IMPROVING THE EFFICIENCY OF FERTILISER UREA ON PASTURE WITH ONE*system*®

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Abstract
Given the importance many farmers place on optimising the pasture response to urea, there has been surprisingly few attempts to improve its performance by the main fertiliser manufacturers and suppliers. In fact, the only efficiency-orientated modified urea sold in significant quantities in New Zealand is SustaiN®, which is granular urea treated with the urease inhibitor nbpt. This product was introduced by Summit-Quinphos in 2002. It is now estimated to comprise 30% of urea sold by Ballance Agri-Nutrients, or 20% of total New Zealand urea sales. SustaiN® is currently sold at a $50/t (8.5%) premium to standard granular urea.

This paper presents results from a field trial conducted on an irrigated dairy farm in mid-Canterbury, comparing granular urea with a new process – ONE*system*® - developed by Dr B. Quin and S. Spilsbury over the last 2 years in east Victoria in Australia and in New Zealand. The system uses prilled (micro-granular) urea, which is passed through a fine water spray containing the urease inhibitor nbpt during application. A nil-N control and 3 rates of each fertiliser (14, 28 and 42 kg N/ha) were applied to large plots (12 x 25) on four occasions after grazing during spring/early summer 2014.

Results showed a substantial and statistically significant increase in extra dry matter (EDM) to N applied with the ONE*system*® compared to the pasture response from traditional granular urea, by a factor of 2.6 (± 0.5) averaged over the 3 application rates. For example, the EDM produced by 30 kg N/ha of granular urea could be produced with only 12.5kgN/ha applied as ONE*system*®. Conversion efficiency (kg EDM/kg N applied) increased from 10.2 with granular urea to 24.6 with *ONEsystem®*. Pregrazed plant N concentrations were also higher following ONE*system*® N application, meaning total N uptake was increased at least 3-fold compared with that resulting from N applied as granular urea.

These results have very significant positive implications for both the economics and environmental impacts of fertiliser N use in New Zealand. Preliminary results from a similar trial in the Waikato, and others conducted in Gippsland, Victoria also indicate very positive benefits (to be published elsewhere).

Introduction

Granular urea is by far the most widely used nitrogen (N) fertiliser in New Zealand (NZ), with an estimated 750,000 tonnes (345,000 tonnes N) applied annually in 2014, most of which is applied to dairy farms. Anecdotal information suggests that approximately 50% is spread by contractors and 50% by farm owners and sharemilkers.

The main reason many dairy farmers choose to spread their own urea is not so much to save the spreading cost (which at typically $8-$12/ha is not high), but rather the importance they place on getting the urea applied at the best time to optimise pasture growth, generally 1-3 days after grazing.

Given the importance many farmers place on optimising the pasture response to urea, there has been surprisingly few attempts to optimise the performance of urea itself by the main fertiliser manufacturers and suppliers. Also, there have been very few comparisons of N fertilisers under grazing, as opposed to the use of small, non-grazed plot trials.

The fertiliser manufacturing industry and some advisors have long claimed that both ammonia volatilisation and other N losses from granular urea are low in NZ conditions, the implication being that no improvement can be, or needs to be, obtained. Edmeades (2005) stated that “measurements of the volatilisation losses have been made and they are typically small (between 0-5% of the N applied). However there are some ‘special conditions’ where losses can be higher.”

A ratio of 10:1 kg extra dry matter (EDM) : kg N, frequently used as the default value by farmers and farm advisors in NZ, represents approximately 30% recovery of urea N for pasture containing 3.5%N. Ratios of 3:1 or worse can occur from January-August (Roberts and Thomson, 1989). Such low recoveries have been attributed by some to incorporation of urea N in soil organic N, despite the lack of evidence of increasing soil organic N levels on established dairy farms, as opposed to dairy conversions from forestry.

In 2002, the nbpt-treated granular urea product SustaiN® was introduced into New Zealand by Summit-Quinphos. Research findings on pasture in Ireland (Watson 2000) had demonstrated the effectiveness of the urease inhibitor nbpt in reducing ammonia volatilisation and increasing pasture response to urea. These findings were supported by field studies in New Zealand (Quin *et al.* 2003). Zaman *et al.* (2005) demonstrated the additional nbpt benefit in reducing nitrate leaching from fertiliser urea. Field trials conducted by Summit-Quinphos throughout NZ (Blennerhassett *et.al* 2007; 5 statistically analysed trials reported), and Ramakrishnan *et al.* 2008 (these 5 plus an additional 4 unanalysed trials reported), gave increases in N efficiency ranging from 1.6 - 72% (mean 28.2) compared to granular urea. Zaman *et al.* (2008) provided more detailed evidence for reductions in ammonia and nitrous oxide emissions, and nitrate leaching, from granular urea using nbpt.

Bishop and Manning (2011) reviewed scientific data on ammonia volatilisation losses from granular urea surface-applied to pastures in NZ and several other countries. They reported that losses in NZ ranged from 4.2 - 33.3% (similar to that found in other countries, and concluded that losses of *less than* 10% would only occur on highly acid soils with pH of 5.3 or less and with high cation exchange capacity. Few if any dairy farms operate at soil pH levels below 5.5.

Sustain® is now strongly promoted by Ballance Agri-Nutrients Ltd as being more effective than granular urea, for example ; ‘Use instead of urea unless 5-10mm of rain is *guaranteed* within 8 hours of applying N’ (Ballance Agri-Nutrients ‘Key Products’ 2015). Sustain® has been a very important step in the right direction, but is not the game-changer in efficiency that New Zealand dairy farming urgently needs.

Other improved-efficiency products or application processes have failed to gain significant market share, generally because of higher product and/or application costs or relative inconvenience of use by farmers and/or contractors. The Quinspread Technology spreading trucks produced an agronomically highly effective fluid of crushed granular urea immediately prior to spreading (Quin & Findlay 2009). However, the very high machinery and operating costs, combined with a narrow swath width of 10m, made for high application costs. This proved to be a significant barrier to adoption of the technology by farmers, despite the improved net profit.

This paper presents results from a trial conducted under grazed dairy farming, in which granular urea was compared with a new process known as ONE*system*®, developed since early 2013 by two of the authors (B.F. Quin and S. Spilsbury) in eastern Victoria and in New Zealand. ONE*system*® uses prilled (micro-granular) urea, wetted with a fine water spray containing nbpt during spreading. Results from similar trials conducted in the Waikato, NZ and Gippsland, Victoria, Australia will be published elsewhere.

Trial design

The trial was conducted on large (12x25m) plots on an irrigated dairy farm near Hororata in mid-Canterbury, South Island, New Zealand. The soil is a Lismore stony silt loam, a Yellow Grey Earth classified as an Ustrechrept under USDA taxonomy. The pasture was ryegrass-dominant, with very little clover. Soil tests were quite adequate for vigorous ryegrass growth on this soil type, being Olsen 26, K 4, sulphate-S 11, and pH 5.6. The main source of fertiliser N used in the 6 months before the trial commenced was SustaiN® which was applied regularly by a spreading contractor. No fertiliser of any type was applied in the 3 months before the trial commenced.

The trial comprised a nil-N control, 3 rates of granular urea and 3 rates of the ONE*system*® processed prilled urea. Each treatment had 4 replicates. The accompanying nbpt and water applications were 2 gm/kg N (0.2%) and 50 L/ha respectively.

The 3 rates of each fertiliser (14, 28 and 42 kg N/ha) were applied to large plots immediately after grazing on four occasions during spring/early summer 2014. These rates were chosen both because they covered the normal rates used by farmers, and were predicted to most clearly define the N response curve. Pasture yields before and after grazing were measured on individual plots using a rising plate-metre, which was calibrated against weighed dry matter (DM) on several occasions (Figs 1- 3). Topsoil (0-75mm) samples were taken on 2 occasions (10 November and 2 December), immediately before the next fertiliser application, for ammonium-N and nitrate-N analysis. The very stony nature of the soil made deeper sampling impossible, given the limited time and resources available.

Fig.1 Maurice Gray pre-checks fertiliser application rates. Note the green water tanks fitted.

Fig.2 Dr Allan Gillingham takes notes while Maurice Gray heads off to apply treatments.

Fig.3 Control pasture (no N applied). Note strong growth from the urine patches.

Results and discussion

Dry matter yields and N uptake

The responses in extra dry matter (EDM) produced per kg of N applied with *ONEsystem*® were much greater than those obtained with granular urea, and were very obvious to the naked eye (Fig.4). At the 30 kg N/ha application, urine-affected areas stood out clearly three weeks after granular urea (right plot in photo, Fig. 4), but were almost unnoticeable with ONE*system*® application of N (left plot in photo).

Fig.4 Pre-grazed treatments with 30kgN/ha as ONEsystem® (left) and granular urea (right). Note how the urine patches have become almost unnoticeable with ONEsystem®.

Statistical analysis of the dry matter yields demonstrated a highly significant difference in EDM produced per unit N applied, by an average factor of 2.6 averaged over the 3 application rates of granular urea (Fig.5). This massive differentiation in performance occurred on each of the measurement occasions (results to be reported elsewhere).

The DM measurements reported here (30 per plot) were made using a rising plate-meter (calibrated against mown DM yields) following a set zig-zag path, which naturally included some urine patches. However, the opportunity was taken to measure inter-urine patch DM production as well. The comparison on N responses on urine-affected and unaffected grazed areas will be reported on in a later paper.

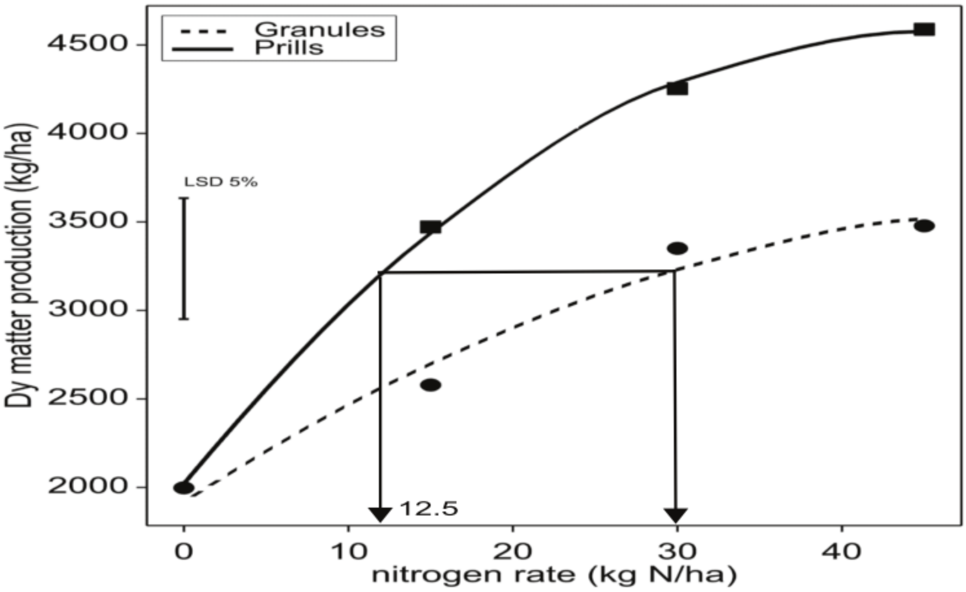

Figure 5. Total pasture dry matter growth responses (greater than control) in mid-Canterbury from increasing rates of N applied per each of 4 applications as either granules or as ONEsystem® prills. The arrowed lines between the fitted quadratic curves shows that an EDM level of 1230 kg EDM/ha was attained with 4 applications of granular urea at 30 kg N/ha (total 120 kg N/ha,), while 4 applications of only 12.5 kg N/ha, a total of 50 kg N/ha) of ONEsystem® were needed to give the same EDM. This example represents N response efficiencies (kg EDM to applied kg N) of 10.2 and 24.6 for granules and ONEsystem® prills respectively, an increase of 2.4 times in this particular comparison.

A contributing factor to the much greater efficiency of ONE*system*® is the better coverage. At 30 kg N/ha, 400-500 prills are applied per square meter, compared to only 45 granules. This means that individual plants (numbering over 400/m^2) automatically get access to a reasonably even supply of N (Fig.6); the 45 granules of urea cannot achieve this, even allowing for lateral movement of urea during dissolution.

Fig.6 Close-up of pasture with ONEsystem® prills adhering to leaves

Other likely factors include (in no particular order) -

- Greatly reduced ammonia volatilisation due to the addition of nbpt;
- A degree of foliar uptake, as the damp prills dissolve *in situ* on plant leaves in the same manner as fluidised fine particles of urea (Dewar *et al.* 2010);
- Reduced nitrate leaching and nitrous oxide emissions (under study).

The magnitude of the increases in pasture response efficiency found with ONE*system*® are not unique to this trial location and conditions. However, indications of a much lower plateau in DM with granular urea are more pronounced at this site than elsewhere. The increased herbage N% (Fig.7) demonstrates that N recovery with ONE*system*® was even greater than that indicated by DM increase alone. At this site, there was little clover and soil N supply was very yield-limiting. Control (nil N) pasture N levels were below optimum for ryegrass-dominant pasture.

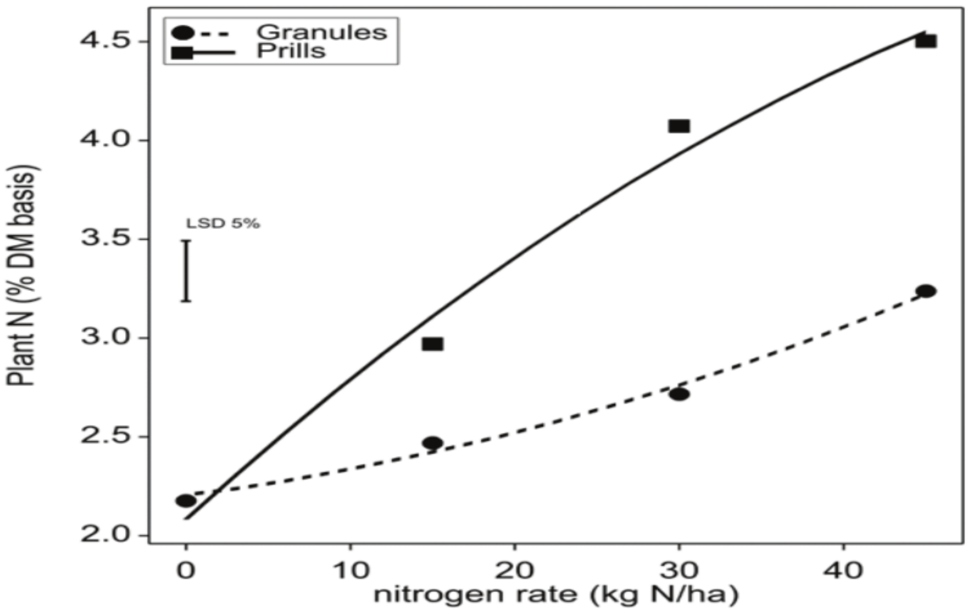

Figure 7. Plant N % averaged from samples taken on 10 November and 2 December 2014 in mid-Canterbury from increasing rates of N applied as either granules or ONEsystem® prills. The curves are the fitted quadratics for each fertiliser type including the control treatment.

Interpretation of soil mineral N data

Mineral N levels in the topsoil, measured on two occasions (10 November and 2 November) immediately before fertiliser re-application took place. Results from these two samplings were averaged. Levels of both ammonium-N and nitrate-N were significantly higher with ONE*system*® prills than with granular urea at the two higher N application rates (Figs 8 and 9).

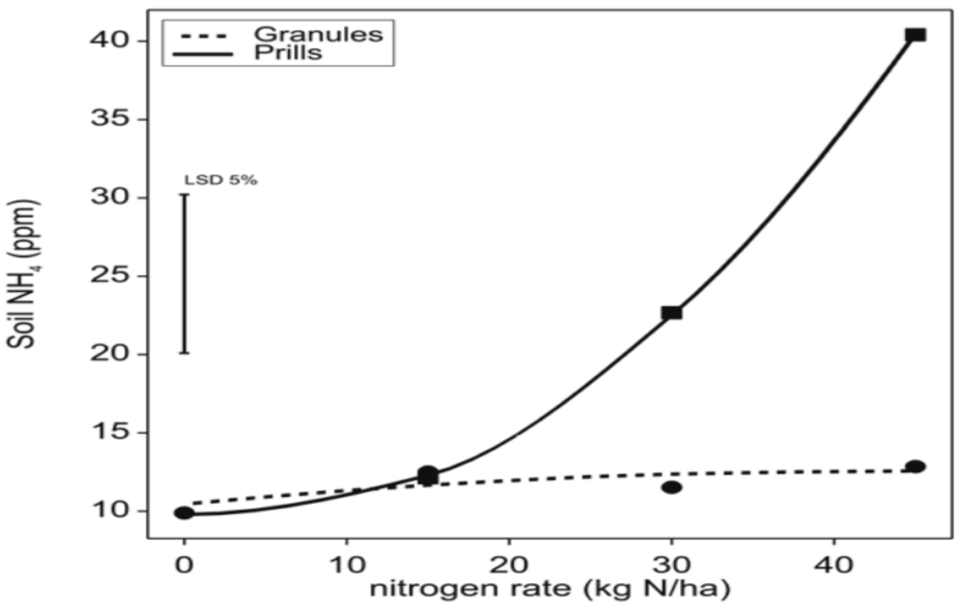

Figure 8. Soil NH_4-N (ppm) averaged from samples (0-75 mm depth) taken on 10 November and 2 December 2014 in mid-Canterbury from increasing rates of N applied as either granules or ONEsystem® prills. The curves are the fitted quadratics for each fertiliser type including the control which is treated as belonging to both curves.

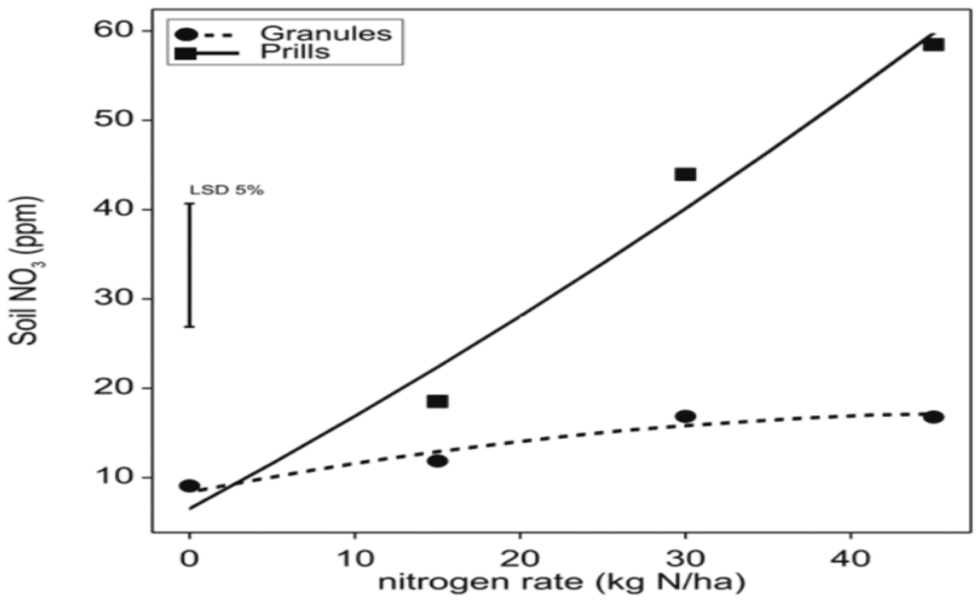

Figure 9. Soil NO_3-N (ppm) averaged from samples (0-75 mm depth) taken on 10 November and 2 December 2014 in mid-Canterbury from increasing rates of N applied as either granules or ONEsystem® prills. The curves are the fitted quadratics for each fertiliser type including the control which is treated as belonging to both curves.

As much greater pasture N recovery took place with the ONE*system*® prills, this indicates that much greater losses from the topsoil, either through nitrate leaching or gaseous emissions, had occurred with granular urea. As farm irrigation rotations were carefully controlled so as not to exceed water-holding capacity, it is likely that gaseous emission was the greatest N loss mechanism from granular urea.

The higher levels of soil nitrate-N and ammonium-N remaining in the surface soil after successive applications of the two higher rates of N applied as ONE*system*® would certainly result in higher residual pasture growth, but with a risk of nitrate leaching if a very heavy rainfall event occurred. Therefore, individual applications of less than 20 kg N/ha as ONE*system*® are likely to be optimum.

Tabular summary of advantages of ONEsystem®

Table 1. Advantages of ONE*system*® *vs* granular urea

ONE*system*® – eliminating N losses and inefficiencies with granular urea	
Granular urea loss/inefficiency	**ONE*system*® answer**
Many plants receive no N at all – insufficient number of particles	Use of prills means 10 times more particles – N supplied more evenly to individual plants
Little if any foliar uptake, missing out on this very efficient mode of N utilisation by the plant	The use of prills, wetted during spreading, ensures that most of the product landing on the leaf dissolves; significant foliar uptake occurs
Very susceptible to ammonia loss	Urease inhibitor minimises ammonia loss
Nitrate leaching is a big problem - too much N is available in the vicinity of individual granules relative to plant N uptake ability.	Faster, more even plant uptake via foliar uptake and better ‘coverage’ (less distance between location of individual prills)

Table 2. Advantages of ONE*system*® vs other technologies

ONE*system*® – eliminating drawbacks with other efficiency alternatives	
Drawbacks of alternative	**ONE*system*® answer**
High cost of product (most coated granular products) or application (FPA, fluidising etc)	Cost of prills is similar to that of granules; application costs remain competitive
Lack of reliable benefit (affects both granular urea and ‘biologically activated’ products)	Wetted prills optimise foliar uptake, nbpt minimises NH_3 volatilisation
Scorching, caused by excessively heavy and rapid leaf uptake (liquid or fluidised urea)	The time required for wetted prills to dissolve on the leaf slows foliar uptake sufficiently to avoid scorching
Lack of placement control can cause direct waterway pollution due to excessively wide spread of granules	Prills give an even coverage, with an acceptably wide but well defined swath width, minimising direct entry into waterways
Difficulty in getting product applied by the contractor exactly when farmer needs it	Focused ONE*system*® contractors will synchronise with clients’ grazing rotation

Conclusions

The results from this field trial under grazing lead to the following conclusions –

- The efficiency of granular urea was extremely poor under the spring-early summer trial conditions, which were typical of irrigated Canterbury dairy farms.
- This efficiency is dramatically improved – by a factor of 2.6 in extra dry matter (EDM) per kg N applied terms averaged over the 3 rates of N application, or 3-fold on an N uptake basis – by using ONE*system*®.
- As an example, a total EDM of 1230 kg DM/ha above the nil-N 2000 kg DM/ha grown during spring/early summer required 4 applications of 30 kg N/ha as granular urea (120 kg N/ha total), compared to 4 applications of only 12.5 kg N/ha (50 kg N/ha total) as ONE*system*®. This represents conversion efficiencies of 10.2 Kg EDM/kg N for granular urea compared to 24.6 for ONE*system*®.
- These results have enormous implications for (a) reducing farmers' input costs and Overseer® N-loss outputs for farmers using ONE*system*®, and (b) Regional Councils' predicted nutrient loadings and water use planning.
- Overall, it is estimated that ONE*system*® achieved 90% recovery of fertiliser N applied, compared to 30% from granular urea.

Acknowledgements

Dr M-L Nguyen (Group ONE Consultancy Ltd) is thanked for his comments on the manuscript. This research was funded entirely by Global Sustainable Farming Ltd, 24 Bridge St, Hamilton 3216, New Zealand.

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'Somewhere, something incredible is waiting to be known.' ***Carl Sagan***