

# Evaluation of nitrate fertilisers as nitrogen sources for spring pasture

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## Abstract

Since 1994 Ravensdown have carried out a series of pastoral trials in South Canterbury, aimed at looking at the relative effectiveness of different forms of nitrogen in the spring. These trials showed that in general those N products containing some nitrate-N (i.e., calcium ammonium nitrate – CAN, and ammonium sulphate nitrate – ASN) could be more effective than urea and ammonium sulphate when soil temperatures were low. However, responses were inconsistent because of spring climatic conditions. In 1994 and 1996 CAN produced the most dry matter but in 1995, responses to the form of N were less clear. Responses to nitrate-N were generally best when spring soil temperatures were 3–5°C at the time of application. The magnitude of N responses varied with the rate applied, and the type of pasture to which N was applied. Responses generally lasted the equivalent of two to three grazings.

**Keywords:** ammonium-N, ammonium sulphate, ammonium sulphate nitrate, calcium ammonium nitrate, nitrate fertilisers, nitrate-N, urea

## Introduction

Increasingly New Zealand pastoral farmers are looking to strategic applications of nitrogen (N) to grow out-of-season grass. While urea remains the most cost effective and widely used N fertiliser there remain concerns about its use. Firstly, it has been well documented in New Zealand (e.g., Black *et al.* 1985) that urea is more prone to ammonia volatilisation losses than other N products on the market. Secondly, some farmers and consultants have questioned the effectiveness of urea at lower soil temperatures, particularly in comparison to products which contain nitrate-N. Two such products, calcium ammonium nitrate (CAN), and a product first introduced in 1994, ammonium sulphate nitrate (ASN), are now available to farmers.

Plants can take up N in either the ammonium or nitrate forms. In theory it is more efficient for the plant to take up ammonium-N, because the plant needs to convert nitrate back to ammonium-N before it can be

used in plant metabolism to produce proteins (Addiscott *et al.* 1988). However, in practice in New Zealand a plant is likely to take up most of its N in the nitrate form, because the soil microbes rapidly convert ammonium-N to nitrate-N when soil moisture and temperatures are optimal, so most plant-available N will be present in the nitrate form. The exception may be if low soil temperatures reduce soil biological activity and therefore nitrification to nitrate. This should not prevent uptake as ammonium-N, but sufficient anecdotal evidence exists to suggest that at low soil temperatures (below 6–8°C), the plant may prefer to take up nitrate-N. This is possibly because it is the more mobile of these two N forms, and is easily absorbed. A fertiliser containing nitrate-N could therefore have some advantages in early spring.

Ball & Field (1982) in New Zealand found no difference between urea, ammonium nitrate and ammonium sulphate over the whole season. In general, overseas there has been little difference between ammonium nitrate (including CAN), and urea over a range of crops and pastures (Anon. 1986). However, if these data are confined to temperate soils, such as occur in Western Europe (and New Zealand), urea is often less efficient than ammonium nitrate. This is demonstrated by a review of Norsk Hydro (UK) data, which showed on silage that in 117 out of 131 experiments (1958–1985) ammonium nitrate was superior to urea (Paulson & Chaney 1986). Work in Ireland has often shown a contrasting view. For example, in pot trials ryegrass has shown a preference for ammonium in the spring when soil temperatures were low (Watson 1986). In the field, ammonium-N produced more growth but only when irrigation was applied (Watson & Adam 1986), leading them to conclude that under high rainfall the nitrate form is too prone to leaching loss.

In short, although the nitrate form may have some advantages, it does not suit all conditions. With this thought in mind it was felt that alternative products to urea needed to be examined under our soil and climatic conditions.

This paper reports on a series of experiments run in the springs of 1994, 1995 and 1996 in South Canterbury, an area with low winter soil temperatures and low to moderate spring rainfall. These cover a range of products,

application rates and timings in relation to soil temperature. During these studies, BASF NZ Ltd, instigated some work and our results are compared with these (Roberts 1996; Sher 1996) where relevant.

## Methods

Trials were carried out in South Canterbury at Seadown in 1994 and 1996 and in the Fairlie basin in spring 1995. In 1994 and 1995 the trials were on mixed ryegrass–white clover pasture. In 1996 the pasture was predominantly second-year short rotation ryegrass with some clover. At Seadown the soil was a Waimakariri stony silt loam, a recent yellow-grey earth in the New Zealand Genetic Classification (or a Pallic soil as an approximate equivalent in the latest New Zealand Soil Classification of Hewitt 1992). At Fairlie the site was on an Ashwick stony silt loam, a yellow-grey earth (or Pallic soil). Fertility was very high at Seadown (Olsen P >30, K >6, SO<sub>4</sub>-S >15) and average at Fairlie (pH 6.1, Olsen P 12, K 4, SO<sub>4</sub>-S 18). In 1994 the Seadown site was limed several weeks before the start of the trials (and immediately watered in), otherwise where necessary basal fertility was rectified at laying down.

Four N fertilisers were used, urea, ammonium sulphate, CAN and ASN (Table 1). All treatments were replicated 4 times in a randomised block design and were applied once soil temperatures had reached target values. The temperatures quoted relate to the average 9 a.m. soil temperature at 10 cm depth for the week following N application. The experiments were:

Spring 1994: The four fertilisers were compared at 30 kg N/ha at three temperatures, 0–2°C (2 August), 3–5°C (25 August), and 8–10°C (3 September). Urea was also compared with ASN at three rates, 25, 50 and 100 kg N/ha applied on 25 August.

Spring 1995: The four fertilisers were compared as per spring 1994 at 30 kg N and 60 kg N/ha. The temperatures were 3–5°C (22 August), 7–10°C (21 September) and 10–11°C (11 October). Calcium nitrate (Ca[NO<sub>3</sub>]<sub>2</sub>·4H<sub>2</sub>O), 12% N was also used at the lowest temperature.

Spring 1996: The same four fertilisers were compared at 30 kg and 60 kg N/ha at 2–5°C applied on 7 August.

**Table 1** Nutrient content of the N products used.

	Total N %	Nitrate N %	% of N as nitrate-N	Sulphate-S %
Urea	46	-	-	-
CAN	27	13.5	50	-
Ammonium sulphate	21	-	-	24
ASN	26	7	26	14

All trials were under mowing, on 4 m × 1 m (1994) or 4 m × 1.25 m (1995, 1996) plots. The top and bottom of each plot were discarded and 1 pass of a 430 mm mower taken for dry matter determination. Approximately 40% of the clippings were returned to the plot to simulate grazing return. After each cut potassium chloride was applied to allow for some crop removal (these soils have high potassium reserves). This equated to 15–20 kg K/ha/cut. No basal fertiliser was required in the Seadown experiments. In 1995, the Fairlie site received a basal fertiliser consisting of 250 kg/ha of 15% potassic super (0–8–8–8) plus molybdenum and magnesium (as 125 kg/ha of kieserite, 15% Mg, 20% S). Plots were harvested until N responses ceased. Normally this lasted 2–4 cuts depending on the timing and the rate of N applied.

## Results and discussion

### Soil temperature and rainfall

Spring climatic conditions were different in the three seasons. In 1994 and 1996 the soil temperature slowly but uniformly increased through the spring. In 1995 after reaching 3°C quickly, the temperature remained unchanged for the next 3–4 weeks. It then increased more rapidly than in the other two years. This phenomenon accounts for much of the variance in the responses noted between seasons.

The rainfall received between the N application date and the time when N responses ceased was not high on the Seadown sites. In 1994 the rainfall during this period was 76 mm (for the 0–2°C experiment, 73 mm (for the 3–5°C experiment) and 90 mm (for the 7–9°C experiment). These all received 15 mm as irrigation in August (this did not coincide with a N topdressing). In 1996 the trial received 99 mm while it remained N responsive. In 1995 at Fairlie the rainfall was higher, 250 mm (for the 3–5°C experiment), 177 mm (for the 7–10°C experiment) and 88 mm (for the 10–11°C experiment). All sites had adequate but not excessive soil moisture at the start of the trials.

### Overall response to form of N

In all three years there was a significant response to 30 kg N/ha (Table 2). CAN was significantly better than the other N fertilisers in 1994, and urea in 1996. In 1994 it was better to use nitrate-N in the absence of S, i.e., use CAN rather than ASN), while in 1996 nitrate forms were significantly better ( $P = 0.051$ ) than non-nitrate forms of fertiliser. Overall there was no effect from the S in the product, therefore where CAN is generally better than ASN it is because it contains more nitrate-N.

**Table 2** Response to 30 kg N/ha applied at 3–5°C in the spring, 1994–96 seasons.

Treatment	1994	1995	1996
	kg DM/ha		
Control	2170	1270	1120
Urea	2830	1700	1920
CAN	3280	1690	2170
Ammonium Sulphate	2900	1650	2000
ASN	2820	1780	2100
LSD 5%	350	260	250
Significance of contrasts			
NO <sub>3</sub> vs non NO <sub>3</sub> effect	n.s.	n.s.	*
S effect	n.s.	n.s.	n.s.
Interaction	*	n.s.	n.s.

In 1995 the BASF-sponsored work compared urea, CAN and ASN. Roberts (1996) concluded that ASN (applied at 50 kg N/ha) had a significant advantage over urea in early spring growth at temperatures below 6°C, based on work at Reporoa (near Rotorua), and in Southland. Sher (1996) also showed a slight advantage to ASN over urea (at 50 kg N/ha) in the early spring of 1995 on two Taranaki sites. CAN performed relatively poorly on the high rainfall Taranaki sites and the moderate rainfall Southland site. On the wetter non-free-draining sites the performance of CAN was likely to be due to denitrification (Ryden 1983), rather than solely to nitrate leaching as suggested by Sher (1996), although on sites where basal S was not applied, S deficiency could be an issue. Denitrification probably was a contributing factor to the performance of three fertilisers containing nitrate at Fairlie, our wettest site, in 1995 (the calcium nitrate data are given in Table 4), although it is debatable whether early soil temperatures were sufficient for significant denitrification to occur (Ryden 1983). Our data also shows no influence of S. However, in the same season at Seadown under cropping (unpublished data), ASN and CAN grew slightly more spring dry matter and ASN and ammonium sulphate significantly increased grain protein over urea, despite adequate soil sulphate levels at planting and subsequent topdressing of S to all treatments in October.

#### Influence of soil temperature on spring production

In 1994, trials were repeated at three different soil temperatures. There was a significant response to 30 kgN/ha applied at all three temperatures (Table 3). The response to the forms of N clearly followed soil temperature.

At 0–2°C, there is a non-significant response to CAN over the other N sources. ASN was next best. At this temperature there is low soil biological activity to

stimulate nitrification of urea and ammonium fertilisers to the nitrate form (and organic-N mineralisation). However, while nitrate fertiliser may be of help the plant itself was not actively growing to fully benefit from the nitrate-N.

At 3–5°C, responses to CAN in particular were good, because the soil biological activity was still low but temperatures were sufficiently warm for plant growth, hence the good response to nitrate-N. The response to ASN may have been low because of the 30 kg N application rate provided only 8 kg of nitrate-N.

At 7–9°C, there was no difference between N fertilisers because soil biological activity was adequate for mineralisation of organic N and to convert non-nitrate forms rapidly to nitrate-N.

The trends shown here suggest that at low soil temperatures pasture may prefer to take up N in the nitrate form. If this is so, then pastures containing more winter-active grasses (i.e., short-rotation ryegrasses) could show larger responses, particularly as they can respond at lower soil temperatures. This was partly demonstrated by the 1996 results.

**Table 3** Response to 30 kg N/ha applied at three different soil temperatures, spring, 1994.

	Experiment 1 0–2°C 3 Aug – 13 Oct	Experiment 2 3–5°C 25 Aug – 13 Oct	Experiment 3 7–9°C 13 Sep – 26 Oct
	kg DM/ha		
Control	2380	2170	2510
Urea	2750	2830	2940
CAN	3000	3280	2970
Ammonium sulphate	2740	2900	3110
ASN	2850	2820	3140
LSD 5%	540	350	450

#### If nitrate nitrogen works when is the dry matter available?

The results of the dry matter data for the 3–5°C timing trial in 1994 have been broken into a cut by cut basis in Figure 1.

CAN significantly ( $P < 0.05$ ) out-produced the other N fertilisers at the first two cuts, showing the immediate benefit from using some nitrate-N. As the site became less N responsive, the others N sources produced at least as much dry matter as CAN, presumably as the N in CAN is depleted and the soil temperature (and hence soil mineralisation and nitrification) increased. The soil temperature was 7–9°C by 13 October.

#### Nitrogen application rate

In 1994 ASN significantly ( $P < 0.01$ ) produced more early dry matter (September growth) than urea (Figure 2).

This tended to increase with rate, although not significantly so. It is understandable that there is the least difference at the lowest N rate because of the low rate of nitrate-N provided by the ASN. However, at the highest rate the response to N would be expected to taper off, giving urea an opportunity to produce as much growth as ASN. A probable reason why this did not happen is because at the highest rate of N, urea suffered from greater volatilisation losses of ammonia-N. This was demonstrated by Black *et al.* (1985), and even though the losses were often slightly lower in spring, the reasoning is still valid.

October production from the single spring application was similar for both products indicating soil temperature was adequate for urea hydrolysis and nitrification to occur. By this time the N supplied by the lowest rate of fertiliser was almost exhausted.

Figure 1 Effect of form of N on dry matter production, on a cut by cut basis, 1994.

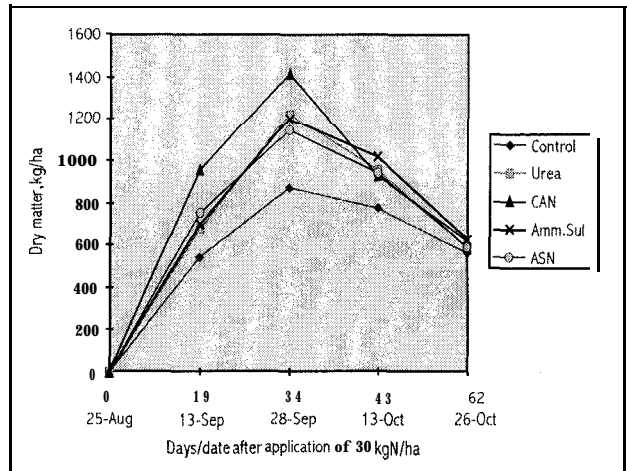


Figure 2 Dry matter production in September and October 1994, to 3 N rates as Urea or ASN.

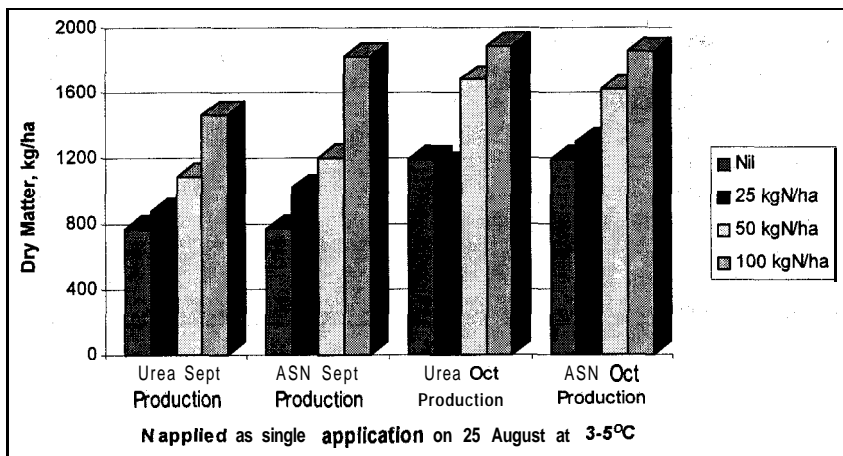


Table 4 Dry matter production from two rates of N applied at 3–5°C soil temperature, in 1995 and 1996.

	1995		1996	
	30 kg N/ha	60 kg N/ha	30 kg N/ha	60 kg N/ha
Control		1270		1120
Urea	1700	1910	1920	2670
CAN	1690	2050	2170	3020
Ammonium Sulphate	1650	2110	2000	2940
ASN	1780	1970	2100	2960
Calcium Nitrate	1790	2090		
LSD <sub>5%</sub>		290		240

It was hard to see any trend between forms of N in the 1995 trial data (Table 4) because of the lower responsiveness. However, in 1996, CAN, ASN and ammonium sulphate all performed significantly better than urea at the higher rate. Ammonium sulphate improved the most at the higher N rate in both years, and urea the least. As neither contains nitrate-N, this again suggests that volatilisation losses from urea increased when the higher rate was used.

Overall, there is some evidence to suggest that fertilisers containing some nitrate-N perform better than urea (but not necessarily ammonium sulphate) in the early spring, particularly at a higher N rate. Given that urea is cheaper than the other N fertilisers, the farmer's choice of product may well be dictated by other factors such as the importance they place on seasonal (spring) dry matter, and the value they place on the sulphur in ASN (or ammonium sulphate). These factors are especially applicable to dairy farmers and on other high-producing enterprises.

## Conclusions

In South Canterbury, nitrate forms of N, in particular CAN, can grow more spring grass than non-nitrate forms of N, in particular urea. The benefit of nitrate-N over urea appears greater at higher N rates.

Responses to nitrate-N can be variable owing to the unpredictability of spring climatic conditions, and are closely related to spring soil temperatures. They are best at 3–5°C when organic N mineralisation and fertiliser N nitrification are low, yet pasture is able to grow. When overly wet spring soil conditions are conducive to denitrification losses, ASN may be the better option than CAN, especially where the sulphur has a value.

Although urea still remains the cheapest source of N, choice of an alternative product may benefit those farmers requiring strategic spring growth, particularly on well maintained (and highly stocked) pasture containing responsive grass species.

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