

Nitrogen - What Is Appropriate Use?

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Increased N use in South Island

Dairy farmers in the South Island have traditionally used relatively little N fertiliser with the main source of N in pasture coming from N fixation by white clover. However, because grass responds readily to N fertiliser, the amount of use has increased considerably in recent years, with a 150% increase in the last 3 years alone (Statistics New Zealand).

Application rates of 150-200 kg N/ha per year are not uncommon today.

Economic rate of nitrogen fertiliser to apply

Research has shown that nitrogen fertiliser is most efficient when applied between 20 to 40 kg N/ha per application (ie. giving a production increase of about 12 kg dry matter per kilogram of nitrogen applied). Application rates above 40 kg N/ha give a smaller increase in dry matter production per kilogram of nitrogen applied and, at 100 kg N/ha, only 7 kg dry matter per kilogram N is achieved (Figure 1).

Ledgard, 1989)

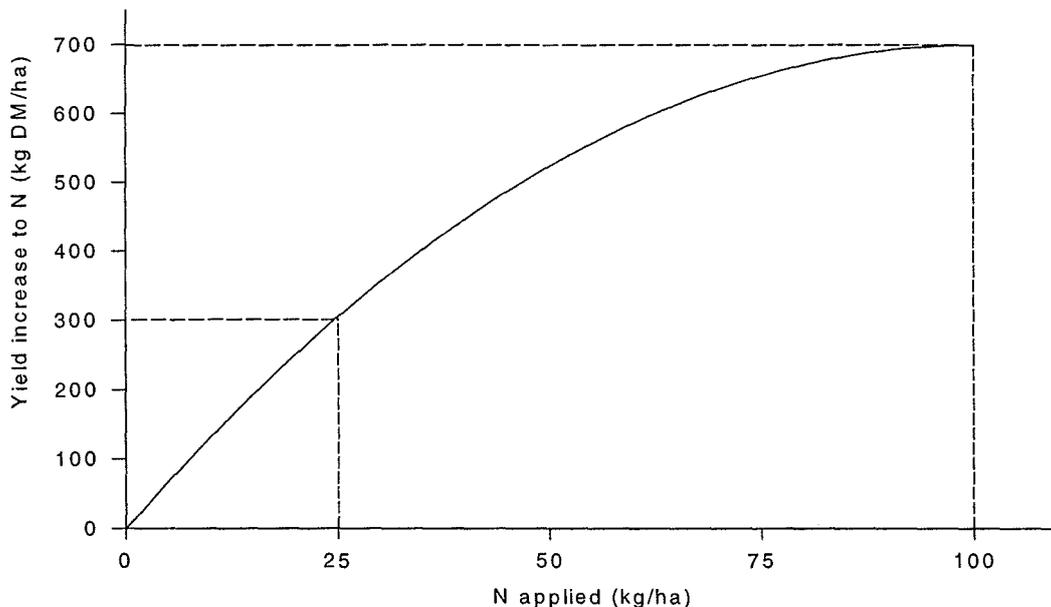


Figure 1: Typical pasture yield response curve to N fertiliser (adapted from Ledgard, 1989).

Timing of fertiliser application

The size of the pasture response depends on the time of application and the soil/pasture/climatic conditions. Results from trials in the South Island show that the best response is generally obtained in the spring, with lower response efficiency in the autumn (Table 1). However, there is a shortage of research data for dairy farms covering the wide range of conditions found in the South Island.

Table 1: Pasture responses to N fertiliser (kg DM/kg N) applied at 25-35 kg N/ha (Ledgard, 1989).

District	Time applied	Average response (kg DM/kg N)	Range
Canterbury irrigated	August	15	10-15
Coastal Otago	Early September	13	5-30
	March	9	6-13
West Coast	Early September	12	9-20
	March	10	6-18
Southland	Early September	12	8-15
	Late February	12	6-24

It is often recommended that it is best to use nitrogen fertiliser strategically, ie to meet feed deficits. For example, nitrogen applied in late-winter/early-spring can help to meet the early season feed demand (Figure 2). The N fertiliser essentially shifts the start of spring pasture growth to an earlier date and provides the feed when it is most needed.

Soil temperature is critical and if it is too cold (ie below about 4°C) then the grass will not be able to respond to the fertiliser. There is also a risk of losing fertiliser if it is applied too early. As a rough rule of thumb, 50 mm of rainfall on a wet soil in spring could leach the band of fertiliser to about 100-150 mm depth (depends on the soil). If the soil is dry then the depth of leaching is less because much of the water is used to satisfy the soil moisture deficit.

There is a shortage of research data covering the full growing season for dairy farms in the South Island. The difference in pasture production curves between the North and the South Islands makes it unreliable to simply transfer research results from the North Island trials; more research is needed here.

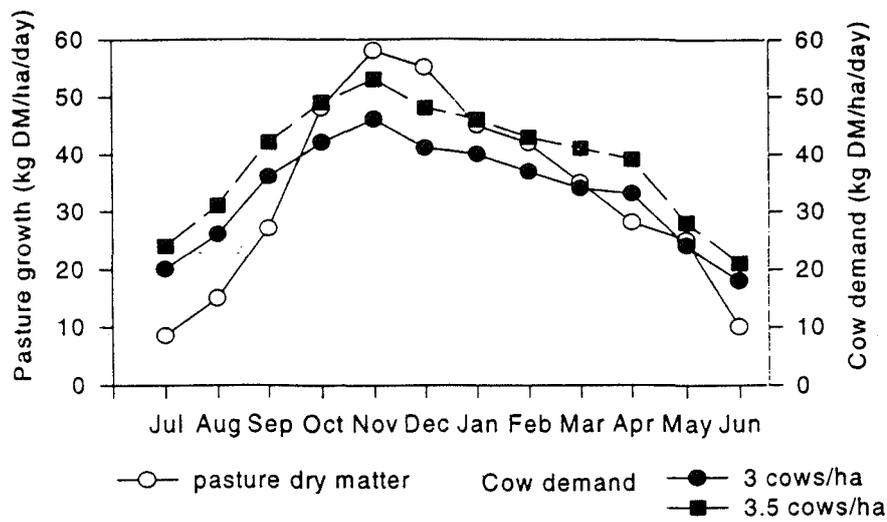


Figure 2: Pasture growth rate and cow demand.

Type of N fertiliser

Research results indicate that there appears to be little difference in pasture response between urea and ammonium fertilisers.

Table 2: Pasture response to three different forms of N fertilisers (Ball and Field, 1982)

Form	Pasture yield (kg DM/ha/y)	Response efficiency (kg DM/kg N)
Urea	13 800	13.9
Ammonium sulphate	13 500	13.1
Ammonium nitrate	13 600	13.3
No fertiliser	8 800	

The choice therefore comes down to cost and if the fertiliser contains other nutrients that are needed as well as nitrogen. If sulphur is not needed, then urea is the cheapest form of N fertiliser available. Urea is however subject to volatilisation (gas) losses of ammonia, which volatilisation loss increases with the rate of urea application (Figure 3)

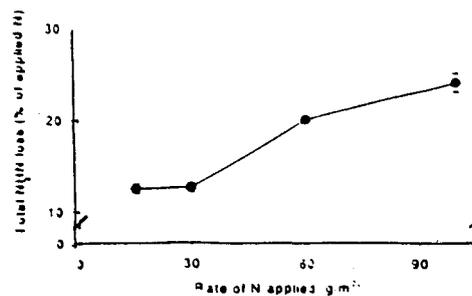


Figure 3: Effect of urea application rate on the percentage of applied N lost by volatilisation may be as high as 28% of the N applied.

Applying the urea immediately before rainfall or irrigation can reduce volatilisation loss (Figure 4). Enough rainfall, or irrigation, is needed to wash the urea into the soil and thus reduce the amount of urea solution sitting on the soil surface. Once the urea is washed below the soil surface the rate of gas loss is reduced and there is a greater opportunity for ammonium to be held by the soil particles. Morning dew is not enough because although this may help to dissolve the urea it does not wash it into the soil. However 5 mm of rain can be effective, provided that it occurs within 3 hours of applying the urea, larger amounts of rain are needed if it occurs more than 8 hours after fertiliser application. Figure 4 shows that the sooner the rainfall or irrigation occurs the greater the effect and the lower the volatilisation loss.

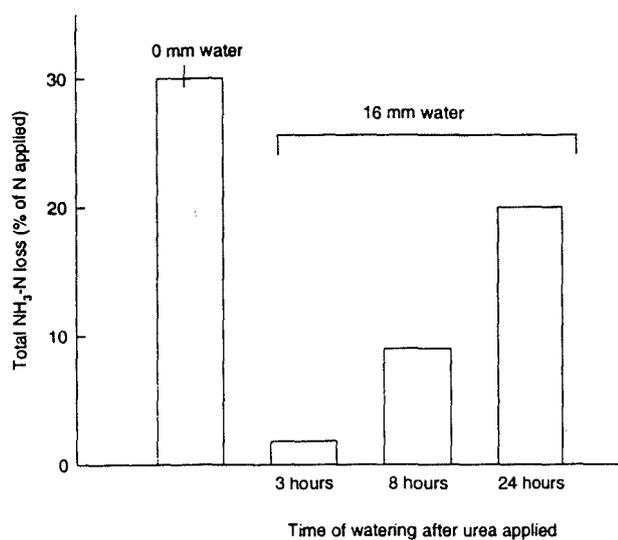


Figure 4: Influence of rainfall or irrigation on the amount of ammonia volatilised over a 7 day period following application of urea on to pasture (adapted from Black et al., 1987).

What is enough N fertiliser

The main risk of using nitrogen fertilisers is nitrate pollution of surface and groundwater. A high concentration of nitrate in drinking water is a health hazard, particularly for infants. The New Zealand Department of Health has therefore set a maximum acceptable value of 11.3 mg N/L for drinking water in New Zealand.

Another problem is that nitrate contamination of rivers and lakes, termed eutrophication, may cause an increase in weed and algae growth. This can make it difficult for boating or swimming, difficult to collect water for irrigation and will also require more frequent cleaning of ditches. Fishing may also be affected as fish cannot survive in water that is overloaded with weed and algae growth.

The nitrate leaching issue has become so serious that many countries have established specific regulations to deal with it. The European Community “Nitrate Directive” has identified nitrate sensitive zones where there are restrictions on farming, eg. manure applications must be below 170 kg N/ha/y and it is not permitted to spread manure in autumn or winter. In the United Kingdom, “Nitrate Sensitive Areas” (15 000 ha) have been established, where all N inputs must be below 150-250 kg N/ha/y and compensation is paid for changes in land use. In the Netherlands, all farms must have a “nutrient accounting system,” with penalties for excessive losses.

The impact of the increase in N fertiliser use in the South Island is unknown at this stage, although overseas research indicates that it is likely to lead to increased nitrate concentrations in groundwater. Many shallow aquifers in Canterbury have concentrations above 11.3 mg N/L, although nitrate concentrations in the deeper aquifers remain very low. High nitrate concentrations have been the focus of recent public concern in the Oreti Plains in Southland. High nitrate levels have also been found in about 30% of shallow aquifers in the Hamilton Basin

Our research at Lincoln University is designed to gather reliable data to help us determine an acceptable and sustainable rate of N fertiliser use. We are doing this using large lysimeters (cores of soil) installed in the field. We measure the pasture uptake and the leaching loss from fertiliser applied at different rates to a typical Templeton sandy loam soil. The results show that the largest leaching losses occur from below cow urine patches rather than directly from the fertiliser.

Results for grazed pasture systems

- The nitrate leaching loss was 54 kg N/ha under grazed pasture with urea applied at 200 kg N/ha per year plus cow urine returns. The average nitrate concentration in the drainage water was 16 mg N/L.
- In grazed pasture where cow urine was deposited but no N fertiliser or effluent was applied, the nitrate leaching loss was about 33 kg N/ha per year. The average nitrate concentration was about 10 mg N/L.
- Different irrigation conditions such as spray vs border dyke irrigation did not result in significantly different annual nitrate leaching losses on this soil.

Results for cut and carry systems

- In cut and carry pasture systems ie. without animal urine returns, only 6 kg N/ha per year was lost by leaching when dairy shed effluent was applied at 200 kg N/ha per

year, giving a annual average nitrate concentration in the drainage water of less than 2 mg N/L.

- When urea was applied at 200 kg N/ha per year to a cut and carry system, then the nitrate leaching loss was about 8 kg N/ha per year, resulting in a nitrate concentration of about 3 mg N/L.

These direct measurements of nitrate leaching show that there is a considerable difference between grazed systems and cut and carry systems, due to the large input of nitrogen in cow urine patches.

Critical N application rate guidelines

- Based on the findings from the lysimeter studies, we have developed a computer model known as NLE (Nitrogen Leaching Estimation) (Di and Cameron, 1999) to estimate the critical N application rates below which the nitrate N concentration in the drainage water will not exceed the drinking water standard (11.3 mg N/L).
- For grazed pastures, critical application rates are 160-200 kg N/ha if urea is used, and 250-300 if dairy shed effluent is used.
- For cut and carry conditions, the critical application rates are about 400 kg N/ha for urea, and about 600 kg N/ha for dairy shed effluent.

There is an urgent need to confirm that these initial guidelines are appropriate by conducting research to make direct measurements of N leaching losses from a range of fertiliser rates and times of application on the key soils used for dairy farming in the South Island.

Long term effects on pasture growth

Soil fertility and N fertiliser use

It is essential to maintain a high soil fertility to get the maximum benefit from the nitrogen applied. Nitrogen fertiliser is a “growth promoter” and should not be used in place of other fertilisers. Regular soil tests are needed to check on fertility and to decide on the fertiliser needs (Roberts *et al.* 1994).

However, it is often asked if the critical Olsen-P level in the soil should increase as the rate of N fertiliser and pasture production increases. Farmer observations indicate that this is probably the case and we need more research to define the relationship and establish target Olsen-P values under intensive dairy farming in the South Island.

Most N fertilisers acidify the soil and is important to monitor soil pH and to apply lime more often.

Effect of N fertiliser use on clover

Clovers can use soil nitrogen as well as fix nitrogen from the atmosphere. High concentrations of nitrate and ammonium in the soil reduce the activity of the N fixing enzyme (nitrogenase) and inhibit root nodule formation. Nitrogen fertiliser use has been reported to reduce N fixation by clover and for every 50 kg of N fertiliser applied you will lose about 25 kg of N fixed by clover (Hoglund and Brock, 1987).

Regular use of high rates of N fertiliser will eventually reduce the clover content of the sward and in the long term the shading by grass plants and the competition for nutrients will reduce the amount of N we obtain “free” from nature. It has been estimated that N fixation by clovers is worth over \$1 billion dollars per year to New Zealand.

Mixes of N and other fertilisers

Some N fertilisers can be mixed with other products, as shown in Table 3, or alternatively compound fertilisers can be used. Urea should not be mixed with other fertilisers such as superphosphate unless it is to be used immediately. Urea absorbs water and should be protected from moisture in the atmosphere.

	Urea	Ammonium sulphate	DAP	Superphosphate
Urea				
Ammonium sulphate	Yes			
DAP	Yes	Yes		
Superphosphate	Only if used immediately	Yes	Only if used immediately	
Potassium Chloride	Only if used immediately	Yes	Yes	Yes

Nitrogen in dairy shed effluent

Land application of effluent allows the valuable nutrients to be recycled back onto the land, but care needs to be taken not to overload the capacity of the soil to remove the nitrogen. The most common regional rules restrict the effluent application rate to less than 150-200 kg N/ha/y. Some regions now also limit nitrogen fertiliser application rates to below 100-200 kg N/ha/y.

Effluent can produce a good pasture response, eg. 10-15 kg DM per kg N applied. The nutrients in the effluent are valuable and could help you save on fertiliser. For example, the value of N, P, K, and S in the dairy shed effluent from a 400 cow herd is about \$4 500 per year.

Recycling effluent onto land will increase soil fertility and increase profit by spending less on fertiliser.

Is more N required to give 1 400 kg MS/ha?

All soil and plant growth conditions need to be optimised to achieve and sustain high production. Nitrogen is only one part of the equation and although it is easy to change there may be other factors that also need attention, for example: irrigation effectiveness; soil aeration and drainage; phosphate, sulphate and potassium status, and soil pH.

Recommendations based on current research

- Apply less than 160 to 200 kg N/ha of N fertiliser per year to grazed pasture, depending on the soil type, climate and management.
- Apply less than 40 kg N/ha per application.
- Apply when soil temperature is above 4°C in spring and above 7°C in autumn. not too early in spring or too late in autumn.
- Remove stock at least 2 or 3 days before irrigation, this will reduce the leaching loss from urine patches.

Acknowledgments

I would like to thank the Foundation for Research, Science and Technology and the Dairying and Environment Committee of the Dairy Board for funding much of this research. We would also like to thank R. Silva, T. Hendry, S. Moore and N. Smith for their expert assistance with the research work

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Workshop Summary. Nitrogen - What Is Appropriate Use?

Recommendations

- Apply less than 150-200 kg N/ha per year.
- Apply less than 50 kg N/ha per application
- Apply when soil temp above 4°C in Spring and above 7°C in Autumn ie. not too early or too late.
- remove stock at least 2 or 3 days before irrigation

Main issues raised

All other things being equal (eg. sulphur not limiting) response efficiency is very similar

N Fertiliser	kg DM/kg N
urea	13.9
ammonia nitrate	13.3
ammonia sulphate	13.1

Tips for using N with irrigation.

The ideal would be to wait for rain then apply N, and irrigate afterwards. Often conditions are not ideal!

Spray. Apply N and irrigate.

Border dyke. If soil profile is shallow (eg. Lismore) it is more preferable to irrigate then apply N. This reduces the chance of N washing straight through the soil profile.

Losses to volatilisation are not high, but occur regularly.

<i>Treatment</i>	<i>N applied after water</i>	<i>Max recorded loss</i>
No rain		27%
16 mm of water	24 hours	21%
16 mm of water	8 hours	8%
16 mm of water	3 hours	3%

Answers to other questions

How much N is required to grow 15 000 kg DM.?

600 kg of N is needed, approximately 4% N for every kg DM

Questions for the future

- What is the effect of leaching at different rates of N application. eg. Is 50 kg N/ha x 4 applications per season comparable with 25 kg N/ha x 8 applications?
- Granules vs fertigation (spray irrigation containing N)?
- What is the optimum Olsen P for N use?
- Are soils from throughout the South Island to be used in lysimeter trials?
- When do clovers start fixing N after N fertiliser applications?