Nitrogen application at stem elongation, is it worth the investment?

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RESEARCH

Location
Cummins - Douglas Green, 2018
Rainfall
Av. Annual: 423 mm
Av. GSR: 314 mm
2018 Total: 361 mm
2018 GSR: 288 mm
Yield
Potential yield: 4.4 t/ha (W) (Hancock 2006)
Actual yield 2018: 3.3 t/ha
Paddock History
2017: Banker canola
2016: Buloke barley
2015: Wyalkatchem wheat
Soil Type
Clay loam
Plot Size
5 m x 1.6 m x 3 reps
Trial Design
Randomised complete block
Yield Limiting Factors
None

Location
Lock - Ian Burrows, 2018
Rainfall
Av. Annual: 390 mm
Av. GSR: 294 mm
2018 Total: 311 mm
2018 GSR: 231 mm
Yield
Potential yield 2018: 2.8 t/ha (W) (Hancock 2006)
Actual yield 2018: 3.3 t/ha
Paddock History
2017: Pasture-vetch-clover
2016: Scope barley
2015: Mace loam
Soil Type
Grey sandy loam
Plot Size
5 m x 1.6 m x 3 reps

Key messages

- **At Cummins, an increase of up to 100% grain yield in wheat to 5 t/ha over the control was reached by applying 120 kg N/ha (two split applications of 60 kg/ha each at emergence and before GS31) and extra irrigation (50 mm) at GS31.**
- **At Lock, up to a 19% higher grain yield to 5 t/ha was achieved compared to control by adding extra irrigation (50 mm) at GS31.**
- **At Minnipa, an increase of up to 31% grain yield to 3 t/ha over the control was achieved by adding extra irrigation (50 mm) at GS31 and applying 120 kg N/ha in two split applications of 60 kg/ha at emergence and by GS31.**
- **Water use efficiency (WUE) improved with N fertilisation by GS31 at Minnipa and Cummins.**
- **The split application of 120 kg N by GS31 may only be a good investment in paddocks where crops with N requirements (e.g. canola) were grown in the previous season or soil N at sowing was low (less than 44 kg/ha) and with average or above average seasonal soil moisture at GS31.**

Why do the trial?

This research aims to determine whether adding extra nitrogen (N) at GS31 will bring benefits above the current standard practice of only applying nitrogen at or near sowing in three different Eyre Peninsula (EP) environments.

Every season, growers need to make choices over limited resources in order to maximise their profitability. Nitrogen and water represent two of the key limiting resources which set the grain yield potential of a paddock. The unpredictability of growing season rainfall patterns restricts in-season N applications for EP growers, due to the associated high economic risks. Therefore, less than optimum N rates are applied in many instances, and maximum grain yield gains and optimum protein contents are not reached on occasions where opportunities have existed. Understanding soil water and N dynamics can be useful to determine if extra N application at GS31 is worth the investment in EP dryland farming systems.

How was it done?

Three trials were established at Cummins, Lock and Minnipa to cover a range of rainfalls for the EP region (Table 1). A complete randomised block design was used for the trials with three replicates. At sowing time, 20 mm of extra irrigation was added to the Minnipa and Lock trials to support crop emergence. Mineral N in control treatments were 74 kg/ha for Minnipa, 61 kg/ha for Lock and 44 kg/ha for Cummins. Rainfall from sowing up to harvest was 178 mm at Minnipa, 231 mm at Lock and 288 mm at Cummins.

Location
Minnipa Agricultural Centre, paddock N10, 2018
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 269 mm
2018 GSR: 208 mm
Yield
Potential yield 2018: 1.6 t/ha (W) (Hancock 2006)
Actual yield 2018: 2.3 t/ha
Paddock History
2017: Scepter wheat
2016: Mace wheat
2015: No seeding
Soil Type
Red sandy clay loam
Plot Size
5 m x 1.6 m x 3 reps

Treatment applications were based on extra N (two applications of 60 kg/ha each of N as urea at emergence and GS31) and water (50 mm applied at the beginning of stem elongation). In this study, four wheat varieties were chosen to cover 50 years of South Australian breeding progress: Halberd (1969), Spear (1984), Mace (2007) and Scepter (2015). Weeds, pests and diseases were controlled following best practices used for National Variety of Trials (NVT).

Soil moisture was measured using the gravimetric method to 90 cm depth, with three replicates per block at sowing, and for each plot at maturity.

Statistical analyses were performed using the R software and the R package ASREML to estimate treatment variability and adjust for spatial trends in the trials. Tukey's test was applied to assess differences between treatments.

What happened?

Water and nitrogen levels up to GS31

As expected, Cummins had high water levels at sowing (214 mm, volumetric) with 165 mm of rainfall by stem elongation, however, N levels were the lowest (44 kg/ha) compared to Lock and Minnipa sites due to the canola rotation in the previous year (Table 2). The dry start at Minnipa and Lock (soil moisture at sowing: 145 and 176 mm, respectively, volumetric water) was supplemented by adding 20 mm of water at sowing (Table 2). Soil N at Minnipa was slightly higher than Lock, however, toxic boron levels were present from 60 cm onwards at the Minnipa site that may have affected N availability (data not shown).

Comparisons of estimated soil water at each site for an average season and for 2018 are important to understand the impact of the extra 50 mm irrigation at GS31 and split applications of N applied at emergence and GS31 across the different locations (Figure 1a-c). The extra water application at Cummins was quite small relative to average moisture conditions at that location (Figure 1a). However, at Lock it increased soil water from low to close to an average soil moisture scenario (Figure 1b, irrigation at GS31 represented by a blue arrow) and to an above-average soil moisture scenario at Minnipa (Figure 1c, irrigation at GS31 represented by the arrow).

Impact of nitrogen and irrigation at GS31 on grain yield

Soil moisture and N levels at sowing may have influenced the impact of extra N and irrigation by GS31 on grain yield (Figure 2a-c). At Cummins, the extra N application produced up to a 90% (Mace, 5.28 t/ha) increase in grain yield over non-fertilised plots (2.78 t/ha, Figure 2a). The high soil moisture and rainfall levels at Cummins may have saturated the soil, making the benefit of extra water at GS31 marginal (Fig. 1c-2a, Table 1).

At Lock, average soil moisture levels produced by 50 mm of extra irrigation at GS31 and 61 kg/ha of N levels at sowing were responsible for the highest grain yield in the trial (Figure 1b-2b). Scepter had a 21% increase in grain yield (4.43 t/ha) by adding extra water at stem elongation over the combination of extra water and N applications (Figure 2b). Similar trends were also observed for the other cultivars (Figure 2b). The negative impact of extra N applied at GS31 on grain yield may have been due to over fertilisation, given the previous rotation consisted of pasture and a lodging effect was observed at harvest.

At Minnipa, the combination of above average soil moisture at GS31 produced by extra irrigation (50 mm) and the extra N in split application by GS31, resulted in the highest grain yield compared to the other treatments and varieties (3.22 t/ha, Figure 2c). Particularly, Mace and Scepter had a 31% and 16% grain yield increase over the control (Figure 2c). N levels at sowing and extra irrigation at GS31 were still beneficial for Scepter and Spear (2.8 t/ha, Figure 2c). These results may indicate that, in specific scenarios (above average soil moisture and extra N at GS31), N and water levels at GS31 may have a synergistic effect on grain yield.

Table 1 Trial details for the three EP environments in 2018

Trial Details	Lock	Minnipa	Cummins
Varieties	Scepter, Mace, Halberd and Spear		
Sowing date	22 May 2018		15 May 2018
Fertiliser	120 kg/ha Triple Super Phosphate		86 kg/ha Triple Super Phosphate
Herbicide	Boxer gold 1.5 L/ha, Avadex® 1.5 L/ha, Treflan 1.7 L/ha, Round up 2 L/ha, Hammer 100 ml/ha, Sulphate Ammonia 800 g/ha		
Harvest date	28 November	13 November	16 November

Table 2 Nitrogen and water details at sowing and rainfall up to stem elongation

Trials	Mineral nitrogen at sowing (kg/ha to 90 cm)	Soil moisture at sowing (mm to 90 cm)	Rainfall up to stem elongation (mm)
Cummins	44	214	165
Lock	61	176 (extra 20 mm irrigation due to the dry start)	56
Minnipa	74	145 (extra 20 mm irrigation due to the dry start)	45

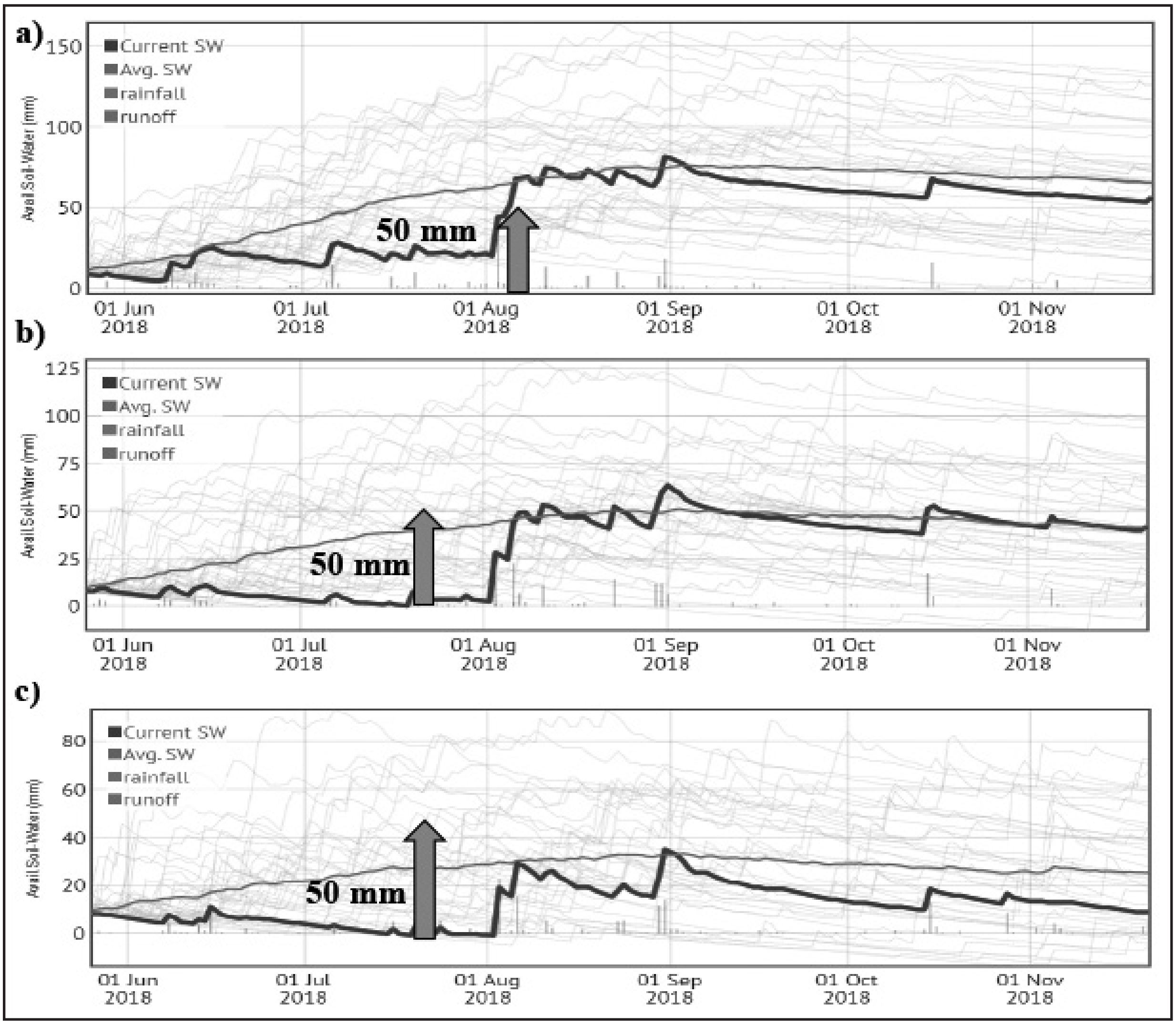

Figure 1 Projections of average historic and actual soil moisture, rainfall and runoff across season 2018 at Cummins (a), Lock (b) and Minnipa (c). The arrow highlights the extra 50 mm irrigation application at stem elongation compared to actual and average historic soil moisture data. Data sourced from: https://climateapp.net.au/A04_HowWetN

Water use efficiency

Across the three trials (Figure 3a-c), N fertilisation had a different impact on water use efficiency (WUE). At Cummins, an increase in WUE was recorded, especially by the newer cultivars. At Lock, the over fertilisation may have affected the WUE response, a higher WUE was found for unfertilised Spear and Scepter (Figure 3b). As previously observed for grain yield (Figure 2c), a higher WUE was assessed from the interaction of the newer cultivars with N and water application at GS31 at Minnipa (Figure 3c). Older varieties had either an opposite water by N interaction (Halberd, Figure 3c) or an increased WUE only due to irrigation at GS31 (Spear, Figure 3c).

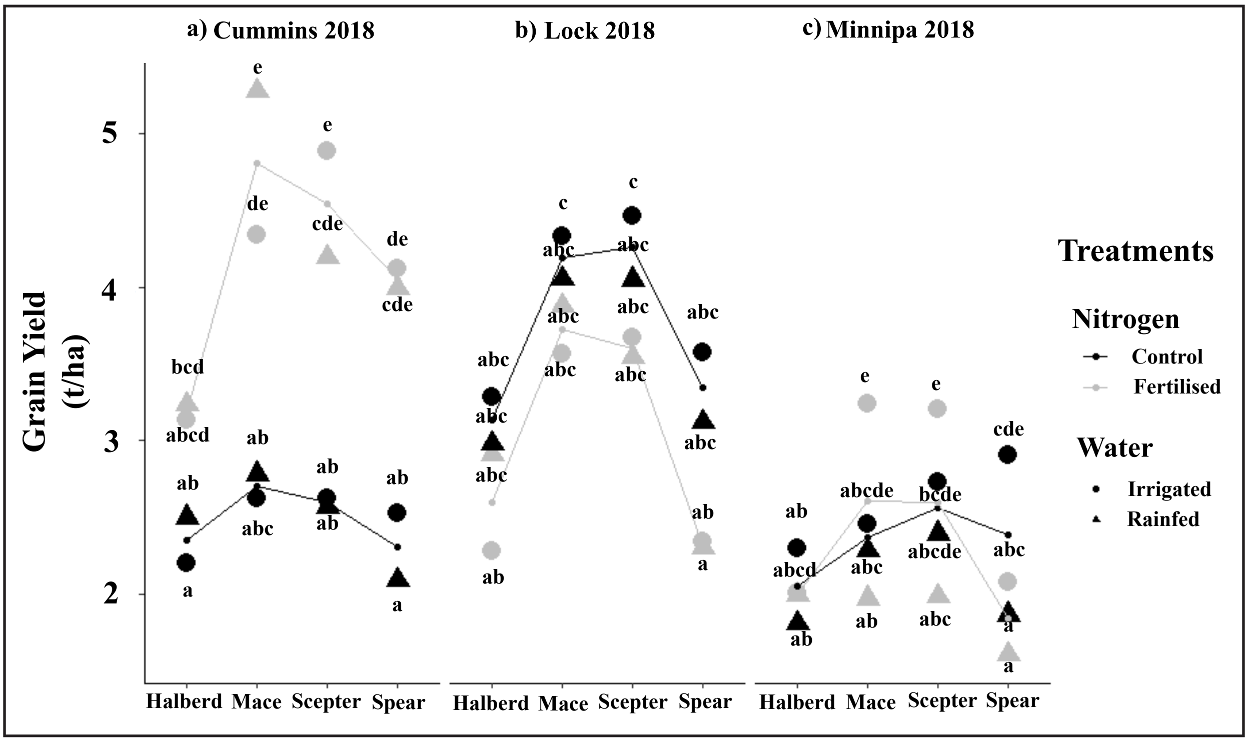

Figure 2 Grain yield (t/ha) of Halberd, Spear, Scepter and Mace at Cummins (a), Lock (b) and Minnipa 2018 (c) in 2018

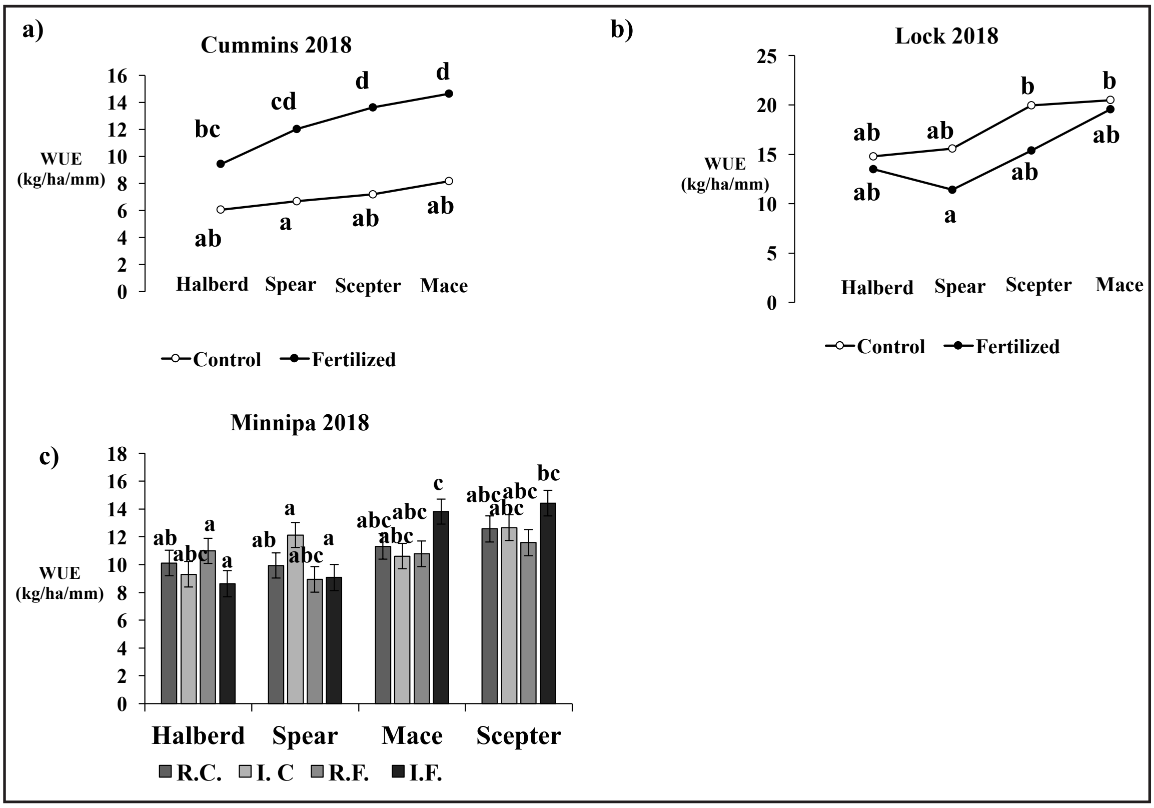

Figure 3 Water use efficiency (WUE) kg/ha/mm across Cummins (a), Lock (b) and Minnipa (c) in 2018
R.C. = Rainfed and no extra N at stem elongation, R.F. = Rainfed and extra N at stem elongation, I.C. = Irrigated and no extra N at stem elongation, I.F. = Irrigated and extra N at stem elongation.

Nutrition

What does this mean?

In this study, three common EP scenarios were considered: high (Cummins), middle (Lock) and low (Minnipa) yielding locations (Fig. 2a-c) to evaluate the possibility of applying extra N at GS31. At Cummins, paddocks with canola as the previous crop and average seasonal soil moisture, an extra 120 kg/ha of N in split application by GS31 achieved up to a 90% increase grain yield over an unfertilised control up to 5 t/ha. At Lock paddocks with close to average seasonal soil moisture at GS31 and pasture as the previous crop, extra N application at GS31 may have caused over fertilisation and reduced grain yield. At Minnipa paddocks under an intensive cropping regime (third cereal), an extra N application provided a 31% increase of grain yield over an unfertilised control (up to 3 t/ha) when seasonal soil moisture at GS31 was average or above average. As previously reported in Cossani *et al*. 2012 and Sadras *et al*. 2006, nitrogen use efficiency (NUE) decreased with extra fertilisation at GS31, while WUE had a positive relationship with N application at Cummins and Minnipa.

In conclusion, when below average growing season soil moisture at GS31 and approximately 60 kg/ha or above N levels at sowing, 120 kg/ha extra N in split application by GS31 was not beneficial at Minnipa. At Cummins, an extra application of 120 kg/ha of N in split application by GS31 brought 90% higher grain yield over unfertilised plots when growing wheat after canola. Further study would be needed to increase the number of different water by N scenarios trialled to develop a predictive model that could support growers' fertiliser decisions at GS31.

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