Effects of N fertiliser rates and variety on crop growth and grain yield

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Key findings

- At Hart, higher N-fertiliser rate (180 and 240 kg N/ha) produced lower grain yields compared to lower N rates (0, 60 and 120 kg N/ha).
- Nitrogen fertiliser rate did not affect yield at the Yield Prophet® site at Wandearah.
- Across all N rate treatments, RAC1843 delivered the highest yield of 5.4 t/ha.

Why do the trial?

Nitrogen (N) is an important nutrient for crop growth. Due to inherently low levels of N in many Australian soils and the financial risk associated with fertiliser applications, this nutrient is often limiting for agricultural production.

Despite the importance of N for crop yields, there is no appropriate benchmark to assess the maximum yield attainable in relation to N use. Therefore, we do not know if cropping systems are getting the maximum benefit for their investment in N fertiliser.

A difficulty in comparing wheat yields among N fertiliser treatments, across different sites and seasons, is that N concentration in wheat is strongly related to the actual biomass of the crop. However, crop biomass in turn is also highly variable and influenced by factors such as soil, variety, sowing date and season. Therefore we cannot compare the N status of crops, without taking the crop biomass into account.

In this project, we are developing a N dilution curve, specifically for the current wheat varieties and the dry climate of South Australia. This curve relates crop biomass to crop N concentration and can then be used to benchmark the N status of grower's crops and determine if fertiliser is applied at a rate that is too low, too high or just right.

At the time the Hart trial results book went to press, we did not have the N concentration data available to produce the Nitrogen Dilution Curve. In this publication we present data on biomass and yield components in an experiment at Hart. At a site at Wandearah, Yield Prophet® was run and N fertiliser rates were compared.

How was it done?

Hart trial

Plot size	1.75 m x 10 m
Seeding date	16th May, 2014
Seeding rate	180 plants / m^2
Initial mineral soil N in the 0 - 60 cm soil layer	47.5 kg N/ha
Wheat varieties	Mace, RAC1843, Scout, Trojan

Fertiliser - urea (46:0) at:

1) 0 kg N/ha
2) 60 kg N/ha applied at seeding
3) 120 kg N/ha split between seeding and beginning of tillering (GS20)
4) 180 kg N/ha split between seeding and beginning of tillering (GS20)
5) 180 kg N/ha split between seeding, beginning of tillering (GS20) and mid stem elongation (GS31).
6) 240 kg N/ha split between seeding and beginning of tillering (GS20)

Yield prophet® site (at Wandearah)

Plot size	1.75 m x 10 m
Seeding date	8th May, 2014
Seeding rate	150 plants / m^2
Initial mineral soil N in the 0 - 70 cm soil layer	48.2 kg N/ha
Wheat variety	Kord CL Plus

Fertiliser – all plots received urea at 12 kg/ha at seeding. Top dressing urea at:

1) 0 kg/ha
2) 50 kg/ha
3) 100 kg/ha
4) 150 kg/ha
5) 200 kg/ha

Methods

The trial at Hart was a randomised block design with 3 replicates, 4 wheat varieties and 6 N fertiliser rates. Three replicate soil samples were taken in the 0 – 30 and 30 - 60 cm soil layer prior to seeding, and analysed for soil moisture and N content. Biomass cuts were taken approximately every 2 weeks from tillering until maturity. At each sampling time, phenology was recorded and canopy traits were measured: chlorophyll content in the leaves was measured using a SPAD meter and the canopy size was measured with a Greenseeker. Both traits will be investigated as proxies for crop N status.

Biomass was oven dried at 60°C, weighed and then separated into leaves, stems and ears. The relative weights of the plant components were recorded and biomass was then analysed for N content. Yield components were determined at maturity: yield, 1000-grain weight, number of ears per m^2, number of grains per ear, number of grains per m^2, grain efficiency (i.e. number of grains per ear / mass of non-grain ear), harvest index (i.e. grain weight / total biomass weight), screenings (data not available yet) and protein content (data not available yet).

At the Yield Prophet® site, soil samples were also taken just before seeding. Biomass samples were taken twice, at flowering and maturity. Biomass at the Yield Prophet® site was separated into leaves stems and ears and then analysed for N content. For the trial at Hart, treatment and variety effects were statistically tested using two-way ANOVA with a 5% significance level.

Results and Discussion

Hart; N rate x variety trial

Both wheat variety and N fertiliser treatment had significant effects on biomass and grain yield and quality. An interaction was only found for leaf:stem ratio. Therefore, data for the N rate are presented with all varieties pooled together, and data for the variety effect are presented with all N rates pooled together.

Nitrogen effect

The higher N-fertiliser treatments (180 and 240 kg N/ha) produced lower yields compared to the lower N-fertiliser treatments (0, 60 and 120 kg N/ha, see Table 1). The nil-fertiliser treatment had a significantly lower grain efficiency and lower number of grains per square metre compared with the fertilised plots. However, the nil treatment had a significantly higher 1000-grain weight compared to the fertilised plots, which resulted in a yield similar to the 60 and 120 kg N/ha rates.

Overall, an increase in N application decreased 1000-grain weight. This has been found by others (e.g. Hocking *et al*., 2001) and is associated with one or more of the following (i) higher vegetative growth resulting in early depletion of soil water and thus increased water stress during grain filling, (ii) reduced storage of water soluble carbohydrates, which are the largest sources of assimilates for translocation during grain fill, and (iii) increased proportion of intrinsically smaller grains from lower hierarchy in the spike. The results showed that while the number of grains per ear increased with increased N application, the weight of those grains decreased. In addition, while total biomass did not differ among the treatments, the leaf:stem ratio at flowering did increase with increased N application (Table 1) as well as chlorophyll content (data not shown).

Variety effect

Across all N-rates, RAC1843 delivered the highest yield (5.4 t/ha), though not statistically different from Mace or Trojan (both yielded 5.0 t/ha, Table 1). Scout had the lowest grain yield of 4.7 t/ha. RAC1843 had the lowest number of grains per square metre, but this was compensated for by a high 1000-grain weight. Total biomass did not differ at maturity or flowering. However the leaf:stem ratio at flowering was higher for Scout and Trojan compared with Mace and RAC1843 (Table 1).

Table 1. Nitrogen and variety effects on yield components and total biomass at maturity at Hart. Averages ± standard error. Different superscript letters indicate a statistical difference (P < 0.05) between the treatments.

	Yield (t/ha)	Biomass (t/ha)	1000-grain weight (g)	Fruiting efficiency	Harvest Index	Ears / m^2	Grains /ear	Grains / m^2 (x 1000)	Leaf:stem ratio at flowering
N application rate (kg N/ha)	**Nitrogen effects at Hart:**								
0	5.4 ± 0.2 ^{ab}	12.0 ± 0.3 ^{a}	44.5 ± 0.9 ^{a}	71.4 ± 2.4 ^{a}	0.45 ± 0.01 ^{a}	400 ± 14 ^{a}	34 ± 1 ^{a}	13.6 ± 0.6 ^{a}	0.21 ± 0.01 ^{a}
60	5.7 ± 0.2 ^{a}	12.9 ± 0.3 ^{ab}	38.9 ± 1.7 ^{ab}	83.9 ± 5.1 ^{ab}	0.45 ± 0.01 a	497 ± 27 ^{b}	34 ± 1 ^{a}	16.8 ± 1.2 ^{ab}	0.27 ± 0.01 ^{a}
120 (2 x 60)*	5.4 ± 0.2 ^{ab}	13.4 ± 0.2 ^{b}	33.0 ± 1.5 ^{bc}	87.2 ± 1.9 ^{b}	0.40 ± 0.01 ^{ab}	499 ± 8 ^{b}	37 ± 1 ^{a}	18.5 ± 0.5 ^{b}	0.32 ± 0.01 ^{b}
180 (2 x 90)*	4.8 ± 0.2 ^{bc}	12.7 ± 0.4 ^{ab}	29.5 ± 1.4 ^{c}	88.3 ± 2.6 ^{b}	0.37 ± 0.01 ^{bc}	503 ± 24 ^{b}	38 ± 2 ^{a}	18.9 ± 0.9 ^{b}	0.34 ± 0.02 ^{b}
180 (3 x 60)*	4.7 ± 0.1 ^{bc}	12.4 ± 0.2 ^{ab}	29.1 ± 1.1 ^{c}	87.3 ± 2.4 ^{b}	0.38 ± 0.01 ^{bc}	486 ± 22 ^{b}	38 ± 3 ^{a}	17.9 ± 0.9 ^{b}	0.36 ± 0.02 ^{b}
240 (2 x 120)*	4.2 ± 0.3 ^{c}	12.7 ± 0.4 ^{ab}	27.3 ± 1.7 ^{c}	89.1 ± 2.6 ^{b}	0.33 ± 0.02 ^{c}	493 ± 15 ^{b}	41 ± 2 ^{a}	19.9 ± 0.8 ^{b}	0.36 ± 0.02 ^{b}
Variety	**Variety effects at Hart:**								
Mace	5.0 ± 0.3 ^{ab}	13.2 ± 0.3 ^{a}	32.8 ± 1.9 ^{a}	88.9 ± 3.3 ^{ab}	0.38 ± 0.02 ^{a}	475 ± 16 ^{ab}	38 ± 1 ^{a}	18.1 ± 0.8 ^{ab}	0.28 ± 0.01 ^{a}
RAC1843	5.4 ± 0.2 ^{a}	12.6 ± 0.2 ^{a}	39.9 ± 1.7 ^{b}	75.8 ± 1.8 ^{c}	0.43 ± 0.01 ^{b}	520 ± 16 ^{a}	30 ± 1 ^{b}	15.9 ± 0.7 ^{a}	0.28 ± 0.01 ^{a}
Scout	4.7 ± 0.2 ^{b}	12.3 ± 0.3 ^{a}	29.3 ± 2.1 ^{a}	92.5 ± 2.1 ^{a}	0.38 ± 0.01 ^{ab}	480 ± 21 ^{ab}	39 ± 1 ^{a}	18.9 ± 1.0 ^{b}	0.34 ± 0.02 ^{b}
Trojan	5.0 ± 0.2 ^{ab}	12.6 ± 0.2 ^{a}	33.1 ± 2.2 ^{a}	80.6 ± 1.8 ^{bc}	0.39 ± 0.01 ^{ab}	442 ± 12 ^{b}	40 ± 2 ^{a}	17.5 ± 0.8 ^{ab}	0.35 ± 0.02 ^{b}

**Split applications i.e. 2 times 60 kg N/ha.*

Yield Prophet® site

Yield and grain traits at the Yield Prophet® site responded slightly different to the range of N application rates, compared with the trial at Hart. Yield did not differ among the N rates. While the biomass, grain efficiency and number of ears per m^2 were similarly lowest in the nil-N treatment, the differences with the other N rates were not significant. There was also no trend of a decrease in 1000-grain weight with an increase in N rate (Table 2), as was observed at Hart.

At Hart we suggested that the increase in leaf:stem ratio in response to higher N rates could point to higher water use throughout the growing season. Consequently increased water stress during grain fill, which might explain the decrease in 1000-grain weight with higher N rates. At the Yield Prophet® site, we did not find such an increase in leaf:stem ratio (Table 2) or total biomass at flowering (data not shown). The lack of a difference in yield may be due to a similar degree of water stress during grain filling among all the N rates.

Table 2. Treatment effects on yield components and total biomass at maturity at the Yield Prophet® site and the farmers' fields. Averages ± standard error. Different superscript letters indicate a statistical difference between the treatments.

	Yield (t/ha)	Biomass (t/ha)	1000-grain weight (g)	Fruiting efficiency	Harvest Index	Ears / m^2	Grains / ear	Grains / m^2 (x 1000)	Leaf:stem ratio at flowering
N application rate (kg N/ha)	Nitrogen effects at the Yield Prophet site								
0	4.4 ± 0.2 ^{a}	9.2 ± 0.5 ^{a}	41.6 ± 0.9 ^{ab}	70.6 ± 1.6 ^{a}	0.48 ± 0.01 ^{a}	298 ± 17 ^{a}	35 ± 4 ^{a}	10.6 ± 1.6 ^{a}	0.40 ± 0.03 ^{a}
50	5.3 ± 0.3 ^{a}	11.8 ± 0.5 ^{a}	43.7 ± 0.9 ^{a}	75.5 ± 1.2 ^{a}	0.45 ± <0.01 ^{a}	413 ± 18 ^{b}	34 ± 1 ^{a}	14.1 ± 0.7 ^{a}	0.39 ± 0.01 ^{a}
100	4.6 ± 0.3 ^{a}	10.7 ± 0.5 ^{a}	39.8 ± 1.2 ^{ab}	74.4 ± 2.8 ^{a}	0.43 ± 0.01 ^{a}	368 ± 11 ^{ab}	34 ± 2 ^{a}	12.7 ± 0.8 ^{a}	0.40 ± 0.01 ^{a}
150	4.9 ± 0.2 ^{a}	11.0 ± 0.4 ^{a}	43.3 ± 1.4 ^{a}	72.3 ± 3.6 ^{a}	0.45 ± < 0.01 ^{a}	379 ± 14 ^{ab}	34 ± 1 ^{a}	12.7 ± 0.1 ^{a}	0.40 ± 0.01 ^{a}
200	5.1 ± 0.3 ^{a}	11.5 ± 1.3 ^{a}	37.9 ± 1.0 ^{b}	72.8 ± 2.0 ^{a}	0.45 ± 0.04 ^{a}	407 ± 34 ^{b}	35 ± 2 ^{a}	14.2 ± 1.1 ^{a}	0.42 ± 0.02 ^{a}

Conclusions

At Hart, the high N-fertiliser treatments (180 and 240 kg N/ha) produced lower yields than the lower N-fertiliser treatments (0, 60 and 120 kg N/ha). This was apparently driven by a reduction in 1000-grain weight. At the Yield Prophet® site, there was no difference in yield or 1000-grain weight among the N rates. Further analyses will be performed which may help explain this difference: i.e. the N nutrition index to assess the N status of the crops, ^{13}C analysis to assess the degree of drought stress that the crop has experienced, and water soluble carbohydrates, to assess the ability of the crop to continue grain fill after photosynthesis declines.

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