Monitoring the response of nitrogen application to wheat under full stubble retention

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Key points

- Two first-wheat trials sown early–mid May showed significant increases in yield where nitrogen (N) was applied. However, the timing of nitrogen application or whether the nitrogen was applied as a single or split application, gave no difference in yield.
- Normalised difference vegetation index (NDVI) assessments showed no differences in crop reflectance (crop canopy greenness) due to timing of nitrogen application. However there were NDVI differences due to the rates of nitrogen applied at the key growth stages (GS31 and GS33) where additional nitrogen could still be applied to the crop to assist in reaching yield potential.
- Nitrogen timing had no effect on tiller and head numbers, however a split application produced a taller crop canopy.
- Higher rates of nitrogen produced more dry matter (DM) and increased plant uptake of nitrogen, but the timing of application did not affect DM and nitrogen uptake.

Method

Two trials were set up under the Riverine Plains Inc stubble project: *Maintaining profitable farming systems with retained stubble in the Riverine Plains region* at Yarrawonga and Dookie, Victoria. They were set up in established wheat crops, sown on 8 May 2014 at Yarrawonga and 15 May 2014 at Dookie. The trials were under host grower paddock practice, except for nitrogen application.

Trials were established as a split plot design with nitrogen rate as the main plot and nitrogen timing the sub plot, replicated four times. To maintain trial balance the trial included two untreated treatments. Data has been statistically analysed using analysis of variance (ANOVA), with means separated using the unrestricted least significant difference (LSD) procedure.

Trial 1: Yarrawonga, Victoria

Sowing date: 8 May 2014
Rotation: First wheat after canola
Variety: Cobra
Stubble: Canola unburnt
Rainfall:
GSR: 372.8mm (April – October)
Summer rainfall: 113.6mm
Soil mineral nitrogen: 67kg N/ha (0–60cm)

Nitrogen was hand-spread across the plots at three rates, 0, 60 and 120kg N/ha at two timings (Table 1). The first 50% of the split application treatments was applied at two true leaves (GS12). The remaining 50% of the split application treatments was applied at GS31 along with the full nitrogen rate of the remaining treatments. Rain followed the GS12 application of nitrogen on 1 June 2014 with 16.3mm falling, applications made on 23 July 2014 had 0.8mm of rainfall in the following five days.

i) Establishment and crop structure

The crop with the highest rate of nitrogen (120kg N/ha) produced significantly higher tiller numbers in comparison to the untreated control crop, however there was no significant difference in final head numbers due to nitrogen rate (Table 2).

TABLE 1 Nitrogen application rates and timings at Yarrawonga, Victoria, 2014

Treatment	30 May 2014 (GS12) (kg N/ha)	23 July 2014 (GS31) (kg N/ha)	Total nitrogen applied (kg N/ha)
1	-	-	nil
2	-	-	nil
3	30	30	60
4	-	60	60
5	60	60	120
6	-	120	120

Note: To maintain trial balance the trial included two untreated treatments.

TABLE 2 Tiller counts 6 August 2014, ear half emerged (GS55), head counts and crop height at harvest (GS99) 19 November 2014

Nitrogen rate (kg N/ha)	Crop structure		
	GS55	GS99	
	Tillers (m^2)	Heads (m^2)	Height (cm)
0	349[b]	343[a]	75.5[b]
60	378[ab]	374[a]	76.0[b]
120	393[a]	358[a]	78.4[a]
Mean	**374**	**358**	**76.6**
LSD	40	43	2.2
Nitrogen timing			
GS31	358[b]	346[b]	76.0[b]
GS12 & GS31	389[a]	370[a]	77.3[a]
LSD	28	23	0.8

The highest rate of nitrogen significantly increased the height of the crop in comparison to the control (nil nitrogen) and 60kg N/ha treatments, although the differences were small (2.4cm).

Applying 50% of the nitrogen shortly after establishment, as part of a split application, significantly increased tiller numbers, head numbers and crop height when compared with the single application timing at GS31.

ii) Dry matter production and nitrogen uptake

There was a trend for the 120kg N/ha rate to produce the greatest amount of dry matter (DM) at each assessment timing, however this was only significant at GS30–31 and GS33 (Table 3).

At GS30–31, 120kg N/ha produced 0.38t/ha more DM than when 0 and 60kg N/ha had been applied, while at GS33 there was significantly less DM production where no nitrogen had been applied.

There was no difference in DM production between the single and split application of nitrogen.

Nitrogen uptake in the crop was assessed at the same time as DM production (Table 4). While there were no significant differences in nitrogen uptake between the single and split applications, there was a trend showing

TABLE 3 Dry matter 3 July 2014, mid tillering–stem elongation (GS24–30), 22 July 2014, stem extension — first node (GS30–31), 29 August 2014, third node (GS33), 15 September 2014, mid ear emergence (GS55), 29 September 2014, early flowering (GS62) and 19 November 2014, harvest (GS99)

Nitrogen rate (kg N/ha)	Dry matter (t/ha)					
	GS24–30	GS30–31	GS33	GS55	GS62	GS99
0	0.84[a]	1.40[b]	3.33[b]	5.52[a]	8.67[a]	11.29[a]
60	0.91[a]	1.37[b]	3.90[a]	5.43[a]	8.75[a]	11.67[a]
120	1.06[a]	1.78[a]	4.22[a]	6.21[a]	9.06[a]	12.17[a]
Mean	**0.94**	**1.52**	**3.81**	**5.72**	**8.84**	**11.07**
LSD	0.25	0.25	0.55	0.83	0.99	1.17
Nitrogen timing						
GS31			3.81[a]	5.82[a]	8.63[a]	11.47[a]
GS12 and GS31			3.81[a]	5.63[a]	9.02[a]	11.95[a]
LSD			0.49	0.47	0.86	0.73

TABLE 4 Nitrogen uptake 3 July 2014, mid tillering–stem elongation (GS24–30), 22 July 2014, stem extension – first node (GS30–31), 29 August 2014, third node (GS33), 15 September 2014, mid ear emergence (GS55), 29 September 2014, early flowering (GS62) and 19 November 2014, harvest (GS99)

Nitrogen rate (kg N/ha)	Nitrogen uptake (kg N/ha)					
	GS24–30	GS30–31	GS33	GS55	GS62	GS99
0	27[a]	36[b]	64[b]	71[b]	81[b]	94[b]
60	28[a]	34[b]	91[a]	90[a]	104[b]	132[a]
120	35[a]	46[a]	82[ab]	96[a]	140[a]	136[a]
Mean	**30**	**39**	**79**	**86**	**108**	**121**
LSD	10	6	20	14	24	21
Nitrogen timing						
GS31			76[a]	82[a]	104[a]	116[a]
GS12 and GS31			82[a]	89[a]	113[a]	125[a]
LSD			16	9	16	25

that nitrogen application increased nitrogen uptake, though the difference between rates was not consistent. From the second assessment timing, at GS30–31, there was significantly more nitrogen in the crop where 120kg N/ha was applied compared with the control, through to and including the assessment at harvest.

iii) Normalised Difference Vegetation Index (NDVI)

Crop reflectance measurements taken with a GreenSeeker® showed little difference in NDVI readings (crop reflectance measurement used as a surrogate canopy greenness reading) between the two different application timings of nitrogen. At the early flowering stage (GS62), the NDVI readings for the crop where no nitrogen was applied were significantly lower than where it was applied (Table 5, Figure 1).

At the start of stem elongation (GS31) the difference in NDVI reading between crops fertilised with additional nitrogen at two leaves fully emerged (GS12) and the untreated crop can give an indication of how responsive the site might be to nitrogen application. This is referred to as the response index (RI). For example, at GS31 120kg N/ha produced an NDVI score of 0.57 compared with 0.54 for the untreated crop. In this case the response index is approximately 0.57/0.54 = 1.055.

iv) Yield and grain quality

Early indications from crop canopy greenness measurements (NDVI) suggested the response to nitrogen was relatively small in this paddock, however the grain yield data suggested that while the trial site was relatively fertile, with 5t/ha yield when no nitrogen was applied, there was still a yield response of 0.46t/ha (9%) from 60kg N/ha and 0.75t/ha (15%) from 120kg N/ha (Table 6). The application of 120kg N/ha created a significant yield and protein increase indicating 60kg N/ha was suboptimal for this situation. Applying the full rate of 120kg N/ha at GS31 resulted in a significantly higher protein content, when 60kg N/ha was applied the split application was more effective at increasing the protein content. For each additional input of 60kg N/ha there was a 1% increase in grain protein. Test weight and screenings showed no differences due to the rate of nitrogen applied.

There were also no differences between the two timings of nitrogen application for yield, test weight, protein and screenings (Table 6).

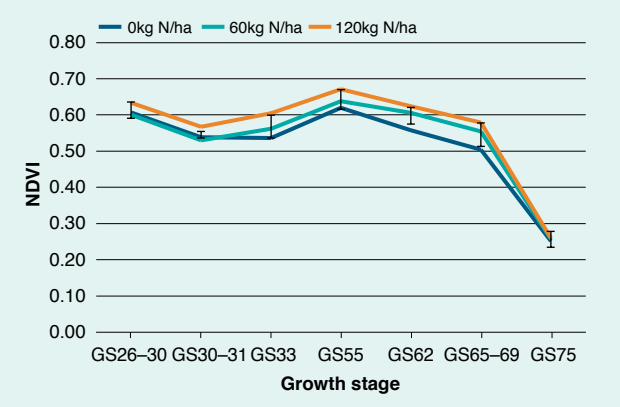

FIGURE 1 Influence of applied nitrogen rate on NDVI scale 0–1
* The error bars are a measure of LSD

TABLE 5 NDVI scale 0–1, 3 July 2014, mid tillering–stem elongation (GS24–30), 22 July 2014, stem extension-first node stage (GS30–31), 29 August 2014, third node stage (GS33), 15 September 2014, mid ear emergence (GS55), 29 September 2014, early flowering (GS62), 16 October 2014, mid–late flowering (GS65–69) and 31 October 2014, mid-milk development (GS75)

Nitrogen rate (kg N/ha)	NDVI						
	GS24–30	GS30–31	GS33	GS55	GS62	GS65–69	GS75
0	0.61^{ab}	0.54^{ab}	0.54^{b}	0.62^{a}	0.56^{b}	0.50^{b}	0.25^{a}
60	0.60^{b}	0.53^{b}	0.56^{ab}	0.64^{a}	0.61^{a}	0.56^{ab}	0.26^{a}
120	0.63^{a}	0.57^{a}	0.61^{a}	0.67^{a}	0.63^{a}	0.58^{a}	0.26^{a}
Mean	**0.61**	**0.55**	**0.57**	**0.64**	**0.60**	**0.55**	**0.26**
LSD	0.03	0.03	0.06	0.05	0.05	0.07	0.04
Nitrogen timing							
GS31			0.56^{a}	0.64^{a}	0.59^{a}	0.54^{a}	0.26^{a}
GS12 and GS31			0.58^{a}	0.65^{a}	0.60^{a}	0.55^{a}	0.25^{a}
LSD			0.05	0.02	0.02	0.02	0.03

TABLE 6 Yield, test weight, protein and screenings at harvest (GS99), 27 November 2014

Nitrogen rate (kg N/ha)	Yield and quality			
	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings (%)
0	5.02[c]	80.4[a]	9.5[c]	6.9[a]
60	5.48[b]	80.2[a]	10.5[b]	6.5[a]
120	5.77[a]	79.8[a]	11.5[a]	5.5[a]
Mean	**5.42**	**80.11**	**10.49**	**6.3**
LSD	0.24	1.1	0.4	1.7
Nitrogen timing				
GS31	5.35[a]	80.0[a]	10.6[a]	6.4[a]
GS12 and GS31	5.50[a]	80.3[a]	10.4[a]	6.1[a]
LSD	0.18	4.1	0.5	1.08

Trial 2: Dookie, Victoria

Sowing date: 15 May 2014

Rotation: First wheat after canola

Variety: Corack

Stubble: Canola unburnt

Rainfall:

GSR: 386mm (April – October)

Summer rainfall: 78mm

Soil mineral nitrogen: 60 kg N/ha

Additional trial nitrogen was hand-spread across the plots at three rates, 0, 60 and 120kg N/ha at two timings (Table 7). The first 50% of the split application treatments was applied at one true leaf (GS11). The remaining 50% of the split application treatments was applied at GS31 along with the full nitrogen rate of the remaining treatments. Rain followed the GS11 application of nitrogen on 1 June with 27mm falling, applications made on 23 July 2014 had 2mm of rainfall in the following five days.

TABLE 7 Nitrogen application rates and timings at Dookie, Victoria, 2014

Treatment	15 May (sowing) (kg N/ha)	22 May (kg N/ha)	30 May (GS11) (kg N/ha)	31 July (GS31) (kg N/ha)	Total N applied (kg N/ha)
1	9.5	5	-	-	14.5
2	9.5	5	-	-	14.5
3	9.5	5	30	30	74.5
4	9.5	5	-	60	74.5
5	9.5	5	60	60	134.5
6	9.5	5	-	120	134.5

Note: To maintain trial balance the trial included two untreated treatments. Small amounts of nitrogen were applied to all treatments (including the untreated) prior to the trial being set up.

i) Establishment and crop structure

Nitrogen application significantly increased tiller production. At the higher nitrogen rate head numbers also increased relative to unfertilised crops. Where nitrogen was applied, the crop canopy height was significantly increased (6.7cm), in comparison to the untreated (nil nitrogen) crop. Varying the timing of nitrogen application did not affect tiller numbers or head numbers, although the split timing of nitrogen significantly increased crop height by 2.9cm (Table 8).

ii) Dry matter production and nitrogen uptake

There were clear differences in crop DM production between crops with nil nitrogen and 120kg N/ha, with the 120kg N/ha rate producing significantly more DM at each assessment (Table 9). Unlike Trial 1 at Yarrawonga (where there was no significant difference), DM production was significantly higher at both the start of ear emergence (GS51) and mid flowering (GS65) assessments, when nitrogen application was split across

TABLE 8 Tiller counts 11 September 2014, start of head emergence (GS51), head counts and crop height 21 November 2014 harvest (GS99)

Nitrogen rate (kg N/ha)	Crop structure		
	GS51	GS99	
	Tillers (m²)	Heads (m²)	Height (cm)
0	332[b]	260[b]	86.5[b]
60	381[a]	307[ab]	93.2[a]
120	393[a]	326[a]	95.2[a]
Mean	**369**	**298**	**91.7**
LSD	32	64	2.9
Nitrogen timing			
GS31	355[a]	286[a]	90.2[b]
GS11 and GS31	382[a]	309[a]	93.1[a]
LSD	32	45	0.8

TABLE 9 Dry matter 3 July 2014, mid tillering–stem elongation (GS24–30), 31 July 2014, stem extension–first node (GS30–31), 11 September 2014, start of ear emergence (GS51), 3 October 2014, mid flowering (GS65), and 21 November 2014, harvest (GS99)

Treatment	Dry matter (t/ha)				
Nitrogen rate (kg N/ha)	GS24–30	GS30–31	GS51	GS65	GS99
0	0.32[b]	1.25[c]	5.63[b]	8.15[c]	9.37[b]
60	0.55[a]	1.99[b]	6.65[a]	10.10[b]	10.34[ab]
120	0.59[a]	2.27[a]	6.41[a]	11.31[a]	10.78[a]
Mean	**0.49**	**1.84**	**6.23**	**9.85**	**10.17**
LSD	0.10	0.21	0.44	0.36	1.37
Nitrogen timing					
GS31			5.88[b]	8.92[b]	10.20[a]
GS11 and GS31			6.58[a]	10.79[a]	10.13[a]
LSD			0.50	1.16	1.31

two timings. However, these differences did not follow through to harvest.

Nitrogen uptake followed similar trends to DM production with untreated crops taking up less nitrogen into the canopy than where nitrogen was applied (Table 10). At GS31 and GS51 there were significant differences due to the rate applied, with 120kg N/ha having the greatest nitrogen content in the crop canopy. The timing of nitrogen also showed that the split application produced significantly higher nitrogen uptake at both GS51 and GS65, however there was no difference at the final harvest assessment.

iii) Normalised Difference Vegetation Index (NDVI)

The greenness of the crop canopy at GS31 (measured with a Greenseeker) was significantly greater where nitrogen had been applied in a split treatment (Table 11, Figure 2). At all later NDVI assessments, carried out after the single nitrogen dose was applied at GS31, there was no significant difference in NDVI reading due to nitrogen timing. Crops fertilised with additional nitrogen above and beyond grower practice (0, 60 and 120kg N/ha) produced NDVI readings significantly different from each other at three assessment times (GS31, 51 and 71), with the highest rate of nitrogen producing the highest NDVI readings (the greener the crop).

At the start of stem elongation (GS31) the response index (RI) of crops treated with 120kg N/ha of the untreated was 1.16 (0.65/0.56 = 1.16) whereas the RI at Yarrawonga was smaller (0.57/0.54 = 1.055). These simple calculations would indicate that the yield response to nitrogen at Dookie was likely to be greater than at Yarrawonga. So was this the case?

Yield and grain quality

There was a significant yield increase from nitrogen application in this trial (Table 12). Both of the nitrogen rates applied (60kg N/ha and 120kg N/ha) out yielded the untreated crop by 1.14 and 1.34t/ha respectively. Timing of nitrogen application had no effect on yield in this trial.

TABLE 10 Nitrogen uptake 3 July 2014, mid tillering–stem elongation (GS24–30), 31 July 2014, stem extension–first node stage (GS30–31), 11 September 2014, start of ear emergence (GS51), 3 October 2014, mid-flowering (GS65), and 21 November 2014, harvest (GS99)

Treatment	Nitrogen uptake (kg N/ha)				
Nitrogen rate (kg N/ha)	GS24–30	GS30–31	GS51	GS65	GS99
0	15[b]	40[c]	66[c]	57[b]	54[b]
60	29[a]	59[b]	111[b]	100[a]	85[ab]
120	32[a]	73[a]	130[a]	113[a]	99[a]
Mean	**25**	**57**	**102**	**90**	**79**
LSD	5	14	9	15	32
Nitrogen timing					
GS31			95[a]	85[a]	80[a]
GS11 and GS31			110[a]	96[a]	78[a]
LSD			20	12	32

TABLE 11 NDVI scale 0–1 31 July 2014, stem elongation–first node (GS30–31), 11 September 2014, start of ear emergence (GS51), 3 October 2014, mid-flowering (GS65), 15 October 2014, grain watery ripe (GS71) and 30 October late milk (GS77)

Treatment	NDVI				
Nitrogen rate (kg N/ha)	GS30–31	GS51	GS65	GS71	GS77
0	0.56[c]	0.58[c]	0.57[b]	0.36[c]	0.17[b]
60	0.59[b]	0.71[b]	0.69[a]	0.39[b]	0.18[ab]
120	0.65[a]	0.78[a]	0.74[a]	0.44[a]	0.19[a]
Mean	**0.60**	**0.69**	**0.66**	**0.39**	**0.18**
LSD	0.04	0.05	0.06	0.02	0.02
Nitrogen timing					
GS31	0.56[b]	0.69[a]	0.67[a]	0.40[a]	0.18[a]
GS11 and GS31	0.64[a]	0.70[a]	0.66[a]	0.40[a]	0.17[a]
LSD	0.02	0.02	0.03	0.01	0.02

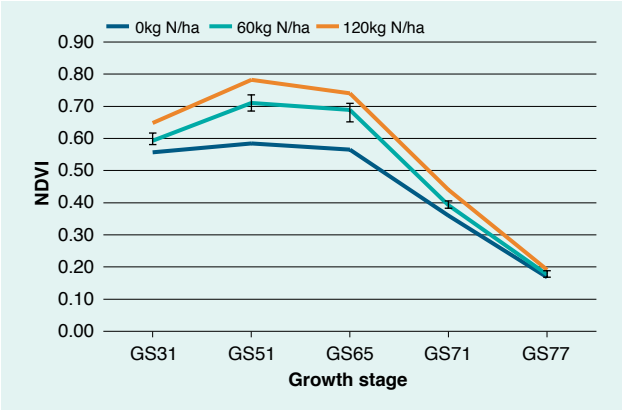

FIGURE 2 Influence of applied nitrogen rate on NDVI scale 0–1*
* The error bars are a measure of LSD

Crops receiving 120kg N/ha produced significantly lower test weights than the untreated crops and the 60kg N/ha treatment. The split timing treatments had significantly lower test weights than when a single application of nitrogen was applied.

The lowest grain protein was produced by the untreated crops with the highest grain protein resulting from the highest rate of nitrogen application. There were differences in grain protein due to timing, with the split application of nitrogen giving significantly higher protein than the single application of nitrogen.

The screening percentage was significantly higher by 0.6% in the untreated crop compared with the 60kg N/ha treatment. A single application of nitrogen resulted in a higher screening percentage compared with the split application.

Conclusions

The Dookie trial indicated greater differences in NDVI at the start of stem elongation between 60kg N/ha applied at one true leaf emerged and the untreated crop (this was manifest as a higher response index (RI) at the Dookie site; RI at GS31 = NDVI 60kg N/ha at sowing divided by NDVI nil nitrogen). In other words there was a bigger difference in crop canopy ground cover/greenness where nitrogen had been applied at Dookie than was observed at the Yarrawonga site from the same application in the window of GS11–12.

TABLE 12 Yield, test weight, protein and screenings 29 November 2014, harvest (GS99)

Treatment	Grain yield and quality			
Nitrogen rate (kg N/ha)	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings (%)
0	4.83[b]	81.8[a]	7.1[c]	2.7[a]
60	5.97[a]	81.7[a]	8.2[b]	2.1[b]
120	6.17[a]	79.7[b]	9.8[a]	1.9[b]
Mean	**5.66**	**81.1**	**8.4**	**2.2**
LSD	0.34	0.9	0.4	0.6
Nitrogen timing				
GS31	5.61[a]	81.4[a]	8.2[b]	2.4[a]
GS11 and GS31	5.70[a]	80.8[b]	8.5[a]	2.1[b]
LSD	0.17	0.2	0.1	0.3

At Yarrawonga the RI measured 1.05 while at Dookie it measured 1.16; these differences led to maximum grain yield responses to nitrogen of 14 and 27% (0.75 and 1.34t/ha for Yarrawonga and Dookie respectively). The ratios of the NDVI measurements at the two sites in effect suggested higher soil fertility at Yarrawonga, a result that was illustrated in the greater harvest off-take of nitrogen (83kg N/ha) at Yarrawonga compared with Dookie (54kg N/ha). The greater nitrogen supply at Yarrawonga was recorded in NDVI assessments throughout the season.

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