Nitrogen - Moddus interaction in perennial ryegrass seed production

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Abstract

Six nitrogen (N) rates were compared with and without trinexapac-ethyl (Moddus®) plant growth regulator in adjacent dryland and irrigated blocks of perennial ryegrass. There was a large positive response to Moddus with an average seed yield increase of 430 and 710 kg seed ha^{-1} for dryland and irrigated crops respectively. Moddus increased the optimum N rate for a biological response from 50 to 150 kg N (applied + mineral 0-30cm) ha^{-1} for irrigated and from 150 to 200 kg N ha^{-1} for dryland respectively using a linear split line regression model. The predicted optimum using a polynomial model was higher. An economic optimum that accounted for both the cost of N and application cost was $\geq$ 30 kg N ha^{-1} lower than the biological optimum. Moddus delayed the onset of lodging and this probably had the greatest influence on the seed yield response. Crops that did not lodge had higher photosynthetically active radiation (PAR) at the flag leaf level in the canopy. There was a minimal irrigation response as only one irrigation application was applied in early spring. Late spring rains were adequate and twice the average rain fell in December. Seed germination in the lowest and highest N treatments was similar.

Additional keywords: *Lolium perenne*, plant growth regulator, seed yield

Introduction

Trinexapac-ethyl (Moddus) plant growth regulator is a stem shortener which blocks gibberellic acid (GA) biosynthesis (Rademacher, 2000) and increases seed yields (Chastain *et al.,* 2003). Surveys in New Zealand indicate that Moddus is used on 99-100 % of all perennial ryegrass (*Lolium perenne* L.) seed crops (Rolston *et al.,* 2004). Trials on N rate responses in the mid-late 1990’s by Rowarth *et al.* (1998) were undertaken prior to the introduction of Moddus. There has been speculation that the seed yield responses to N, reported from the 1990’s trials may differ when crops are grown with Moddus. The effect of moisture stress on response to Moddus has also been the subject of speculation. Trials were established to compare N rate responses in adjacent dryland versus dryland versus irrigated blocks with and without Moddus at each N rate.

This study reports on a series of trials started in 2003 with the aim of predicting the spring N requirement for perennial ryegrass seed crops based on combined soil N and applied N responses. Earlier data in this series has been included in joint Danish-US-NZ research (Gislum *et al.,* 2007; Hart *et al.,* 2007). Seed yield N responses are commonly polynomial, with an optimum followed by a decline at higher N rates (Rowarth *et al.,* 1998; Gislum *et al.,* 2007).

Materials and Methods

The trial was established at Wakanui (Ashburton) in a perennial ryegrass cv Hillary field sown in 30 cm rows.

The trial site was maintained by the grower including inputs of herbicides, grazing and irrigation. Nitrogen rates were split equally between two applications at closing (23 September 2006) and at mid stem elongation (16 October 2006), with urea at 0, 17, 67, 117, 167 and 217 kg N ha^{-1}. Moddus at 0 or 1.2 l ha^{-1} was applied on 31 October to all N treatments. Early spring 0-30 cm available mineral N (NO_3 and NH_4) was 33 kg ha^{-1} in both the dryland and irrigated blocks with mineralisable N (incubation N) of 89 kg ha^{-1} (dryland) and 62 kg ha^{-1} (irrigated). Because of the rainfall pattern with a dry early spring and a very wet December, the irrigated area was only irrigated once with 45 mm, applied in early October. The trials compared irrigation versus dryland as two separate but adjacent trials; with a 20 m buffer between them. There were 4 replicates in a randomised block design. Plots were 10 m x 3.2 m.

Assessments

At weekly intervals staring prior to flowering plots were scored for percent lodging. At mid seed fill a 0.25 m^2 quadrat was cut to ground level to assess reproductive growth components and to provide a straw sample for N %. Seed and straw N % data was based on a bulk sample from the four replicates. Roots were assumed to have 40 kg N ha^{-1} at maximum above ground plant mass and were calculated as a proportion of 40 kg ha^{-1} at lower masses. Nitrogen recovery efficiency (NRE) was calculated (Rowarth, 1997) as:

$$\frac{\text{N uptake in Treatment } N_x - \text{N uptake in Treatment } N_0}{\text{N added in Treatment } N_x}$$

Intercepted photosynthetically active radiation (PAR) was measured using a linear PAR ceptometer (AccuPAR Model PAR-80, Decagon Devices Inc, Pullman, WA, USA) with an 80 cm quantum sensor with 80 independent sensors spaced 1 cm apart. These sensors measure PAR in the 400-700 nm waveband and display PAR in units of µE sec^{-1} m^{-2} with 1 µE sec^{-1} m^{-2} resolution. Fertile florets were determined without optical enhancement. Fertile floret site utilization (FFSU) percentage was calculated as the number of seeds per number of fertile florets. Harvest index (HI) was calculated as seed mass/seed + straw mass.

Harvest

At harvest a 1.7 m swath was cut from the centre of all plots with a modified plot windrower, and then harvested with a “Sampo 3” plot combine. The crop was windrowed on 17 January 2007 and combined on 31 January 2007. Seed from plots was retained for later processing. Seed samples were machine dressed on a small-scale air-screen separator to achieve a 1st Generation seed purity standard. Cleaned plot samples were weighed and converted to yield ha^{-1}.

Thousand seed weight (TSW) and germination

Germinations were compared for at least two low and two high N treatments. Seed was pre-chilled at 5 ^{o}C with 0.2 % KNO_3 for five days and then germinated at 20 ^{o}C. For each replicate one lot of 50 seeds were weighed to calculate the TSW and then germinated, giving 200 seeds treatment^{-1}.

Economic models and statistical analysis

Nitrogen was priced at \$1.26 kg^{-1} N and application at \$15 ha^{-1}; with two applications for rates ≥ 100 kg N ha^{-1}. Seed was valued as net of dressing costs at \$1.65 kg^{-1} (equivalent to \$1.80 minus \$0.15 kg^{-1} for dressing). Data was analysed using GenStat Version 9.

Results and Discussion

Moddus response

Moddus increased seed yield by an average of 710 and 430 kg ha^{-1} respectively for irrigated and dryland trials (Table 1).

Table 1. Moddus seed yield response compared to 0 Moddus and relative seed yield (RSY) when 0 Moddus = 100.

Total N (kg ha^{-1})	Irrigated Seed yield response (kg ha^{-1})	Dryland	Irrigated Relative seed yield	Dryland
33	380	260	134	124
50	500	260	139	119
100	700	450	154	133
150	920	380	169	123
200	870	600	164	137
250	900	620	165	139
Mean	710	430	154	129
LSD 5 %	280	332		

The seed yield response to Moddus was 28 and 30 % respectively for the irrigated and dryland trials. At low N rates the increase in seed yield was 260 to 500 kg ha^{-1}; increasing to 600 to 900 kg ha^{-1} at the highest N rate. The average relative seed yield response to Moddus was 165 and 129 for irrigated and dryland crops respectively. In the irrigated trial the RSY from Moddus increased from 134 at the lowest N to 165 at the highest N; whereas in the dryland trial the RSY response was broadly similar across N rates (Table 1).

Nitrogen response and Moddus interaction

Seed yield responded to increased N with a plateau at 150 kg N ha^{-1} (applied + mineral N) for irrigated Moddus (Figure 1) and 200 kg N ha^{-1} for dryland Moddus (Figure 2). In the response phase seed yields increased at 5.6 and 5.0 kg seed kg^{-1} N for irrigated and dryland blocks treated with Moddus respectively.

Using a linear split line regression model the optimum N rate for a biological response increased from 50 kg N (applied + mineral 0-30cm) ha^{-1} for 0 Moddus to 150 kg N ha^{-1} with Moddus for the irrigated block (Figure 1

). For dryland the optimum N increased from 150 to 200 kg N ha^{-1} respectively for 0 and + Moddus (Figure 2).

Irrigation Response

The N treatment mean yields for irrigated and dryland with Moddus 1.2 l ha^{-1} were similar (2,000 and 1,870 kg ha^{-1} respectively) (Figure 3); and the same (1650 and 1660 kg ha^{-1} respectively) for irrigated and dryland when all data is combined. However, there was a larger seed yield response to Moddus for irrigated (710 kg ha^{-1}) compared to dryland (430 kg ha^{-1}) (Table 1). Possibly the early October irrigation changed the growth dynamics enough to influence the Moddus response.

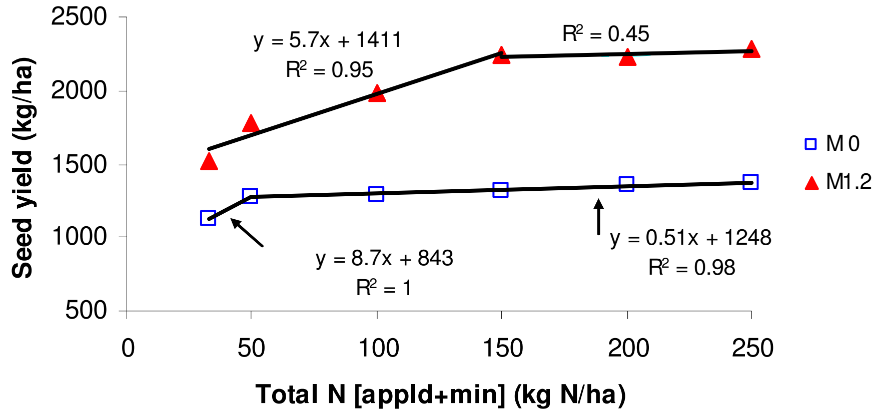

Figure 1: Linear split line regression for irrigated N rate responses for Moddus nil or 1.2 l ha^{-1} (LSD 5% = 202).

Model Predictions and Economic Response

The optimum N rate predicted using the linear models was lower than from the polynomial model (Figure 3) and substantially lower for the irrigated treatments (Table 2). The economic optimum based on the polynomial model was 30 and 70 kg N ha^{-1} lower than the biological optimum for dryland and irrigated blocks respectively (Table 2).

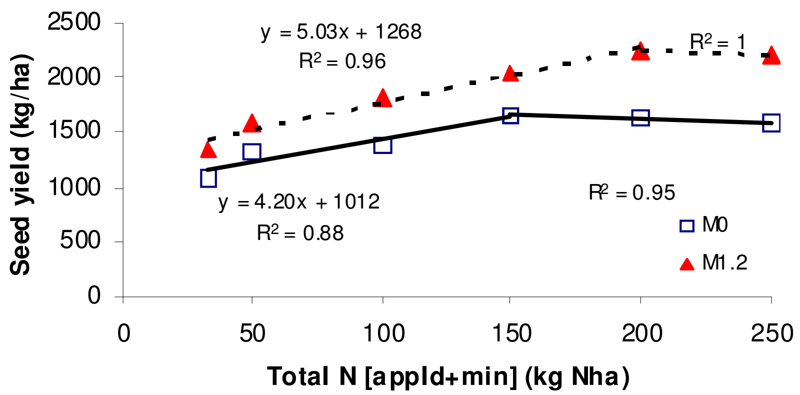

Figure 2: Linear split line regression for dryland N rate responses for Moddus nil or 1.2 l ha^{-1} (LSD 5 % = 193).

Table 2: Biological optimum N (applied + mineral N) predicted from linear and polynomial models and economic optimum N rate from polynomial model for Moddus 1.2 l ha^{-1} treatments.

	Biological N		Economic N
	Linear	Poly (kg N ha^{-1})	Poly
Dryland	200	240	210
Irrigated	150	260	190

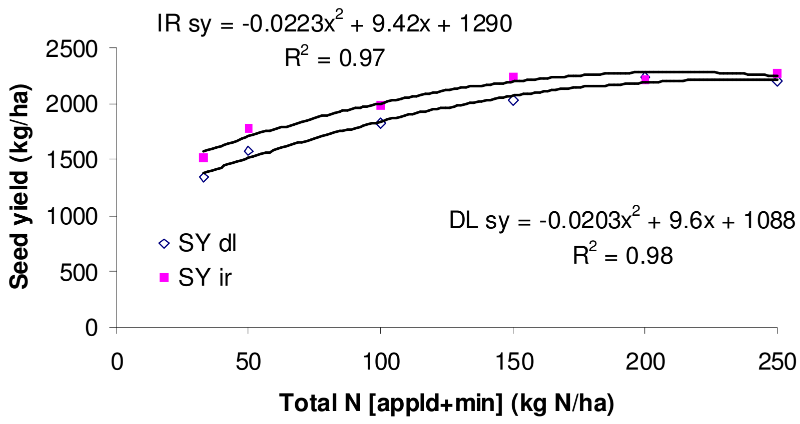

Figure 3: Polynomial seed yield (SY) response curves for irrigated (IR) and dryland (DL) with Moddus 1.2 l ha^{-1} (LSD 5 % irrigated = 196; dryland = 189).

Plant N uptake

Crop N uptake was calculated from straw and seed N % (Table 3). Assuming 100 % utilization of applied N and mineral N (0-30 cm). The balance of plant N represented, on average, 67 % of the mineralisation N (0-30 cm). The NRE including the root N averaged 139 % (Table 3) and 126 % excluding root N. Rowarth (1997) describes "high" NRE ryegrass seed crop values of 68 %. Ryegrass seed crops are very efficient N scavengers.

Table 3. N rate (applied + mineral N 0-30 cm), straw and seed N, above ground and total plant N (roots assumed to have 40 kg N ha^{-1} at maximum plant mass), nitrogen recovery efficiency (NRE) for irrigated Moddus 1.2 l ha^{-1}.

N	Straw		Seed		Total above ground	Total above ground and roots	NRE
(kg ha^{-1})	(N %)	(kg N ha^{-1})	(N %)	(kg N ha^{-1})	(kg N ha^{-1})		%
33	0.7	45	1.9	29	74	87	Na
50	1.1	85	1.8	32	117	132	265
100	1.0	93	1.9	38	131	148	91
150	1.3	132	2.0	45	177	217	111
200	1.9	199	2.3	51	250	290	122
250	2.2	228	2.4	55	283	323	109

Lodging

The onset of severe lodging measured as days from the start of anthesis to when the crop was > 50 % lodged was 20 to 30 days later in Moddus treated plots compared to the 0 Moddus plots (Figure 4). At 100 kg N ha^{-1} Plants in 0 Moddus plots lodged within 5 days after the start of anthesis. Moddus treated plots did not lodge until 35 days after the start of anthesis. We suggest that the seed yield response from Moddus is largely the result of delayed lodging; thus ensuring better light penetration into the canopy (Figure 5) and delayed vegetative tiller development that is common when soil moisture and N are in surplus.

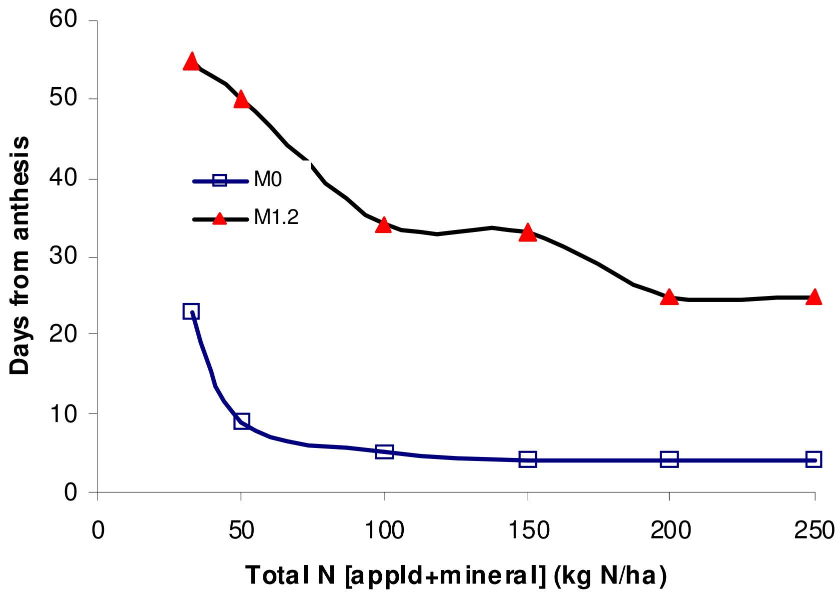

Figure 4: Days from the start of anthesis to 50 % lodging for N rates at nil (M_0) or 1.2 l ha^{-1} Moddus ($M_{1.2}$).

Photosynthetically Active Radiation (PAR)

At all levels in the canopy the PAR was lower for high N treatments compared to low N. PAR levels were 50 % of above canopy levels in high N treatments compared to 75 % for low N treatments. During seed fill there was a strong negative relationship between PAR measurements and increased lodging (Figure 5).

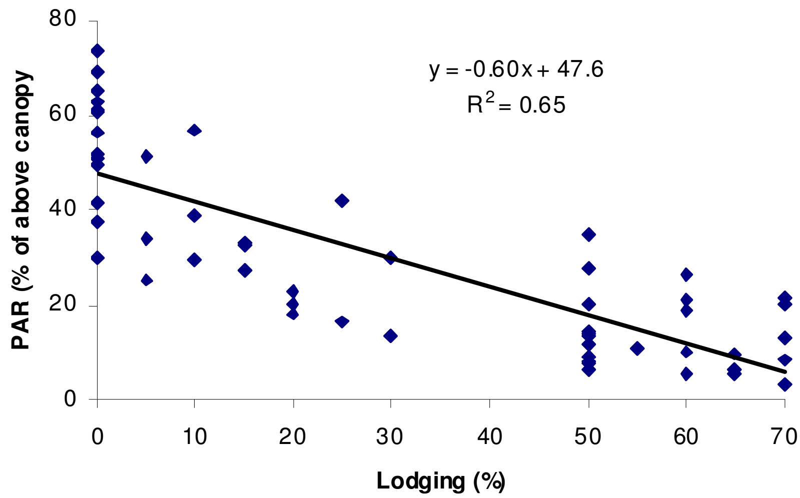

Figure 5: Flag leaf photosynthetic active radiation (PAR) as a percent of above canopy PAR measured on 24 December.

Components of yield

Seed head density for Moddus at 1.2 l ha^{-1} was a positive linear response to increased N rate (R^2 = 0.94; b = 4.2 heads kg N^{-1}). In contrast to seed head density in the 0 Moddus treatments the result of abortion from lower light with high crop mass.

Nitrogen increased dry weight mass from 6.4 to 10.4 t ha^{-1} (Table 4). Harvest index was relatively constant (17.5 to 19.0 %) over the range of N treatments. Thousand seed weight (TSW) was similar for all N rates but was reduced at the highest N rate (Table 4).

Floret fertility, FFSU and germination

Floret fertility did not limit seed yield. Although December was very wet and there were no significant clouds of pollen from the crop, there were still a high percentage (>70 %) of florets that were fertile and had produced a developing seed (Table 5). Although there was no difference in the number of fertile florets m^{-2} between +/- Moddus treatments there was a large difference in saleable seeds m^{-2} while Moddus resulted in a 50 % increase in fertile floret site utilization (Table 6).

Table 4. Crop mass at harvest as dry weight (DW) head density, dry matter (%) (Irrigated average M_0 and $M_{1.2}$), harvest index (HI), 1,000 seed weight (TSW) and fertile floret site utilization (FFSU) for irrigated Moddus treatments at six total N (applied + mineral N 0-30 cm) rates.

Total (kg N ha^{-1})	DW (kg ha^{-1})	Heads (m^{-2})	DM (%)	HI (%)	TSW (g)	FFSU (%)
33	6,480	1,130	32.1	19.0	2.70	45.9
50	7,750	1,410	32.1	18.7	2.64	51.2
100	9,280	1,460	31.6	17.7	2.67	53.1
150	10,150	1,770	29.1	18.1	2.67	43.2
200	10,470	1,910	26.2	17.5	2.71	44.4
250	10,360	1,810	24.6	18.0	2.51	41.4

Table 5. Number of fertile and sterile florets $spikelet^{-1}$ and percent of total that were fertile for irrigated and dryland.

	Fertile	Sterile	Total	Fertile (%)
Irrigated	5.4	2.2	7.7	71
Dryland	6.2	2.4	8.6	73

There was no difference in germination between low or high N treatments.

Table 6: Fertile florets (FF), number of seeds and fertile floret site utilization.

Moddus (l ha^{-1})	'000 FF m^{-2}	'000 seeds m^{-2}	FFSU (%)
0	159	46.6	30.1
1.2	167	76.0	46.5

Conclusion

1. Moddus increased seed yields by 28%.
2. The Moddus treatments lodged later and had better light interception in the upper canopy.
3. Nitrogen increased seed yields and the response was associated with increased head density.
4. Moddus increased fertile floret site utilization.
5. Moddus increased the optimum N response. The economic optimum N rate for perennial ryegrass in this trial was 190 and 210 kg N (applied + mineral N) for the dryland and irrigated Moddus treatments.
6. The plant N uptake was equivalent to all the applied N and mineral N and 2/3rds of the mineralized N (0-30 cm).

Acknowledgement

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