Predicting spring nitrogen for perennial ryegrass seed crops from NDVI

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Abstract

Nitrogen (N) fertiliser makes up approximately 15 % of the total cost of growing a perennial ryegrass seed crop. Therefore accurate estimates of applied N fertiliser are important both financially and environmentally. Optical sensors may have the ability to determine the nitrogen requirements and the output expressed as normalized difference vegetation index (NDVI).

In two experiments carried out in the 2008/09 season a treatment based on estimating nitrogen requirements using NDVI calculations was implemented. Results were promising with NDVI reading increasing as N rate increased until a saturation level. The NDVI readings were then converted in to a nitrogen nutrition index (NNI) where resulting treatments ranked in the top statistical seed yield group in both experiments. In each experiment this technique applied a lower or equal amount of N fertiliser compared to standard best practice while achieving similar seed yields.

If NDVI and NNI can be used to predict N requirement of perennial ryegrass this method could provide a tool for variable rate N applications based on crop variability within a field.

Introduction

Perennial ryegrass (*Lolium perenne* L.) seed production is responsive to the application of nitrogen (N) fertiliser, averaging 36% response above control treatments in 17 trials throughout Canterbury (Rolston *et al*. 2008). The availability of nitrogen to the ryegrass seed crop is a major determinant of seed yields. At various points throughout the growing season N content varies between 5 (possible in early spring) and 1.5% (typical at harvest) of herbage dry matter. Nitrogen influences dry matter production, tillering and therefore number of inflorescences which develop to maturity. Currently best practice in New Zealand is to record soil mineral N in early spring to determine the application rate of nitrogen for each field. Recent work by the authors has identified that testing soil mineral N is a reliable indicator to the amount of applied N required to achieve optimum seed yields in New Zealand. Currently application rates can be estimated by; 185 – measured soil mineral N (kg ha^{-1}) (Rolston *et al*. 2008). However this approach relies on an average target application rate and may be excessive or insufficient in any given year. Therefore if a method exists of using ’real time’ data for crop N status (and also biomass production, growth rate, chlorophyll content etc) then profitablity could be improved.

Optical sensors have the potential to determine stress in arable crops and therefore may have the ability to determine the nitrogen requirements. The "Greenseeker" is an active type optical sensor that measures canopy reflectance in the red (~650nm) and near infrared (770nm) wave bands. The output is then converted to normalized difference vegetation index (NDVI) as calculated by. Normalized difference vegetation index has been used previously to provide an estimate of crop nitrogen (N) concentration in wheat (Flowers *et al*. 2003).

With a lack of New Zealand data, results published by Flowers *et al*. 2007 were used to estimate N% and unpublished New Zealand data used for estimating dry matter per hectare based on NDVI values (FAR unpublished data 2008). From these data sets a nitrogen nutrition index (NNI) (Lemaire & Gastal 1997) was estimated with critical levels as described by Gislum and Boelt (2009). It was assumed that 40 kg N would raise plant N tissue by 0.5 % based on data presented by Cookson (1999).

Typically spring nitrogen is applied in two or three applications at 14 to 21 day intervals, to limit the potential for leaching and/or volatilisation losses. The aim of this study was to investigate tools for determining the amount of additional nitrogen required after the first application.

Methods

Two trials, each with 22 treatments including applied N from 0 to 240 kg N ha^{-1} in 40 kg increments, were undertaken within irrigated commercial seed crops at Greendale and Methven (Canterbury, New Zealand) with cv Grasslands Samson and cv Alto respectively. Plots were 10 m long and 3.2 m wide with four replicates in a randomized block design. The crops were managed by the grower for all inputs except N. The soil N levels (Table 1) are based on analysis by Hills Laboratories[1] for samples collected in September before closing. The mineral N (MnN) is the combined NH_4^+ and NO_3^- levels. A "Greenseeker" NDVI assessment was made 21 days after the initial spring N application. Two treatments used NDVI values for making a decision on total spring N.

At approximately 40% seed moisture content a 1.7 m swath was cut from the centre of all plots with a modified plot windrower. Seed was then harvested at 12% seed moisture content with a plot combine. Seed samples were machine dressed on a small-scale air-screen separator to achieve a 1st Generation seed purity standard and converted to a yield/ha.

Results and Discussion

Soil Mineral N

Soil mineral N levels were slightly below the long term average (41 kg ha^{-1}, range 10 – 122 kg ha^{-1}) (Rolston *et al*. 2008) at both sites (Table 1) indicating that winter leaching had removed much of the available N below the rooting zone.

[1] Hills Laboratories see www.hill-labs.co.nz

Table 1. Recorded soil Mineral N (MnN, combined NH_4^+ and NO_3^-) levels in early spring at two sites, Canterbury, New Zealand.

Depth	Greendale	Methven
	Soil N (kg/ha)	
0-30cm	35	25
30-60cm	12	6

NDVI

The application of N at closing significantly increased ($P<0.05$) the NDVI for all treatments when assessed three weeks later (prior to the second N application) (Figure 1). Variation in NDVI for individual plots with the same base N application existed. One possible explanation for this is variation in the number of urine patches produced by grazing animals prior to closing, which could lead to variability in results. Saturation in NDVI occurred from approximately 40 kg ha^{-1} of applied N.

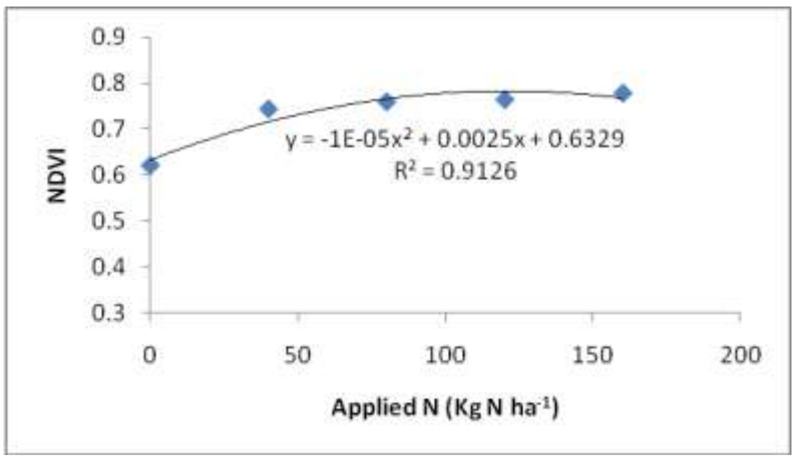

Figure 1. Normalized difference vegetation index response to applied N at Greendale, cv Grasslands Samson $LSD_{0.05} = 0.047$.

Nitrogen Response

Both experiments showed increased seed yield to applied N up to approximately 140 kg N ha^{-1} and had relatively flat optimum response zones, approximately 130 – 170 kg applied N ha^{-1} (Figure 2). Some of the variability within Nitrogen rates can be explained by differences in application timings.

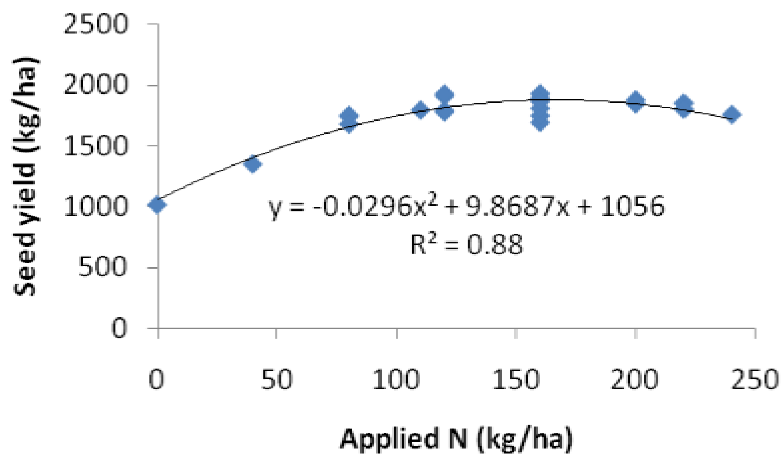

Figure 2. Seed yield response to applied N rates with quadratic model for Greendale ($LSD_{0.05}$ = 160).

Greenseeker treatments

In both experiments the Greenseeker treatments were associated with the highest seed yielding groups ($P<0.05$) and tended to recommend N application rates close to the beginning of the plateau at both experimental sites (e.g. 130 kg ha^{-1} at Greendale). The commercial standard for application at the sites would be approximately 160-175 kg N ha^{-1}. At the Methven site the Greenseeker treatment gave the highest yielding plot at 2340 kg/ha (Table 2). This result requires further investigation to confirm the calibration data which was obtained from published literature where turf cultivars were grown. These results require caution as they may not apply to those cultivars which reflect/absorb radiation differently e.g. turf verses forage and/or diploid verses tetraploid.

Table 2. Nitrogen application rates and associated seed yields at two sites (not all data presented), Canterbury New Zealand.

Nitrogen application timing and rate (N kg ha^{-1})			Applied N	Greendale	Methven
Closing	3 weeks later	Mid ear emergence	(N kg ha^{-1})	Seed yield (kg/ha)	
0	0		0	1010	1240
0	120		120	1780	2080
0	160		160	1690	2010
40	80		120	1790	2290
40	120		160	1740	1970
80	40		120	1910	2160
80	80		160	1890	2060
80	30	20/40*	130/150	1790	2340
120	0		120	1920	2140
120	40		160	1800	2050
160	0		160	1929	2060
160	80		240	1750	2020
		LSD 5%		160	220

* Greenseeker-Greendale 20 and Methven 40 kg N ha^{-1} at mid ear emergence

Conclusion

- Preliminary trials suggest that an optical sensor has the potential to estimate N requirements, however further calabration is required.
- NDVI has the potential for identifying early season variation, however saturation at higher biomass levels suggests limitations later in the season

Acknowledgment

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References

Cookson, W.R. (1999). Nitrogen fertiliser use efficiency in ryegrass (*Lolium perenne* L.) seed crops. PhD Thesis, Lincoln University, New Zealand.

Gislum, R.& Boelt, B. (2009). Validity of accessible critical nitrogen dilution curves in perennial ryegrass for seed production. Field Crops Research. 111:152-156.

Flowers, M., Weisz, R., & Heiniger, R. (2003). Quantitative approachesfor using color infrared photography for assessing in season nitrogen status in winter wheat. Agronomy Journal. 95:1189-1200.

Flowers, M. D., Hart, J.M., Young III, W.C. Christensen, N.W., Garbacik, C.J. Mellbye, M.E., Silberstein, T.B. & Gingrich, G.A. (2007). Exploring remote sensing applications in perennial ryegrass seed production. In: Young III, W.C. (Ed.), Seed Production Research at Oregon State University USDA-ARS Cooperating. 1-8.

Rolston, M.P., McCloy, B.L., & Chynoweth, R.J. (2008). Predicting nitrogen requirement in perennial ryegrass seed crops. *Seeds for futures symposium.* In Press.Lemaire, G., & Gastal, F., (1997). N uptake and distribution in plant canopies. In: Lemaire, G. (Ed.), Diagnosis of the Nitrogen Status in Crops. Springer-Verlag Publishers, Heideberg, pp. 3–43.