Comparison of Agrotain-treated and standard urea on an irrigated dairy pasture

R.J. MARTIN[1], T.J. VAN DER WEERDEN[2], M.U. RIDDLE[1] and R.C. BUTLER[1]
[1] *Crop & Food Research, Private Bag 4704, Christchurch*
[2] *AgResearch, Invermay Agricultural Centre, PB 50034, Mosgiel*
martind@crop.cri.nz

Abstract
Trials were started in spring, summer and autumn to compare the effect of Agrotain-treated urea and standard urea, at application rates of 25, 50, 75 and 100 kg N/ha, on dairy pasture production on a commercial dairy farm in Canterbury. There were six replicates of these eight treatments, plus two control plots per replicate where no urea was applied. Each trial was mown three times at around the second fully emerged leaf stage, and a subsample taken for dry matter determination. Yields generally increased with increasing rates of urea. There was no difference in pasture yield response between Agrotain-treated urea and standard urea in the wet conditions of the summer trial. In the dry conditions of the spring and autumn trials, Agrotain-treated urea produced 327 kg/ha more pasture dry matter than standard urea, although the yield advantage was small (130 kg/ha) at fertiliser application rates of 50 kg N/ha or less, compared to 524 kg/ha at 75 kg N/ha or more.
Keywords: nitrogen, urea, Agrotain, pasture, yield

Introduction

New Zealand dairy farmers need high yields of pasture for profitable milk production. This requires significant inputs of nitrogen, either as nitrogen fixed by clovers or as N fertiliser, usually urea, which is the cheapest source of N. However, not all the N inputs are utilised for grass growth and some are lost by leaching as nitrate or to the atmosphere as ammonia (NH_3). These losses can be up to 30–40% of the nitrogen supplied (Edmeades 2004).

Urea applied as a fertiliser or in urine is rapidly hydrolysed to ammonium by urease enzymes (Mobley & Hausinger 1989). Of the differing N fertilisers, urea results in the largest NH_3 volatilisation losses (Black *et al*. 1985) due to the temporary lift in soil pH under the urea granule. This promotes the conversion of the newly-formed ammonium to NH_3, which is lost to the atmosphere from the soil surface, especially if the soil surface is wet (Black *et al.* 1987) Consequently, there has been considerable research into materials that will either inhibit or reduce the activity of the urease enzyme to reduce these losses.

Sustain is currently the only urea fertiliser coated with a urease inhibitor that is commercially available in New Zealand. The active ingredient is Agrotain (N-(n-butyl) thiophosphoric triamide, or nBTPT for short). A 25% w/w solution of nBTPT in stabiliser solution is coated onto granulated urea at a rate of 1 L/tonne (Quin *et al*. 2005). The coated urea can then be applied in the same way as ordinary urea. In the soil, the nBTPT is oxidised to nBTPTO, which rapidly binds to the urease in the soil (Manunza 1999).

Quin *et al*. (2005) showed a 10% increase in yields from Agrotain-treated urea compared with standard urea at 30 and 60 kg N/ha application rates. In a subsequent paper, responses to Agrotain-treated urea applications at two rates of inhibitor and an N rate equivalent to 600 kg N/ha ranged from 6 to 12% at Ashburton, and from -4% to 6% at Te Awamutu (Ramakrishnan *et al*. 2008). Other results from that trial, presented by Blennerhassett *et al*. (2006), showed that the response varied between seasons, with the biggest responses in summer in Ashburton (450 kg/ha pasture dry matter), and in winter in Te Awamutu (677 kg/ha).

Ramakrishnan *et al*. (2008) reported an average N response advantage to Agrotain treated urea over standard urea of 41% (23-72%) over 6 to 16 months in two Waikato and three Canterbury trials, where an average of 25 kg N was applied after each cut. In contrast, at 10 sites from Northland to Southland, Stafford *et al*. (2008) found the average yield advantage was less than 10% (-29% to +26%) over spring where only 30 or 60 kg N was applied.

The trials described in this paper were carried out to determine whether there was an advantage to using Agrotain-treated urea over standard urea for dairy farmers, and whether that varied between seasons.

Materials and Methods

All the trials were carried out on a long-term dairy pasture near Kirwee in Canterbury. The soil type was a Lismore Shallow Silt Loam, and the paddock, rotationally grazed and irrigated when required by a centre pivot. The background soil fertility was determined prior to the first trial being established and showed 59 kg mineralisable N/ha, pH 5.9, Olsen P 22 µg/ml, exchangeable K 5 (MAF Quick Test), exchangeable Ca 7 (MAF Quick Test), exchangeable Mg 9 (MAF Quick Test), Sulphate-S 15 ppm, and CEC 12 me/100 g.

Three trials were started in spring 2007, summer 2006–07, and autumn 2007 (Table 1) with two fertilisers (Agrotain urea, standard urea) at four rates (25, 50, 75 and 100 kg N/ha). Six replicates of these eight treatments

Table 1 Dates of application of Agrotain-treated urea and standard urea in three trials and subsequent harvest dates.

Trial	Application date	First cut	Second cut	Third cut	Trial duration (days)
Spring	19-Sep-06	11-Oct-06	10-Nov-06	12-Dec-06	83
Summer	18-Dec-06	18-Jan-07	14-Feb-07	20-Mar-07	92
Autumn	23-Mar-07	24-Apr-07	3-Aug-07	21-Sep-07	182

were used in each trial. Two control (no applied N) plots were also included in each replicate in each trial. Each trial was laid as three columns of 20 plots, as a row-column design, such that there was a complete replicate in each column of 10 plots, chosen so that no treatment appeared more than once in each row of three plots.

The trials were adjacent to each other along a fence line. Each trial was set up by mowing off the original pasture to a height of 5 cm. A rain gauge was placed in the trial area and soil temperature probes installed at a depth of 10 cm adjacent to the experimental plots. Other meteorological data were also collected from a local NIWA site at Darfield, about 4 km away.

Once mown, the trial was then marked out and pegged, with each plot 1 m wide by 5 m long with a 1 m buffer between each of the three columns. The treatment fertiliser was broadcast onto the plots by hand from individual paper bags. Trial fertiliser application dates are given in Table 1. The farmer agreed not to irrigate the paddock for at least 5 days after fertiliser application.

Each trial was harvested on three occasions, each time at around the second fully emerged leaf stage (Table 1). A single mown strip was then taken down the middle of every plot to a height of 5 cm and this was weighed and subsampled for dry matter determination.

Initial analyses indicated that the patterns found for the total yields were present in a similar way at each cut, and so analyses of variance were carried out on the combined yields from each plot using GenStat (9th Edition, VSN International, Hemel Hempstead UK, 2006). A level of P=0.05 was used to determine significance. For the autumn trial, data for one plot were omitted as an outlier, as it had double the yields of any other plot.

Results

Rainfall and soil temperature data around the fertiliser applications for the three trials are given in Table 2. During the 5 days after the treatments were applied, it was hoped that no significant rainfall would occur, to attempt to quantify the maximum benefit of using Agrotain-treated urea.

The "no rain" requirement was met for the spring and autumn trials. For the summer trial, no rain fell in the first 24-48 hours, but then there was 45 mm of rain the next day. That trial also had significant rainfall both prior to fertiliser application and in the 8-15 days after fertiliser application, so the soil in that trial would have been moist over most of the detailed measuring period. The autumn trial also had rain before fertiliser application, and so the soil surface was likely to be moist.

Mean 9 am soil temperatures at a 10 cm depth over the 7 days subsequent to fertiliser application were 2^{o}C higher in the autumn trials than in the summer trial, and 5^{o}C higher than the spring trial.

There were significant differences in pasture yield between some treatments for all three of the trials ($P<0.05$) (Table 3). In all three trials, application of Agrotain urea and standard urea increased yield compared with the Nil controls. The only exception was in the autumn 2007 trial when yield in the Nil treatments was not significantly different from both urea and Agrotain-treated urea applied at 25 and 50 kg/ha. On average, yield increased with increasing rates of applied N ($P<0.05$).

There were no significant pasture yield differences between the fertiliser types for the summer trial. However, in the spring trial, there was a significant difference between the fertilisers (P=0.001), with yield increasing more rapidly with increasing rates of N for Agrotain urea than for standard urea. At the lowest level of applied N, this difference was quite small (66 kg), but the difference increased with rate: 258 at 50 kg/ha N, to 358 at 75 kg/ha N, to 606 kg at the highest rate of 100 kg/ha. Only at the highest rate of 100 kg N/ha was there a significant difference between the fertiliser types (Table 3). In the autumn trial, there was a significant difference in yield observed at the two higher rates (75 and 100 kg/ha) for Agrotain urea compared to standard urea.

Discussion

There was no significant difference in pasture production between Agrotain-treated urea and standard urea when applied in summer 2007 at all levels of N application. In this trial, a combination of 34 mm rainfall before fertiliser application, 45 mm rainfall in the 7 days after application, and a further 31 mm in the 8 days after that, would mean that most of the urea would have been carried into the soil. There could have been some volatilisation in the 24-48 hours after fertiliser application, as Black *et al.* (1987) found that up to 31% of applied N as urea was volatilised from soil at field capacity in 24 hours, with lesser amounts for drier soil. However, the 42 mm of rain recorded in the

Table 2 Total rainfall data for (a) 10 days previous to fertiliser application; (b) 7 days subsequent to fertiliser application; (c) 8-15 days after fertiliser application; together with (d) mean 9 am 10 cm soil temperatures for the 7 days subsequent to fertiliser application. Rainfall data are from the Darfield Meteorological Station, and 10 cm soil temperatures were measured in the trials.

Trial	(a) Rainfall preceding 10 days (mm)	(b) Rainfall subsequent 7 days (mm)	(c) Rainfall subsequent 8-15 days (mm)	(d) Mean 10 cm soil temperatures 7 days subsequent (°C)
Spring 2006	5	3	2	9.3
Summer 06/07	34	45	31	12.2
Autumn 2007	34	5	11	14.6

Table 3 Mean total yields (kg DM/ha) after application of four rates (kg/ha) of urea (U) and Agrotain-treated urea (A) in spring 2006, summer 2006/2007 and autumn 2007 in three separate trials.

Treatment and rate	Spring 2006	Summer 06/07	Autumn 2007
Nil 0	4763.6	4712.1	4627.3
A 25	5433.5	5342.1	4818.9
A 50	6170.7	5864.3	5027.7
A 75	6344.5	5965.9	5725.8
A 100	6885.5	6456.8	5970.3
U 25	5367.2	5573.1	4704.8
U 50	5912.7	5580.8	4946.7
U 75	5986.5	5934.1	5195.6
U 100	6279.1	6408.1	5369.4
Lsd 5% (d.f.=46[1])			
Nil vs. any Treatment	319.5	433.0	444.9
To compare 2 treatments	368.9	500.0	513.7

[1] 45 d.f. for Autumn trial

24 hours to 8 am on the third day after application would have washed the remaining urea and urea breakdown products into the soil, since Black *et al.* (1987) suggested that 16 mm was sufficient to do this. There would appear to have been enough urea and urea breakdown products washed in from the standard urea to result in no overall difference in pasture growth between Agrotain-treated urea and standard urea.

In the spring and autumn trials, Agrotain-treated urea produced significantly more pasture dry matter than standard urea. This difference in pasture production was strongly influenced by the difference in pasture response at the higher N rates. The pasture yield responses from these two trials were very similar, with the yield advantage to Agrotain-treated urea increasing from 2% at 25 kg N/ha to 10% at 100 kg N/ha. Black *et al.* (1985) found a proportional increase in N volatilisation losses with increasing urea application rates, and attributed it to an increase in soil surface pH increasing the amount of urea hydrolysed to ammonium carbonate.

The spring and autumn trials were both characterised by very little rainfall in the 15 days after fertiliser application. However, Black *et al.* (1987) showed that, although volatilisation from dry soils proceeds at a slower rate than from wet soils, much of the hydrolysed urea is lost by volatilisation by 30 days after fertiliser application.

Dairy farmers tend to apply small amounts of urea (up to 50 kg N/ha) at intervals through the season and, at these rates, even under the relatively dry conditions encountered in the spring and autumn trials, the pasture production differences between the two fertiliser types was not significant.

So how does this match up with previous research? Our yield advantage of Agrotain-treated urea over standard urea ranged from 0% to 9%, with an average of 5%, similar to data presented by Stafford *et al.* (2008). If the Canterbury data presented by Ramakrishnan *et al.* (2008) is analysed in the same way, then their yield advantage to Agrotain-treated urea in Canterbury ranged from 6 to 13%, with an average of 10%. Similarly, the Ashburton data of Blennerhassett *et al.* (2006) showed a 7% yield advantage to Agrotain-treated urea. Conversely, if our data are analysed the same way as Ramakrishnan *et al.* (2008), i.e. comparing the yield responses of both Agrotain-treated urea and standard urea to the control, then the response advantage of Agrotain-treated urea ranged from -3% to 32% (average 21%), compared to a range of 23% to 72% (average 41%) of Ramakrishnan *et al.* (2008) and an average of 34% for the Ashburton data of Blennerhassett *et al.* (2006). So our results are similar to previous studies, and indicate small, but variable, pasture yield increases of Agrotain-treated urea over standard urea in Canterbury.

Conclusions

- In this limited set of trials on a single site, Agrotain-treated urea increased dairy pasture yields more than standard urea in situations where irrigation and rainfall was not sufficient to wash the broadcast fertiliser into the soil.
- There was no significant difference in pasture production between Agrotain-treated and standard urea at fertiliser application rates of 50 kg N/ha or less, but the difference increased with higher application rates.
- Where there was sufficient water to wash the fertiliser in, then there appeared to be no yield advantage in using Agrotain-treated urea over standard urea.

ACKNOWLEDGEMENTS

Funding for this project was provided by Ravensdown Fertiliser Co-operative Limited. We thank Selwyn and Jenny McLachlan and Paul and Ingrid Rabbidge for allowing us to run the trials on their farm, and Sarah Sinton, Richard Gillespie and Shane Maley for assistance.

REFERENCES

Black, A.S.; Sherlock, R.R.; Smith, N.P.; Cameron, K.C.; Goh, K.M. 1985. Effects of form of nitrogen, season and urea application rate on ammonia volatilisation from pastures. *New Zealand Journal of Agricultural Research 28*: 469–474.

Black, A.S.; Sherlock, R.R.; Smith, N.P. 1987. Effects of timing of simulated rainfall on ammonia volatilisation from urea, applied to soil of varying moisture content. *Journal of Soil Science 38*: 679–687.

Blennerhassett, J.D.; Quin, B.F.; Zaman, M.; Ramakrishnan, C. 2006. The potential for increasing nitrogen responses using Agrotain treated urea. *Proceedings of the New Zealand Grassland Association 68*: 297–301.

Edmeades, D. 2004. Nitrification and Urease Inhibitors. Environment Bay of Plenty Environmental Publication 2004/11. 23 p. http://www.ebop.govt.nz/water/media/pdf/nitrification.pdf

Manunza, B.; Deiana, S.; Pintore, M.; Gessa, C. 1999. The binding mechanism of urea, hydroxamic acid and N-(N-butyl)-phosphoric triamide to the urease active site. A comparative molecular dynamics study. *Soil Biology and Biochemistry 31*: 789–796.

Mobley, H.L.T.; Hausinger, R.P. 1989. Microbial ureases: significance, regulation, and molecular characterization. *Microbiological Reviews 53:* 85-108.

Quin, B.F.; Blennerhassett, J.D.; Zaman, M. 2005. The use of urease inhibitor-based products to reduce nitrogen losses from pasture. pp 288–304. *In*: Developments in fertiliser application technologies and nutrient management. Eds. Currie, L.D.; Hanly, J.A. Occasional Report No. 18. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand.

Ramakrishnan, C.; Zaman, M.; Blennerhassett, J.D.; Livermore, N. 2008. Improving the efficiency of N fertilisers. pp 278-285. *In*: Carbon and nutrient management in agriculture. Eds. Currie, L.D.; Yates, L.J. Occasional Report No. 21. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand.

Stafford, A; Catto, W.; Morton, J. 2008. Balance Agri-Nutrients approach to sustainable fertiliser use. pp 197-205. *In*: Carbon and nutrient management in agriculture. Eds. Currie, L.D.; Yates, L.J. Occasional Report No. 21. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand.