The effect of irrigation management on wheat grain yield, grain quality and water use efficiency

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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).

irrigation & climate

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.

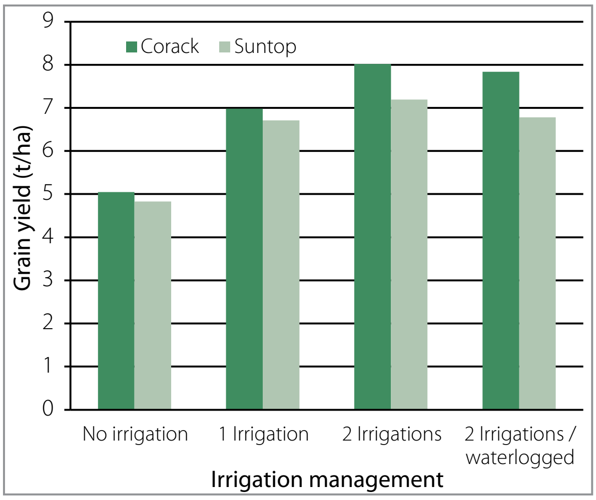

Figure 2. Grain yield (t/ha) for irrigation by variety interaction, averaged across nitrogen treatments (l.s.d. ($P < 0.05$) = 0.40).

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.

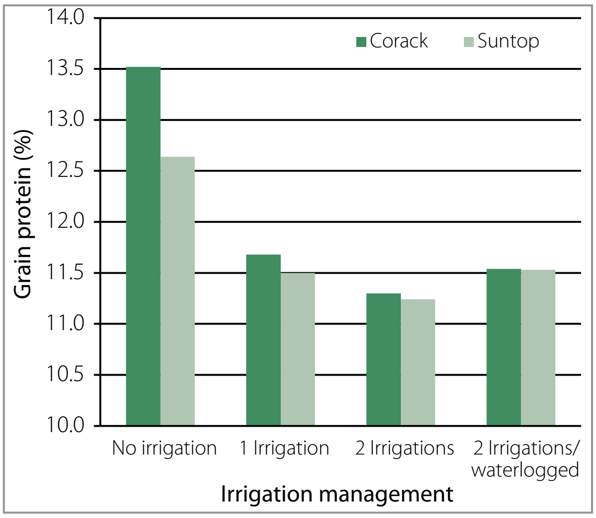

Figure 3. Grain protein (%) for irrigation by variety interaction, averaged across nitrogen treatments (l.s.d. ($P < 0.05$) = 1.6).

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

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