Can urease inhibitor N-(n-butyl) thiophosphoric triamide (nBPT) improve urea efficiency: effect of different application rate, timing and irrigation systems

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Abstract
Granular urea applied onto pastures has lower N response efficiency (NRE) compared to other chemical fertilizers. Improving N use efficiency of applied urea is therefore critical for sustainability and to minimise its adverse effects on the environment. Field trials were conducted to identify the best rate of urease inhibitor, [N-(n-butyl) thiophosphoric triamide (nBPT) or "Agrotain"] to coat urea for improving its efficiency. Further field trials were carried out during 2006 to 2009 to compare NRE of Agrotain treated urea versus standard urea applied to pasture soils in different application rates (split versus single fertiliser applications), granular and fine particle suspension (FPA) form under different management systems and environmental conditions. The results showed that 1 liter Agrotain/ton of urea was the best economic rate to achieve maximum pasture production in grazed pastures. Agrotain treated urea significantly increased pasture dry matter (PDM), N response, NRE and pasture N uptake compared to urea alone in all trials. Pasture dry matter, NRE and pasture N uptake showed further improvements when Agrotain treated urea were applied in FPA form compared to granular form. Applying light irrigation after one day of FPA application had a positive effect on PDM and NRE. These results suggest that there is considerable potential for improving farm production and profitability by treating urea with Agrotain.

Key Words
Agrotain, FPA, N response, N uptake, pasture dry matter.

Introduction
Nitrogen (N) is an essential plant nutrient in most demand for crops and pastures and soil is the major source of N for plant uptake, however continuous supply of N from various N fertilisers (chemical or organic) is also vital to sustain productivity. Majority of N inputs in clover/ryegrass pasture systems in New Zealand come from excreta (urine + dung) of grazing animals and biological fixation of atmospheric N (Saggar 2004); however, farmers still apply N fertilisers, mainly granular urea (80%), after every single or two grazings to meet animal feed demand. The obvious reasons of more granular urea use worldwide (46% of the total N consumption) are its high N concentration (46%), low cost of manufacturing, low price per unit of N and easy transportation and spread. However, granular urea applied onto pastures has been reported to have lower NRE (10 to 15 kg of dry matter produced per kg of applied N) compared to other chemical fertilizers (Blennerhassett *et al.* 2006; Zaman *et al*. 2008). The lower NRE of urea is attributed to a number of factors including its fast hydrolysis, uneven spread, high application rates and less optimum soil conditions (extreme low/high soil moisture and temperature) after urea application. After granular application, fast urea hydrolysis occurs within 1 to 2 days, which increases soil ammonium (NH_4^+) concentration and temporarily raises soil pH around urea granule. High NH_4^+ concentration coupled with high soil pH are likely to increase the gaseous emissions of ammonia (NH_3) (Watson *et al*. 1994; Zaman *et al*. 2008). Such NH_3 losses from applied urea are clearly undesirable because, in addition to lowering the efficiency of applied N fertiliser, these losses also pose a potential environmental threat via eutrophication of lakes, rivers and other vegetation and may add to global warming by acting as a secondary source of nitrous oxide (N_2O) in the atmosphere. It is therefore essential to develop fertilization management strategies that improve fertiliser N efficiency and decrease N losses.

Among the different options available to improve urea efficiency are: applying lower rate application of urea to synchronise plant N demand with the available N, deep placement/injection or applying medium irrigation to wash applied urea from surface soil, coating urea with polymers and applying urea with urease inhibitor N-(n-butyl) phosphorothioic triamide (NBPT), trade name "Agrotain". Among these options, coating urea with Agrotain has the most potential to improve its efficiency. A number of field and glasshouse trials have reported significant improvement in N response after applying granular urea with Agrotain (Blennerhassett *et al*. 2007; Zaman *et al*. 2008); however fertilizer N efficiency of applied urea is reported to vary with

Agrotain rates. Majority of urea fertilizer onto pastures in New Zealand are applied in Similarly, response efficiency of applied urea is reported to be improved further if urea is applied in FPA form (Quin *et al.* 2005). The objectives of our study were to investigate the potential of applying urea fertiliser with or without Agrotain in FPA form to enhance its fertiliser N efficiency and to identify the different management factors affecting its efficiency in clover-ryegrass pasture systems. We tested the hypothesis that urea applied in FPA form with Agrotain will improve N response through even spread and direct uptake of N in urea form by pasture leaves/cuticles.

Methods

To determine the best rate of Agrotain, field plots of 1 x 1 m area were established on permanent grazed pasture sites in Ashburton and Lincoln Canterbury, New Zealand. Four replicates of urea treated with 4 different rates of Agrotain (0.5, 1, 2 and 3 liter/ton of urea) were applied to field plots at rate equivalent to 25 kg N /ha. After treatments application, pastures from each plot were harvested twice to determine pasture dry matter yield, N response and response efficiency. To determine pasture moisture fraction and N uptake, 3 randomly picked small pasture samples were obtained from each plot, weighed fresh and dried at 70^{o}C for 7 days. After drying, pasture was weighed and analysed for total N.

To compare the difference in pasture responses between standard urea and Agrotain treated urea, field plots were established on permanent pasture sites in mid Canterbury and Ashburton area. Four replicates of 3 treatments [urea alone; urea + Agrotain; urea with Agrotain and elemental S; each applied at 50 kg N /ha after every 2 pasture cuts and 25 kg N /ha after every single pasture cut; and a control (no N)], were randomly applied to those plots in a randomized block design during Aug 2006-Feb 2007.

To compare FPA and granular application methods, three field trials were conducted in mid Canterbury, Ashburton and Lincoln. In the first trial, 4 replicates of 3 fertiliser treatments: urea, urea + Agrotain, and 75% urea + Agrotain and 25% sulphate of ammonium (Rapid-S), each applied at 30 kg N /ha, were applied in FPA form in mid Canterbury on 20th August 2008 through helicopter. In the 2nd experiment at Ashburton, 4 replicates of 2 treatments: urea, urea + Agrotain each applied at 25 or 50 kg N /ha, were applied in FPA and granular forms on 26th February, 2007 through a specially designed truck. In the Lincoln-spray-irrigation experiment, 4 replicates of urea + Agrotain was applied at 25 kg N /ha by truck to 2 pasture heights (5 cm and 10 cm) and 10 cm pasture height with 10 mm of spray irrigation after 1 day of fertiliser application on 2nd March, 2007. Control treatment (no N) was also included in each experiment. After fertiliser application, pastures from each experiment were harvested twice to determine pasture dry matter yield, N response and response efficiency.

Results

Agrotain rate trial

Among the different rates of Agrotain, urea treated with 1 liter of Agrotain per ton of urea, exhibited significantly higher PDM and NR compared with its lower or higher rates (Figure 1). Urea is uncharged particle and can move easily both laterally and downward, therefore prolonged urea hydrolysis through higher rates of Agrotain may increase its likelihood of leaching losses. Similarly the lower Agrotain rate (0.5 L/ton) may not be sufficient to slow urea hydrolysis, which may improve urea-N efficiency.

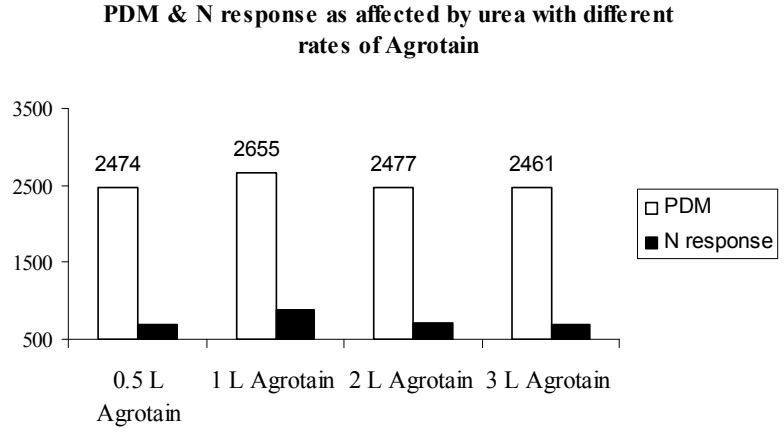

Figure 1. Pasture dry matter and N response as affected by urea coated with different rates of Agrotin.

Pasture dry matter and N response

The 3 trials conducted at Canterbury clearly showed that the applied fertiliser significantly increased pasture dry matter yield and N uptake compared to the control. Overall, Agrotain treated urea showed better N response compared with urea (Table 1). Applying Agrotain treated urea or urea in split or single applications had no significant effect on measured pasture dry matter or N uptake. The individual pasture cut data showed that pasture N response varied with time and was maximum around spring time. Nitrogen response efficiency of urea applied at two split applications of 25 kg N/ha (total of 50 kg N/ha), were 11 and 16 kg DM/kg N applied for standard urea and peat Agrotain treated urea respectively; representing 45% increased over standard urea.

Table 1. Pasture dry matter and N response (kg /ha) after applications of Agrotain treated urea at different rates.

Treatments	PDM (kg/ha)	NR (kg/ha)	PDM (kg/ha)	NR (kg/ha)
	Mid Canterbury Trial		Ashburton trial	
Control (no N)	8,245		8,228	
Urea @ 25kg N/ha	10,425	2,181	10,396	2,168
Agrotain treated Urea @ 25kg N/ha	11,467	3,222	11,485	3,257
Agrotain treated Urea + S @ 25kg N/ha	11,606	3,362	11,273	3,045
Urea @ 50kg N/ha	10,979	2,735	11,184	2,956
Agrotain treated Urea @ 50 kg N/ha	12,140	3,896	11,876	3,648
Agrotain treated Urea + S @ 50 kg N/ha	12,000	3,755	12,031	3,803
LSD 5%	821	915	824.8	884

Fine particle application of urea with or without Agrotain

Fine particle application of urea with Agrotain significantly increased PDM, NR, NRE and N uptake in all three trials. Fine particle application of urea, urea + Agrotain and rapid-S in experiment-1 exhibited significant improvements in pasture dry matter and N response compared to their corresponding granular treatments (Figure 2). Nitrogen response efficiencies were 47, 46 and 38 kg of pasture dry matter per kg of applied N for rapid-S, urea + Agrotain and urea alone applied in FPA form respectively. The high N response in our trial despite low soil temperatures (6^{o}C) and excessively soil wet conditions at the time of fertiliser application could be attributed to a number of factors. Unlike granular application, FPA results in even spread of applied fertiliser on a per plant basis and therefore a significant proportion of the applied fertilisers were found stuck on the pasture leaves. Urea improves the permeability of the cuticle and thus facilitates diffusion into the leaf therefore the deposited urea particles on pasture leaves could have provided pasture plants an opportunity to absorb some of that urea directly through their leaves/cuticles for a short time (as dew washed away the deposited urea next day). Agrotain improves bioavailability of urea-N by delaying plant urease activity, thus providing plant an opportunity to convert the absorbed urea into plant protein more efficiently; therefore rapid-S and urea with Agrotain treatments exhibited even further improvement in N response compared to FPA urea alone. Urea and NH_4^+ are known to require less energy to metabolize and to convert them to plant protein than NO_3^-N. Similarly direct absorption of urea through the leaves/cuticles may save the plant some energy in transporting urea/NH_4^+ from root to shoot, and thus enhance plant growth.

Trial-2

In the 2nd trial at Ashburton, fertiliser applied at low rate (25 kg N /ha) in FPA form exhibited higher N response improvements compared to their corresponding high rate (50 kg N /ha) (Data not shown due to space shortage). Agrotain treated urea applied at 25 kg N/ha in FPA form exhibited 52% improvement in N response over its urea treatments applied in granular form; while such improvements were only 15% for high rate. The lower pasture yield improvements at 50 kg N /ha rate compared to 25 kg N /ha highlight that the plants had perhaps reached their maximum uptake potential through the leaves therefore decreased the N efficiency. The response efficiencies of urea with Agrotain applied in FPA forms were 19 and 21 kg of pasture dry matter per kg of applied N for low and high rates respectively. These values of N response efficiencies by FPA treatments were lower than those we observed in experiment-1 and 3. Such lower N responses by FPA treatments were probably related to the extremely dry soil conditions and high soil temperature (25^{o}C) and air temperature (32^{o}C) on the day of fertiliser application which also caused moderate to severe pasture burning. Hot dry conditions are likely to inhibit N uptake through the leaves due to lack of sufficient solute to transport it. However such pasture burning was temporary and pastures came

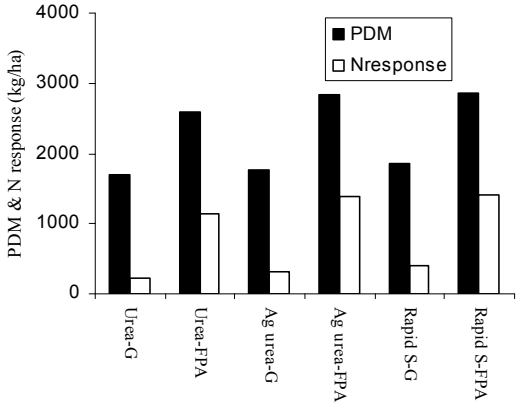

Figure 2. Pasture dry matter and N response as influenced by urea with or without Agrotain applied in FPA and granular form in mid Canterbury trial.

back to their normal growth after 1 week of fertiliser application. In trial-3, dry soil conditions and high soil temperature on the day of fertiliser application also affected N responses from urea with Agrotain applied in FPA form in the Lincoln trial (data not shown). Applying FPA to higher pasture covers and then applying light irrigation significantly improved N response and response efficiency in these conditions. FPA treatments applied to pasture cover of 5 cm, 10 cm and 10 cm with 10 mm leaf irrigation produced 27, 29 and 46 kg of pasture dry matter per kg of applied N respectively. This indicates that light irrigation is a critical after applying fertilisers in FPA form on a hot day to avoid N losses via NH_3 volatilisation and leaf burning. These results suggest that applying chemical fertiliser in FPA form has the potential to improve fertiliser N response efficiency; while leaf irrigation pushes the applied N from surface soil and enable them to make good contact with plant roots.

Conclusions

Applying urea with Agrotain (1 liter Agrotain per ton of urea) in both granular and in FPA forms showed significantly better pasture growth, N response and response efficiency compared to urea alone. Nitrogen response and response efficiency decreased with higher rates of fertiliser applied in FPA form and extreme soil and environmental conditions. These results suggest that that there is considerable potential for improving farm production, profitability and sustainability by treating urea with Agrotain. FPA is a good management tool for enhancing N response and has a greater potential for improved economic returns if applied in the right conditions (avoiding extreme hot and windy days), lower application rates (25 to 30 kg N /ha) and reasonable pasture cover (5 to 10 cm).

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