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

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Key points:

- At both Yarrawonga and Dookie, Victoria, there was no yield response to nitrogen (N) application, with yields of 4.34t/ha and 3.88t/ha respectively.
- Although there was no yield response, there was significantly higher dry matter (DM) production and greater nitrogen offtake as a result of applying nitrogen at both sites.
- The maximum nitrogen offtake in the unfertilised crops at both sites equated (approximately) to the level of available nitrogen at the start of the season during April (assessed 0–60cm).
- The normalised difference vegetation index (NDVI) response index (NDVI of fertilised/NDVI of unfertilised plots equated to 1.25) assessed at first node stage (GS31) and the subsequent divergence of NDVI scores between fertilised and unfertilised crops suggested that both sites would benefit from additional nitrogen, however late moisture stress and high temperatures compromised any potential yield response.
- The NDVI canopy scores taken at Dookie during October 2015 from the 120kg N/ha plots clearly show a more rapid senescence than unfertilised crops (control) or those crops fertilised with 60kg N/ha.

Methodology

Two trials were set up under the Riverine Plains Inc stubble project: *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region (2013–18)* at Yarrawonga and Dookie, Victoria. They were set up in an established wheat crop, sown 22 April at Yarrawonga and 19 May at Dookie. The trials were run according to host farmer standard paddock practice except for nitrogen application.

Nitrogen was hand spread across the plots at three rates, 0, 60 and 120kg N/ha using two split-dose strategies. The first strategy was based on 50% of the nitrogen dose targeted at sowing (GS00) and 50% at the start of stem elongation (GS30). The second strategy was based on timings where 50% of the nitrogen rate was applied at the start of stem elongation (GS30) and 50% was applied at third node stage (GS33).

Trial 1: Yarrawonga, Victoria

Sowing date: 22 April 2015
Rotation: First wheat after canola
Variety: Trojan
Stubble: Canola unburnt
Rainfall:
GSR: 266mm (April–October)
Summer rainfall: 120mm
Soil mineral nitrogen: 84kg N/ha (0–60cm 21 April 2015)

Results

The application rates and timings of nitrogen applied to the trial are presented in Table 1. Since the effectiveness of nitrogen is clearly influenced by subsequent rainfall Table 2 presents the rainfall data for the five days following application and the next rainfall event greater than 5mm. The early stem elongation (GS30) application was the most affected by dry conditions following application.

i) Establishment and crop structure

Crops receiving either 30kg N/ha or 60kg N/ha at sowing produced significantly higher tiller numbers compared with the unfertilised crop. However at harvest (GS99) there were no differences in the final head numbers due to the rate of nitrogen applied (Table 3).

TABLE 1 Nitrogen application rates and timings at Yarrawonga, Victoria, 2015

Treatment	23 April 2015 (GS00) (kg N/ha)	29 June 2015 (GS30) (kg N/ha)	23 July 2015 (GS33) (kg N/ha)	Total nitrogen applied (kg N/ha)
1	-	-	-	nil
2	-	-	-	nil
3	30	30	-	60
4	-	30	30	60
5	60	60	-	120
6	-	60	60	120

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



TABLE 2 Rainfall measured for five days following each nitrogen application

	Five days rainfall following nitrogen application (mm)					Date of rainfall >5mm after application
Application 1: 23 April	23 April	24 April	25 April	26 April	27 April	
	0	4.2	8.6	0.4	0.2	25 April (2 days)
Application 2: 29 June	29 June	30 June	1 July	2 July	3 July	
	0.2	0	0.2	0	0.4	11 July (13 days)
Application 3: 23 July	23 July	24 July	25 July	26 July	27 July	
	0.2	6.8	3	1	0	24 July (2 days)

TABLE 3 Tiller counts 28 August, flag leaf fully emerged (GS39); head counts and crop height 16 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Crop structure		
	GS39	GS99	
	Tillers (m²)	Heads (m²)	Height (cm)
0	307^{b}	279^{a}	73^{b}
60	370^{a}	318^{a}	76^{ab}
120	415^{a}	327^{a}	77^{a}
Mean	**364**	**308**	**75**
LSD	55	50	3
Nitrogen timing			
GS00 and **GS30**	372^{a}	314^{a}	75^{a}
GS30 and **GS33**	355^{a}	303^{a}	76^{a}
LSD	45	41	3

Figures followed by different letters are regarded as statistically significant.

The highest rate (120kg N/ha) significantly increased crop height (by 4cm) compared with the nil plots. The timing of nitrogen did not have any significant impact on tiller numbers, head numbers or crop height.

ii) Dry matter production and nitrogen uptake

The 120kg N/ha rate produced significantly more DM at the flag leaf fully emerged stage (GS39) and the start of flowering (GS61), compared with where no nitrogen was applied. However at harvest (GS99) both rates of nitrogen (60, 120kg N/ha) produced higher biomass production than the unfertilised plots (Table 4). Again the timing of application did not affect DM production.

Nitrogen uptake in the crop was assessed at the same time as DM and also showed nitrogen uptake to be significantly greater where nitrogen was applied at all three crop stages assessed (GS33, GS39 and GS99). However at the start of flowering (GS61) only the highest rate of nitrogen applied had significantly greater nitrogen uptake (143.5kg N/ha) with the unfertilised plots showing the least nitrogen uptake (94.4 kg N/ha) (Table 5).

At the third node stage (GS33) there was significantly more nitrogen in the crop, an increase of 13.7kg N/ha, where the nitrogen was split between sowing (GS00) and start of stem elongation (GS30). However this effect was reversed at the start of flowering (GS61) where there was 12.5kg/ha more nitrogen when the

TABLE 4 Dry matter 12 June, early tiller (GS22); 29 June, stem elongation (GS30); 18 August, third node stage (GS33); 28 August, flag leaf emergence (GS39); 30 September, start of flowering (GS61) and 16 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Dry matter (t/ha)					
	GS22	GS30–31	GS33	GS39	GS61	GS99
0	0.38	0.65	3.64^{a}	3.79^{b}	8.79^{b}	8.77^{b}
60	0.40	0.92	3.82^{a}	4.28^{ab}	9.51^{ab}	10.26^{a}
120	0.46	0.89	3.94^{a}	4.5^{a}	10.5^{a}	10.35^{a}
Mean	**0.41**	**0.82**	**3.80**	**4.19**	**9.60**	**9.79**
LSD			0.49	0.65	1.12	0.86
Nitrogen timing						
GS00 and **GS30**	0.41	0.82	3.80^{a}	4.15^{a}	9.58^{a}	9.96^{a}
GS30 and **GS33**			3.80^{a}	4.23^{a}	9.61^{a}	9.63^{a}
LSD			0.40	0.53	0.92	0.70

Figures followed by different letters are regarded as statistically significant.
Note. Since nitrogen wasn't applied at the time of application no LSD values are presented for GS22 and GS30.

TABLE 5 Nitrogen uptake 12 June, early tiller (GS22); 29 June, stem elongation (GS30); 18 August, third node stage (GS33); 28 August, flag leaf emergence (GS39); 30 September, start of flowering (GS61) and 16 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Nitrogen uptake (kg N/ha)					
	GS22	GS30-31	GS33	GS39	GS61	GS99
0	19.5	32.5	77.0^{b}	74.6^{b}	94.5^{b}	75.7^{b}
60	21.2	46.7	101.8^{a}	103.1^{a}	116.5^{ab}	112.2^{a}
120	24.4	47.1	111.8^{a}	116.0^{a}	143.5^{a}	115.2^{a}
Mean	**21.7**	**42.1**	**96.9**	**97.9**	**118.1**	**101.0**
LSD			11.7	16.7	35.2	17.8
Nitrogen timing						
GS00 and **GS30**	21.7	42.1	103.7^{a}	97.9^{a}	111.9^{b}	98.2^{a}
GS30 and **GS33**			90.0^{b}	97.9^{a}	124.4^{a}	103.8^{a}
LSD			9.5	13.6	9.8	14.5

Figures followed by different letters are regarded as statistically significant.
Note. Since nitrogen wasn't applied at the time of application no LSD values are presented for GS22 and GS30.

timing was split between start of stem elongation (GS30) and the third node stage (GS33). There was however no significant difference at harvest (GS99) in nitrogen uptake in the crop.

iii) Normalised Difference Vegetation Index (NDVI)

Crop reflectance measurements taken with a GreenSeeker® showed significant differences in NDVI readings (crop reflectance measurement used as a surrogate canopy greenness reading) between the two different nitrogen application timings when measured at stem elongation (GS30), flag leaf emergence (GS39) and 17 days after flowering (Table 6). The early split timing (GS00 and GS30) was significantly greener (higher NDVI reading) at both stem elongation (GS30) and flag leaf emergence (GS39) than the later split timing crop. This changed 17 days after flowering where the later split timing of nitrogen was significantly greener.

Both rates of nitrogen applied were significantly greener than where no nitrogen was applied across all assessment timings (Table 6, Figure 1). At the start of stem elongation (GS30), flag leaf emergence (GS39) and flowering (GS61), the 120kg N/ha treatment was significantly greener than the 60kg N/ha treatment. At the flowering assessment (GS61) the NDVI readings for the earlier split of nitrogen were statistically significant, but this was not case with other four assessments.

iv) Yield and grain quality

Increased DM in the 120kg N/ha treatments at both timings did not increase grain yields (Table 7, Figure 2). The hard finish to the season, with little rainfall during September and October, combined with high temperatures at the start of October, decreased the yield potential and negated the need for higher rates of nitrogen. The crop yielded 4.45t/ha where 60kg N/ha

TABLE 6 NDVI (scale 0–1), 30 June, stem elongation (GS30); 19 August, third-node stage (GS33); 28 August, flag leaf emergence (GS39); 29 September, start of flowering (GS61) and 16 October (GS61 + 17 days)

Nitrogen rate (kg N/ha)	NDVI (scale 0–1)				
	GS30	GS33	GS39	GS61	GS61 + 17 days
0	0.39^{b}	0.51^{c}	0.54^{c}	0.40^{c}	0.26^{b}
60	0.41^{a}	0.58^{b}	0.63^{b}	0.51^{b}	0.29^{a}
120	0.41^{a}	0.64^{a}	0.67^{a}	0.57^{a}	0.30^{a}
Mean	**12.7**	**0.40**	**0.58**	**0.61**	**0.50**
LSD	3.27	0.02	0.05	0.03	0.03
Nitrogen timing					
GS00 and **GS30**	0.41^{a}	0.59^{a}	0.63^{a}	0.50^{a}	0.27^{b}
GS30 and **GS33**	0.40^{b}	0.57^{a}	0.60^{b}	0.49^{a}	0.29^{a}
LSD	0.01	0.04	0.03	0.03	0.01

Figures followed by different letters are regarded as statistically significant.

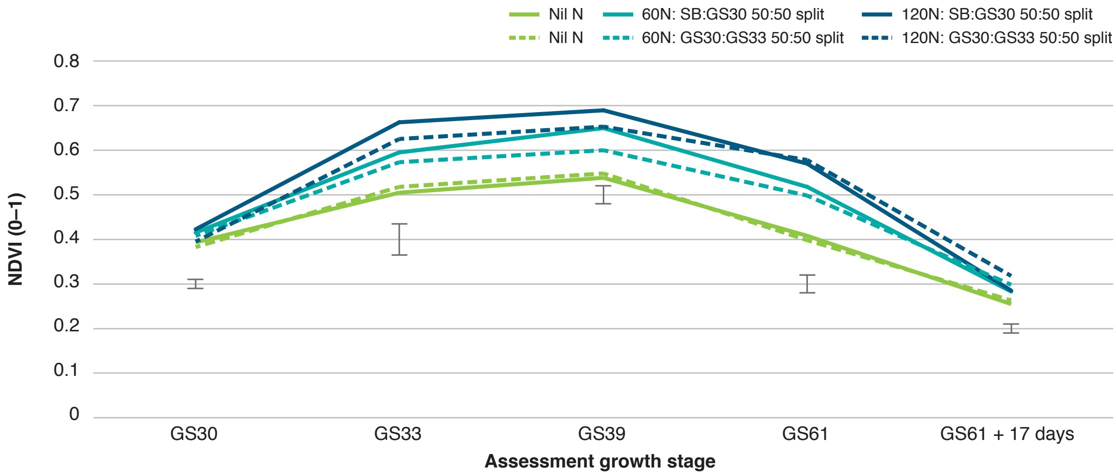

FIGURE 1 Influence of applied nitrogen timing and rate on NDVI (scale 0–1)*
The error bars are a measure of LSD.

TABLE 7 Yield, test weight, protein and screenings at harvest (GS99), 24 November 2015

Nitrogen rate (kg N/ha)	Yield and quality			
	Yield (t/ha)	Test weight (kg/hL)	Protein (%)	Screenings (%)
0	4.34[ab]	78.0[a]	8.6[c]	7.3[c]
60	4.45[a]	78.4[a]	11.2[b]	11.1[b]
120	4.23[b]	75.9[b]	14.1[a]	19.8[a]
Mean	**4.34**	**77.4**	**11.3**	**12.7**
LSD	0.22	1.34	0.7	3.27
Nitrogen timing				
GS00 and **GS30**	4.39[a]	77.5[a]	11.2[a]	12.4[a]
GS30 and **GS33**	4.29[a]	77.3[a]	11.4[a]	13.0[a]
LSD	0.18	1.1	0.6	2.7

Figures followed by different letters are regarded as statistically significant.

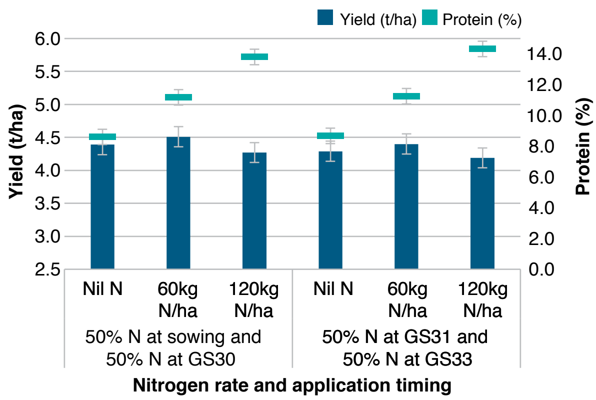

FIGURE 2 Grain yield and protein results, 24 November Yarrawonga, Victoria
The error bars are a measure of LSD

was applied (averaged across both split timings), which was significantly more than the 120kg N/ha treatment, which yielded 4.23t/ha (Table 7). Grain protein increased significantly as nitrogen rate increased, however screenings also increased with increased nitrogen. Test weight was less at the 120kg N/ha rate compared with the other nitrogen treatments.

There were no differences between the two nitrogen timing strategies for yield, test weight, protein or screenings (Table 7).

Trial 2: Dookie, Victoria

Sowing date: 19 May 2015
Rotation: First wheat after canola
Variety: Corack
Stubble: Canola unburnt
Rainfall:
GSR: 386mm
Summer rainfall: 78mm
Soil mineral nitrogen: 61kg N/ha

Results

The application rates and timings of nitrogen applied to the trial are presented in Table 8 with the rainfall surrounding application outlined in Table 9. The conditions for uptake of nitrogen at the Dookie site were more challenging than at Yarrawonga, since there were no rainfall events exceeding 5mm for more than 50 days following the GS33 application.

i) Establishment and crop structure

The application of 120kg N/ha significantly increased tiller production but not final head number relative to unfertilised crops (Table 10). The height of the crop canopy at harvest (GS99) was not increased with additional nitrogen. Varying the timing of the nitrogen application did not affect tiller numbers, head numbers or crop height.

TABLE 10 Tiller counts 24 September, flag emergence (GS39), head counts and crop height 20 November, harvest (GS99)

Nitrogen rate (kg N/ha)	GS39	GS99	
	Tillers (m²)	Heads (m²)	Height (cm)
0	325[b]	278[a]	72.8[a]
60	349[ab]	270[a]	72.3[a]
120	377[a]	289[a]	71.4[a]
Mean	**350**	**279**	**72.2**
LSD	45	42	1.5
Nitrogen timing			
GS00 and **GS30**	366[a]	285[a]	72.0[a]
GS30 and **GS33**	335[a]	273[a]	72.3[a]
LSD	37	35	1.9

Figures followed by different letters are regarded as statistically significant.

ii) Dry matter production and nitrogen uptake

There were clear differences in crop DM production between crops with nil nitrogen and where the crop was fertilised, with 120kg N/ha producing significantly more DM at each assessment, except the start of grain fill/milky ripe (GS71) (Table 11). At flag leaf emergence (GS39) crops with 120kg N/ha applied had significantly more DM than crops with 60kg N/ha.

Timing of nitrogen application did not affect DM production across any of the assessment timings.

Nitrogen uptake followed similar trends to DM production with no differences in nitrogen uptake due to the timing of

TABLE 8 Nitrogen application rates and timings at Dookie, Victoria, 2015

Treatment	19 May (sowing) (kg N/ha)	26 May (GS00) (kg N/ha)	11 August (GS30) (kg N/ha)	11 September (GS33) (kg N/ha)	Total nitrogen applied (kg N/ha)
1	4.4	-	-	-	4.4
2	4.4	-	-	-	4.4
3	4.4	30	30	-	64.4
4	4.4	-	30	30	64.4
5	4.4	60	60	-	124.4
6	4.4	-	60	60	124.4

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

TABLE 9 Rainfall measured for five days following each nitrogen application

	Five days rainfall following nitrogen application (mm)					Date of rainfall >5mm after application
Application 1: 26 May	27 May	28 May	29 May	30 May	31 May	
	0	0	0.5	1	0	5 June (11 days)
Application 2: 11 August	11 August	12 August	13 August	14 August	15 August	
	1.6	0.2	2.8	0	0	27 August (17 days)
Application 3: 11 September	11 September	12 September	13 September	14 September	15 September	
	0	0	0	0	2	2 November (53 days)

TABLE 11 Dry matter 24 July, mid-tillering (GS23); 11 August, first node stage (GS31); 11 September, third node stage (GS33); 22 September, flag leaf emergence (GS39); 22 September, grain fill (GS71); and 20 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Dry matter (t/ha)					
	GS23	GS31	GS33	GS39	GS71	GS99
0	0.41	0.64	1.8^{b}	3.5^{c}	6.0^{a}	7.8^{b}
60	0.45	0.75	2.1^{a}	4.1^{b}	6.4^{a}	10.2^{a}
120	0.42	0.76	2.1^{a}	4.6^{a}	6.0^{a}	9.7^{a}
Mean			**2.0**	**4.0**	**6.1**	**9.2**
LSD			0.2	0.5	0.6	1.3
Nitrogen timing						
GS00 and **GS30**	0.43	0.72	2.0^{a}	4.0^{a}	6.3^{a}	9.4^{a}
GS31 and **GS33**			2.0^{a}	4.1^{a}	6.0^{a}	9.1^{a}
LSD			0.2	0.4	0.5	1.0

Figures followed by different letters are regarded as statistically significant.

TABLE 12 Nitrogen uptake 24 July, mid-tillering (GS23); 11 August, first node stage (GS31); 11 September, third node stage (GS33); 22 September, flag leaf emergence (GS39); 22 September, grain fill (GS71); and 20 November, harvest (GS99)

Nitrogen rate (kg N/ha)	Nitrogen uptake (kg N/ha)					
	GS23	GS31	GS33	GS39	GS71	GS99
0	19.4	29.8	47.6^{b}	54.1^{c}	62.6^{c}	51.0^{b}
60	21.3	35.3	59.2^{a}	75.0^{b}	75.9^{b}	97.1^{a}
120	20.5	37.3	66.1^{a}	100.9^{a}	86.3^{a}	97.6^{a}
Mean			**57.6**	**76.7**	**74.9**	**81.9**
LSD			7.7	9.0	8.5	21.6
Nitrogen timing						
GS00 and **GS30**	20.4	34.1	59.9^{a}	77.1^{a}	75.7^{a}	85.9^{a}
GS31 and **GS33**			55.4^{a}	76.2^{a}	74.2^{a}	77.8^{a}
LSD			6.3	7.3	6.9	14.5

Figures followed by different letters are regarded as statistically significant.

application (Table 12, Figure 3). At flag leaf emergence (GS39) and grain fill (GS71) the nitrogen uptake increased significantly with the addition of each nitrogen rate, with 120kg N/ha having the greatest amount of nitrogen accumulated in the crop.

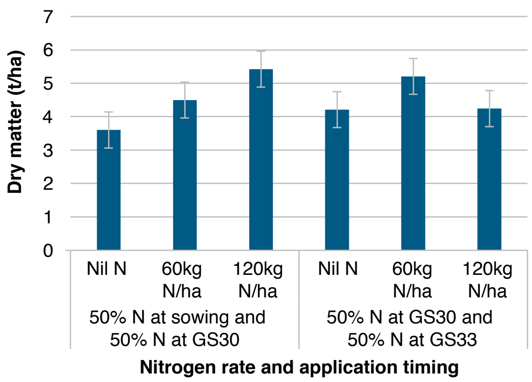

FIGURE 3 The effect of nitrogen application rate and timing on dry matter at harvest (GS99) at Dookie, 2015

iii) Normalised Difference Vegetation Index (NDVI)

The greenness of the crop canopy at the third node stage (GS33), flag leaf emergence (GS39), grain fill (GS71) and 12 days after the start of grain fill (GS71 + 12 days) (measured with a GreenSeeker) was significantly greater where nitrogen had been applied than where left untreated (Table 13). The crop treated with 120kg N/ha was the greenest throughout the assessment period. At grain fill (GS71) the crop greenness started to even out because of the dry and hot weather conditions (Figure 4).

The early split of nitrogen (GS00 and GS30) was significantly greener, from first node (GS31) until flag leaf was fully emerged (GS39) reflecting the higher nitrogen rates applied before third node stage (GS33) (Table 13).

At the start of stem elongation (GS31) the difference in NDVI readings between crops fertilised with nitrogen at sowing and the untreated crops gave an indication of how responsive the site might be to nitrogen application at each timing. This is referred to as the response index (RI). For example, at the third node stage (GS33)

TABLE 13 NDVI (scale 0–1), 11 August, first node stage (GS31); 11 September, third node stage (GS33); 22 September, flag leaf emergence (GS39); 15 October, start of grain fill (GS71) and 12 days after grain fill (GS71 + 12 days)

Treatment	NDVI (scale 0–1)				
Nitrogen rate (kg N/ha)	**GS31**	**GS33**	**GS39**	**GS71**	**GS71+12d**
0	0.37[a]	0.45[c]	0.50[c]	0.38[b]	0.24[b]
60	0.39[a]	0.53[b]	0.58[b]	0.41[b]	0.27[a]
120	0.39[a]	0.57[a]	0.67[a]	0.43[a]	0.29[a]
Mean	**0.38**	**0.52**	**0.58**	**0.41**	**0.27**
LSD	0.03	0.03	0.04	0.03	0.02
Nitrogen timing					
GS00 and **GS30**	0.40[a]	0.54[a]	0.60[a]	0.41[a]	0.27[a]
GS33 and **GS33**	0.37[b]	0.49[b]	0.56[b]	0.41[a]	0.27[a]
LSD	0.02	0.02	0.03	0.02	0.02

Figures followed by different letters are regarded as statistically significant.

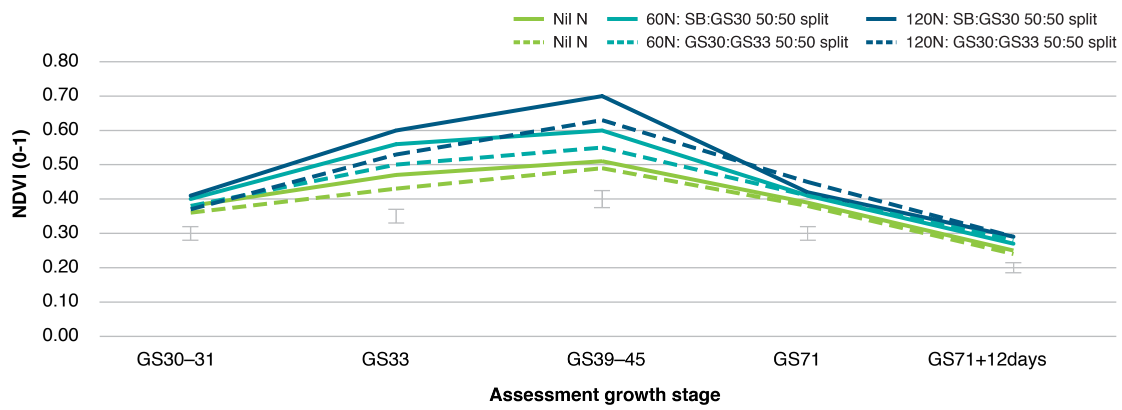

FIGURE 4 Influence of applied nitrogen timing and rate on NDVI (scale 0–1)
The error bars are a measure of LSD.

120kg N/ha produced an NDVI score of 0.57 compared with 0.45 for the untreated crop. In this case the RI was 1.26 (0.57/0.45 = 1.26), with a similar RI at Yarrawonga of 1.25 (0.64/0.51 = 1.25). These simple calculations indicate the yield response to nitrogen at Dookie was likely to be similar to that at Yarrawonga, albeit at a slightly lower level of background fertility.

iv) Yield and grain quality

Applying the highest rate of nitrogen (120kg N/ha) significantly decreased yield with a 0.18t/ha yield penalty compared with the untreated and 60kg N/ha treatments (Table 14, Figure 5).

TABLE 14 Yield, test weight, protein and screenings 24 November 2015, harvest (GS99)

Treatment	Grain yield and quality			
Nitrogen rate (kg N/ha)	**Yield (t/ha)**	**Protein (%)**	**Test weight (kg/hL)**	**Screenings (%)**
0	3.93[a]	10.2[b]	84.2[a]	4.2[b]
60	3.96[a]	11.9[a]	82.8[b]	4.9[b]
120	3.75[b]	13.2[a]	81.5[c]	7.2[a]
Mean	**3.88**	**11.8**	**82.8**	**5.4**
LSD	0.13	1.4	1.1	1.4
Nitrogen timing				
GS00 and **GS30**	3.9[a]	12.0[a]	82.8[a]	5.4[a]
GS33 and **GS33**	3.9[a]	11.5[a]	83.0[a]	5.4[a]
LSD	0.1	1.1	0.9	1.2

Figures followed by different letters are regarded as statistically significant.



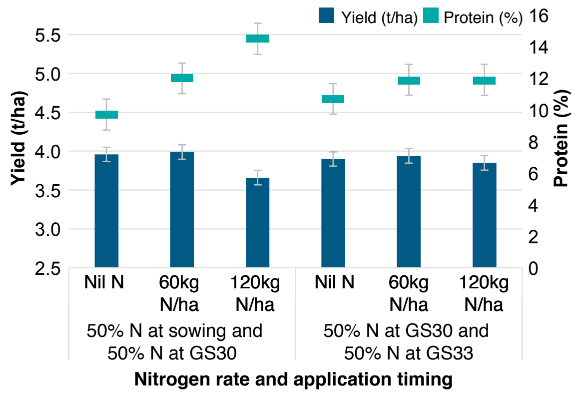

FIGURE 5 Grain yield and protein 24 November 2015, harvest (GS99)

The errors bars are a measure of LSD

Crops receiving 120kg N/ha also produced significantly lower test weights than the untreated crops and the 60kg N/ha treatment.

Grain protein was significantly less in the untreated crops compared with those where nitrogen was applied.

Screenings were significantly higher (by 2.3%) in the 120kg N/ha treatment compared with the other treatments.

As with the Yarrawonga trial, the timing of nitrogen did not influence yield or grain quality.

Conclusions

At both the Yarrawonga and Dookie sites the NDVI scores (a measurement of crop reflectance) indicated additional nitrogen was required. This was supported by strong DM growth responses as a result of nitrogen application. However, hot conditions between ear emergence (GS59) and the end of flowering (GS69) resulted in no yield advantage. At the Yarrawonga site applying the higher rates of nitrogen may still have been advantageous if the crop was cut for hay, as the fertilised crops had greater biomass.

Acknowledgements

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