USE OF CROP SENSORS IN WHEAT AS A BASIS FOR APPLYING NITROGEN DURING STEM ELONGATION

Rob Craigie and Nick Poole

Foundation for Arable Research (FAR), PO Box 80, Lincoln, Canterbury, New Zealand

Abstract

Wheat crops are responsive to the application of nitrogen (N) fertiliser typically increasing yield by 40% in FAR trials over unfertilised crops. Currently, most growers calculate their N requirements with a nutrient budget using soil mineral N test results and potential yield. This practice may result in insufficient or excessive N fertiliser rates in any given year and across a paddock with variable soil mineral N and yield. Therefore, a more accurate estimate of plant N requirements is required for economic and environmental sustainability.

Measurement of canopy reflectance with crop sensors has the potential to use the plant as an indicator of N requirements. In wheat crops N is typically applied in two or three applications. It is envisaged that normalised difference vegetation index (NDVI) may be used to better assess N requirements at the second and third applications to determine which zones will or won't respond to further applications of N. Therefore, crop sensors, measuring the reflectance from the cereal crop canopy, may offer a better opportunity of matching crop needs to nitrogen input, when combined with GPS technology.

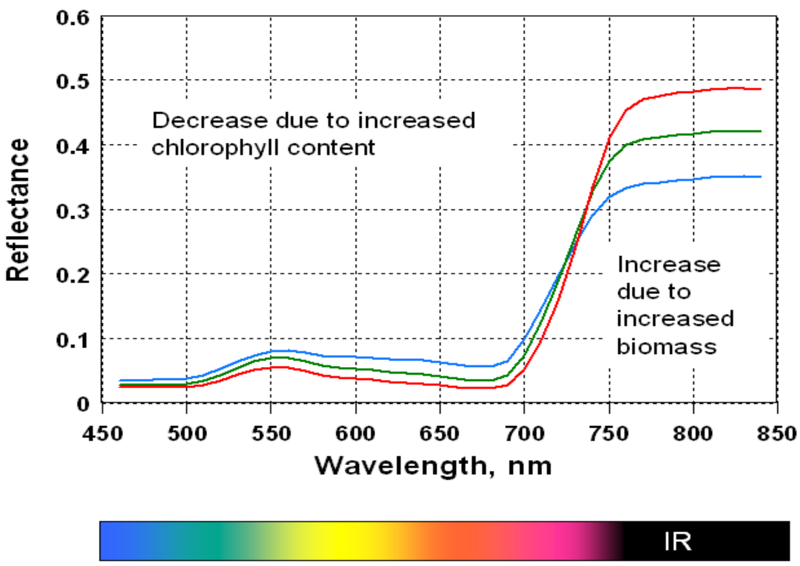
The objective of this study was to determine if crop sensing could be used to assess the in-season plant N status of wheat under different sites, environmental conditions and cultivars. For two seasons, crop NDVI has been collected with a Greenseeker optical sensor as a measurement of crop N status and dry matter production. Following the application of N, a significant and strong curvilinear relationship was found between N uptake and NDVI.

Introduction

Although there are a number of ways of estimating the nitrogen requirement for a crop, for example soil nitrogen testing and budgeting, tractor mounted crop sensors may offer the following advantages in better N management:

- Instant assessment of canopy N status.
- Indication of N status across the whole paddock.
- Objective measurement of crop response to applied N (i.e nitrogen rich strips)
- Better indication of N supply to the plant than soil testing, since the plant can be an indicator of available N on a spatial basis.
- Could be more easily linked to variable rate fertiliser.
- Form the basis of a change map where the grower could use the sensor to record the degree of change or growth following an earlier N application.
- Management of other inputs that could be linked to crop canopy size and N status such as plant growth regulator linked to lodging risk, disease control linked to canopy density.

Current active light source (ALS) sensors such as Crop Spec®, Grenseeker® and Crop Circle® measure the amount of reflectance at specific wavelengths of light, particularly in the red and near infrared wavebands. Since light reflected from the crop diminishes with distance from the crop, reflectance values from the specific wavelengths are ratioed so that any difference in distance from the target is nullified. These ratioed reflectance values from different wavelengths can be made into a plethora of vegetative indices the most most common of which is NDVI (Normalised Difference Vegetative Index).



As nitrogen application increases there is an increase in biomass and increased NIR reflectance (move from blue line to red line at 760nm - 800nm+) but increased chlorophyll content reduces visible red reflectance (move from blue line to red line at 650nm)

NDVI =

$$\frac{(\rho_{NIR} - \rho_{VIS})}{(\rho_{NIR} + \rho_{VIS})}$$

Where ρ is crop reflectance at that wavelength of light

E.g.
NIR – Near infrared – ρ=0.3
VIS – visible red ρ=0.05

$$\frac{(0.3 - 0.05) = 0.25}{(0.3 + 0.05) = 0.35}$$

= NDVI of 0.71

Figure 1. Typical reflectance spectra for a crop (Reusch, 2008) NDVI=reflectance NIR-reflectance Red/ reflectance NIR+ reflectance Red

Crop sensor measurements are related to increased chlorophyll content of the crop canopy which is linked to nitrogen concentration, which as it increases and the leaf gets greener reduces the reflectance in the visible red. Plants absorb light in the red zone of the spectra. As the biomass of the crop increases so does the near infrared reflectance, therefore as the crop grows with adequate water and nitrogen supply biomass and chlorophyll content increase, as a consequence NDVI increases (by virtue of greater reflectance in NIR and lower reflectance in visible red).

Strong relationships between NDVI and N uptake in wheat have been reported by Flowers et al. 2003. In 2009 a research project was initiated to examine the use of crop sensing to assess the in season N status of wheat in New Zealand.

Methods

Three trials with 15 to 23 N rate (0 to 310 kg N/ha) and timing treatments were undertaken within irrigated commercial wheat crops at Dorie and Wakanui, Canterbury, New Zealand. Plots were 10 m long and 3.0 m wide with four replicates in a randomised block design. The crops were managed by the grower for all inputs except N. Greenseeker NDVI assessments, dry matter and N % measurements were taken at GS32, 39 and 61.

Results and discussion

NDVI values changed with both growth stage and soil nitrogen status (Figure 2). At early stem elongation (GS32) the NDVI was low (0.42) on the nil nitrogen treatment at the Dorie site reflecting the lower soil mineral N status (52 kg N/ha) in contrast with the Wakanui site (NDVI 0.56, soil mineral N 90 kg N/ha). Also, there was a greater increase in NDVI with applied nitrogen at the Dorie site. If little or no nitrogen has been supplied to the crop at the start of stem elongation the NDVI value could be a useful spatial indicator of soil nitrogen reserves in the paddock, prior to fertilizer application in the spring (N.B. using N rich strips or calibration strips to verify that any differences in biomass and chlorophyll content are due to nitrogen rather than other nutritional factors).

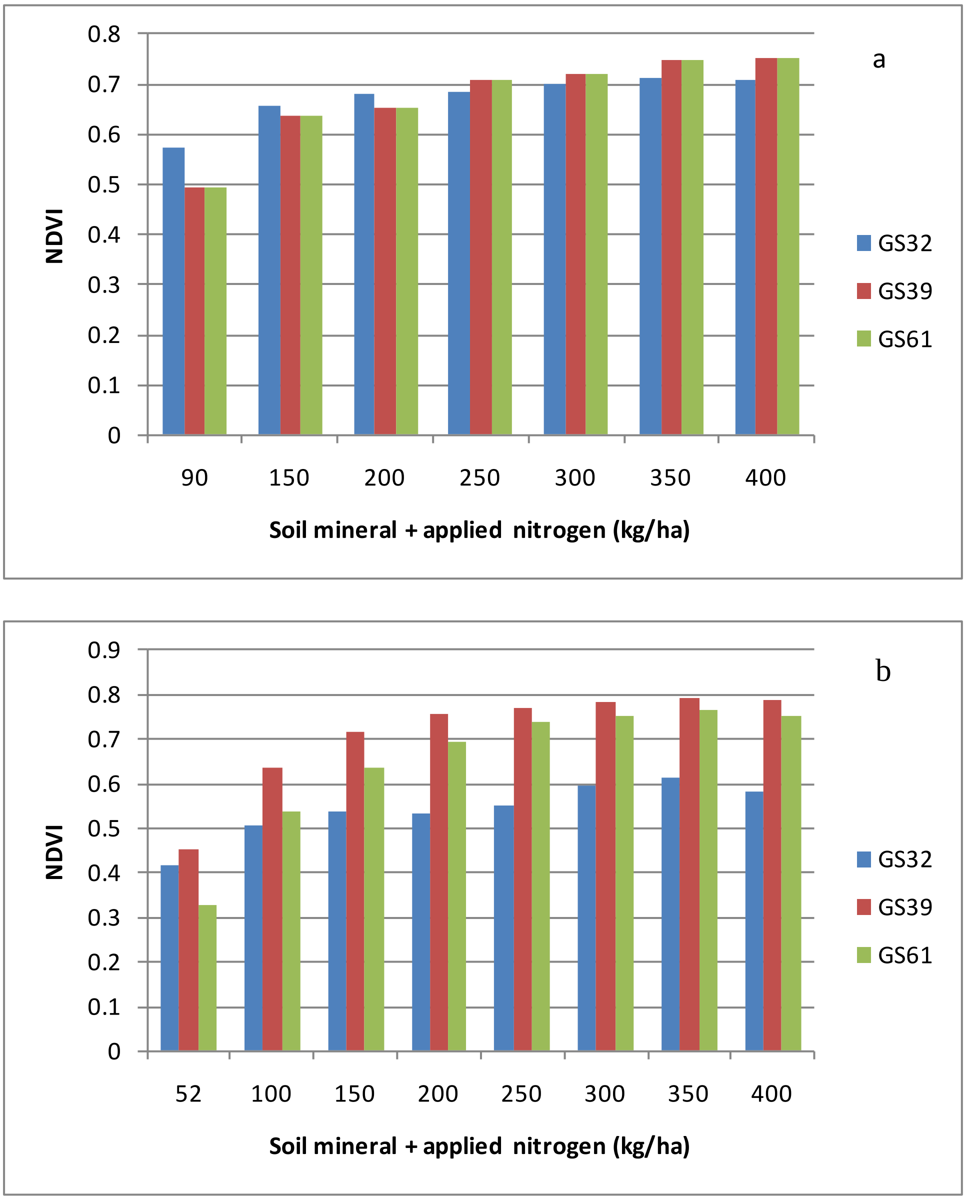


Figure 2. A comparison of NDVI values recorded from a wheat crop fertilised with seven rates of nitrogen a) cv Conquest, at Wakanui, and b) cv Amarok, at Dorie, Canterbury, 2009-2010 season.

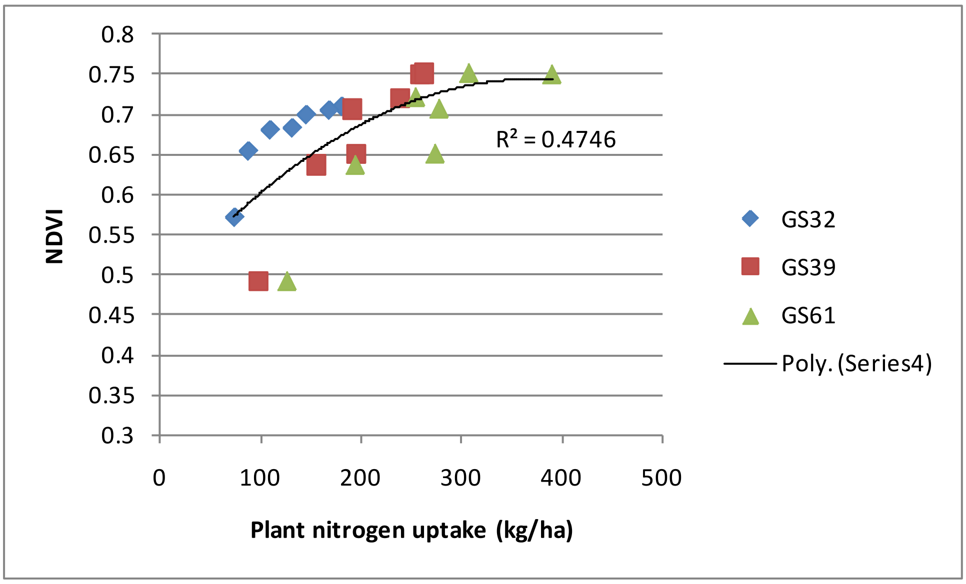


Figure 3. Relationship between N uptake and the normalised difference vegetative index (NDVI) assessed at three different growth stages from early stem extension to flowering (GS32 – GS61) cv Conquest, Wakanui, Canterbury.

Whilst NDVI clearly relates to applied nitrogen, it is the relationship with nitrogen in the plant that ultimately determines the reflectance signal (i.e. whether the N is taken into the plant). NDVI gave a good relationship with the nitrogen content of the plant biomass (Figure 3), though the correlation becomes weaker at NDVI levels approaching 0.75 (due to saturation of greenness). Good relationships between NDVI and plant nitrogen uptake have been observed to be strong throughout stem elongation and up to flowering (GS61).

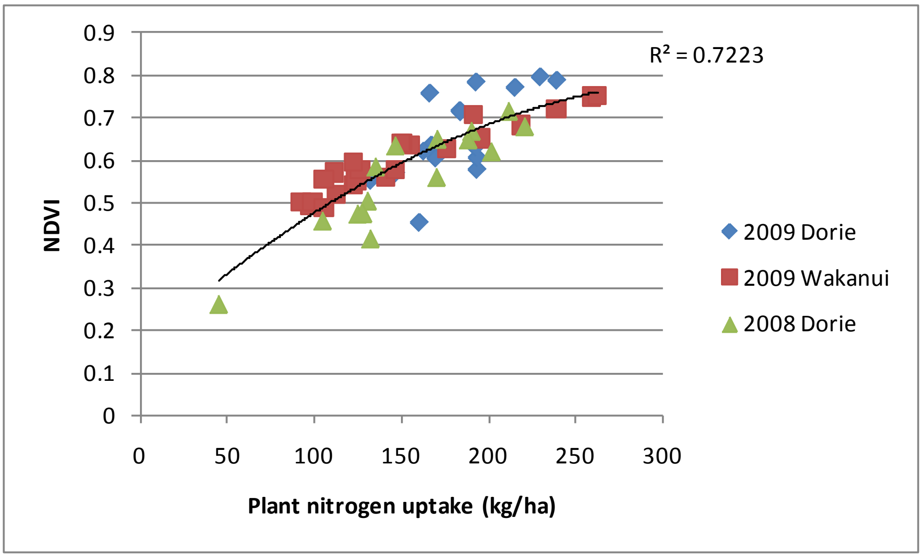


Figure 4. Relationship between N uptake and the normalised difference vegetative index (NDVI) at GS39 at three sites in 2008 and 2009.

NDVI measured at GS39 was also able to account for 72% of the variation in N uptake across three sites and two years. Figure 4 shows the curvilinear relationship between N uptake and NVDI across the sites.

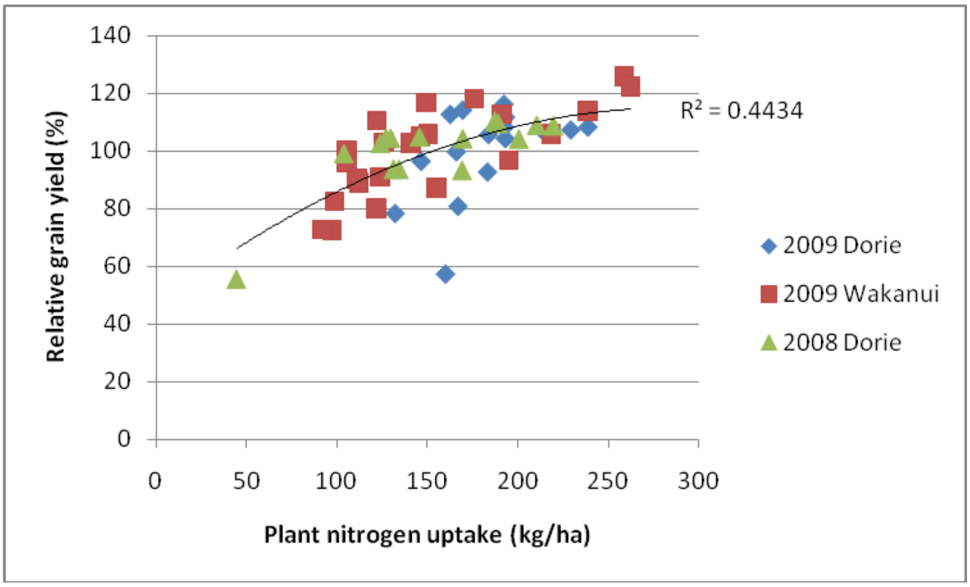


Figure 5. Relationship between N uptake and the relative grain yield at GS39 at three sites in 2008 and 2009.

If a critical N uptake value that relates to maximum grain yield could be derived it appears the Greenseeker could assess the N status of the canopy. Also, the relationship needs to be developed for GS39, the typical timing for a second N application to a wheat crop in New Zealand. There is a good relationship between plant N uptake and relative grain yield over the three trials (Figure 5). The critical N uptake value is about 220 kg N/ha at GS39. This value equates to a canopy N status of about NDVI 0.7 for maximum yield.

These results are promising but a method still needs to be developed to calculate the optimum N rate from the N status of the canopy measured by the crop sensor. There are also a number of complicating factors which need to be considered. Absolute NDVI values are influenced by a range of factors other than nitrogen that could distort NDVI values from one paddock to the next. For example:

- different cultivars and row spacing
- soil nutrition imbalances e.g. pH, other nutrient deficiencies other than nitrogen
- weed patches

These complicating factors have lead to the use of paddock N Rich strips or N ramps (where more than one rate of N has been applied at sowing as a test strip) which give the grower a gauge as to how much nitrogen is being supplied from the paddock, but also some degree of confidence that the difference in the crop canopy NDVI is due to nitrogen uptake. In some cases the grower still makes the choice on the overall N dose to be applied and crop reflectance values (and calculated indices) are used to determine variable rate N distribution based on the variation in NDVI recorded on a pass through the paddock. This pass through the paddock becomes the basis of a calibration strip which sets the range of nitrogen rates for application.

Conclusion

The Greenseeker crop sensor shows a promising ability to assess the N status of a wheat canopy. Following the application of N, a significant and strong curvilinear relationship was found between N uptake and NDVI. However a method still needs to be developed to calculate the optimum N rate from the N status of the canopy measured by the crop sensor. The current overseas commercial practice is to scan an average region of the paddock as a reference and to vary the N rate according to the relative difference between the crop and the reference strip.

References

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