AGKNOWLEDGE 2024 LTD
THE INDEPENDENT FERTILISER EXPERTS
Spring 2025

Fertiliser Review

ISSUE 53

SLOW RELEASE NITROGEN

Nitrogen (N) fertiliser use in New Zealand has increased rapidly from less than 50,000 tonnes in 1990 to about 450,000 tonnes in 2020. Virtually all of this fertiliser N is applied in a readily available, water-soluble form, such as urea, ammonium sulphate or diammonium phosphate. The N in such products is subject to losses to the environment via: volatilisation (ammonia), denitrification (nitrogen and nitrous oxides gases), leaching (nitrate) and runoff (ammonium and nitrate).

As fertiliser N use increases, so does the environmental footprint of farming and there are initiatives, both locally and internationally, to find ways to increase nitrogen use efficiency (NUE) (kg DM/kg N applied) which will provide economic benefits while simultaneously reducing losses to the environment. One avenue that is being explored is the development of slow-release nitrogen fertilisers.

There are several categories of slow-release N fertilisers:

1. N fertilisers, which are chemically modified to reduce the solubility of the N compound in the fertiliser (e.g. urea-aldehyde polymers).

2. N fertilisers, which are coated with a sparingly soluble material to slow the movement of the N from the granule to the soil solution (e.g. sulphur coated urea).

3. N fertilisers, to which bio-active chemicals (e.g. urease and nitrification inhibitors) are added which slow down the transformations of the fertiliser N once it is in the soil (e.g. SustaiN®, N Protect®, EcoN®).

4. N fertilisers, which are coated with a semi-permeable membrane to control the rate of release of the N from the granule to the soil solution (e.g.Smartfert).

It is noted that there are several slow-release N products on the market - typically of the types found in categories 1 and 2 above (e.g. Osmocote). Most are too expensive for use on the ‘broad-acre’ situation but are used in high-end turf culture settings (e.g. golf courses, bowling greens).

SustaiN®, N Protect®, EcoN®

EcoN® contains the chemical DCD (dicyandiaminde) which slows the rate of conversion of ammonium (NH_4^{+1}) to nitrate (NO_3^{-1}) in the soil (Figure 1). This product was introduced onto the New Zealand market some years ago and showed some promise as a tool for reducing NO_3^{-1} leaching in dairy pastures. However, the product was withdrawn from the market when DCD residues were found in milk.

Both of the fertiliser co-ops, Ravensdown and Ballance AgriNutrients, have, in recent years introduced what they call, stabilised urea products - SustaiN® and N Protect®. The chemical agrotain is added to the urea to slow down the conversion of urea ($CO(NH_2)_2$) to ammonium (NH_4^{+1}), in the soil (Figure 1). Under certain conditions the ammonium can be lost to the atmosphere (volatilised) as the gas ammonia (NH_3). It is claimed agrotain reduces volatilisation by up to 50%.

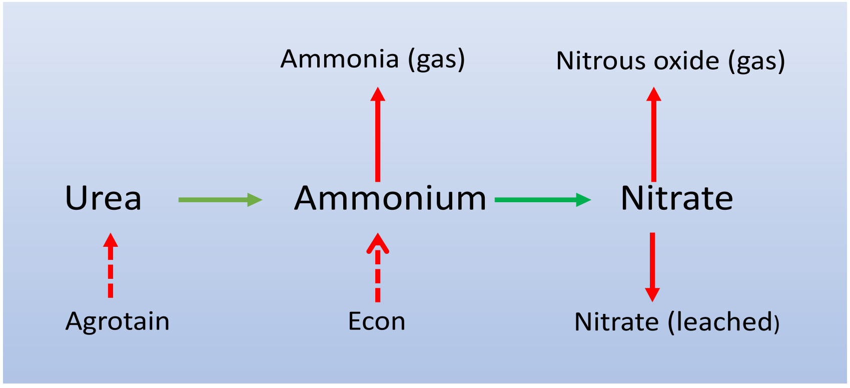

Figure 1 Some of the nitrogen transformations in the soil affected by agrotain and DCD.

Some science

There are two ways to test this claim, either directly or indirectly.

Ammonia volatilisation can be measured directly in the field by placing small micro-chambers over the soil. Clean air is flushed through the chamber, and the ammonia emitted from the chamber is trapped and measured. Chambers are placed on untreated (control) and urea-treated soil, normally with a number of replications. Of course, the experimental technique is a little more complicated than this because it is important to control the temperature and moisture conditions in the chamber, but nevertheless this is the essence of the technique. Experiments of this type have been done in New Zealand and internationally at different temperatures and rates of fertiliser applications.

The fertiliser co-ops claim on their respective websites that, based on this evidence, adding the chemical agrotain to urea can reduce ammonia volatilisation by up to 50%.

There is another way to estimate the effect of agrotain-treated urea, relative to urea-alone. Assuming that if the volatilisation of ammonia (NH_4^{+1}) is reduced (Figure 1) more available plant N will accumulate in the soil and this will stimulate plant growth. In other words, the yields from plants grown with agrotain-treated urea should be greater than the yields grown with untreated urea.

To test this hypothesis, we reviewed data from trials reported in the national and international literature on a range of crops, including pastures. The results are summarised in Table 1. Considering all the data (All Crop Types) there were 348 trials, the mean effect of agrotain (the trade name for N-(n-butyl) thiophosphoric triamide) treated urea, relative urea alone, was 3.1% and the confidence interval of 0.9%. The results were similar for all crop types (Table 1).

[The full paper can be found here: Edmeades DC and McBride RG (2023). An assessment of the agronomic effectiveness of N-(n-butyl) thiophosphoric triamide (nBTPT) - treated urea on dry matter yields of clover-based pastures, grasses and arable crops. Journal of New Zealand Grasslands 85: 149-153 (2023)]

Table 1. Summary of the aggregated and subsets of the data comparing crop and pasture responses to agrotain treated urea relative to untreated urea.

Crop type	Number of observations	Mean DM yield response (%)	Range of DM yield response (%)	95% confidence interval (%)
All crop types	348	3.1	-23 to +32	0.9
Arable crops	114	2.8	-23 to +26	1.8
Grasses	234	3.2	-18 to +32	1.0
Clover based pastures	153	2.9	-13 to +32	1.1

Note that range in the “responses” (I have used parentheses for reasons I will shortly explain) are broad, typically -20% to +30%). To explain, this it is best to plot the data as the cumulative distribution of the “responses” to agrotain treated urea relative to urea alone (Figure 2).

All of the measured effects of agrotain-treated urea were less than +32% and all were above -23%. They were distributed around a mean of +3%. In other words, about 65% of the observed effects are positive and 35% negative. Other international studies, in which many trial results have been summarised, have reported similar effects both in terms of quantifying the effect, and the presence of both positive and negative results.

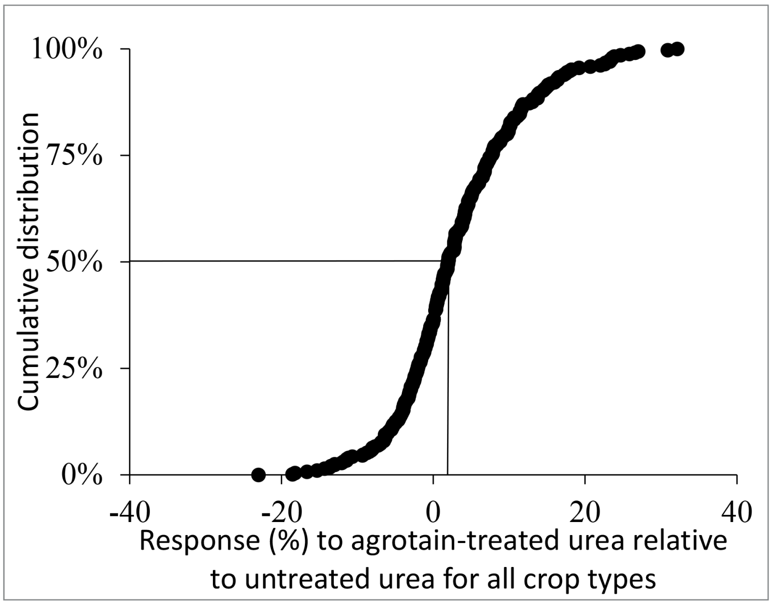

Figure 2 Cumulative frequency distribution of plant dry matter (DM) responses to agrotain-treated urea relative to urea for all crop types (%).

It is unlikely that adding agrotain to urea has a detrimental effect *per se* on plant growth and hence there must be other reasons why they occur, and are apparent, especially in large data sets, such as in the current study. The likely explanation for the observed range in negative "responses" is that they reflect the inherent uncontrolled variability – 'the background noise' - that occurs in all field trials. If this is accepted, then logically the range in the positive effects will also reflect this variability, and should not necessarily be attributed to *real treatment* effects (hence the parentheses). The average "response" in the current data-set is about +3% (Table 1), which indicates that the normal distribution is moved slightly to the right, suggesting that agrotain has a small effect on plant growth, which lies within the limits of error in field trial work.

[For a greater understanding of the application and interpretation of cumulative distribution functions refer to Fertiliser Review No 34 or Edmeades, D.C. 2002. The effects of liquid fertilisers derived from natural products on crop, pasture and animal production: A review. Australian Journal of Agricultural Research 53: 965-976].

The effect of agrotain-treated urea was affected by the rate of N applied – the higher the rate of application of N the great the effect of agrotain (Table 2). This is to be expected given that the more N that is applied the greater the potential effect on the amount of N volatilisation.

Table 2. Effect of the rate of fertiliser nitrogen (N) application on the plant dry matter (DM) yield responses (%) to agrotain-treated urea relative to urea alone.

Rate of N fertiliser application (kg N/ha)	Number of measurements	Mean response (%)	Range (%)	95% confidence interval (%)
0-50	104	1.4	-18 to +23	1.4
51-100	126	2.6	-18 to +30	1.6
101-200	53	4.9	-23 to +26	2.6
+200	34	7.5	-13 to +32	3.1

At low rates of application (< 50 kg N/ha) the mean response was 1.4% with a confidence interval of 1.4%; the mean lies within the confidence interval, meaning that the measured effects are within the margin of error for this type of experimentation. To put this in some context, urea when used on pastures in New Zealand is typically applied at 20-30 kg N/ha per application. It is more likely than not, that agrotain-treated urea will have no measurable effect on pasture growth. When cropping, higher rates of N are normally applied and it is likely that there will be a small, but significant effect on crop yields from adding agrotain to urea.

The small effect of agrotain-treated urea has on plant DM growth is in contrast to the large reported effects that it has (up to 50%) on reducing ammonia volatilisation when measured directly in the field. This raises a question; are the techniques currently used to measure ammonia volatilisation directly in the field over-estimating ammonia volatilisation?

These field trial results suggest that either a) the amount of N volatilised from urea applied to the soil is typically small or b) that the conserved N is not taken up by the plant or c) the conserved N is incorporated into the soil N pool and is not accessible to the plant. These later two suggestions are unlikely given that the yield from clover-based pastures, grasses and crops are always limited by N and they will respond to applied fertiliser N up to very high rates of N.

Simple calculation reinforces the conclusion that the amount of N volatilized from urea is typically small. For example, assume that urea was applied to a pasture and that the pasture yield over the duration of the fertiliser N effect (say 2 months) was 2000 kg DM/ha. If agrotain- treated urea was used instead of straight urea, the increase in pasture production would be on average 3% i.e. 60 kg DM/ha. Assuming a pasture N concentration of say 4%, this would represent about 2-3 kg N/ha.

There is something ironic in these results. In my early career it was generally accepted that volatilisation of ammonia from temperate pastoral soils where N was applied at low rates (< 50 kg N/ha), was small – i.e. < 5% of the N applied - consistent with the present results. In other words, in the overall scheme of things, it was of little practical importance, especially to the farmer. It intrigues me that ammonia volatilisation has only recently become an issue on the farm, coinciding with the introduction of products like agrotain-treated urea. My question is this: Is it possible that ammonia volatilisation has been exaggerated in New Zealand to create a market for agrotain-treated urea?

TNUE SMARTFERT

[Dr Doug Edmeades is the science advisor to Tnue Smartfert]

Smartfert is a *controlled* release urea fertiliser. The urea granule is coated with a semi-permeable membrane which contains nanopores through which water can enter the granule and soluble urea can diffuse out from the granule (Figure 3).

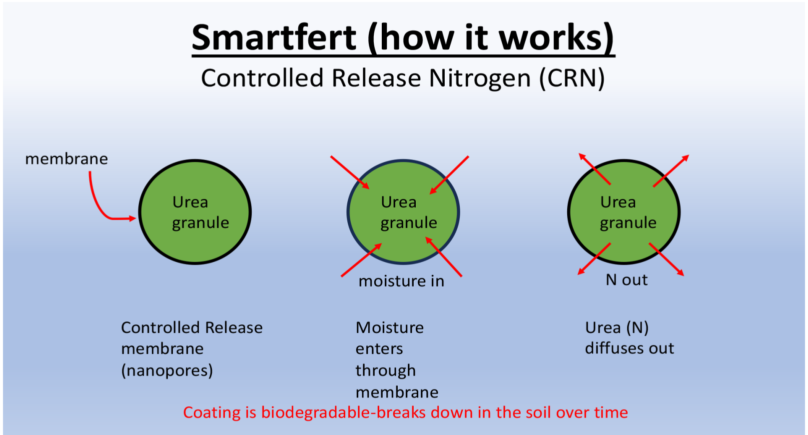

Figure 3 Schematic diagram explaining how Tnue SmartFert works.

The chemistry of the coating can be altered to give with different release rates – hence the terminology “controlled release” urea (Figure 4). The ideal is to match the rate of release of N from the granule to the rate of N uptake by the crop. Theoretically, this should increase the NUE (kg DM/unit N applied) and reduce losses via leaching and from Greenhouse Gas (GHG) emissions (see Figure 1).

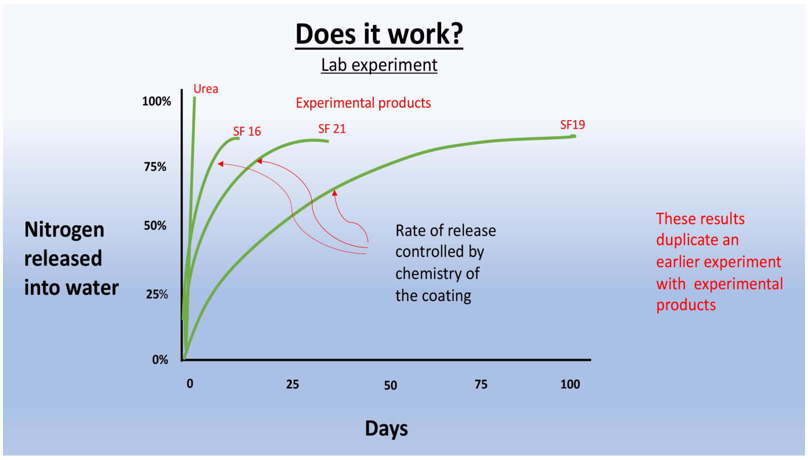

Figure 4 The release of nitrogen over time (100 days) from urea and some experimental Smartfert products (Smartfert (SF) products 16, 21, 19).

Laboratory experiments have shown that this process is not affected by soil moisture but is affected by temperature. It has also been shown to reduce N leaching (Figure 5).

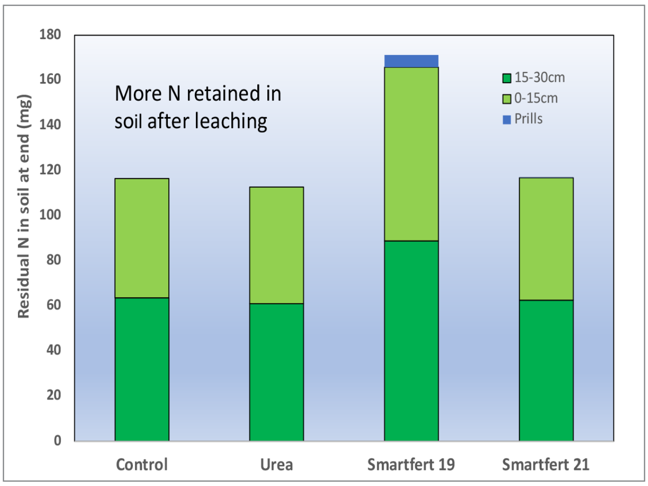

Figure 5 The amounts of nitrogen (N) retained in the soil column after leaching with water for 130 days.

The performance of Tnue Smartfert (Experimental product SF 19 - see Figure 4) has been examined in 6 field trials on white clover-based pastures. The results from one representative trial conducted in the Rotorua district is shown in Figure 6.

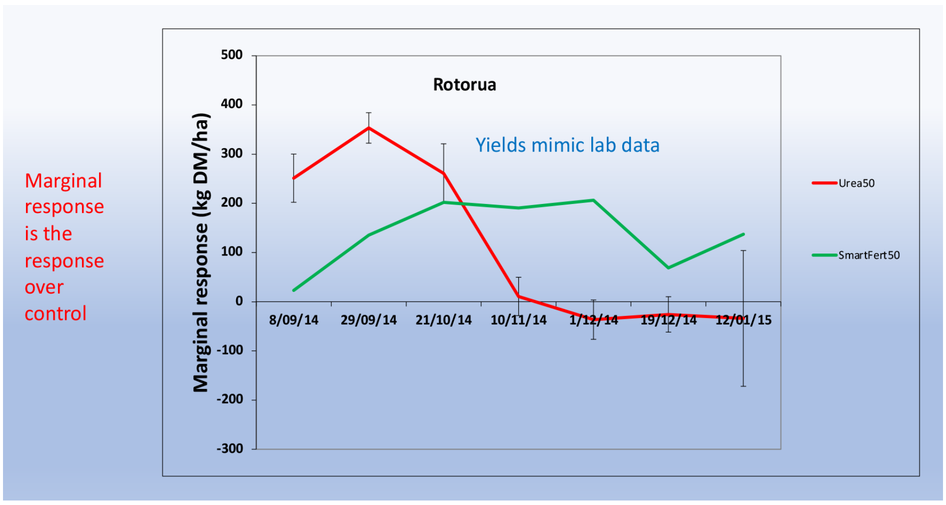

Figure 6 The effect of urea and Smartfert on the marginal pasture response relative to control over a six-month period.

Single applications of 50 kg N/ha of urea and Smartfert 19 were applied in spring and the pasture production was measured at intervals over several months. The results (Figure 6) mimic what was found in the laboratory. There was a large response to urea initially – in the first month - but it declined thereafter. The pasture response to Smartfert 19 was delayed by several months and reached a maximum 3-4 months post application.

On a very N responsive site in the Hawkes Bay the cumulative effect over time of Smartfert 19 was 35% over control (Figure 7)

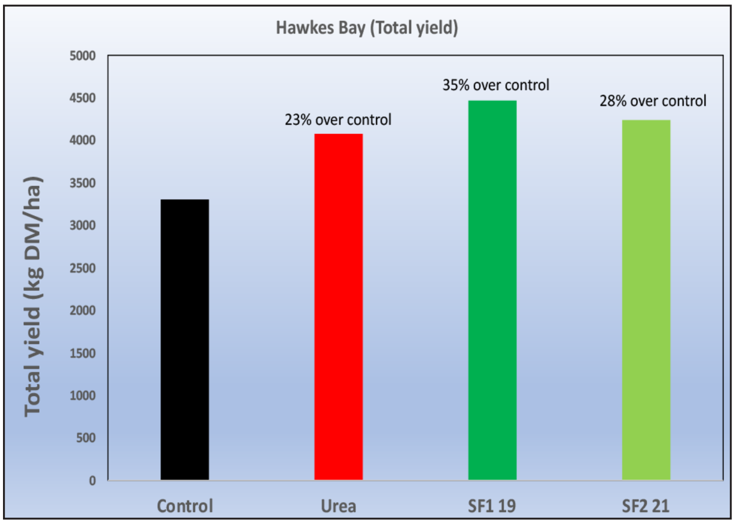

Figure 7
Pasture responses to urea and Smartfert 19 and 21, over control in a trial in the Hawkes Bay.

Typically, the nutrient efficiency of urea in clover-based pastures in New Zealand is about 10-12 kg DM per kg N applied. In the 6 Smartfert trials completed to date, the NUEs were in the range 20-50 kg DM per kg N applied, indicating that the N losses are lower for Smartfert. This is consistent with the results from the leaching experiments conducted in the laboratory.

Given the research to date it is reasonable to conclude that 'proof of concept' is established and that it could now be used to:

1. Front load N on crops at planting (e.g. maize and cereals)
2. Front load N on pastures pre-lambing
3. Modify the seasonal growth pattern of pasture growth over time.
4. Improve the economics of urea fertiliser use.
5. Reduce N leaching.

The environmental benefits of Smartfert currently include:

1. Using geothermal energy at Taupo, to manufacture the coated product and hence a lower environmental foot print.
2. Reducing N leaching.
3. Less frequent N applications reducing the fuel and spreading-time costs.

More research is of course required to estimate how Smartfert performs under different soil and climate conditions and to develop products which better match the rates of plant N uptake of different crops. Overseas research indicates that controlled release urea reduces GHG emissions. This needs to be quantified under New Zealand conditions.

Tnue Smartfert is available from Ballance agriNutrients, Ravensdown and Dickie Direct.