

## Predicting nitrogen requirement in perennial ryegrass seed crops

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### Abstract

Results from 17 nitrogen (N) rate response trials using current best management including the plant growth regulator trinexapac-ethyl (Moddus) were used to predict optimum applied N rates for perennial ryegrass. The average optimum applied N rate was 145 kg/ha. A simple model using late winter soil mineral N (0-30 cm) and a total N requirement (mineral N + applied N) of 185 kg N/ha is recommended for growers to predict the applied spring N rate.

**Keywords:** nitrogen, optimum rate, *Lolium perenne*, seed yield

### Introduction

In 2004 we identified that many perennial ryegrass (*Lolium perenne* L.) seed growers were using excessive rates of nitrogen (N), typically 216 kg N/ha and that ryegrass seed yields were being depressed by the higher N rates (McCloy & Rolston 2005). Our trials showed that there was a high economic cost to the farmer when excess N was applied. Most applied N to seed crops is in the form of urea. High rates of N, especially as urea, have the potential for environmental costs associated with nitrate leaching, ammonia volatilisation, soil acidification, and a large carbon footprint due to the high energy cost to manufacture urea. Urea costs have doubled in the last two years associated with rising oil and energy prices, increasing from \$NZ 420/T to \$NZ 1100/T (Ballance 2008), making N application the single most expensive input for seed production.

During the 1980s and 1990s there was a considerable amount of research undertaken on ryegrass seed crop responses to and

requirements for N (Brown 1980a, b; Hampton 1987; Rowarth & Archie 1995; Rowarth *et al.* 1998; Cookson *et al.* 1999; Williams *et al.* 2001). In 2000 the plant growth regulator (PGR) Moddus (trinexapac-ethyl) was introduced increasing seed yields by 50% with a near 100% adoption by ryegrass seed producers (Rolston *et al.* 2004). Interviews with seed growers indicate that there was a perception that because Moddus reduced lodging, higher N rates could be used to increase seed yields still further. In the same period, mineral soil N testing was being adopted as a tool to predict applied N rates for wheat (Jamieson *et al.*, 2003). Late winter soil N testing was not generally used in New Zealand for N use predictions in ryegrass. In winter wheat the soil N tests commonly sample a 0 to 90 cm deep profile, although stones restrict depth of sampling to about 60 cm on many Canterbury soils. Perennial ryegrass sown in autumn has the bulk (>90%) of its roots in the 0 to 15 cm depth range. A decision was made in the trials to sample for mineral N at 0 to 30 cm. Deeper soil samples 30-60 cm were collected, and incubation (mineralisable N) analysis were undertaken in some trials.

In New Zealand perennial ryegrass seed crops are sown in autumn as a one harvest crop. This is in contrast to Oregon and Europe, two areas that produce large volumes of perennial ryegrass seed, where crops are multi-year harvested and N rate trials are commonly based on the second production year (Hart *et al.* 2007). This makes the New Zealand production system unique and highlights the need for New Zealand-based research in perennial ryegrass seed production.

This paper summarises the results of 17 field trials conducted from 2003 on N rate responses from perennial ryegrass seed crops managed with Moddus PGR and with known soil mineral N ( $\text{NH}_4 + \text{NO}_3$ ) values and evaluates a simple N rate prediction.

### Methods

Trials were undertaken in Canterbury (Methven, Ashburton, and Timaru) from 2003 to 2007 in farmer's fields. The trial management inputs (except spring N) were undertaken by the grower and were the same as his field management. The grower inputs include sowing rate and timing, autumn fertiliser, herbicides, grazing and closing date, heavy rolling, fungicides, Moddus PGR and irrigation. The cultivars varied (Table 1) but most were early- to mid-flowering diploids with various endophyte combinations (data not presented). All sites were autumn sown (March to mid April) and harvested in the first summer. Trials had a nil N control with either five or six N rates in 50 kg/ha increments, in randomised block designs with four replicates. Plots were 3.2 m wide and 9.0 to 10 m long. All sites except Trial 11 were irrigated. Urea (46% N) was applied at closing (late September/early October) and at mid-stem elongation (usually three weeks after the first application) in an equal split rate.

Mineral soil N (sum of nitrate-N and ammonium-N calculated on a dry weight basis) for 0 to 30 cm samples taken in late winter (end August/early September), frozen and was analysed at a commercial laboratory based on a 2M KCl extraction with nitrate-N determined by cadmium reduction and N-(1-naphthyl) ethylenediamine dihydrochloride (NED) colorimetry; and ammonia-N by Berthelot colorimetry. Crop bulk at harvest was assessed from a 0.25 m<sup>2</sup> quadrant. At harvest seed and straw samples were collected and the N content determined at a commercial laboratory using an estimated N% by Near Infrared Spectrometry (NIRS) with a calibration based on N by Dumas

combustion. Above ground N uptake (kg/ha) by the crop was calculated as straw mass (kg/ha) x straw N concentration (g/kg) + seed mass (kg/ha) x seed N concentration (g/kg).

At harvest the trial was windrowed on the same day or the day after the farmer windrowed the field at ca. 38 to 40% seed moisture content. A 1.7 m wide swath by the full plot length was cut in each plot with a modified plot windrower. The trial was harvested using a plot combine the day the farmer combined. This was 7 to 10 days after windrowing. The seed was machine dressed to a First Generation Seed Certification purity standard (MAF 2006) and seed yield calculated at 12% seed moisture content.

Data were analysed using GenStat (v9) (Payne *et al.* 2007). The optimum N rate was calculated using both a polynomial model and a linear-plateau model (a conservative model where the optimum was the least value not significantly different from the highest seed yield value). The total N was calculated as the combined applied N + mineral N (0-30 cm). Economic analysis used 2008 grower prices; seed (\$2.50/kg); N (\$2.10/kg N) and application cost of \$20/ha per application.

### Results

The average soil mineral N (0-30 cm) concentration in the trials was 12 mg/kg soil, equivalent to 41 kg N/ha with a range from 10 to 122 kg N/ha, with most sites in the range of 30 to 50 kg N/ha (Table 1). In the mineral N fraction the  $\text{NO}_3$  and  $\text{NH}_4$  proportions were 68 and 32% respectively.

The average seed yield of the nil N control treatment was 1,590 kg/ha, and for the optimum N treatment 2,170 kg/ha, a 43% yield increase (Table 1).

The average optimum applied N for the 17 trials was 143 kg N/ha (range 70 to 240 kg N/ha) (Table 1). An example of a linear-plateau response with an optimum applied N of 117 kg/ha is shown in Figure 1. This trial

had a mineral N (0-30 cm) value of 33 kg/ha and a total optimum N of 150 kg/ha. For the 17 trials the average total optimum N value was 184 kg N/ha (Table 1).

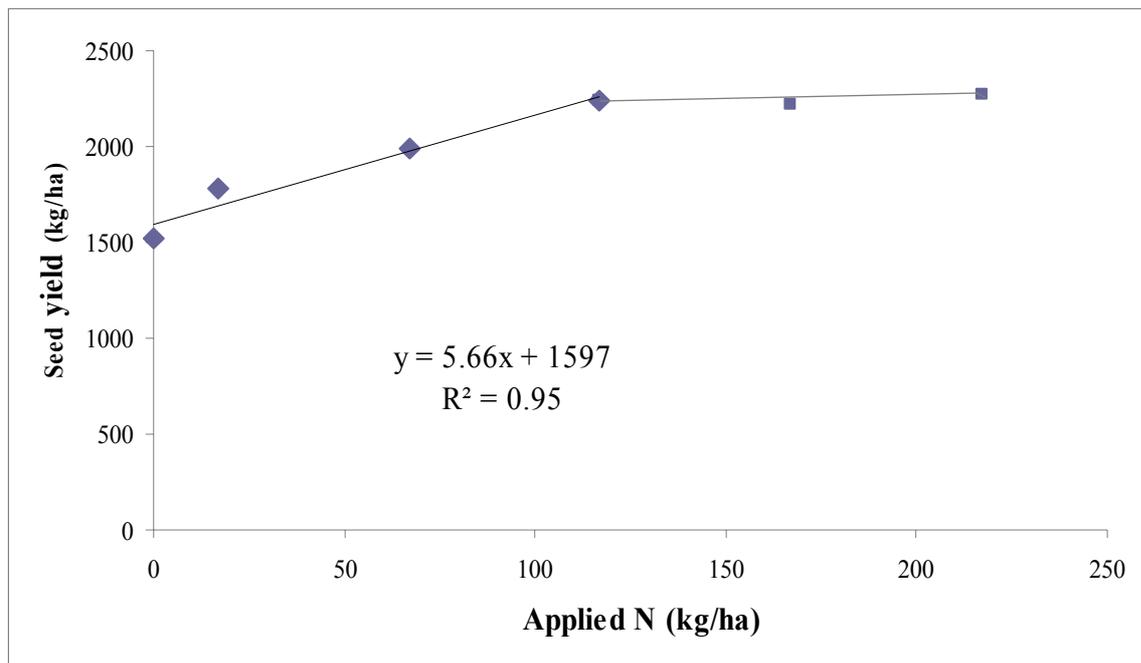
The choice of model to predict optimum N has a large influence on the prediction value. The linear-plateau model predictions are conservative. The linear-plateau model was chosen if the yield response to higher N rates were not significantly different from each other; and the polynomial response when

highest N rates depressed yields. Both response types were observed, the latter when very high rates of N (>250 kg N/ha) were included. For trial 12 the data has a good fit to both a linear-plateau model  $R^2=0.95$  (Figure 1) and to a polynomial model ( $R^2=0.97$ ) (Figure 2). However the optimum applied N using the polynomial model is 170kg N/ha (Figure 2) compared with 117 kg/ha in the linear-plateau model (Figure 1).

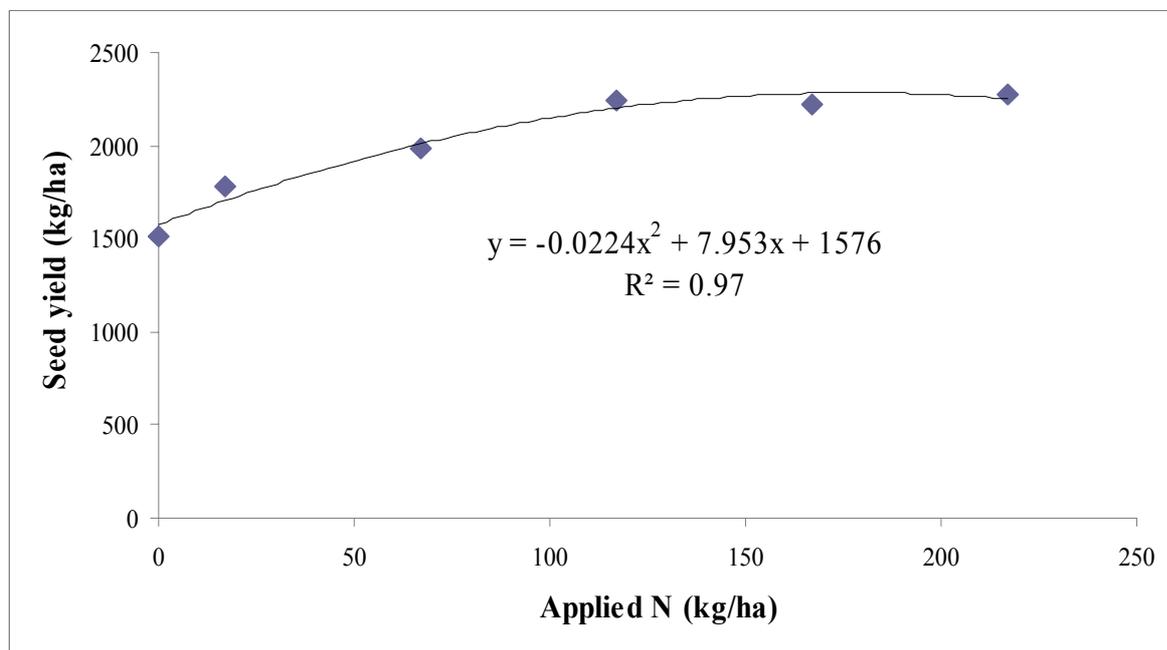
**Table 1** Summary of trials, year, cultivar, mineral N ( $\text{NH}_4+\text{NO}_3$ ) in the 0 to 30 cm soil profile, the optimum N required using linear-plateau model and the seed yield for N0 (nil N) and optimum N rate. All trials grazed at closing and irrigated unless specified.

No.	Year	Cultivar	0-30 cm	N opt	Total	N0	N opt
			Min N (kg/ha)	Applied (kg/ha)		Seed Yield (kg/ha)	
1	2003/04	Banquet	46	154	200	1010	1710
2	2003/04	Bronsyn	50	150	200	1440	1820
3	2004/05	Bronsyn	71	129	200	1600	1970
4	2004/05	Aries	29	171	200	1870	2030
5	2005/06	Impact	36	214	250	1210	2050
6	2005/06	Hillary	122	104	226	1170	1790
7	2006/07	Bealey	36	164	200	2170	2630
8	2006/07	Bealey <sup>1</sup>	36	114	150	1420	2230
9	2006/07	Bronsyn	10	140	150	1610	2510
10	2006/07	Bronsyn <sup>1</sup>	10	240	250	1100	1880
11	2006/07	Hillary	33	167	200	1340	2240
12	2006/07	Hillary	33	117	150	1520	2240
13	2006/07	Commando	30	70	100	2510	2790
14	2007/08	Hillary	36	114	150	1590	2250
15	2007/08	Commando	54	144	200	1810	2250
16	2007/08	Arrow	30	120	150	1910	2340
17	2007/08	Arrow <sup>1</sup>	30	120	150	1810	2230
<b>AVG</b>			<b>41</b>	<b>143</b>	<b>184</b>	<b>1590</b>	<b>2170</b>

<sup>1</sup>mown at closing time in late September.



**Figure 1** Linear-plateau applied seed yield response to N for Trial 12 (LSD 5% = 202).



**Figure 2** Polynomial model applied seed yield response to N for Trial 12.

**Table 2** Average and data range (kg N/ha) for 2003/07 trials for above ground biomass at optimum N, total plant N (including roots), amount of soil N in above ground biomass of nil applied N treatments and total soil N (mineral + organic) 0-30 cm.

	Average	Range
N in above ground biomass	192	159 to 280
Total N in plant (assumed)	232	199 to 320
Total N in plant nil N	93	44 to 141
Total soil N	5400	4190 to 8900

***Plant uptake of N***

In the nil N treatments the average above ground plant uptake N was 93 kg N/ha (Table 2) and the average soil mineral N/ha was 41 kg (Table 1). The difference (52 kg N/ha) in N uptake was from either deeper mineral N and/or from mineralisable N released during the growing season. At the optimum N rate above ground N uptake averaged 192 kg/ha (Table 2). Based on published data (Cookson *et al.* 1999; Williams *et al.* 2001; Carbacick *et al.* 2003) roots in perennial ryegrass seed crops will have an estimated 40 kg N/ha; giving total plant N uptake of 232 kg/ha.

***Economic benefit and price sensitivity***

Using a linear-plateau model the N rate response in the linear phase averaged 3.7 kg seed per kg applied N with a range from 0.7 to 5.9 (Table 1). This equates to a \$4.40 return for every dollar invested in N. The effect of N price variation on the sensitivity of optimum N rate was examined with a polynomial response and found to be insensitive to large price fluctuations as shown by Gislum *et al.* (2007). Calculating the optimum N rate for maximum economic treatment net benefit, using a polynomial model for trial 16 as an example, showed that increasing the price of N by 46% from \$1.50 (2007 price) to the current price of \$2.20 /kg N lowered the economic optimum N from 167 to 160 kg N/ha. Increasing the price of seed shifted the optimum N to a slightly higher rate.

***Predicted applied N rate***

In 2007 using preliminary data sets from Trials 1-13 (Table 1) we recommended that growers could predict their spring N from using the following simple calculator:

$$\text{Spring applied N} = 200 - \text{mineral N (0-30cm)} \text{ (kg/ha)}$$

In 2008 this equation was tested against the 17 optimum applied N values calculated in Table 1. In 3 fields the predicted applied N was below the optimum; while in 7 trials the predicted applied N was correct and in the other 7 trials overestimated. The 200 model predicts an average applied N of 160 kg/ha compared with the 17 trial average of 143 kg/ha. If the model is adjusted to a total optimum N requirement of 185 kg N/ha with a  $\pm 20$  kg/ha accuracy the model has the same number of under and over predictions but gives an average prediction of 143 kg applied N/ha, which is similar to the 17 trial average. Thus for spring 2008 our recommendation will be:

$$\text{Spring applied N (kg/ha)} = 185 - \text{mineral N (0-30 cm)} \text{ (kg/ha)}$$

***Discussion***

The trials predict that on average 145 kg applied N/ha is required for high yielding perennial ryegrass seed crops. Using late winter mineral N (0-30 cm) values growers can predict their applied N rate using a total N requirement model of 185 kg N/ha. The data confirm that the average N rate on 30

South Canterbury monitor perennial ryegrass crops during 2003/04 was too high. As a result of this research and associated extension activities the average N use rate on these monitor farms had declined to 150 kg applied N for the 2006/07 year. Total above ground plant uptake of N at the optimum applied N rate was higher than the amount of applied N by an average of 47 kg N/ha, i.e., perennial ryegrass is using at least 47 kg N/ha of soil N assuming 100% efficiency in uptake of applied N.

Future work will focus on an improved understanding of N uptake with thermal time (canopy growth and development), growth stage and attempt to develop predictions of N requirement using early spring NDVI (normalised difference vegetative index) reflectance (Flowers *et al.* 2003).

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