GRDC Fast Track Project: SFS – 00025

Evaluation of Late Nitrogen Applications to Achieve Yield Potential and increased protein content in wheat

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Contents

Introduction

This project aims to contribute to the knowledge gaps identified by the HRZ RCSN in the program logic for the very high priority issue of nitrogen management. The research question is – Can we achieve optimum yield (measured at 11% protein) and still increase the grain protein (to 12%) of wheat produced in the HRZ? The specific question addressed is – "What impact will delaying the timing of nitrogen applications after GS32 have on wheat yield and protein and is there an advantage of using solid or liquid fertiliser?"

Trial sites were established in existing wheat crops to evaluate the impact of late (post GS32) nitrogen applied at different application rates, using different products and different timings on yields and grain quality.

Background

Growers and agronomists have to make a number of key tactical decisions, each season, in respect of their overall nitrogen management. These decisions include such things as:

- Application rates, based on seasonal conditions and their effect on yield potential
- The price of nitrogen fertiliser and how this will impact on the potential $ return/ha
- The timing of applications and the ability to get nitrogen into the crop with sufficient rainfall or moisture, especially when applied later in the season.

In the 2013 season there was good soil moisture in both medium and high rainfall areas and a positive outlook for the spring from the majority of climate models, and taking advantage of the opportunity to increase yields given these conditions has been identified as a high priority issue by the GRDC HRZ RCSN.

The low protein levels of wheat from last season would suggest that the optimum nitrogen requirements were not being met and therefore N is likely to have limited the potential yield. The above average yields in 2012 combined with low protein grain leads us to assume that the soil nitrogen supply will also be low. This was confirmed by the results of deep soil nitrogen tests both prior to sowing and those taken over recent months. Given the dry summer, little mineralisation of nitrogen and a wet winter it is likely that protein levels of wheat could again be low. Another factor contributing to lower available nitrogen inputs into the system is the lack of nitrogen fixing break crops.

The consequence of lower mineral nitrogen levels is that nitrogen fertiliser input requirements will be significantly higher than previous grower experience to achieve yield potential and grain quality (protein and screenings). The timing of nitrogen applications is also important to ensure that the supply of nitrogen matches that of the crop demand, as well as deferring investments in response to seasonal conditions.

The need for additional nitrogen fertiliser inputs in 2013 to achieve yield potential at accepted grain receival standards for protein concentration is not clearly understood and/or under-estimated by the majority of agronomists and growers. The type of nitrogen fertiliser applied, whether as a liquid or in the solid form, has not been researched when applied after GS32, as in many seasons the conditions are not suitable for further yield gains and grain protein enhancement.

Objectives

These trials will provide objective data to assist farmers make decisions on late nitrogen applications from GS32 (second node detectable) through to GS70 (grain watery ripe) comparing solid urea with two forms of liquid nitrogen. This will demonstrate strategies growers can use in the future to achieve increased grain yields, whilst maintaining acceptable grain protein, in seasons where crops have adequate soil water.

The trial objectives, updates, results and the application of this information for nitrogen budgeting and decision-making will be extended through the farming systems and GRDC networks. The extension activities will include newsletters, field days, trial results publications, "Groundcover" and HRZ RCSN members' networks.

Methodology

Eight trial sites were established and used a common set of protocols to evaluate the effect of nitrogen rates, products and application times on wheat yield and grain quality under a wide range of environmental conditions.

The protocols were developed by the Project Co-ordinator with technical expertise and review provided by Rob Norton (Regional Director, Australia and New Zealand with the International Plant Nutrition Institute). These standard protocols ensured consistency and limit the variables between the sites to improve the statistical validity of the trials across multiple site locations.

Table 1: Trial sites background information

Cooperating Group	Site	Location	Variety	Sowing Date
Farmlink	Temora	Southern NSW	Bolac	15 May
SFS	Inverleigh	Western Districts VIC	Derrimut	25 May
SFS	Murnong	Western Districts VIC	Revenue	3 June
SFS	Westmere	Western Districts VIC	Forrest	22 May
MFMG	Conmurra	South East of SA	Revenue	30 May
MFMG	Wolseley	South East of SA	Axe	11 June
SFS	Rokeby	Midlands - TAS	Revenue	28 May
SFS	Woodbury	Midlands - TAS	Revenue	17 May

The trials were placed into existing areas of wheat and set up to start the first application at GS32. This would be applied in addition to what had already been applied, up to that point, by the grower. Unfortunately due to the late start of the project the site at Temora missed out on the GS32 application as it was already more advanced than this in late August.

The trial designs were the same for seven of the eight experiments, and so the data were analysed using a factorial analysis of variance, with the factors tested being seven sites, four timings, three sources and two rates. Analysis was done using Minitab-14. Grand means for the main treatments and main factor effects presented are from these seven sites. The data for each site was derived from this analysis, as this provided the greatest precision in estimating the treatment effects at the site. The data for the Temora site were analysed individually.

Where significant effects were noted from the analysis of variance, the means were compared using a least significant difference at $p<0.05$.

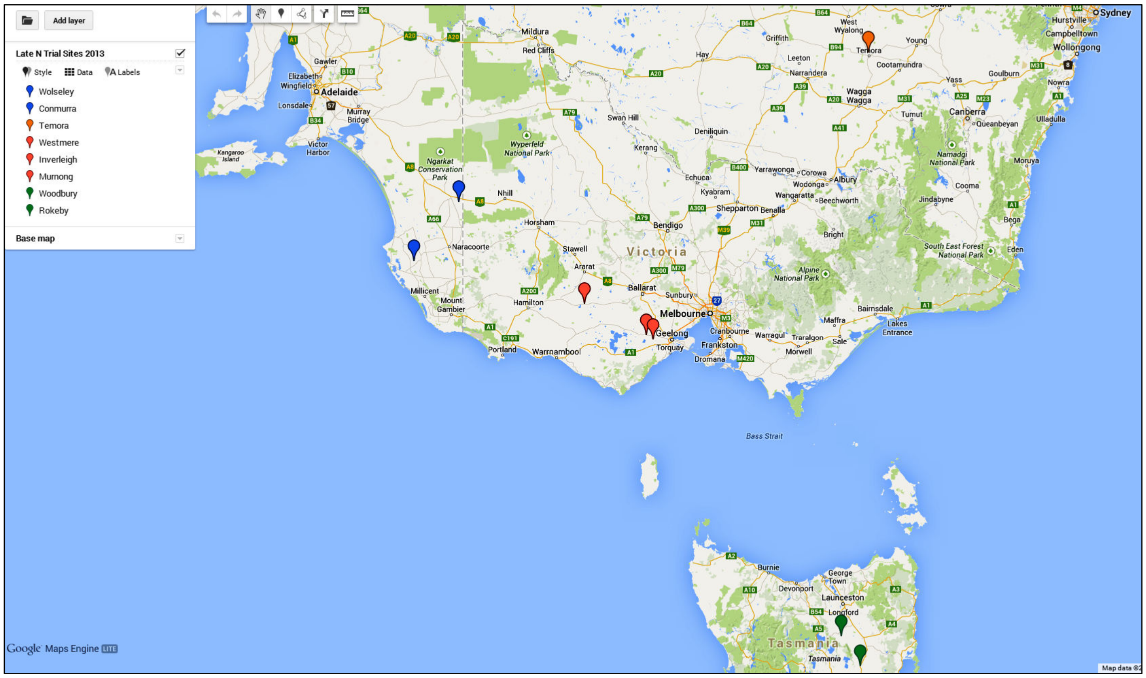

Figure 1: Late N Project trial site locations across Southern Australia

The treatments were set up to look at the influence of three key factors:

1. **Rate**
   - Two nitrogen rates – 25 and 50 kg of N/ha (these were additional to what had been applied up to GS32)

2. **Product type**

   Three nitrogen products:
   - Urea Ammonium nitrate (UAN) 42.5% N
   - Granular Urea 46% N
   - Liquid Urea 24% N

   - UAN and Liquid Urea applied through streaming nozzles at GS32 and GS39 and through Flat fan nozzles at GS55 and GS70
   - Urea was top dressed.

3. **Timing**
   - Application times:
     - GS32 2nd node detectable
     - GS39 Flag leaf fully emerged
     - GS55 Head 50% emerged on main stem
     - GS70 Grain watery ripe

   - Control – Whatever the grower had applied up to and including GS32

Table 2: Trial site descriptions and N management prior to GS32 treatments

Site	Location	Sowing Date	Variety	Previous Crop	Pre GS32 N (kg/ha)	Soil Type	Soil N (kg/ha)*
Temora	NSW	15 May	Bolac	Wheat	80	Clay Loam	
Inverleigh	VIC	25 May	Derrimut	Canola	84	Clay Loam	100
Murnong	VIC	3 June	Revenue	Wheat	45	Clay Loam	96
Westmere	VIC	22 May	Forrest	Canola	70	Grey Loam	115
Conmurra	SA	30 May	Revenue	Beans	45	Black Clay	
Wolseley	SA	11 June	Axe	Canola	90	Clay	
Rokeby	TAS	28 May	Revenue	Potatoes	36	Sandy Loam	103
Woodbury	TAS	17 May	Revenue	Poppies	100	Sandy Loam	

* Deep N tests taken before the first trial application applied (Oct 2013)

Results

Eight sites were selected from across the southeastern Australian high rainfall zone, although the site at Temora (NSW) was not particularly high yielding due to drought. The site yields and proteins for the 'Control' or Farmer practice treatments are shown in the table below.

Table 3. Site mean yields, grain protein and quality for the control treatments (Farmer Practice). Grain values are adjusted to 12.5% moisture content. N removed is in the grain only.

Site	Yield (t/ha)	Protein (%)	N Removed (kg N/ha)	Test Weight (kg/hl)	Screenings (%)
Temora	2.62	13.2	60	76.8	3.5
Conmurra	5.04	11.9	105	73.4	4.5
Wolseley	5.18	11.8	107	83.5	1.2
Inverleigh	6.10	9.8	105	77.6	10.7
Murnong	3.71	7.2	47	73.4	7.8
Westmere	5.39	10.5	99	75.8	2.9
Rokeby	7.70	7.8	105	76.2	1.6
Woodbury	9.27	8.7	141	78.8	14.4
Means	**5.63**	**10.1**	**96**	**77.0**	**5.8**

- There were high screenings (<2 mm) in the controls at most sites except Rokeby and Wolseley.
- The highest grain protein was at Temora. This is most likely the impact of drought and the addition of 80kg N/ha pre GS32.
- Conmurra, Wolseley and Westmere all delivered grain proteins above 10.5%, so the pre GS32 N status of these paddocks was probably quite good.

The data were analysed to assess if there were significant responses to N, comparing the control, where no additional nitrogen was applied after GS32, with the applied treatments.

Firstly the data was analysed by site and as a group to compare the mean N response of all the treatments to the control yield and protein %. The results of these analyses are given in Table 4.

Table 4. Mean effects of N treatments compared to the control or farmer practice

	Yield (t/ha)	Protein (%)	N Removed (kg N/ha)	Test Weight (kg/hl)	Screenings (%)
Temora	ns	**	***	ns	ns
Conmurra	*	ns	*	ns	ns
Wolseley	ns	ns	ns	ns	ns
Inverleigh	**	**	*	ns	ns
Murnong	**	***	**	ns	*
Westmere	ns	***	ns	ns	ns
Rokeby	ns	**	ns	ns	ns
Woodbury	ns	ns	ns	*	ns
Means					
FP	5.63	10.1	99	77.0	5.8
FP+N	5.92	10.6	108	76.7	5.9

* p<0.10. ** p<0.05, ***p<0.001

When considered across all treatments, there were yield responses at 3 of 8 sites, and protein responses at 5 of 8 sites. This does not necessarily mean there were no N responses as some of the sites had individual treatments that were significantly different to the control but the N treatment values are the means of all the rates, timings and sources used. The mean response overall was 0.29 t/ha and a protein increase in 0.5%. The added N (mean of 37.5kg N/ha) showed an average recovery of 24% in these experiments. There were few effects of the additional N on screenings or hectoliter weights.

In summary, across these sites, there were more protein responses than yield responses.

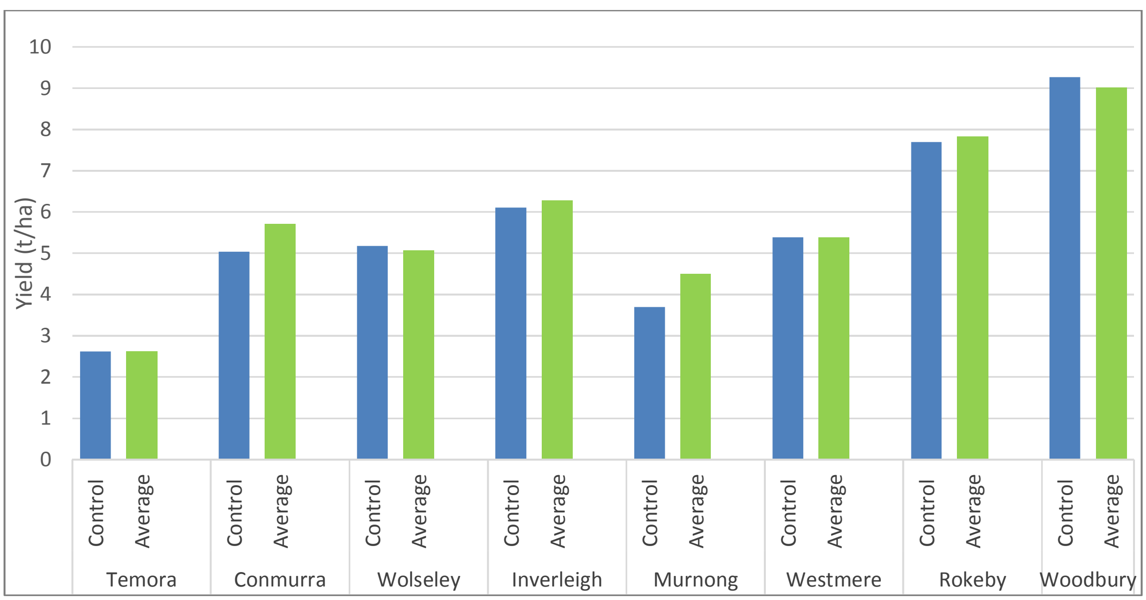

Figure 2. Effect of Nitrogen (combination of timing, rate and type) on grain yield across 8 sites. Pairs of site means followed by the same letter do not significantly differ (p<0.05).

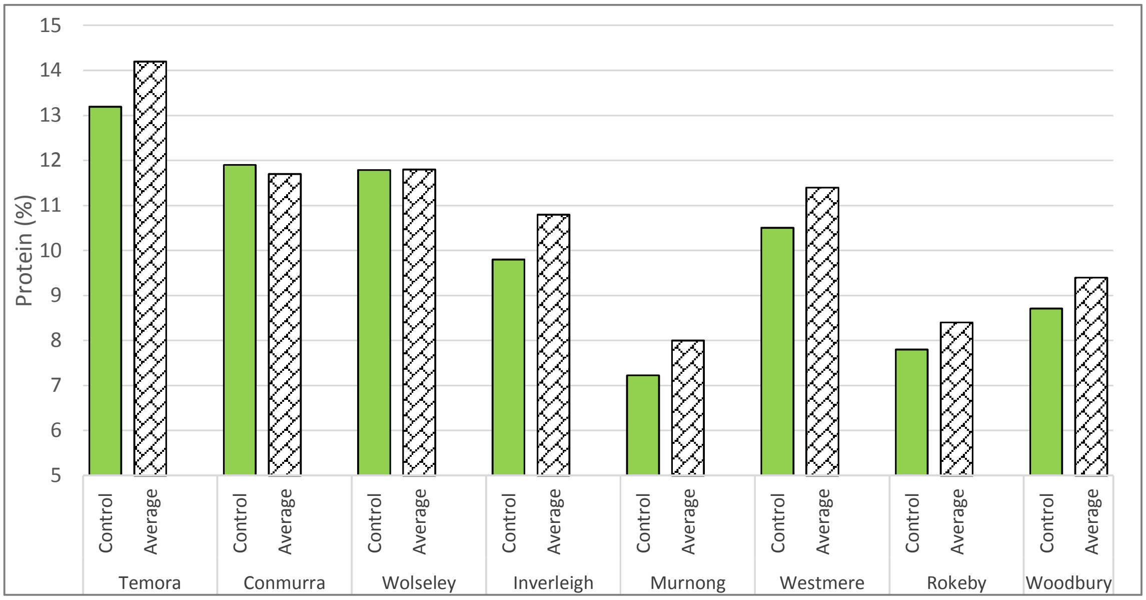

Figure 3. Effect of Nitrogen (combination of timing, rate and type) on grain protein across 8 sites Pairs of site means followed by the same letter do not significantly differ (*p*< 0.05).

Multi-site Analysis - Response to the time, rate and type of N.

The data set comprised responses to four application times, two rates and three N sources. Grain yield (t/ha), grain protein (%), nitrogen removed in produce (kg N/ha), hectoliter weight (kg/hl) and the screenings (%) were collected and analysed using a balanced factorial (4*2*3) analysis of variance for 7 of the 8 sites. At the Temora site, the earliest N application was not undertaken at GS32, so the analyses there was a 3*2*3 analysis of variance. In addition, the seven sites where there were balanced data were analysed as a 7*4*2*3 analysis of variance.

The overall analyses showed main treatment effects (Table 4). The seven sites had different responses due to N source/rate/time combinations on all five variables measured. Overall, there were a few yield effects due to any factor other than site, although there was a weak effect of rate. Grain protein was affected by the timing and rate of N applied, and there were different responses at different sites (Site*Time interaction), and also different responses to the N sources used across sites.

Table 5. Analysis of variance results for 7 sites, 4 timings, 2 rates and 3 sources on grain yield, grain protein, nitrogen removal, hectoliter weight and screenings.

	Yield	Protein	Nrem	HLW	Screenings
Site	***	***	***	***	***
Timing	ns	***	**	*	ns
Rate	*	***	***	***	ns
Source	ns	ns	ns	ns	*
Site*Time	ns	***	ns	***	ns
Site*Source	ns	**	ns	*	ns
Site*Rate	ns	*	**	ns	ns
Time*Source	ns	*	ns	ns	ns
Time*Rate	ns	ns	ns	***	ns
Rate*Source	ns	ns	*	ns	ns
Time*Rate*Source	ns	ns	ns	*	ns

* p<0.10. ** p<0.05, ***p<0.001

Grain hectoliter weights (*i.e*. test weight) were affected by a range of factors in the analyses, but these changes were generally small (<1 kg/hl). At Conmurra, Murnong, and Temora, test weights were all below 76 irrespective of the N treatment. At the other sites, test weights were all above 76 irrespective of N treatments.

The percentage screenings in the grain samples were generally unaffected by any of the treatments, although there was a weak effect of different sources.

Effect of N Rate

N rate had a significant effect on grain protein and test weights across 7 of the 8 sites and other treatments (Table 6). Temora was not included in this part of the analysis, so the N0 data differ between Table 1 and Table 5.

Table 6. The effect of N rate on grain yield, protein, N removal and hectoliter weight averaged across 7 sites and all other N treatments.

Rate	Yield	Protein	Nrem	HLW
N0⁺	5.24	8.6	92.0	67.3
N25	6.20	10.0	111.5	76.7
N50	6.30	10.4	116.1	77.0
	*	***	***	***

* p<0.10. ** p<0.05, ***p<0.001

⁺Nil N treatments are the means of sites other than Temora

The 50 kg N/ha rate had a larger effect on grain protein than the 25 kg N/ha rate. Application rate also increase N removal, and the marginal nitrogen use efficiency across all these experiments were 36% for the 25 kg N/ha and 28% for the 50 kg N/ha rates.

Effect of Timing

Timing had a significant effect on protein response but not grain yield. In the higher yielding sites, it seems likely that the N supply before GS32 was adequate, and the main effect of the additional N was to increase grain protein rather than yield. Even so, the average size of the increase was small (~0.4%) and was only seen in applications made at GS55. Application at GS39 had a smaller increase, and the applications as GS70 were too late to affect grain protein. There was only a weak interaction between N rate and timing, so that the rate effects did not differ at different times – so there was no strong indication that later applications required higher (or lower) rates than earlier applications.

Table 7. The effect of timing of N application on grain yield, protein, N removal and hectoliter weight averaged across 7 sites and all other N treatments.

Timing	Yield	Protein%	Nrem	HLW
GS32	6.22	10.10	112.5	76.9
GS39	6.35	10.17	114.9	76.8
GS55	6.25	10.37	115.7	77.1
GS70	6.17	10.12	112.1	76.7
LSD (p<0.05)	ns	0.12	3.0	ns

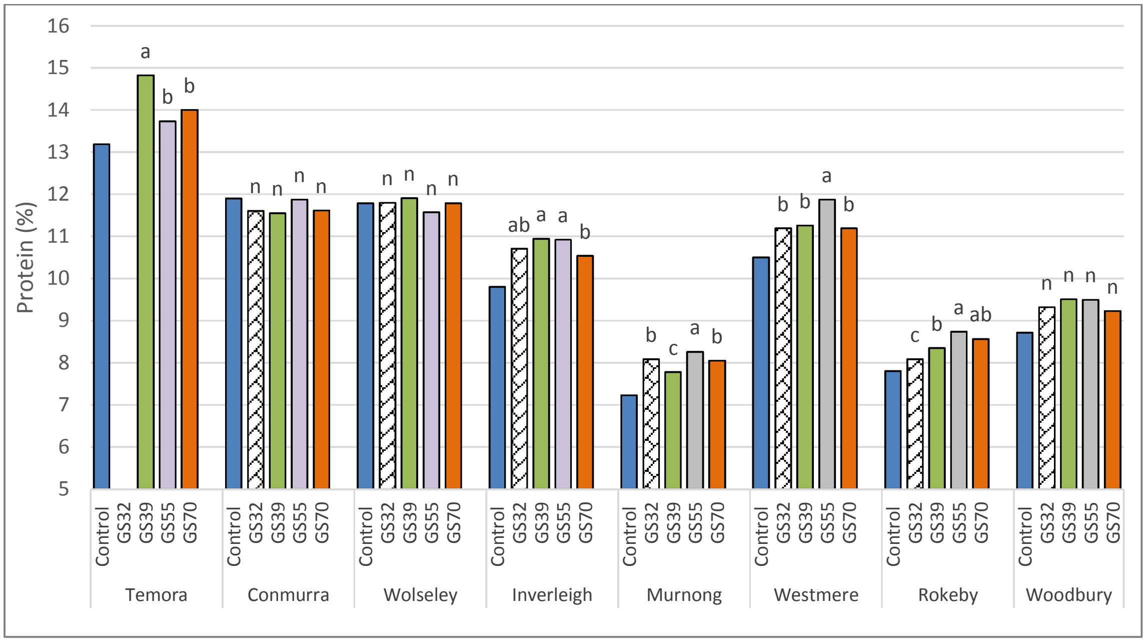

Figure 4. Effect of Nitrogen timing (combined rate and type) on grain protein across 8 sites. Means followed by the same letter do not significantly differ (*p*<0.05).

<u>Effect of Source</u>

The response to additional N occurred largely irrespective of the type used although the effects seen did vary from site to site. Table 8 shows the response to the two fluid N sources – UAN and urea, compared to granular urea. There was no difference in protein concentration at Conmurra, Murnong, Rokeby and Westmere, but the granular source resulted in decreased protein at Temora and Woodbury. At Inverleigh and Wolseley, the granular urea resulted in a protein increase compared to the fluid N sources. Again, these differences are on average only very small.

Table 8. The effect of N fertiliser type on grain protein % at 8 sites. Values are the means of two N rates and four N timings.

Site	UAN	Urea-Liquid	Urea-Granular	Significance (p<0.05)
Conmurra	11.6	11.8	11.6	b
Inverleigh	10.6	10.8	10.9	d
Murnong	8.0	8.0	8.2	g
Rokeby	8.5	8.3	8.5	f
Temora	14.6	14.5	13.5	a
Westmere	11.3	11.3	11.2	c
Woodbury	11.8	12.0	11.5	b
Wolseley	9.2	9.4	9.6	e
LSD (*p*<0.05)		0.29		

Means followed by the same letter do not significantly differ (*p*<0.05).

Site by site analysis

Each individual site was also analysed for effects among the N strategies, and these results are presented in the following section. The focus is on the yield and protein response, particularly to timing, which was significant at 6 of the 8 sites (5 p<0.05, 1 p<0.10). Rate differences were also significant at 7 of the eight sites (5 p<0.05, 2 p<0.10) but there were few interactions to rate with timing.

Temora NSW

- *Significant (P=0.05) increase in grain protein application at GS39.*
- *Yield increase to N at GS55 compared to N applied GS39.*

This was the lowest yielding of all the sites, and showed a significantly lower grain protein concentration with later, rather than earlier N applications. Conversely, the grain yield was higher with the later application of N when compared to the earlier application. This pattern of response is consistent with a dry late winter/early spring, and then some recovery from late rains which were co-incident with the later N application.

Table 9. Summary table of maximum and minimum values

	Value	Units	Timing	Rate (kg N/ha)	Type	P<0.05
Highest yielding treatment	2.76	t/ha	GS55	25	Liquid Urea	No
Lowest yielding treatment	2.48	t/ha	GS39	50	UAN	No
Highest Protein	15.3	%	GS39	50	Liquid Urea	Yes
Lowest Protein	12.2	%	Control			Yes
Highest Test Wt	78.1	kg/hl	GS70	25	Urea	Yes
Lowest Test Wt	73.0	kg/hl	GS39	50	UAN	Yes
Highest Screenings	8.3	%	GS39	50	Liquid Urea	Yes
Lowest Screenings	1.9	%	Control			Yes

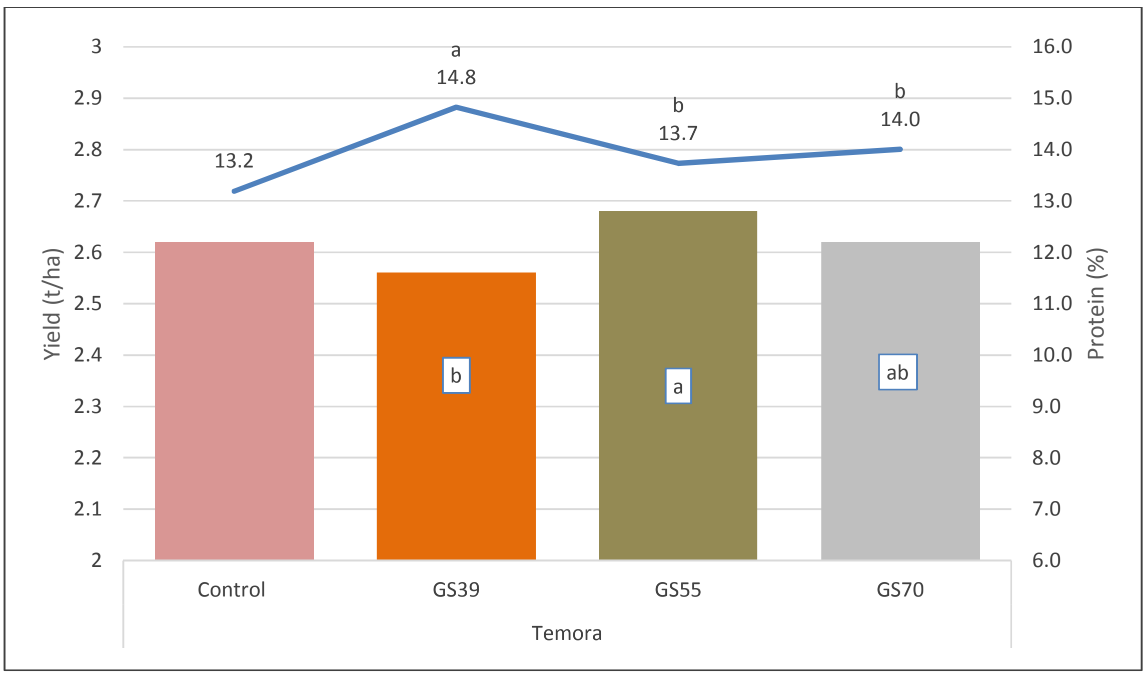

Figure 5. Effect of Nitrogen timing (combined type and rate) on grain yield (bars) and protein (line) – Temora. Means followed by the same letter do not significantly differ (p<0.05).

Conmurra SA

- *Small effect of adding extra N on yield over control*

There were no significant differences seen in the timing, rate or type of N on yield or screenings. Protein concentration was only weakly affected by the timing – with the highest at GS55. There were very few other effects noted at this site due to the treatments applied.

This was a site with very high soil organic matter and it received moderate N before GS32. This high soil organic matter content would be likely to supply large amounts of N through in-crop mineralization, and so there is likely to be little or no N limitation. Even so, all post GS32 applications increased yield over the control.

Table 10. Summary table of maximum and minimum values

	Value	Units	Timing	Rate (kg N/ha)	Type	P<0.05
Highest yielding treatment	6.32	t/ha	GS55	25	Liquid Urea	No
Lowest yielding treatment	4.98	t/ha	GS70	25	Urea	No
Highest Protein	12.33	%	GS55	50	Liquid Urea	Yes
Lowest Protein	11.25	%	GS70	25	UAN	Yes

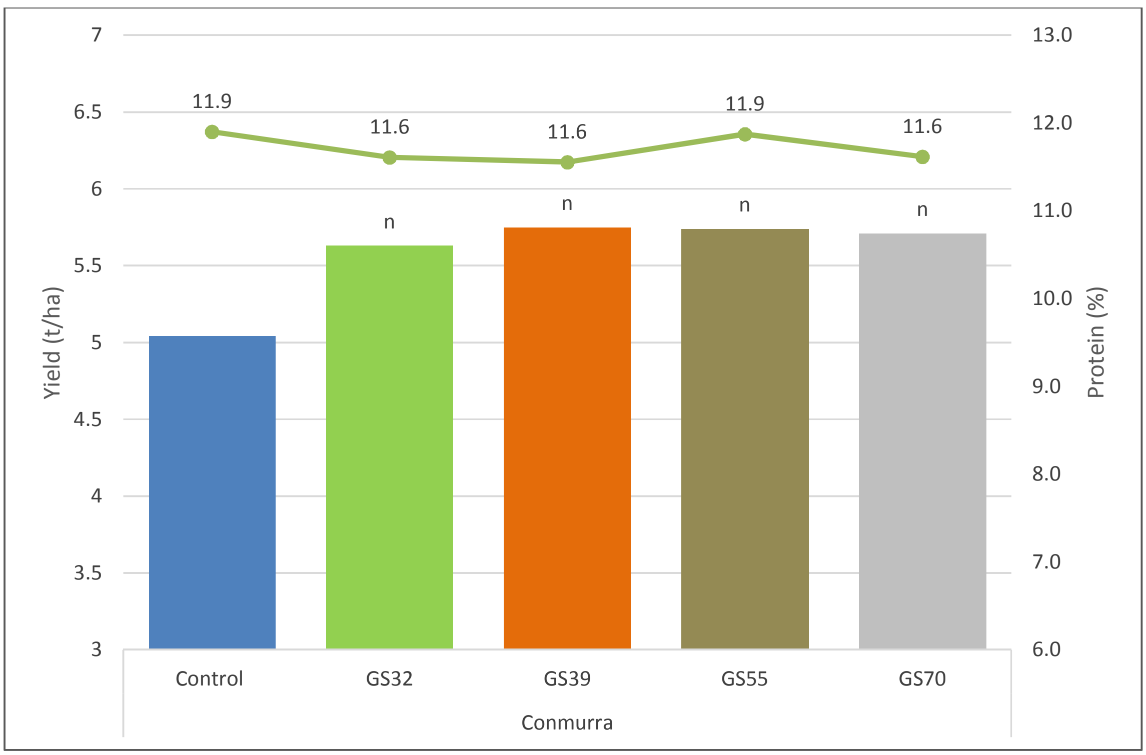

Figure 6. Effect of Nitrogen timing (combined type and rate) on grain yield (bars) and protein (line) – Conmurra. Means followed by the same letter do not significantly differ (*p*<0.05).

Wolseley SA

- *No yield response, no protein response*.

This was the only site where there was no effect of the additional N on either yield or protein. There were no effects of N on any of the parameters tested at this site, which was relatively late sown compared to the other sites. This would suggest that for Axe, sown in June, with 90kg N/ha applied pre-GS32, the yield potential had already been achieved. What is surprising however is that the grain protein content was not affected by increasing the rate or delaying the timing.

Table 11. Summary table of maximum and minimum values

	Value	Units	Timing	Rate (kg N/ha)	Type	P<0.05
Highest yielding treatment	5.37	t/ha	GS39	25	Urea	No
Lowest yielding treatment	4.67	t/ha	GS32	50	Liquid Urea	No
Highest Protein	12.4	%	GS39	50	Liquid Urea	No
Lowest Protein	10.68	%	GS55	25	Urea	No

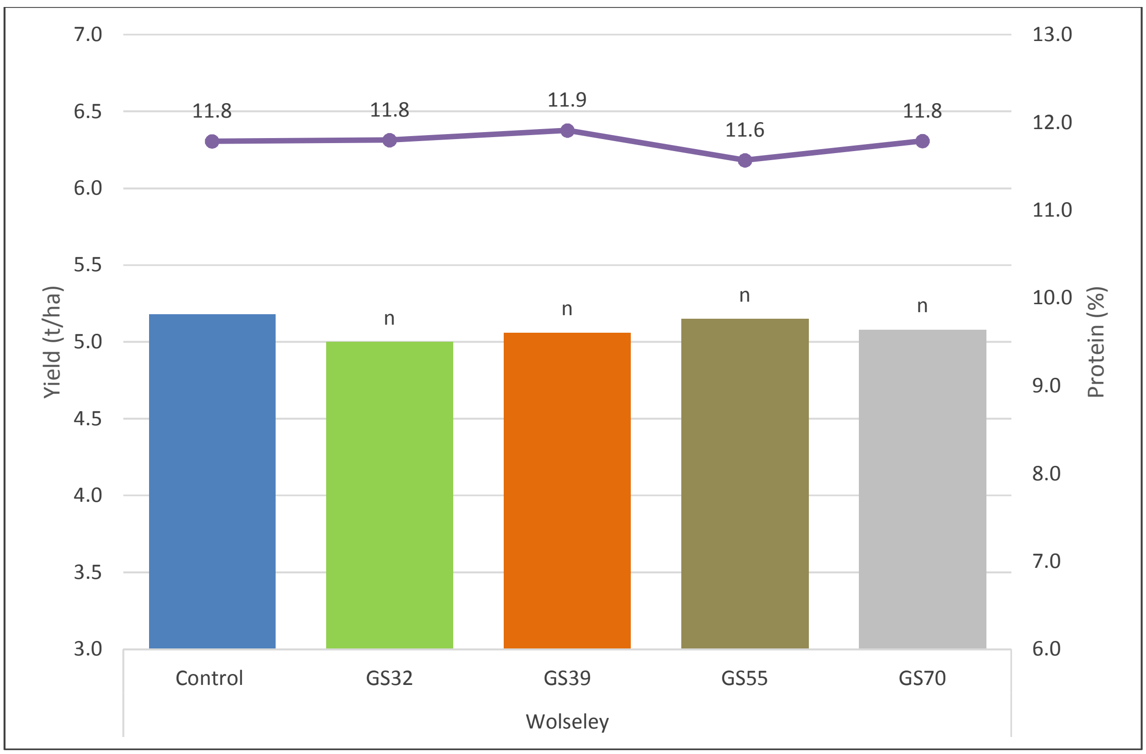

Figure 7. Effect of Nitrogen timing (combined type and rate) on grain yield (bars) and protein (line) – Wolseley. Means followed by the same letter do not significantly differ (*p*<0.05).

Inverleigh VIC

- *Significant (P=0.05) effect of additional N on yield from GS32 timing*
- *Significant (P=0.05) increase in protein from applications made at GS39 and GS55 compared to GS70.*
- *Significant (P=0.05) increase in protein from using Urea compared to UAN when applied across all timings and rates.*

At this site there were few other effects seen. Grain yield was significantly higher from a GS32 application compared to all other treatments except GS50. Grain protein concentration was significantly higher with N applied at GS39 and GS55 but not at GS32 (too early) or GS70 (too late). This site had very high screenings overall, but this was not increase by the extra N applied.

Table 12. Summary table of maximum and minimum values

	Value	Units	Timing	Rate (kg N/ha)	Type	P<0.05
Highest yielding treatment	7.21	t/ha	GS32	50	UAN	Yes
Lowest yielding treatment	5.81	t/ha	GS70	25	Urea	Yes
Highest Protein	12.6	%	GS55	50	Liquid Urea	Yes
Lowest Protein	10.5	%	Control			Yes

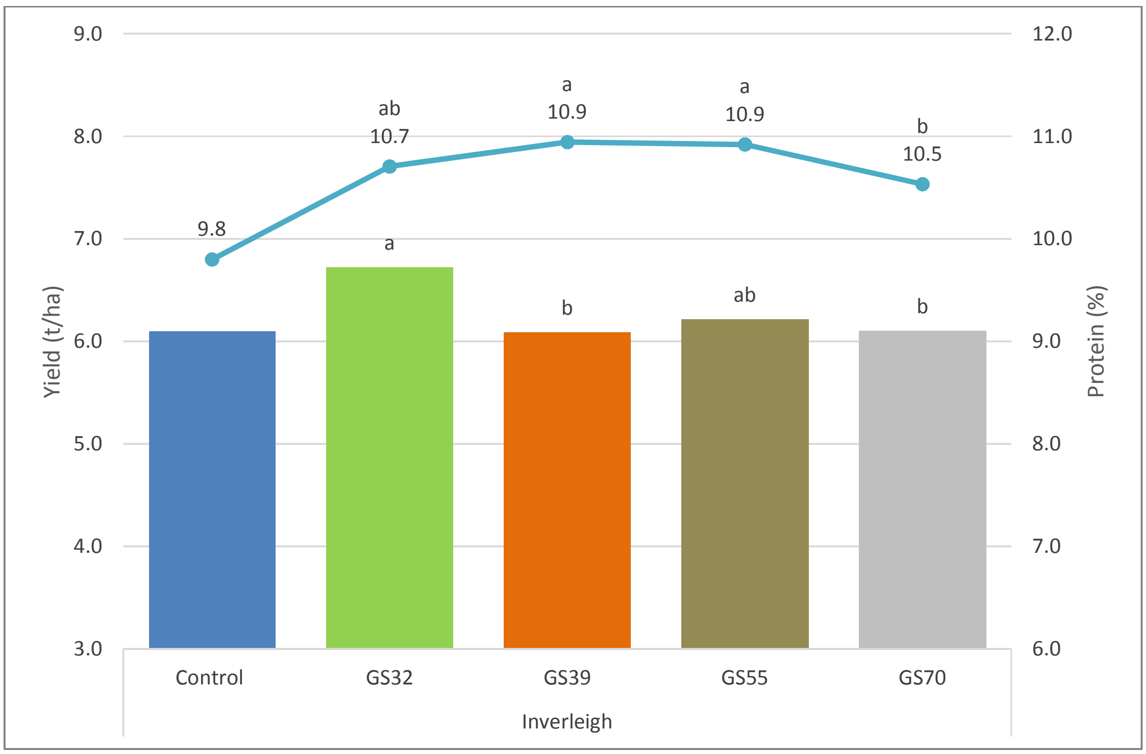

Figure 8. Effect of Nitrogen timing (combined type and rate) on grain yield (bars) and protein (line) – Inverleigh. Means followed by the same letter do not significantly differ (*p*<0.05).

Figure 9 below shows the differences in grain protein using the three sources of N evaluated. The means presented are from the combined rate and timing values. The interaction between timing, source and rate is shown in figure 9 below. Although the highest yielding treatment is 50 kg N/ha at GS32 using UAN it is not statistically (P=0.05) higher yielding than most of the GS32 treatments, two GS39 and GS55 treatments and one GS70 treatment.

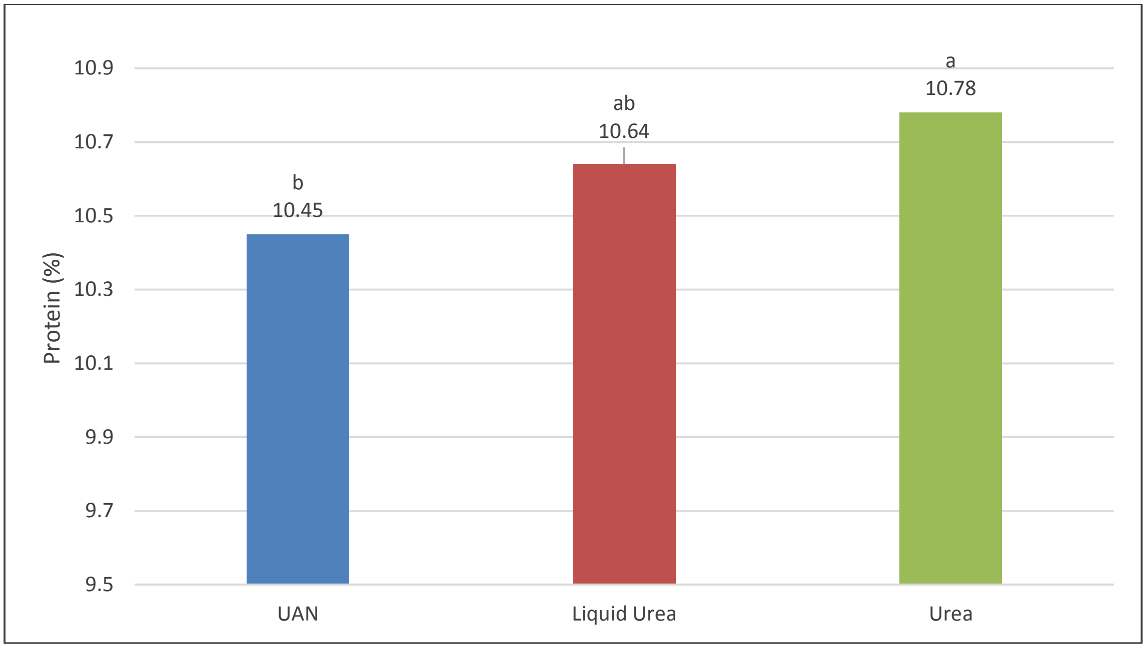

Figure 9. Effect of Nitrogen type (combined rate and timing) on grain protein – Inverleigh. Means followed by the same letter do not significantly differ (*p*<0.05).

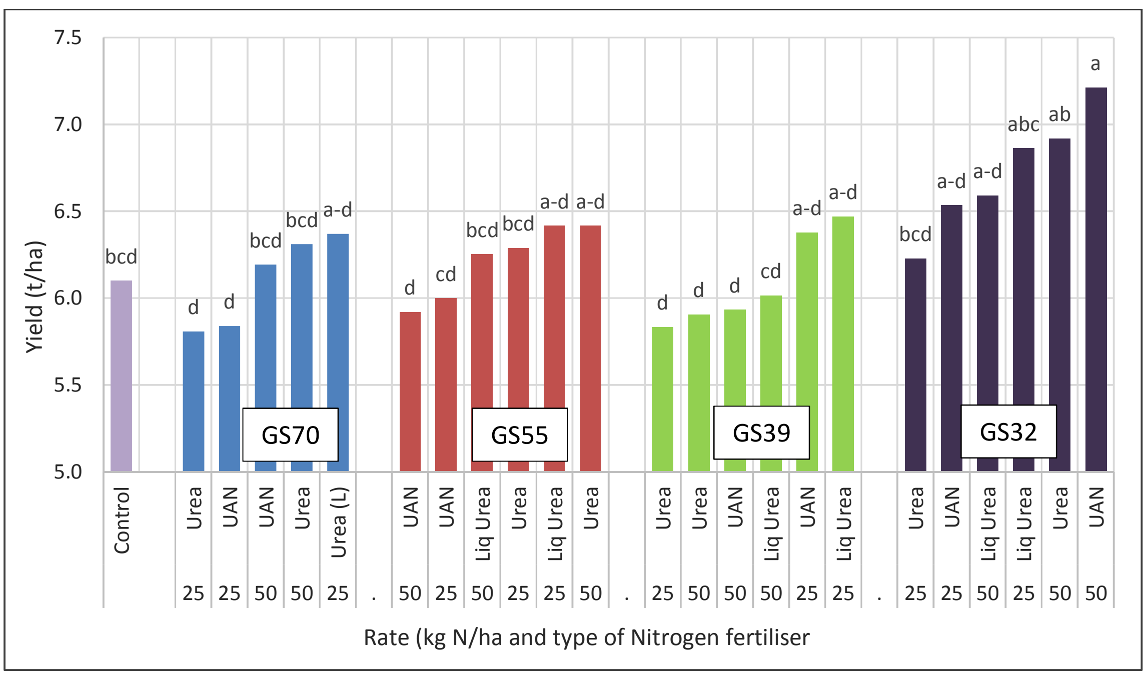

Figure 10. Yield of the Nitrogen treatments – Inverleigh. Means followed by the same letter do not significantly differ (*p*<0.05).

Murnong VIC

- *Significant (P=.05) effect of additional N on yield from GS39 timing compared to GS70 and control.*
- *Significant (P=.05) increase in protein from application made at GS55*
- *Yield dilution on protein very obvious at GS39.*

This site had the lowest grain proteins of all the 8 sites evaluated, but yields were the second lowest, which suggests that N was limiting on the site. Nitrogen removal by wheat is around 20 - 25 kg per tonne of grain, with a nitrogen use efficiency of 40 to 50%. Therefore, a crop with a 4 t/ha target yield will need to be supplied with between 140 and 160 kg N per hectare.

The deep soil N test showed there was 50 kg N/ha before sowing, and there was an additional 45kg N/ha that was applied by the end of August, the 4 t/ha wheat crop will have needed to be supplied with an additional 45 to 65 kg N to meet its potential. While in-crop mineralisation may have made up some of this deficit, it seems that restricted supply resulted in the 4 t/ha yield target being met, but seasonal conditions were probably conducive to a yield of 6-7 t/ha, so very low protein levels resulted from the limited N supply.

A significant yield response to extra N over the control was seen from applications at both GS32 and GS39, with the largest responses overall at GS39 timings. Protein levels were still low and this was likely to be due to the highest rate of N at 50kg N/ha not being high enough at this site. The GS70 N applications showed a slight, but not statistically significant, lower yield.

Table 13. Summary table of maximum and minimum values.

	Value	Units	Timing	Rate (kg N/ha)	Type	P<0.05
Highest yielding treatment	5.21	t/ha	GS39	50	Liquid Urea	Yes
Lowest yielding treatment	3.25	t/ha	GS70	25	UAN	Yes
Highest Protein	9.1	%	GS55	50	Urea	Yes
Lowest Protein	7.2	%	GS39	25	UAN	Yes

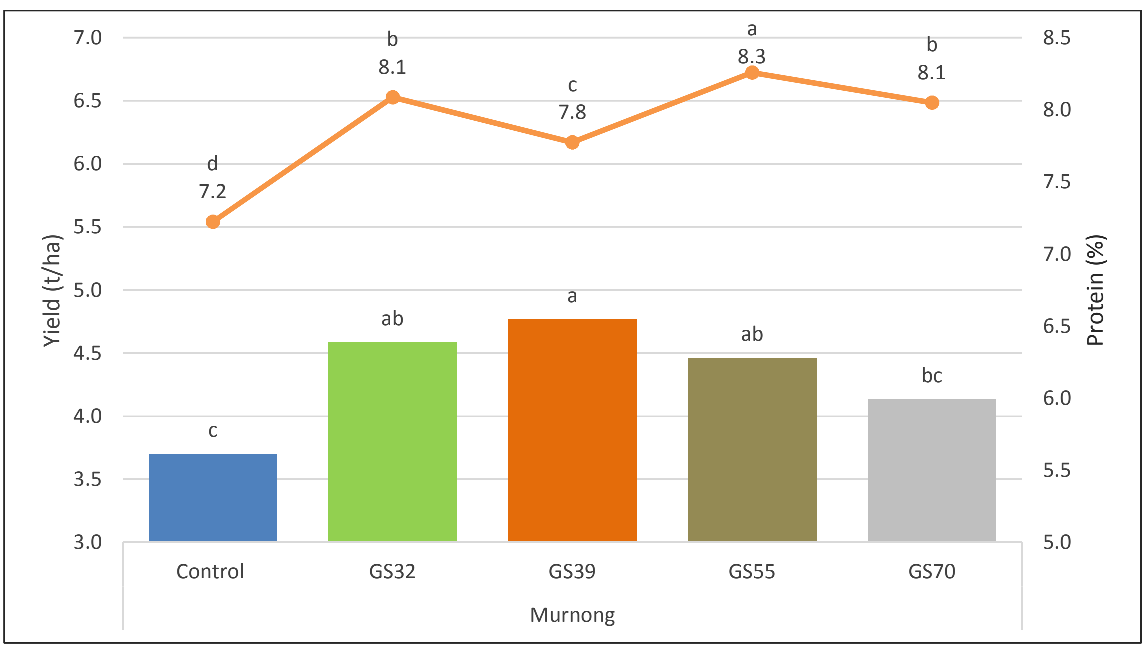

Figure 11. Effect of Nitrogen timing (combined type and rate) on grain yield (bars) and protein (line) – Murnong. Means followed by the same letter do not significantly differ (p<0.05).

Westmere VIC

- *Small yield response from a GS32 application only significantly different to the GS70 timing*
- *Significant (P=.05) increase in protein from application made at GS55*

The main effect seen in response to added N was an increase in grain protein concentration with the N applied at GS55 (11.2 to 11.9%). Later applications had no significant effect. There was a weak trend with later applications having smaller yield response.

The grain protein content suggests that N supply pre GS32 was probably adequate for yield, but the GS55 protein response suggests that for an APW receival standard a late season application makes sure a grower hasn't misjudged the potential of the season and gained more yield than expected but at the expense of a minimum 10.5% protein. At this site the Forrest wheat just got in at 10.5%!

Table 14. Summary table of maximum and minimum values

	Value	Units	Timing	Rate (kg N/ha)	Type	P<0.05
Highest yielding treatment	6.00	t/ha	GS39	25	Liquid Urea	Yes
Lowest yielding treatment	5.00	t/ha	GS55	25	Urea	Yes
Highest Protein	12.6	%	GS55	50	Liquid Urea	Yes
Lowest Protein	10.5	%	Control			Yes

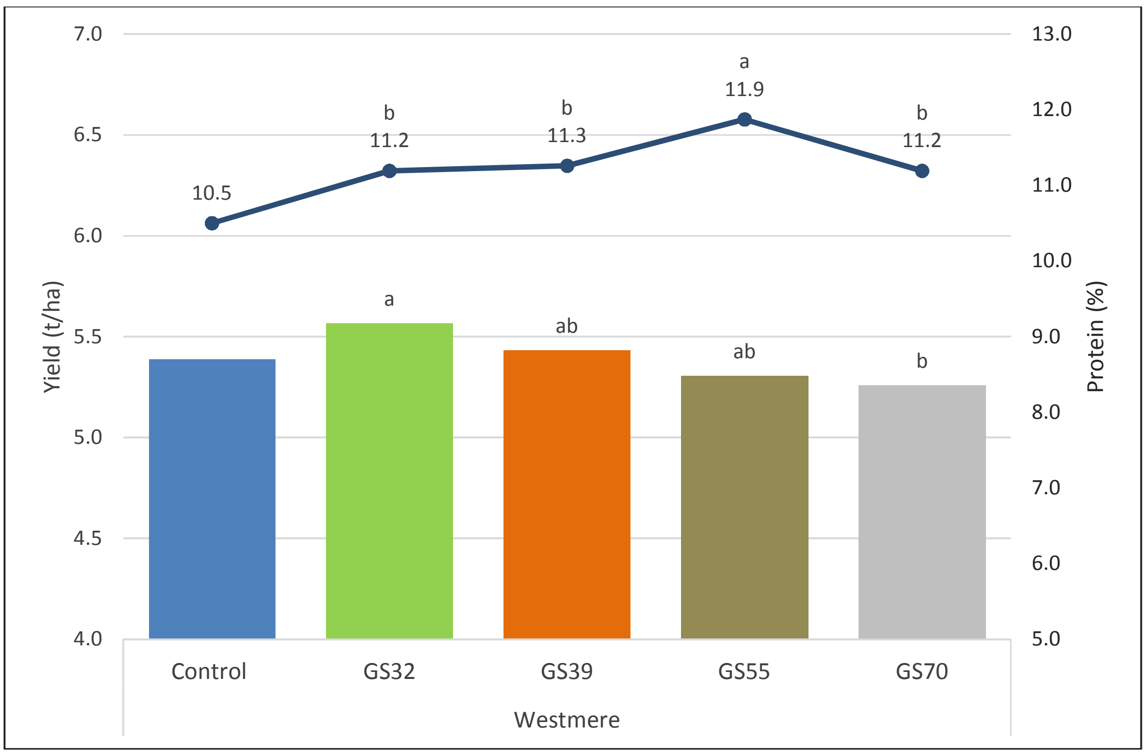

Figure 12. Effect of Nitrogen timing (combined type and rate) on grain yield (bars) and protein (line) – Westmere. Means followed by the same letter do not significantly differ (*p*<0.05).

Rokeby TAS

- *No statistically significant yield response although the highest yield came from a GS39 application*
- *Significant (P=.05) increase in protein from application made at GS55*

Grain protein concentration increased above the control in response to all applications, with the late applications of N at GS55 and GS70 giving a larger increase than the earlier applications. This may be because of a longer more active green canopy at this site, which was the second highest yielding site overall.

Grain proteins overall were less than 10% and the rate response to grain protein seen here (Figure 13 below) suggests that there may have been even higher yields with additional N. The pre-GS32 N used was only 35 kg N/ha, although there was 100 kg N/ha in the profile at sowing.

The highest yields came from applications at GS39 (see figure 14 below) but many other combinations of timing and product type also gave a similar increase.

Table 15. Summary table of maximum and minimum values.

	Value	Units	Timing	Rate (kg N/ha)	Type	P<0.05
Highest yielding treatment	8.67	t/ha	GS39	50	Urea	No
Lowest yielding treatment	6.88	t/ha	GS70	25	Urea	No
Highest Protein	9.1	%	GS55	50	Urea	Yes
Lowest Protein	7.7	%	Control			Yes

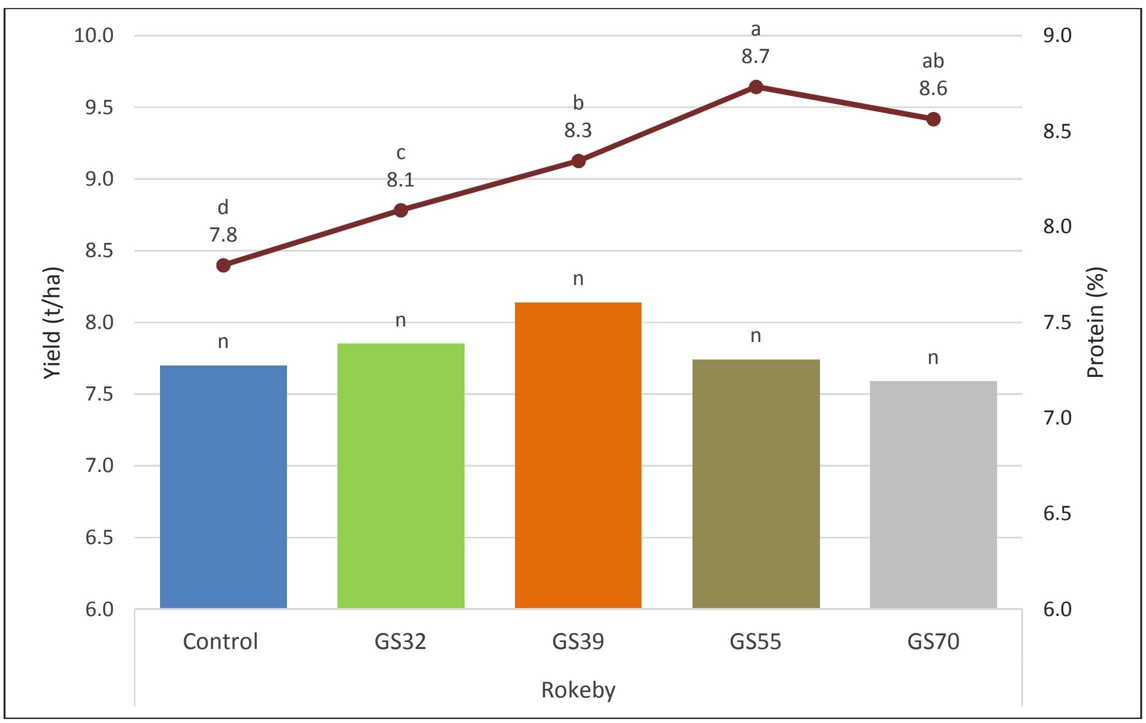

Figure 13. Effect of Nitrogen timing (combined type and rate) on grain yield (bars) and protein (line) – Rokeby. Means followed by the same letter do not significantly differ (p<0.05).

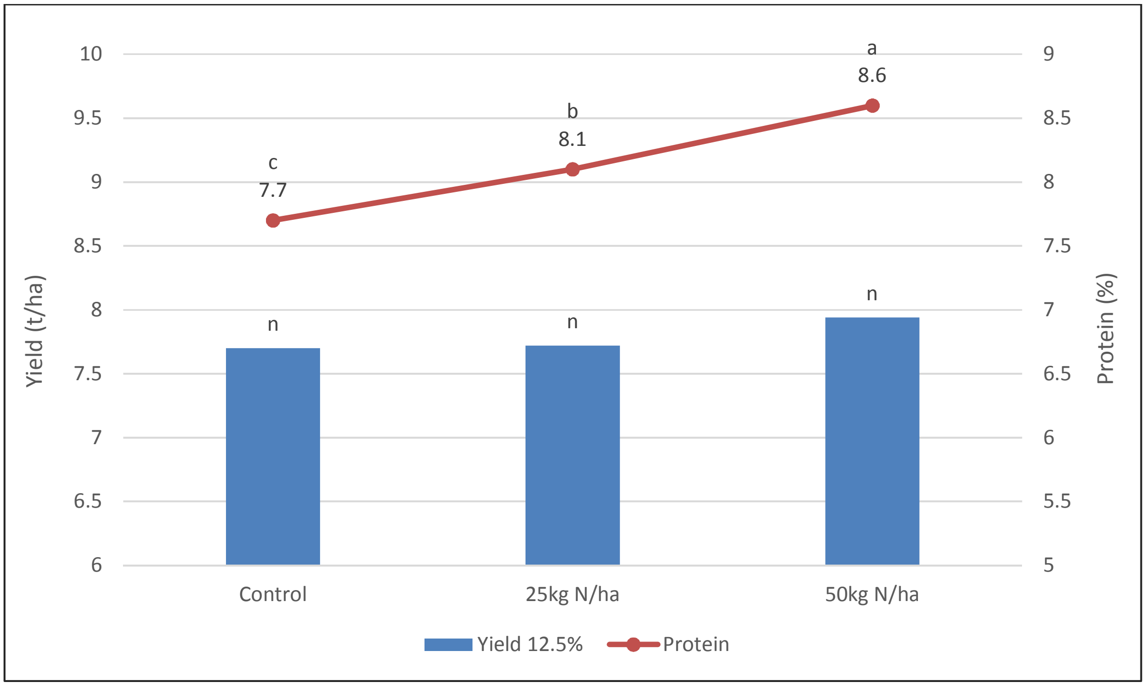

Figure 14. Effect of Nitrogen rate (combined type and timing) on grain yield (bars) and protein (line) – Rokeby. Means followed by the same letter do not significantly differ (p<0.05).

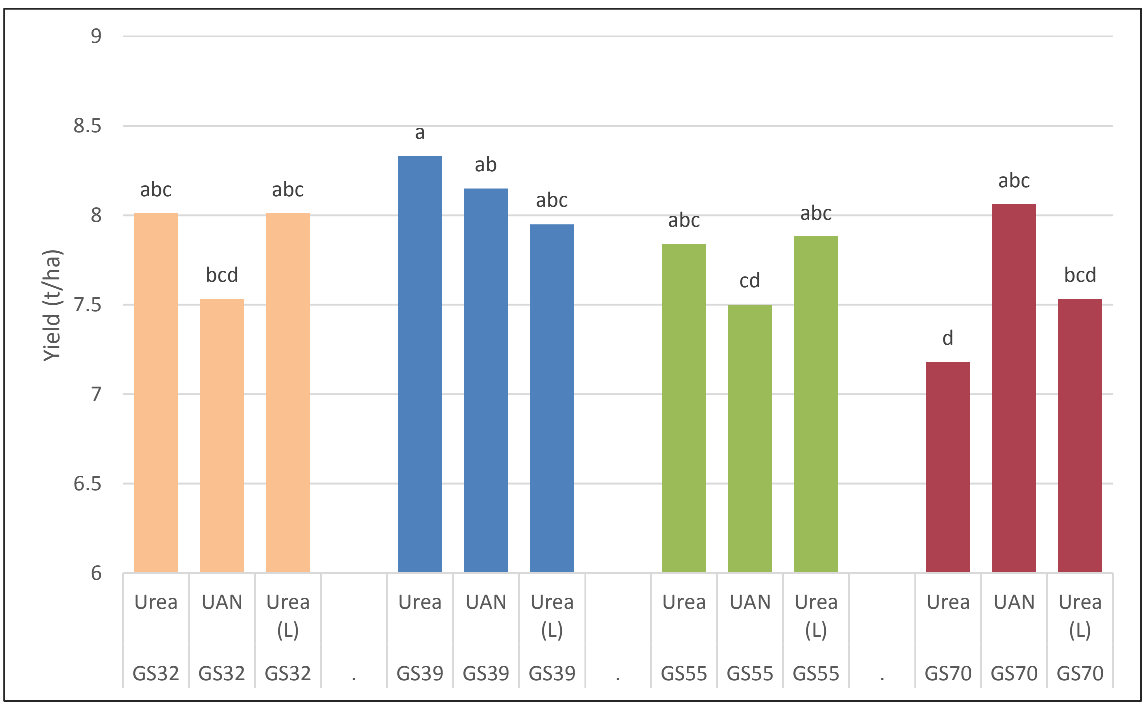

Figure 15. Effect of Nitrogen timing and type (combined rate) on grain yield – Rokeby. Means followed by the same letter do not significantly differ (p<0.05).

Woodbury TAS

- *Early Nitrogen applied before GS32 gave the best yield response*
- *Although not statistically significant there was a protein response to GS39 and GS55 applications of N.*

This was the highest yielding site, was one of the earliest sown and had to 100kg N/ha in three splits applied before GS32.There were progressively smaller responses to N as applications became later, but grain protein concentration increased with the GS39 and GS55 applications giving the largest increases. This site also had the highest screenings, although test weight was still above 76 kg/hl.

Table 16. Summary table of maximum and minimum values.

	Value	Units	Timing	Rate (kg N/ha)	Type	P<0.05
Highest yielding treatment	9.51	t/ha	GS32	25	UAN	No
Lowest yielding treatment	8.06	t/ha	GS39	25	UAN	No
Highest Protein	10.0	%	GS32	50	Urea	Yes
Lowest Protein	8.7	%	Control	25	UAN	Yes

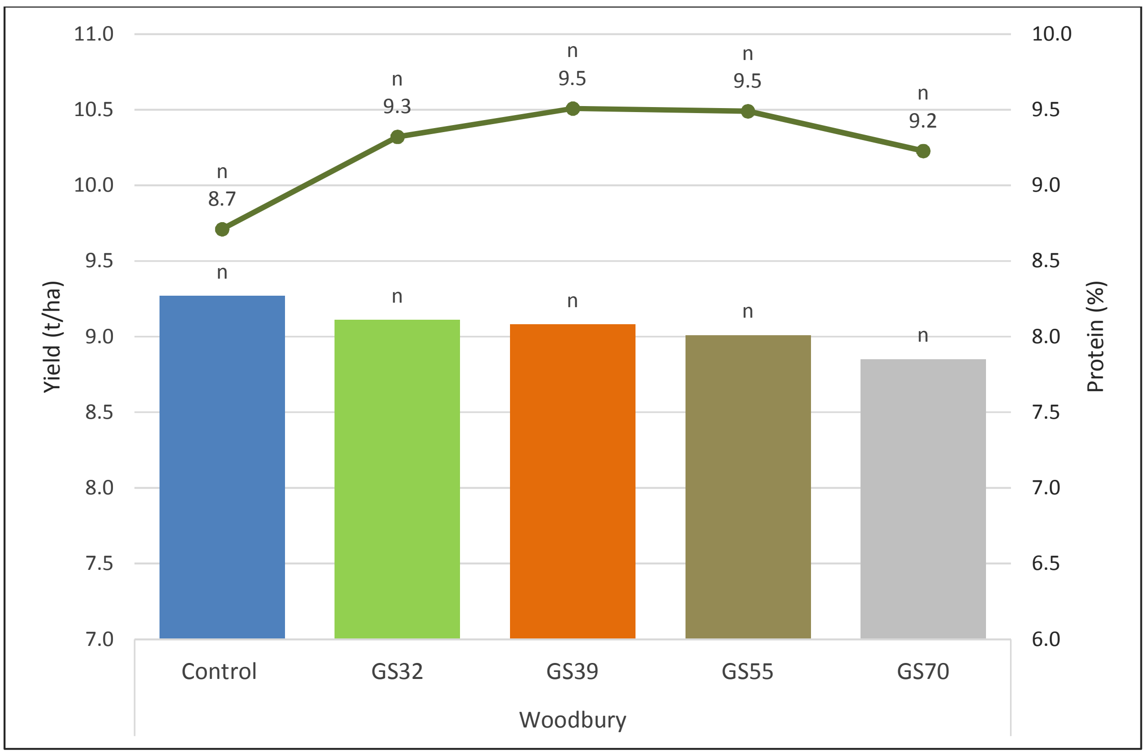

Figure 16. Effect of Nitrogen timing (combined type and rate) on grain yield (bars) and protein (line) – Woodbury. Means followed by the same letter do not significantly differ (*p*<0.05).

Conclusions

When looking across all treatments, there were yield responses at 3 of 8 sites, and protein responses at 5 of 8 sites. This does not necessarily mean there were no N responses, because some of the sites had individual treatments that were significantly different to the control. The mean response overall was 0.29 t/ha and a protein increase in 0.5%.

For the majority of sites the key timing that influenced yield was GS39, there were no differences between product type, and rate had a small effect with the higher rate of 50kg N/ha just having a higher yield than 25kg N/ha. This timing is slightly later than we have previously thought for applying nitrogen for yield, with GS32 being the recognised standard. The data in this trial needs to be interpreted with the 2013 season in mind, as a tighter finish in the spring could mean plant uptake of late applied N could be limited.

The most significant outcome from this series of trials was the very strong effect seen to increasing grain protein. In nearly all cases the higher rate of nitrogen at 50kg N/ha had a more significant effect as did delaying the timing until GS55. Interestingly product type had very little effect on increasing grain protein, but this may well have been influenced more by the softer finish to the season that most sites experienced. The late application at GS70 was just too late to impact on grain protein, even with a liquid fertiliser. This practice is widely used in Europe to increase grain protein but that may suit a longer grain filling period than we experience in Australia.

Guidelines for Growers

- Grain protein as an indicator of N management
  - Previous research has indicated that there is a strong negative correlation between grain yield and protein. The general rule is that if protein is below 11% then it can be assumed that yield was sub-optimal given the growing season, the crop and some yield potential could well have been missed. Unfortunately knowing your grain protein only allows you to look back retrospectively rather than react ‘in season’. It is certainly important that all cereals have grain protein recorded, even if they are for feed and do not go through receivals, as this is a really good guide to N management for that crop.

- Selecting the Right Source - Solid v Liquid N
  - This trial looked into three different forms of nitrogen: granular urea, UAN and liquid urea. The data indicated there were no significant differences between the three products. This may well be related to the 2013 season and the result may differ in drier finishes to the season.
  - In terms comparing liquid N and urea, there are a number of factors that farmers still need to take into consideration, granular urea is by far the cheapest form of N; however granular urea can show an increase in losses via volatilisation when compared to liquid N.
  - Spreading widths are getting wider and wider and there may well be a case for considering fluid fertiliser sources as they can be applied through a boom sprayer at the correct width, compared to a spinning disc spreader which is highly reliant on limited wind, good machine set up and a good quality product.

  - Scorch is a problem to consider despite not being an issue in these trials. When applying liquid nitrogen fertiliser there are some simple rules to follow to minimize scorch or leaf burn:

- Use stream jets as opposed to flat fan nozzles
- Do not apply to water stressed crops
- Do not apply to wet foliage (including dew)
- Do not apply in windy weather when the streams will break up into small drops!
- Do not apply UAN in temperatures > 20°C, so applications are best applied at the end of the day/early evening
- Do not apply after frost, wait at least 1 day for each day of frost
- Do not apply when temperatures are above 25°C, so applications are best applied at the end of the day/early evening
- Do not apply within 3 days of other foliar treatments

- Selecting the Right Rate - Assessing a suitable application rate
  - Assess the Nitrogen supply from the soil which includes both residual nitrogen and also an estimation of what may be mineralised.
  - Estimate a realistic yield potential.
  - Nitrogen removal by wheat is around 20-25 kg N per tonne of grain, with a nitrogen use efficiency of 40 to 50%. Therefore, a crop with a 4 t/ha target yield will need to be supplied with between 140 and 160 kg N per hectare. This will be supplied from the soil or the spreader or a combination of the two.

- Selecting the Right Time - What growth stage should I apply my fertiliser to optimise yield?
  - The main timing for nitrogen fertiliser is just prior to its maximum demand by the crop which is during early stem extension.
  - This project has shown that an inadequate supply of Nitrogen prior to GS32 can still be rectified by treatments up to and including GS39, as long as seasonal moisture and rainfall conditions after this application are suitable for enhanced yield.
  - Applications after GS39 can increase yield in some cases but are more likely to start having a greater effect on grain protein.

Recommendations for future work

Because of the late start to this project we missed a GS32 timing in NSW and even though we used two rates of Nitrogen (25 kg N/ha and 50 kg N/ha) on top of previously applied treatments many sites were under fertilised in 2014 and our aim of getting at least some samples from each trial site >12% protein did not happen.

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- Rob Norton - IPNI
- The growers and the trial managers from the various grower groups who participated in this project

Appendices

Details of communication and extension activities, events and attendances:

- SFS weekly update articles/newsletter
- Mackillop Group weekly update articles/newsletter
- Ground Cover article pending (July 2014)
- GRDC Regional Cropping Solutions Networks
- GRDC Southern Weekly Update (with Chris Brown)
- Trial Report write up for SFS Annual trials results book (attached)