# The evaluation of a controlled release nitrogen fertiliser

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## Abstract
Experiments in the laboratory, glasshouse and in the field assessed the chemical and agronomic characteristics of four polymer-coated urea products manufactured to different specifications, by altering the number and chemical nature of the coatings. (The chemical and physical nature of the coatings and the coating process are the property of the New Zealand distributor, Eko 360 Ltd.) They are claimed to be controlled release nitrogen (N) fertilisers. The N release characteristics of the experimental products were measured, relative to water soluble urea, in the laboratory in the absence of soil. These results confirmed that the N release rates were consistent with the distributor's specifications and were slower than urea. A glasshouse experiment was designed to use N uptake by ryegrass as a proxy for the N release rate in a soil. These results confirmed those from the laboratory, indicating that soil had little effect on the relative N release characteristics of the fertilisers. The experimental product with the slowest release rate was selected for evaluation in the field. In three field experiments the effect the experimental product, applied once at two rates, on pasture production was compared with the same rates of N applied once as urea, over 5–6 months. The experimental product tested increased N use efficiency (NUE, kg DM/kg N applied) by between 5–50% depending on the site and rate of N application. Thus it is concluded that the products are as claimed – contolled release N fertilisers, relative to urea – and that this characteristic is expressed under field conditions. Proof-of-concept was therefore established.

**Keywords:** fertiliser, nitrogen, nitrogen use efficiency, pasture, SmartFert™, urea

## Introduction
Nitrogen (N) fertiliser use in New Zealand has increased rapidly from less than 50 000 tonnes in 1985 to about 350 000 tonnes in 2010 (Fertiliser Matters 2010). This trend is likely to continue because of the economic pressure on farmers to increase production per unit area. 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 (ammonium), denitrification (nitrogen and nitrous oxides gases), leaching (nitrate) and runoff (ammonium and nitrate). Thus, as fertiliser N use increases, so does the environmental footprint from farming.

One solution to this problem is to develop controlled release N fertilisers – products whose N release rates can be controlled and matched to a rate commensurate with the plant N demand. In theory (Shaviv 2000; Chien *et al.* 2009) this has two potential benefits that match stated international (Our Nutrient World 2013) and national (Ministry of Primary Industries 2013) goals to increase nitrogen use efficiency (NUE; kg DM/kg N applied) to provide economic benefits while simultaneously reducing losses to the environment. Of particular relevance to this paper, neither review provides convincing field evidence that such products do infact increase NUE.

There are several categories of slow release fertilisers (Shaviv 2000; Chien *et al* 2009):

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 material to slow or control 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®).

In New Zealand there has been considerable interest in, and research on, Type 3 products (SustaiN® – urea coated with a urease inhibitor, LessN – urea treated with an unknown bio-active material and EcoN – a solution containing the nitrification inhibitor DCD). Independent research on these products indicates that they are not as effective as claimed. (Martin *et al.* 2008; Stafford *et al*. 2008; Edmeades & McBride 2012). Bishop *et al.* (2008) compared the effectiveness of laboratory prepared polyurethane urea, and urea coated with DCD, with urea, in the field over 4 months and found that none of the experimental products were better than urea in terms of pasture production. Internationally many products (of all three types) have been developed and introduced to the market but because of their cost their use is resticted to high value situations (horticultural crops and amenity grasses) (Shaviv 2000; Chien *et al.* 2009).

ISSN 2463-2872 (Print) ISSN 2463-2880 (Online)

This paper describes research undertaken in the laboratory, glasshouse and field to establish "proof of concept" under New Zealand conditions of a polymer coated, controlled-release, urea-based N fertiliser distributed by Eko 360 Ltd, New Zealand.

## Methods

### Laboratory Studies

After some initial experimentation, four experimental products (SmartFert (SF) 1, 2, 3 and 4) were prepared by coating urea granules with different amounts of a polymer coating derived from an organic source. The N release characteristics of these four experimental products, relative to urea, were evaluated in the laboratory using a leaching method developed by Perrott & Kear (2000). Duplicate samples (0.5 g) of each product were placed on glasswool in a leaching tube and eluted with 100 ml aliquots of distilled water. Leaching was carried out over three, 7 hour working-day periods (total time 21 hrs). Overnight the samples were left to stand. Total N was measured in each 100 ml of eluent.

### Glasshouse Trial

This experiment, conducted in Hamilton, New Zealand, consisted of five replicates of five treatments: control, urea, and SmartFert 1, 2 and 4 applied at the equivalent of 50 kg N/ha. Field moist soil (0.68 kg of Horotiu silt loam, pH 5.9, Olsen P 32, MAF QT K 17, MAF QT Mg 36, Sulphate S 32) was weighed into pots (15 cm diameter) into which single ryegrass seedlings were transplanted. After a uniformity harvest the fertilisers were applied by inserting the granules (about 12 per pot) 1 cm into the soil. The granules were covered with soil and the pots watered daily to 75% water holding capacity to ensure that no N leaching or volatilisation occured. The pots were harvested six times to a height of 5 cm over a 10-week period from 30 September to 16 December 2014. Total dry matter (DM) and ryegrass N concentration were measured at each harvest.

### Field Trials

Four field trials (mowing with clippings removed, plot size 2 × 6 m) were laid down in August 2014, on clover-based pastures. Three experiments located in Northland (peat soil), Bay of Plenty, Rotorua (Kaharoa pumice soil), and Hawke's Bay (Gisborne volcanic soil) comprised six replicates of five treatments (control, urea at 25 kg N/ha (urea25), urea at 50 kg N/ha (urea50), SmartFert 4 at 25 kg N/ha (SmartFert25) and SmartFert 4 at 50 kg N/ha (SmartFert50), each applied once in a randomised block design. Standard management and measurements techniques were applied (Lynch 1966). After an initial uniformity harvest in August 2014, the treatments were applied and seven harvest cuts were made on the Northland and Rotorua sites, with the last in January 2015. The Hawke's Bay trial was abandoned after four harvests because the site was not N responsive, and hence an inappropriate site to compare N fertiliser types. The results from this trial are not included in this paper. Pasture dry matter (DM) was measured at each harvest (per plot basis), together with "available" soil N (anerobic mineralised soil N) and mixed-pasture N concentration (both bulked per treatment).

A fourth trial (mowing clippings return, plot size 2 × 6 m) was laid down in the Taupo district on a free-draining pumice soil. It comprised six replicates of six treatments applied once (control, urea30, urea90, urea90 split into three applications of 30 kg N/ha, SmartFert30 and SmartFert90) in a randomised block design. This trial commenced in July 2014 and the treatments applied after an intial uniformity harvest and continued until February 2015 (eight harvests). Pasture DM and mixed-pasture N concentration on a per plot basis were measured at each harvest.

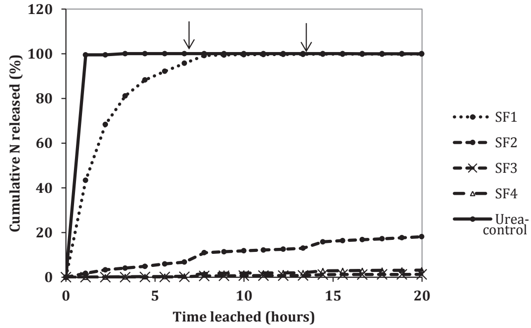


**Figure 1** Cumulative nitrogen (N) released (% of total) over time from urea and four experimental controlled release products (SmartFert, SF) with differing manufacturing specifications. The arrows on the graph represent the over-night pauses in the leaching experiment.

## Results and Discussion

The N release characteristics of the four experimental SmartFert products over time, relative to urea, are shown in Figure 1. They indicate that, relative to water soluble urea, the SmartFert products demonstrated a range of slow release characteristics, consistent with the distributor's specifications. This demonstrates that the greater the number of coatings the slower the release of N. Thus in the absence of soil, the controlled release charactercs of the SmartFert products was established.

The glasshouse experiment was designed and managed such that there were no nutrients other than N limiting plant growth, and to eliminate N losses via leaching, volatilisation and denitrification. Thus, leaving aside the possible incorporation of fertiliser N into the soil organic matter, the ryegrass N uptake

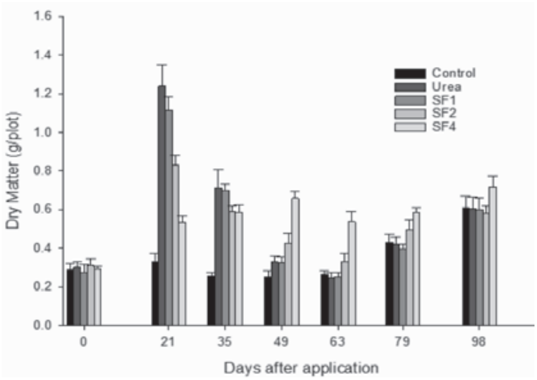


**Figure 2** Ryegrass production (g/pot) after treatment with single applications of urea and SmartFert (SF, 1, 2, 4) over time.

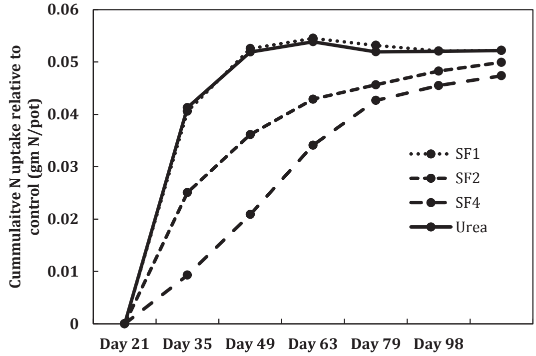


**Figure 3** Cumulative nitrogen (N) uptake by ryegrass after single applications of urea and SmartFert (SF 1, 2 & 4) over time in the glasshouse study at Hamilton, New Zealand, in the spring.

should reflect the N release characteristics of the fertilisers when in contact with soil. The ryegrass production (DM) over time is shown in Figure 2 and the cumulative ryegrass N uptake is given in Figure 3. Qualitatively the rates of N uptake of the fertilisers reflect the N release characteristics of the products in the absence of soil.

The total pasture production from the field trials are given in Table 1 (Northland and Rotorua) and Table 2 (Taupo). Increasing rates of urea increased ($P<0.05$) pasture DM production on all three sites which indicated that the sites were N responsive, an essential requirement in trials designed to test the relative effectiveness of types on N fertiliser. SmartFert25 had no consistent effect on pasture production, relative to urea25 on both sites ($P>0.05$). SmartFert50 increased pasture DM production relative to urea 50 at both sites but these effects were not statistically significant ($P>0.05$). In contrast the Taupo site was more N responsive than the other two sites (see Figures 4, 5 and 6) and DM production from the SmartFert treatments was greater than from the equivalent urea treatments. This effect was statistically significant ($P<0.05$) only at the 90 kg N/ha rate. At this site a single application of SmartFert90 gave a similar yield to three split applications of urea of 30 kg N/ha/application (total N 90 kg/ha), suggesting that one of the benefits of controlled release N fertiliser is that less frequent applications can be made for the same pasture production outcome.

The marginal responses to the N fertilisers at each harvest are shown Figures 4, 5 and 6 for the three sites. The controlled release nature of the SmartFert N fertiliser, relative to urea, at all rates, was demonstrated in all three trials. A further feature of these data is that single applications of both urea and SmartFert, and in the case of the Taupo trial, multiple applications of urea, appear to depress pasture production over time. This effect occurs sooner after application for urea.

The calculated NUEs of the various rates and forms of N fertiliser are given in Table 3 (Rotorua and

**Table 1** Total pasture production (kg DM/ha) after treatment with single applications of two rates of urea and SmartFert (SF) relative to control for the field trials at Northland and Rotorua.

| Trial | control | urea25 | urea50 | SF25 | SF50 | SED |
|---|---|---|---|---|---|---|
| Rotorua | 5648 | 6025 | 6428 | 6034[1] | 6611 | 289 |
| Northland | 4496 | 5026 | 5246 | 4835 | 5431 | 237 |

1) after treating an outlier plot as a missing plot

**Table 3** The nutrient use efficiency (NUE in kg DM/kg N applied) of a single application of two rates of urea and SmartFert (SF) relative to control for the field trials at Northland and Rotorua.

| Trial | urea25 | urea50 | SF25 | SF50 | SED |
|---|---|---|---|---|---|
| Rotorua | 15.1 | 15.6 | 15.8[1] | 19.3 | 7.2 |
| Northland | 21.2 | 15.0 | 13.6 | 18.7 | 5.2 |

1) after treating an outlier plot as a missing plot.

**Table 2** Total pasture production (kg DM/ha) after treatment with a single application of two rates of urea and SmartFert (SF), or a multiple application of urea (3 × 30 kg N/ha) relative to control for a field trial at Taupo.

| Trial | control | urea | urea90 | urea30×3 | SF30 | SF90 | SED |
|---|---|---|---|---|---|---|---|
| Taupo | 8972 | 9742 | 10139 | 11103 | 9989 | 10720 | 280 |

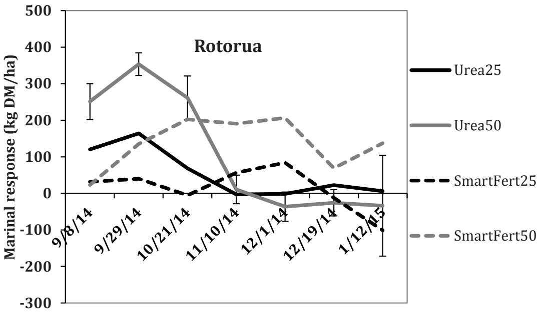


**Figure 4** Marginal pasture responses (kg DM/ha) relative to control over time after applications at two rates of urea and SmartFert (25 and 50 kg N/ha applied once) on a pumice soil near Rotorua. The error bars are ±SED for each harvest.

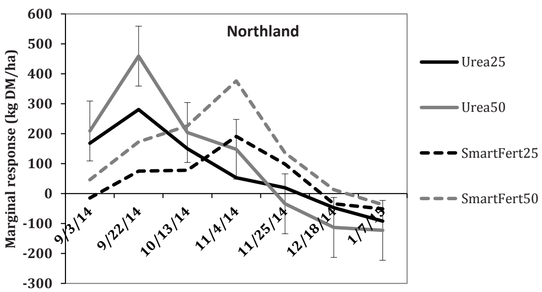


**Figure 5** Marginal pasture responses (kg DM/ha) relative to control over time after applications of two rates of urea and SmartFert (25 and 50 kg N/ha applied once) on a peat soil in Northland. The vertical bars are ±SED for each harvest

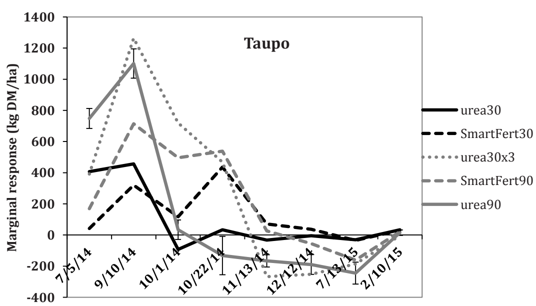


**Figure 6** Marginal pasture response (kg DM/ha) relative to urea over time after applications of two rates or urea or SmartFert (30 and 90 kg N/ha applied once) and a split application of urea (30 kg N/ha × 3) on a pumice soil at Taupo. The vertical bars are ±SED for each harvest.

Northland) and Table 4 (Taupo). They are all positive and ranged from about 5% to 52%, noting the one exception in the Northland trial where the pasture production from SmartFert25 was less than urea25. These effects were not statistically significant (P>0.05) and are interpreted as examples of Type II errors, which arise in hypothesis testing (Snedecor & Cochrane 1967). The implication is that the effects of the treatments, in this case SmartFert, were real but the experiments were insufficiently powerful to detect real differences when they exist (Type II errors). Justification for this interpretation is based on the consistency of the results from the laboratory, glasshouse and field experiments, in the later case considering both the nature of the marginal responses to N and calculated NUEs.

The suggestion that SmartFert N increased NUE implies that losses of N via leaching, volatilisation or denitrification are less than those from urea. Of relevance to this, it is noted that there was no consistent effect of fertiliser type or rate on mixed-pasture N concentration (data not given) from either the replicated (Taupo) or the unreplicated (Northland, Rotorua) data. Intriguingly, the average concentrations, over time, of anaerobically mineralisable soil N were greater for the SmartFert treatments than the urea treatments (156 ppm urea; 178 ppm SmartFert) on the Rotorua site and 292 ppm urea vs 316 ppm SmartFert on the Northland site). The implications are that assimilation of fertiliser N into plant growth is not affected by the release rate of N into the soil, but that this may affect the accumulation of fertiliser N into the soil organic N pool.

It is concluded that SmartFert can be classified as a controlled release N product and suggest that this product has potential to increase fertiliser NUE. Further research is required to a) quantify this effect under a range of soil and climatic conditions in New Zealand b) confirm the mechanism for this effect c) quantify any environmental benefits especially in terms of N leaching, and d) assess the possibility of manufacturing controlled release N products which match the rate of plant N uptake for a range of crops and climatic conditions.

## ACKNOWLEDGEMENTS

This project was funded by Agmardt with a matching contribution from Eko360 Ltd. Technical assistance for the laboratory and glasshouse work (Martin Kear) and the field work (Sarah Anderson and Duncan Bayne) is appreciated and acknowledged.

***Disclosure:*** The author was retained as a science advisor by Eko360 Ltd, a New Zealand based company

**Table 4** The nutrient use efficiency (NUE in kg DM/kg N applied) of a single application of two rates of urea and SmartFert (SF) and a multiple application of urea (3 × 30 kg N/ha) relative to control for the field trial at Taupo.

| Trial | urea30 | urea90 | urea30×3 | SF30 | SF90 | SED |
|---|---|---|---|---|---|---|
| Taupo | 25.7 | 12.9 | 23.7 | 33.9 | 19.7 | 6.0 |

licensed to market SmartFert, and has no pecuniary interest in the company or its products.

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