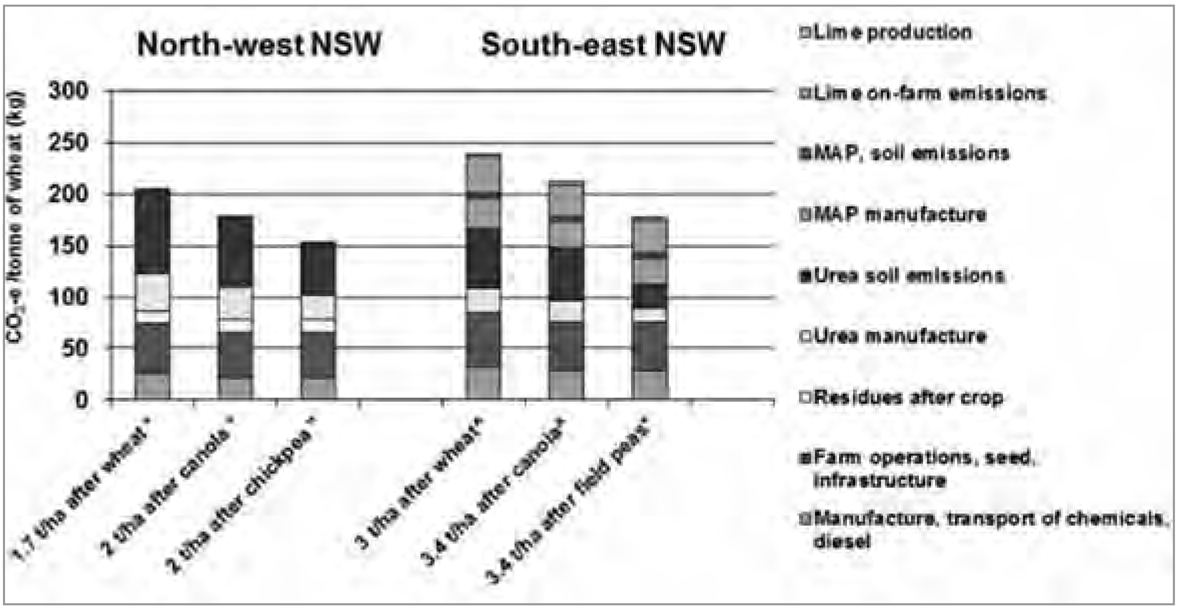

Figure 1. GHG emissions profile of short fallow wheat–wheat, canola–wheat and chickpea–wheat rotations in north-eastern NSW and wheat–wheat, canola–wheat and field pea–wheat in south-eastern NSW. Labels followed by * = 40 kg N/ha as urea, "= 30 kg N/ha as urea, ^ = 60 kg N/ha as urea and MAP, '= 40 kg N/ha as urea and MAP.

Figure 1 shows how the wheat emissions profile can differ due to fertiliser type, yield, previous crop and region, noting that these four variables are dependent.

Summary

- Nitrogen fertilisers make considerable contributions to a crop's overall carbon footprint.
- Lime also makes a considerable contribution.
- The wheat emissions profile can differ according to fertiliser type, yield, previous crop and region.

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