Use of crop sensors for determining nitrogen application during stem elongation in wheat

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Take home messages

- *The optimum nitrogen (N) rate, regardless of timing, to maximise yield was 75kg N/ha (4.3t/ha), though protein content was maximised at higher N rates.*
- *N timings examining a 50% split of N applied after the end of tillering (GS30) and third node (GS33) were not significantly different in yield to single N doses applied at seeding and after the end of tillering (GS30)*
- *Normalised difference vegetative index (NDVI) measured early in stem elongation illustrated lower fertility this year (starting N = 60kg N/ha compared to 2008 starting N = 253kg N/ha). This also correlated to much lower plant uptake of N at GS30 than was recorded in the equivalent trial in 2008. Thus, NDVI should not be used to compare results across seasons without specific reference to the growth stage of the crop.*
- *Further investigation is required to define correlations between crop reflectance (NDVI) and N uptake.*

Background

Research conducted by BCG and FAR since 2001 has led to a movement away from nitrogen (N) application at sowing (pre-drilled or deep banded). Common practice is now to apply most of the crop's needs in-crop during stem elongation (GS30 – 39). This change in timing allows inputs to be better matched to seasonal conditions and has led to the use of crop sensors, so that the crop itself can now be used as an indicator of its need for N.

In this trial, N timings developed from previous canopy management studies have been expanded to explore whether crop sensors can be used to support N decision making in-crop where N is either applied in a single dose at GS30, or split during stem elongation between GS30 (end of tillering) and GS33 (third node, early flag emergence).

How do crop sensors work and what is NDVI?

- Crop reflectance sensors, such as the Crop Circle and GreenSeeker, measure light reflectance from the crop canopy at different wavelengths of light.
- Reflectance, in the red and infrared wavelengths is strongly influenced by the chloropyhll content ('greenness') and biomass of the crop. The greater the chlorophyll content of the crop the less red light is reflected.
- With greater biomass content, there is an increase in near infrared (NIR) reflectance.
- These wavelengths are used to calculate NDVI (normalised difference vegetative index) for the crop, which is a index of canopy greenness and is one of many indices used in crop sensing.

- $\text{NDVI} = \dfrac{\text{reflectance at red} - \text{near infrared wavelength}}{\text{reflectance at red} + \text{near infrared wavelength}}$
- For most agricultural crop canopies readings are between 0 and 1. The higher the reading the greater the canopy greenness.
- Further analysis of this years trial data is planned to examine the correlation of other vegetative indices to N uptake, biomass and N concentration. This paper represents preliminary results looking only at NDVI.

Aim

To determine whether crop reflectance at particular wavelengths of light can be used during stem elongation to determine N content of the plant and the need for applied N. This trial is part of GRDC Project SFS 00017.

Method

Location:	*Mayo Park Farms*, Lubeck
Replicates:	4
Sowing date:	17 May 2009
Seeding density:	150 plants/m²
Fertiliser:	45kg/ha MAP (10% N, 21.9% P)
Crop type:	Derrimut wheat
Seeding equipment:	Knife points, press wheels on 22.5cm row spacing.

Agronomy

Derrimut wheat was established in a large plot replicated trial (individual plot 6m x 30m) using farm scale equipment, following oaten hay in 2008. The crop was fertilised with 5 different N rates (0, 25, 50, 75 and 100kg N/ha) applied at 3 different timings (Table 1). Fertiliser product used was granular urea (46% N). Growing season rainfall for the trial site was 305mm (April – Oct).

Table 1. N timing and rainfall subsequent to application (mm).

N timing	Description	Date of application	Rainfall following
1. 100% Pre-drill	Single dose 8mm (25 April)	21 April	5.5mm (24 April)
2. 100% GS30	Single dose – at start of stem elongation	4 August	4mm (10 August)
3. 50% GS30 50% GS33	Split dose applied at start of stem elongation and third node	4 August 8 September	4mm (10 August) 1mm (on the day)

The trial was assessed at regular stages for crop structure assessments, dry matter and N content analysis, green area index, assessment with a handheld Greenseeker, and Yield Prophet® simulations. The trial was harvested on 15 December. Grain protein and quality was also measured. In order to determine whether there was a relationship between plant N uptake and crop reflectance (measured with the Greenseeker), above ground dry matter was assessed at key growth stages and measured for % N content. N uptake was determined by multiplying the dry matter by the % N content of the sample.

Other crop sensors were measured at the same stages as the Greenseeker. However, for the purpose of this report this data was not presented.

Results

Soil N

Based on soil samples taken on 7 April there was 60kg/ha of available N in the soil (0-100cm) following the previous year's oaten hay crop, with 40kg N/ha in the top 40cm of the profile. These figures were based on both ammonium and nitrate N. This compared to 253kg N/ha following lentils in last season's trials.

Crop Structure

There were no significant differences found in plant emergence between any of the pre-drilled rates. All treatments were established at 157plants/m^2. In relation to the number of tillers across the N rates, there was no difference observed.

The effect of N-timing on dry matter at flowering (GS61) is shown in Figure 1. The application of N resulted in a significantly higher biomass compared to the zero N control. However, no difference was apparent in biomass resulting from the timing of N application.

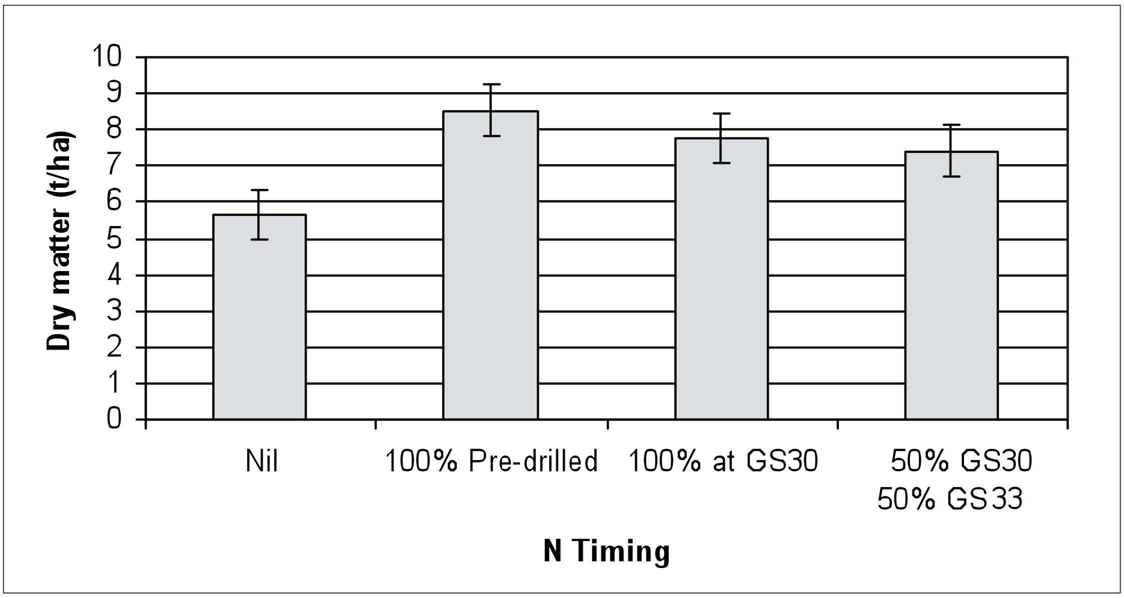

Figure 1. The effect of N timing, including all rates, on dry matter at flowering (GS61), (P<0.001, LSD = 1.41, CV 16.2%).

Crop reflectance – crop canopy greenness (chlorophyll content & biomass)

Crop canopies of the different N rates and timings were scanned with the crop sensor, Greenseeker (Trimble) Reflectance measured by the Greenseeker was presented as NDVI (normalised difference vegetative index) and not tranformed for the simplicity of this article.

Differences in NDVI due to different rates of pre-drill N did not show up in the initial crop scanning carried out at tillering GS22, but were apparent at the start of stem elongation (GS30) and at all later assessments (Figure 2).

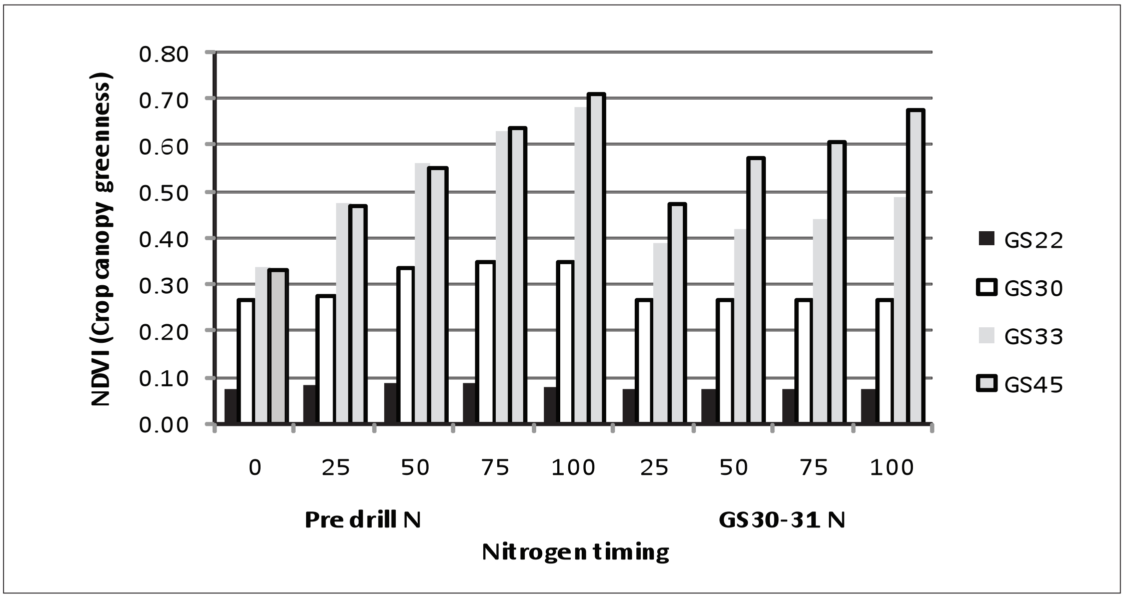

Figure 2. Influence of N rate and timing on crop canopy greenness (NDVI) when assessed at tillering (GS22), end of tillering (GS30), third node (GS33) and booting (GS45).

Nitrogen timing

Crop canopy greenness (measured as NVDI) peaked at GS33 (third node) where N was pre-drilled but peaked at GS45 (booting) where N application was delayed until stem elongation (Figure 3). Where N rates were split equally between GS30 and GS33 the peak in NDVI was much less pronounced than with the earlier timings.

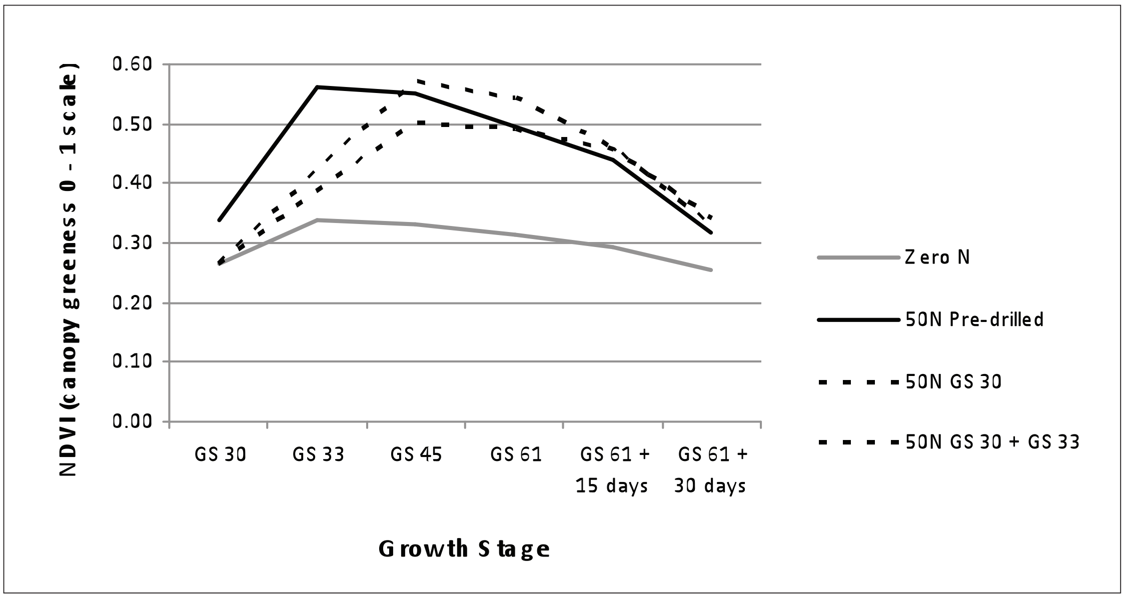

Figure 3. Crop canopy greenness (measured as NDVI) of zero N, 50kg N/ha pre sow, 50kg N/ha GS30 and 50kgN/ha split GS30/33 (expressed in terms of NDVI measured with Greenseeker).

Nitrogen rate

Irrespective of N timing the crop sensors clearly registered the N response relative to the zero N plots (Figure 4). Increasing N rates produced higher peaks in NDVI. For all N rates, the shape of the curve was related to N timing (Figure 4 and 5).

Agronomy

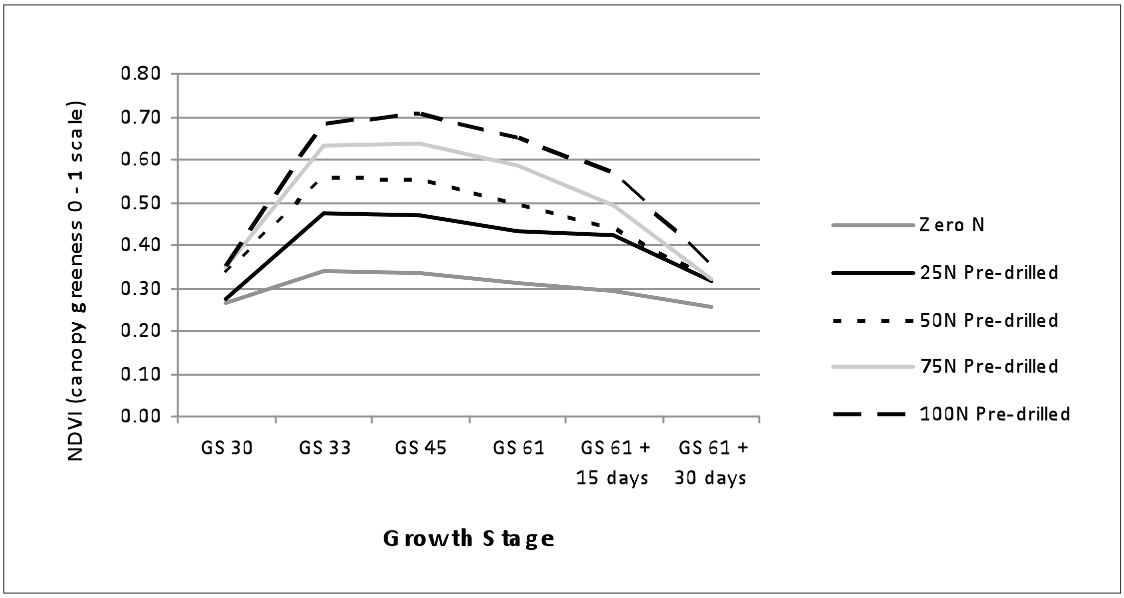

Figure 4. Influence of N rate (0, 25, 50, 75 and 100kg N/ha) applied pre sowing on crop canopy greenness (expressed in terms of NDVI measured with Greenseeker).

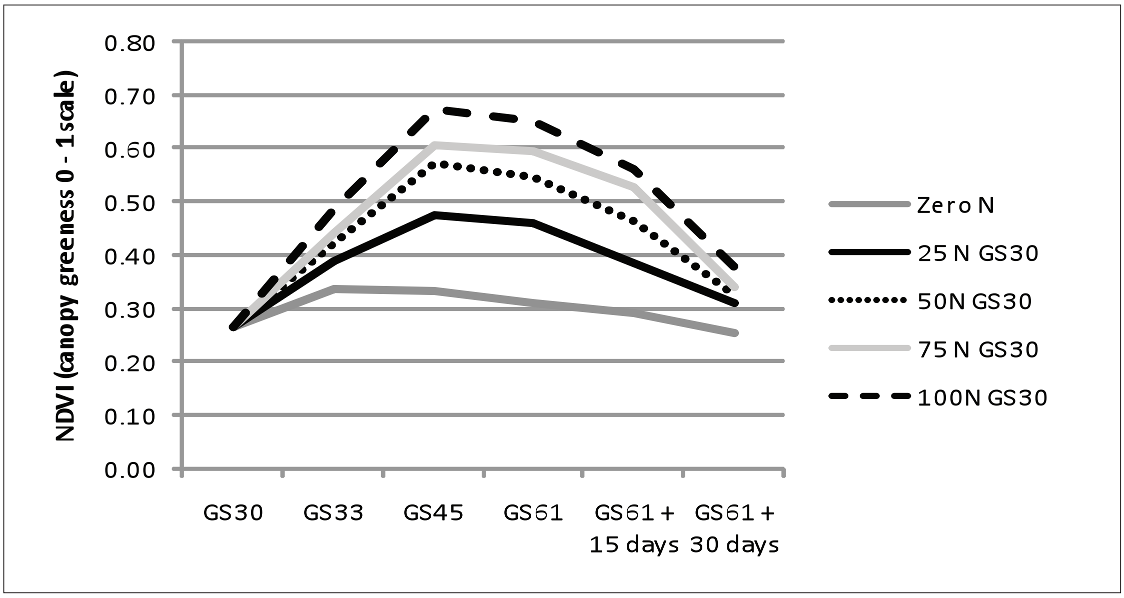

Figure 5. Influence of N rate (0, 25, 50, 75 and 100kg N/ha) applied at GS30 (start of stem elongation) on crop canopy greenness (expressed in terms of NDVI measured with Greenseeker).

Overall, later applied N resulted in slightly smaller but later peaks in crop canopy greenness (NDVI) with greenness peaking at GS30 – 45 for predrilled N and not until GS45 where N was applied at GS30.

Correlation between N uptake and crop reflectance (NDVI)

By scanning those plots that received different rates of N at seeding, correlations between N uptake in the plant and crop reflectance were assessed from tillering (GS22) to grain fill (GS80). The strongest correlation between crop reflectance (NDVI) measured with the Greenseeker and N content of the plant was found to be at GS32 with a correlation of $R^2 = 0.76$ (Figure 6).

In 2008, the same trial was sown into a lentil stubble rather than oaten hay. The starting soil N was 253kg N/ha (0 – 100cm). In this more fertile trial, different rates of pre-drilled N had little effect on crop canopy greenness, though NDVI still correlated to plant N uptake of plants at different growth stages (Figure 7). This year's results found crop NDVI at GS30 registered no more than 0.35 which correlated to 40 – 45kg N/ha, compared to approximately 0.82 NDVI at the same stage in 2008 and N uptake of 70 – 75kg N/ha. Clearly the NDVI readings of the crop revealed the lower fertility of this year's trial and the lower N uptake at the start of stem elongation.

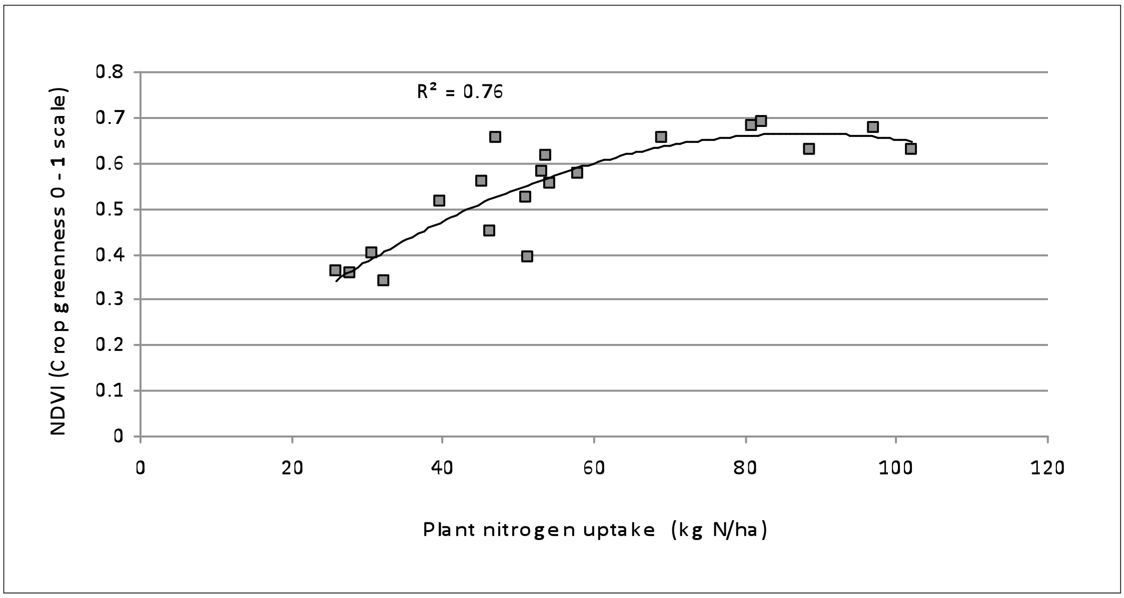

Figure 6. Correlation between N uptake (kg N/ha) and crop canopy greenness (expressed in terms of NDVI measured with Greenseeker) at GS32 following application of different rates of pre-drilled N.

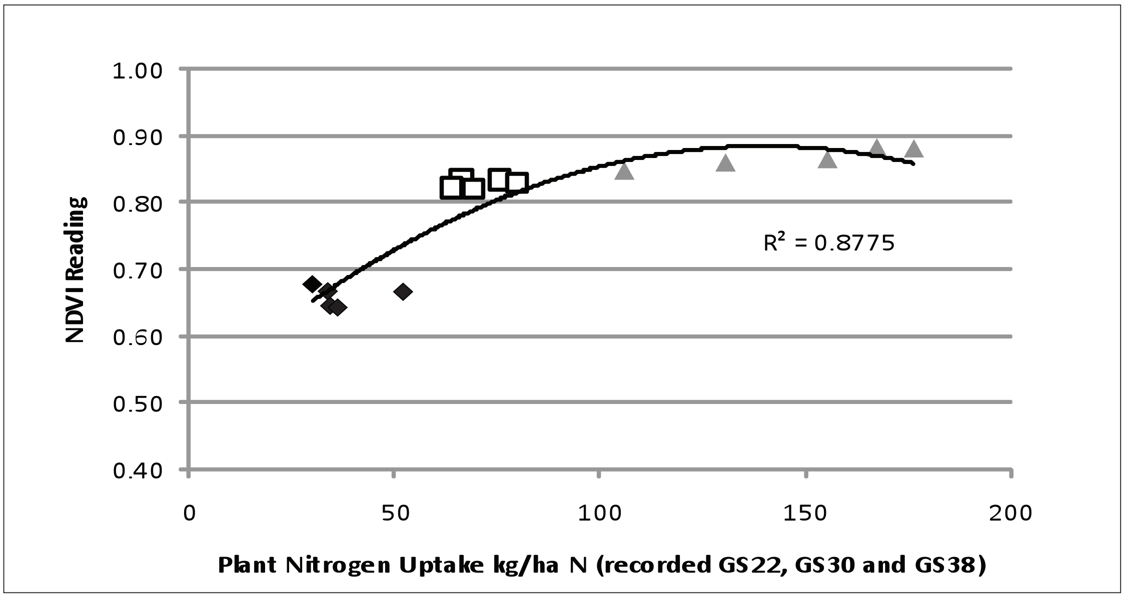

Figure 7. Correlation between N uptake (kg/N ha) and crop canopy greenness (expressed in terms of NDVI measured with Greenseeker) at GS22 (♦), 30 (☐) and 38 (▲) following application of different rates of pre-drilled N in 2008 following lentils (soil N 0-100cm 253kg N/ha) – Derrimut wheat, Lubeck, Victoria.

Yield (t/ha) and quality data (% protein & screenings)

There was a significant yield increase (approximately 1.05t/ha) associated with N application, with the optimum response obtained at 75kg N/ha of applied N (Figure 8). The 75kg N/ha of applied N was not significantly higher yielding than 50kg N/ha with no difference found between 50, 75 or 100kg N/ha. There was also no significant yield differences due to the timing of N, the same yield results were obtained whether the N was applied all pre-drilled (21 April) or split during stem elongation (August 4 and September 8) and just prior to flag leaf emergence (GS33 – third node). The mean yield of the different N timings was 4.1t/ha.

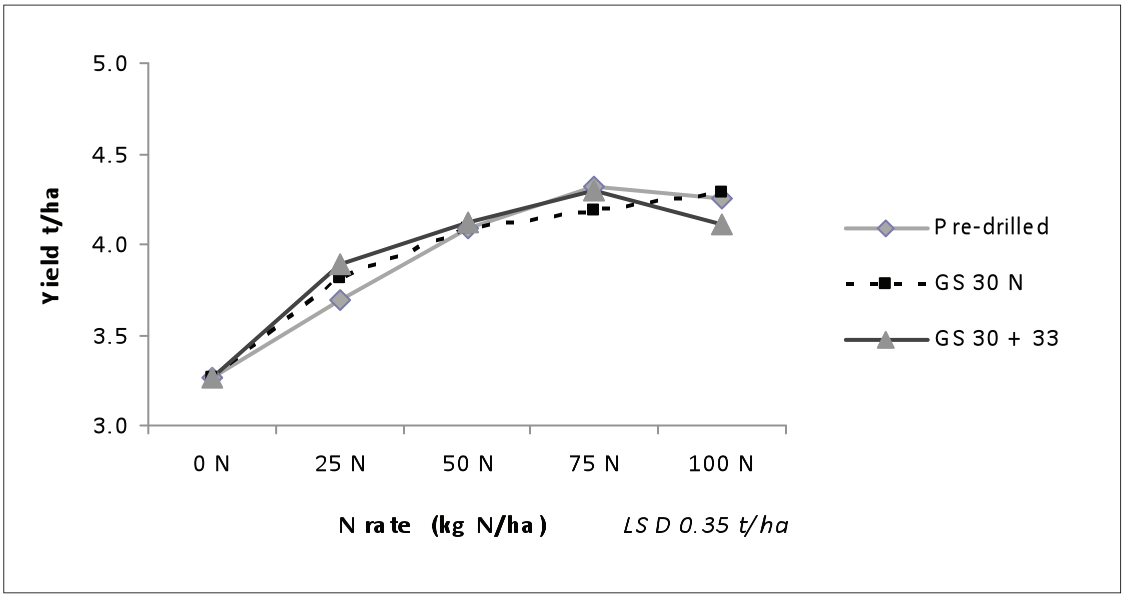

Figure 8. Influence of N rate applied as a single doses at pre-drilled, GS30 and as a 50% split GS30 & GS33 on yield (t/ha).

Protein and screenings data

Protein levels in the trial were low with no grain samples reaching 11.5% (H2 grade) protein. At lower rates of applied N, 50kg N/ha and below, there was no significant difference in protein, though there was a trend for proteins to be higher wherever N was top-dressed at stem elongation (Figure 9). This superiority became statistically significant at 75kg N/ha and 100kg N/ha. The mean protein (%) levels resulting from the different N timings were the pre-drilled treatment at 8.5%, GS30 at 8.8% and GS30 & 33 at 9.1%.

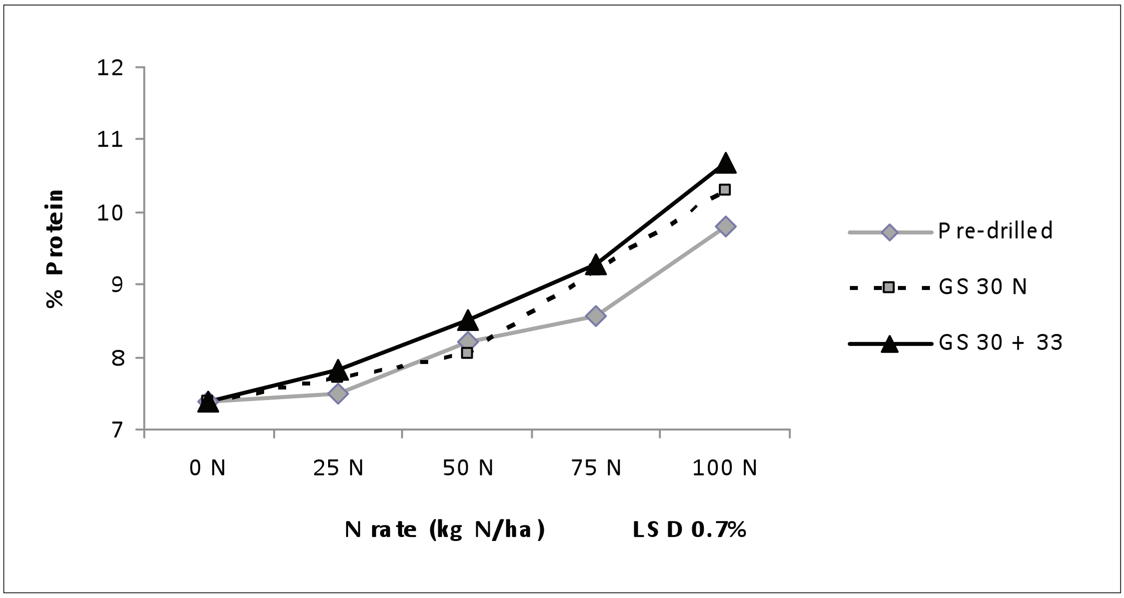

Figure 9. Influence of N rate applied as a single doses at pre sowing, GS30 (and as a 50% split GS30 & GS33 on protein %).

In terms of pre-drilled N, screenings were reduced as applied N increased, though the biggest reductions occurred between 0 – 50kg N/ha (Figure 10). N applied at stem elongation initially reduced screenings but then increased relative to the untreated. As a consequence, screenings for N applied during stem elongation were, in the majority of cases, greater than 5%.

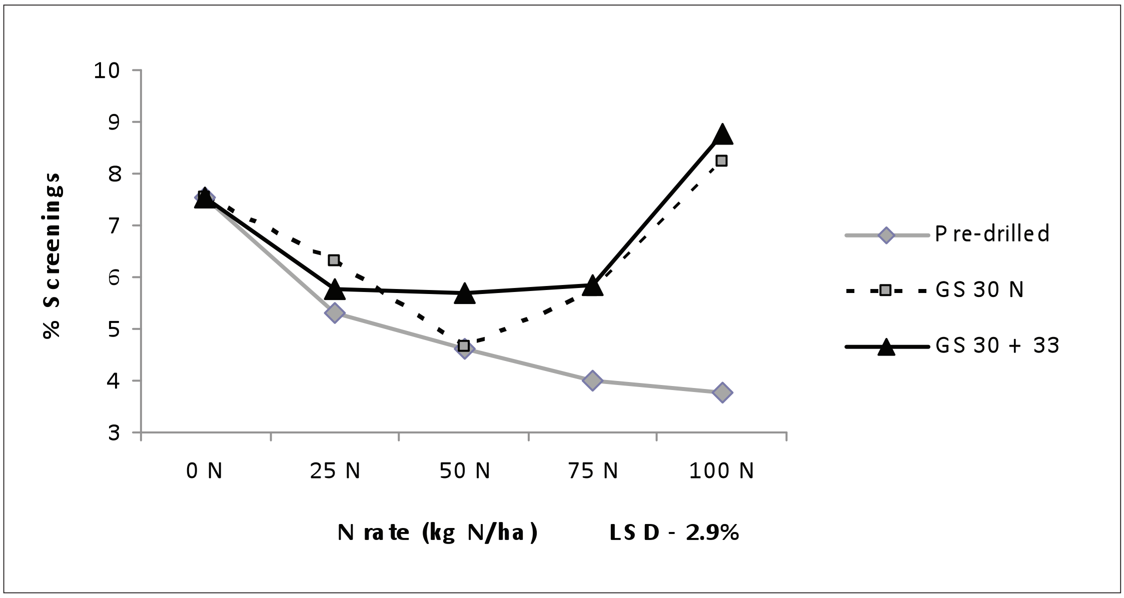

Figure 10. Influence of N rate applied as a single doses at pre sowing, GS30 and as a 50% split GS30 & GS33 on screenings (%).

Gross margins

Optimum margins were generated by applied N rates of 50 – 75kg N/ha with timing having little influence on overall margin (Table 3). Above 75kg N/ha there was little yield response to extra N and the protein increases did not attract a premium. Since there was no protein premium for grain samples which had screenings over 5% and protein less than 11.5%, the increases in protein created by stem elongation N at higher N levels did not improve margins. Pre-drilled N, whilst having lower protein levels than the stem elongation single and split doses benefited from screenings that were generally lower than 5%.

Table 3. Influence of N rate applied as a single dose at pre-drilled, GS30 and as a 50% split GS30 & GS33 on yield, quality and gross income after urea cost.

N Timing	N Rate	Yield t/ha	% Protein	% Screenings	Grade $/t	Margin $/ha*
1. Nil	0	3.26	7.4	7.6	AGP1	**548**
2. 100% Pre drill	25	3.69	7.5	5.3	AGP1	**582**
	50	4.09	8.2	4.6	ASW1	**639**
	75	4.32	8.6	4.0	ASW1	**642**
	100	4.25	9.8	3.8	ASW1	**592**
3. 100% GS30	25	3.81	7.7	6.3	AGP1	**602**
	50	4.08	8.1	4.7	ASW1	**638**
	75	4.19	9.2	5.8	AGP1	**590**
	100	4.29	10.3	8.3	AGP1	**569**
4. 50% GS30 & 50% GS33	25	3.89	7.8	5.8	AGP1	**615**
	50	4.12	8.5	5.7	AGP1	**616**
	75	4.30	9.3	5.9	AGP1	**608**
	100	4.11	10.7	8.8	AGP1	**539**

**Margin is based on gross income minus urea cost (at $700/t). Growers should apply their own application costs, the following are guidelines only. Pre drilling application costs – $33/ha, Top dressing – $9/ha, at sowing (triple bin – $5/ha). APW1 @ $185/t, AGP1@$168/t and ASW1@$175/t.*

Interpretation

In order to make the greatest use of crop sensors for variable rate N application, the majority of N would need to be applied at stem elongation, since this is the key period in the crops development where reflectance of the crop (at specific wavelengths of light) can be related to N levels in the plant and N supply from the soil.

If a split N application during stem elongation (GS30 – 39) could be employed in the knowledge that it was not inferior to other N strategies, then it would give greater flexibility to respond to the season (eg spring rainfall). It would also allow the growth changes (eg NDVI 'change map') to be recorded with crop sensors (on a spatial basis) following the first application. Thus growth rate in different parts of the paddock following the first application as assessed with the crop sensor might be the basis of variable N rate for the second dose.

This trial illustrated similar returns from split N applications (GS30 and GS33) as for single N applications applied at seeding and GS30 – 31, in a trial where N response was higher than in any previous trials in this series. This gives greater confidence that these more flexible N timings might have the potential to be employed with spatial crop sensing data and variable rate N application in the future.

Could plant N uptake have been predicted in this year's crop from last year's relationship between plant N uptake and NDVI?

In 2008, a plant N uptake of 40 – 45kg N/ha equated to a Greenseeker reading of 0.65-0.7 at the tillering stage (GS22), whilst under lower fertility this season the same N uptake wasn't registered until GS30, but with an NDVI of only 0.35. Clearly the NDVI status of the crop revealed the lower fertility of this year's trial, but without reference to growth stage, similar N uptake in plant could be represented by 2 different NDVI scores. This would illustrate that NDVI correlation to N uptake cannot be used without specific reference to growth stage, since the reading is related to both biomass and N concentration.

Further analysis of data using different vegetative indices is now being undertaken to see if correlations with N uptake or the parameters of biomass and N concentration is better than those correlations with NDVI.

Acknowledgments

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