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Agronomic drivers of yield in rain-fed wheat production systems – Liverpool Plains

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Key findings

- Sowing wheat varieties in the early part of their optimum sowing window was found to be a key determinant of yield. Delays in sowing date (SD) averaged across sites resulted in yield losses of 13% for EGA Gregory⁽ᵈ⁾ and ranged from 8% to 28%.
- Commercially available mid–late maturing spring wheat varieties (e.g. EGA Gregory⁽ᵈ⁾) were observed to be broadly adapted and plastic in their yield responses, performing consistently across sowing windows.
- Altering variety and/or maturity type, and increasing target plant populations in response to delays in SD could not fully compensate for the yield losses associated with delayed sowings.
- Yield responses to nitrogen (N) and phosphorus (P) fertiliser application rates, were variable and influenced by the starting soil nutrition and seasonal conditions.
- Crown rot (CR) was shown to be a significant factor influencing yield potential in inoculated *vs.* uninoculated experiments – the delayed SD decreased yields by 12%. Results highlight the compounding negative impact of delayed sowing and CR infection on yield potential and underline the need for awareness of risk levels from soil-borne pathogens before sowing in order to guide management decisions.

Introduction

It is currently estimated that growers in the Northern Grains Region (NGR) are achieving around 49% of water-limited yield potential (www.yieldgapaustralia.com.au). Water-limited yield potential is defined as the potential yield achieved under non-limiting nutrition and biotic stresses (e.g. plant pathogens) using best management practices, but subject to environmental constraints, namely plant available water and temperature. To put this into perspective, leading growers in Australia using best management practices and available technology are estimated to be achieving around 80% of water-limited yield potential, indicating that yield is being limited by factors other than available water. Based on these observations, there is an exploitable yield gap between actual and attainable yields i.e. 80% of water-limited yield potential. This is considered to be the approximation of where growers' yields plateau within most major cropping systems due to economic constraints and climatic variability.

Identifying the key drivers of yield in water-limited, rain-fed environments is clearly an important strategy for reducing the exploitable yield gap and for increasing dryland wheat production. The aim of this research was to benchmark yield potential across a range of growing environments in the NGR over two consecutive seasons, and to quantify the effect genotype (G), management (M) and environment (E) had on yield. Possible yield-limiting factors investigated included variety selection (maturity type), sowing date (SD), plant population and fertiliser inputs (nitrogen and phosphorus). In addition to these factors, crown rot, which is a major disease of wheat and barley crops in the NGR, caused by the fungus *Fusarium pseudograminearum* (*Fp*), was also incorporated into this study.

This report outlines findings from a series of dryland wheat experiments conducted on the Liverpool Plains of northern NSW in 2014 and 2015.

Site details

All sites were soil cored to ~1.2 m prior to sowing to determine plant available water capacities (PAWC) along with starting soil nutrition and other soil properties.

Locations	Site descriptions including site location, year of experiments and in-crop rainfall (May – October) are outlined in Table 1.
Soil type and nutrition	Soil type, starting soil nitrate nitrogen and Colwell P for each experiment are outlined in Table 2.

Trial design	A series of 36 treatment combinations (two sowing dates × 18 treatments) were examined in a partially factorial split-plot design, with three replicates at all sites (Table 3).

Table 1. Sowing date, growing season rainfall and plant available water holding capacity (PAWC).

Site and year	SD1	SD2	Growing season rain*(mm)	PAWC (mm)
Nowley 2014	14 May	1 July	174	~120
Mullaley 2015	20 May	8 July	185	~140
Tamarang 2014	9 May	30 June	170	~210
Tamarang 2015	19 May	9 July	252	~150

* May to October

Table 2. Soil type, starting soil nitrogen (nitrate N) and Colwell P.

Site and year	Soil type	P (Cowell) (mg/kg) 0–10 cm	Soil NO_3 (kg N/ha) 0–120 cm
Nowley 2014	Black vertosol	25	123
Mullaley 2015	Grey vertosol	46	178
Tamarang 2014	Brown vertosol	77	167
Tamarang 2015	Brown vertosol	60	213

Table 3. Summary of treatments: sowing date, variety, plant population, nitrogen and phosphorus rates and crown rot inoculum levels.

Treatment	Details	
Two sowing dates (SD)	SD1: early/main season	SD2: delayed
Four varieties	EGA Gregory (SD1 & 2) LRPB Spitfire (SD2)	Sunvale (SD1) LRPB Crusader (SD1 & 2)
Three targeted plant populations	60, 120 or 180 plants/m^2	
Five nitrogen rates	0, 50, 100, 150 or a 50 + 50 kg N/ha split application all applied as urea (46% N). Treatments were side banded at sowing, apart from the split application, which was applied at sowing and broadcast at stem elongation (GS31).	
Four phosphorus rates	0, 10, 20 or 30 kg/ha P applied as triple super at sowing	
Four crown rot inoculum rates	0, 0.5, 1.0 or 2.0 g/m row sterilised durum grain colonised by at least five different isolates of *Fp* ± added at sowing i.e. 0, CR+, CR++ or CR+++	

Treatments

Treatments were designed similar to an exclusion experiment, with a high input treatment (i.e. 100 kg N/ha, 120 plants/m^2, 20 kg P/ha) aimed at providing the perceived optimum combination of factors, and a low input treatment comprising a base set of agronomic factors to benchmark agronomic or management variables.

Four commercial spring wheat (*Triticum aestivum*) varieties widely grown and well adapted to targeted growing environments were selected and sown at each location. Varieties were from two different maturity groupings: two main season–moderate maturing varieties, EGA Gregory⊕ and Sunvale⊕; and two fast–moderate maturing varieties LRPB Crusader⊕ and LRPB Spitfire⊕. At each location, varieties were sown at two SDs: an early–main season and a delayed SD (Table 1). Plant populations were grouped as low, moderate (district practice) or high and were targeted at 60, 120 and 180 plants/m^2 respectively.

Results

The Liverpool Plains included the site locations of Tamarang, Mullaley and Spring Ridge, with all experiments conducted on vertosol soils (Table 2).

Sowing date

Yield results varied between site and year, and ranged from 5.91 t/ha at Tamarang in 2014 for SD1, to 2.62 t/ha at Spring Ridge for SD2 in 2014, averaged across treatments (Table 4).

Table 4. Mean site yield (t/ha) and corresponding yield range (t/ha) for two sowing dates averaged across varieties.

Site and year	SD1 mean	Range	SD2 mean	Range
Spring Ridge 2014	3.80	3.97–3.77	2.62	2.83–2.44
Mullaley 2015	4.34	4.38–4.21	3.56	4.00–3.06
Tamarang 2014	5.91	5.94–5.50	4.40	4.52–4.01
Tamarang 2015	4.23*	4.25–4.06	4.67*	4.93–4.29

* All SD contrasts significant ($P<0.05$) except Tamarang 2015.

When looking at the across-site analysis, timely sowing was found to be a significant driver of yield. Delays in SD reduced yields by 0.60 t/ha or 13.1% when comparing high input (100 kg N/ha, 120 plants/m^2, 20 kg P/ha) EGA Gregory(D treatments (Table 5); yield declines ranged from 8% to 28%.

On an individual site basis, when comparing SDs for EGA Gregory(D, delays resulted in yield declines of 6.0 kg/day up to 28.8 kg/day. The only site not to show a yield response due to an earlier SD was Tamarang in 2015. This was most likely due to the impact of frost-induced sterility, with minimum temperatures of <0 °C occurring during the period from the 28 August to 1 September, coinciding with head emergence/anthesis, delivering a 14.5% decrease in EGA Gregory(D yield between SD1 and SD2.

Table 5. Effect of management and crown rot (*Fp*) on grain yield potential – LPP across site analysis.

Variety	Population (plants/m^2)	Applied N (kg/ha)	Applied P (kg/ha)	*Fp* (CR+++)	Yield (t/ha)	Yield gap (t/ha)
SD1						
EGA Gregory	**120**	**100**	**20**	**0**	**4.57[¥]**	
EGA Gregory	120	100	20	+++	4.26	–0.31*
SD2						
EGA Gregory	**120**	**100**	**20**	**0**	**3.97[¥]**	**–0.60***
LRPB Crusader	120	100	20	0	3.65	–0.32*
LRPB Spitfire	120	100	20	0	3.55	–0.42*
LRPB Spitfire	120	100	20	+++	3.13	–0.84*

* Contrast are significant ($P<0.05$)
¥ EGA Gregory SD1 *vs*. SD2 contrast.

Variety

Maturity type was not a significant factor in SD1, with no difference (P<0.05) in yield between varieties. Variety choice did, however, affect yield in SD2, with EGA Gregory(D significantly (P<0.001) out yielding both the quicker maturing varieties LRPB Crusader(D and LRPB Spitfire(D by 0.32 t/ha and 0.42 t/ha respectively. The yield contrast between EGA Gregory(D at SD1 and LRPB Crusader(D at SD2 equated to 0.92 t/ha or 20%, compared with 0.60 t/ha or 13.1% for EGA Gregory(D at SD2.

Crown rot disease pressure

Increasing CR disease pressure (±*Fp* applied at sowing) resulted in a decreased yield for SD1 of 0.31 t/ha equating to a 7% decrease (Table 5). Similarly for SD2, CR also affected yield, with LRPB Spitfire(D showing a 0.42 t/ha or 12% decrease in yield due to CR, when all other variables were held constant. Importantly, when contrasting the combined effects of SD, CR disease pressure and genotype, potential yield decreased by 1.44 t/ha or ~31.5%.

Nutrition

Varying N and P application rates had a limited effect on yield potential, most likely due to the relatively high starting soil N and Colwell P values at the sites (Table 2). There was a small, but significant, (P<001) response to P application rates (nil vs 30 units of P) of 0.17 t/ha (3.44 vs. 3.61 t/ha) for SD2 (data not shown). Interestingly, when looking at high input (100 kg N/ha + 20 kg P/ha) versus the low input treatments (nil N and P), there was a 0.31 t/ha or ~7% difference in yield for SD1 (data not shown). The only site to show a significant yield response to N application was Tamarang for SD1 in 2014, showing a 9% increase in yield with 100 kg N applied compared with the nil treatment.

Plant population

Results from the LPP showed that apart from Tamarang in 2014, where there was a yield response to increased plant population with delayed sowing, altering targeted plant population (Table 5) did not have a significant effect on yield, underscoring wheat's ability to compensate for lower plant populations, under good growing conditions.

At Tamarang in 2014, the low target population of 60 plants/m^2 was significantly ($P<0.05$) lower yielding at 3.67 t/ha than the 120 plants/m^2 and 180 plants/m^2 treatments at 4.01 t/ha and 4.04 t/ha respectively with a delayed SD, supporting the accepted principal of increasing targeted plant population with a delayed SD.

Conclusions

Timely sowing of broadly adapted bread wheat varieties in the early part of their optimum sowing window was found to be a key determinant of yield potential. The exception was the Tamarang site in 2015, however, all other sites demonstrated significant increases in yield with an early–main season sowing for SD1 vs. SD2 contrasts.

The LPP, with a mean predicted yield of 4.57 t/ha for EGA Gregory⚘ in SD1, had a 0.60 t/ha or 13.1% decrease in yield between SD1 and SD2 averaged across sites and years (Table 5). By delaying the SD, the growing environment is, in effect, being altered reducing the length of the growing season along with potentially the timing and extent of stresses, such as terminal drought or heat.

The adaptability or plasticity of mid–late maturing spring wheat varieties and yield stability across the sowing window was also demonstrated. On the LPP, the main season variety EGA Gregory⚘ performed well across SDs, out yielding faster-maturing varieties (LRPB Crusader⚘ and LRPB Spitfire⚘), even with delayed sowings. These findings support previous observations that commercially released Australian spring wheat varieties tend to be broadly adapted to a wide range of environments, with the best performing mid-season spring wheat variety for a region, often performing consistently across the main sowing window. This indicates that breeding companies are releasing more broadly adapted varieties that display good yield stability/plasticity across a range of growing environments.

Yield responses to N and P fertiliser application rates, were found to be variable and influenced by starting soil nutrition levels (relatively high starting soil N and Colwell P at some sites) and, to some extent, seasonal conditions (e.g. Tamarang in 2014). This highlights the value in determining starting soil nutrition levels through testing and considering critical nutrient response values (e.g. Colwell P) in fertiliser decisions. Nitrogen and P nutrition, based around predicted yield and critical soil values were, however, crucial in ensuring that optimum yield potentials were achieved.

Crown rot caused by the fungus *Fusarium pseudograminearum*, affected yield potential, decreasing yields by up to 12% on the LPP with delayed sowings. Timely sowing of wheat varieties in the early part of their sowing window increased yield potential and reduced the extent of yield losses from crown rot.

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