Nitrogen – Growth promotant for pastures

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Summary
All plants need nitrogen (N) for growth but most pasture systems are deficient of N at times during the year and can respond economically to tactical applications of N fertiliser. However, as N is susceptible to numerous loss processes, the rate, source and timing of N fertiliser applications are critical to ensure maximum benefit. As N fertiliser will increase the growth rate of the pasture, adjusting grazing management is also critical to ensure efficient utilisation of the additional pasture produced.

This paper discusses the key management factors that can influence the efficient use of N fertiliser and discusses the positive and negative impacts of N fertiliser on pastures and animals. Further information, including a summary list of recommended management practices for N fertiliser use on pastures can be found at www.nitrogen.unimelb.edu.au.

Introduction
All plants need nitrogen (N) for growth and usually derive their N needs from either the soil or from the atmosphere via legumes. In most intensive grazing systems N will be in short supply, as it is constantly removed from the soil/plant system through animal products being sold off the property, through losses or through the uneven distribution of dung and urine on farm. Due to this continual shortfall in N, farmers are increasingly finding that tactical applications of N fertiliser provides them with a very useful management tool for manipulating seasonal pasture growth rate. Unfortunately, N is subject to many loss processes and is not efficiently recycled back to the pasture, with only 30 to 40% of the N applied to the soil (fertiliser plus dung and urine) eventually used to grow more pasture (Whitehead, 1995).

Management is the key to profitable use of N fertiliser. Not only are the rate, source and timing of N fertiliser applications important, but equally grazing management must be adjusted to fully utilise the additional forage produced. A recent review conducted by Martin Staines, Greener Pastures project, Vasse Research Centre, Western Australia, reported that N fertiliser use on Australian dairy farms has increased by almost 300% over the past 13 years. However, milk production had only increased by 65% over this same period (Figure 1). Furthermore, the Greener Pastures team found that the correlation between N fertiliser applied and farm profit is generally weak in pasture-based dairy farming in Ireland, New Zealand and Australia. The assumption that more N fertiliser means more grass and thus more profit is by no means a certainty!

There are a number of reasons why N fertiliser use may never translate fully into extra animal production and more profit. This paper discusses some of the key management issues that can improve N fertiliser use efficiency.
Nitrogen fertiliser rates
Nitrogen not like other fertilisers that can be applied in single annual applications, but must rather be applied at a rate appropriate for each regrowth period separately, otherwise significant losses will occur. Annual N fertiliser rates are also therefore relatively meaningless, as the response to each application is really dependant on the conditions at the time of application.

Pasture growth rate responses to N fertiliser follow the law of diminishing returns; as you apply increasing rates of N fertiliser pasture growth rate increases initially, but reaching a point where more N fertiliser cannot produce additional growth and the response efficiency declines (Figure 2). What is obvious from the generalised response curve in Figure 2 is that N rates of between 25 and 50 kg N/ha produce reasonably consistent and predictable pasture growth responses, while applications below and above these limits may be far less efficient.

Figure 1. Changes in milk production and N fertiliser use on Australian dairy farms (M. Staines, Agriculture WA, derived from ABARE and Dairy Australia data).

Figure 2. The pasture response to N fertiliser, both as the percentage of the maximum growth rate that can be achieved, and as the daily growth rate change for a single grazing rotation for a well fertilised perennial ryegrass pasture in late winter.
While there are differences between soil types and seasons, in most cases pasture responses to N rates higher than 50 kg N/ha in a single grazing rotation are increasingly less efficient (Figure 2), but also have potential to result in severe environmental impacts. These higher rates exceed that capacity of the soil-plant system to utilise the surplus N for any single regrowth cycle, making the unutilised N highly vulnerable to loss. Likewise responses to very low rates of N can be highly unpredictable where legumes are part of the sward mixture, as it is hard to predict the N being supplied by the legume. Rates below 20 kg N/ha in a single application are thus not recommended.

Therefore to maximise the efficiency of each N application and minimise the risk of losses, N application rates should be between 25 and 50 kg N/ha per application for a single grazing rotation.

**Nitrogen fertiliser timing**

The timing of N fertiliser applications is critical to efficient use. Research has shown that N fertiliser is best applied after grazing, as it takes at least 4 to 5 days for the N to work its way into the soil and be detectable in the plant, and this is about the time required by the plant to recover from grazing and produce its first new photosynthesising leaves. A simple rule of thumb has shown that delaying the application of N fertiliser reduces the potential pasture response by about 1% per day post grazing (Mundy and Wilson 1995b).

The time of year is also critical in maximising N responses. If N fertiliser is applied when plants are too dry or too cold to grow, then the pasture growth response to N fertiliser will be limited. The best time to apply N is usually after the autumn rains but before soil temperatures have dropped prior to winter. This way, the pasture growth rate is increased and a more vigorous plant can be carried into the winter. Likewise an application of N in the late winter/early spring (late July onwards) will usually produce additional forage at a time of year when additional pasture growth is most needed.

**Nitrogen fertiliser source**

Recent research has shown that there are no consistent differences in pasture growth responses between N fertiliser sources (Eckard 1998), and losses from fertilisers vary depending on the seasonal conditions. However, there are large differences in both cost and N content between fertilisers (Figure 3).

![Figure 3. An illustration of the amount of N in a 40 kg fertiliser bag (right), either as urea, ammonium nitrate (AN), calcium ammonium nitrate (CAN), ammonium sulphate (AS), ammonium sulphate nitrate (ASN) or Di-Ammonium Phosphate. The actual N content of each source is in brackets (i.e 100 kg urea has 46 kg N).](image-url)
Urea is by far the cheapest ‘pure’ source of N being around 30% cheaper than any other N source. If both N and P are required at the same time then DAP is the cheapest source of both P and N. As long as the different sources of N fertiliser are applied at the same N rate (see Figure 3) there is no difference in quantity or quality of pasture produced.

If urea is applied to pastures during warm summer conditions, during which time it is usually too dry and therefore not recommended in southern Australia, losses of ammonia gas can be as high as 25% (Eckard et al. 2003). However, applying urea between the autumn break and late spring seldom results in ammonia losses above 10% and therefore does not justify using another N source. However, applying ammonium nitrate or CAN during the wet season has been shown to result in higher denitrification (Eckard et al. 2003) and leaching losses (Eckard et al. 2004b), both of which contribute to environmental contamination (Eckard et al 2004a).

**Grazing Management**

One of the major problems identified from surveys conducted by the Greener Pastures project team in Western Australia is that farmers may be applying more N, but are not utilising the extra pasture grown equally. At first glance, the data in Figure 4 appears to show that there is no relationship between N fertiliser application rate and pasture used on farm. However, what Figure 4 really shows is that at any given N rate, some farmers are harvesting up to 4 times more pasture than others (eg. 8 t/ha versus 2 t/ha at 65 kg N/ha), with a full range in between. This clearly shows that some farmers gaining large returns from using N while others are clearly not. To use N fertiliser profitably it is therefore important to adjust grazing management and stocking rate to the higher growth rate, otherwise pasture utilisation will suffer.

![Figure 4](image)

**Figure 4.** Pasture response to nitrogen fertiliser application on 79 Western Australian dairy farms using the Dairy Farm Performance Program in 1999/2000 (D Windsor, Greener Pastures Project, unpublished data).

**Optimum conditions for applying N fertiliser**

*Soil Temperature*

As soil temperature affects both plant growth and the soil microbes that covert N into various forms, N responses at soil temperatures below 3 to 4 °C are fairly limited, with the N applied being susceptible to leaching and denitrification loss. However, the direction of soil temperature change over the regrowth period may be more important the actual temperature. For example, a soil temperature of 10 °C in late May could still decrease to less than 4 °C during the response
period, whereas a soil temperature of 10 °C in late July is likely to increase over the regrowth period. In the former case it would be advisable to apply the N fertiliser earlier in May to allow the pasture time to respond at higher soil temperatures. The latter case, coupled with increasing day length which also has a marked effect on plant growth, is more likely to deliver an efficient response.

Measurements taken on a number of properties in NW Tasmania (Eckard & Franks, 1998; Eckard, Unpublished data) showed the impact of soil temperature on N responses, and that a north facing slope may be as much as 2°C warmer than a south facing slope in winter. Thus splitting the N application to only apply to north facing slopes in July and then south facing slopes in August may be more efficient that apply N to all paddocks in July.

**Soil Moisture**

As a guide, if the pasture is green and growing there is sufficient soil moisture for it to respond to N fertiliser. However, if the pasture is even slightly moisture stressed the response to N fertiliser will be restricted. If there is sufficient moisture for pasture growth then urea should not require rainfall to wash it into the soil. Urea is hygroscopic and will readily dissolve using the humidity in the plant-soil zone.

Under waterlogged conditions, commonly encountered in the low lying pastures in winter or flood irrigation areas, Urea is the best source of N fertiliser to use, as waterlogged pastures tend to take up more ammonia from the soil than nitrate (Whitehead 1995). As nitrate sources of N are not recommended under these conditions as nitrate is highly mobile in soil water and can denitrify, leach or be lost in surface run-off.

**Species Composition**

The species composition of the pasture is important in determining the response to N fertiliser. The N responses in Figure 5 show the impact of pasture with reasonable (65% ryegrass) and poor pasture composition (25% ryegrass). Annual, short rotation and perennial ryegrasses respond most efficiently to N fertiliser in that order (Eckard 1998). Therefore it would make sense to target pastures high in these species rather than all paddocks on the property.

Figure 5. An illustration of the effect of basal fertility of the N responsiveness of a pasture (Frank McKenzie, Western Victoria).
Generally, a pasture with poor species present (i.e. fog grass, brown top/bent grass, sweet vernal) is a sure indicator of poor fertility as well; N fertiliser applied to such a pasture would be wasted. The primary investment here would be other basic fertilisers and renovation to improve the species.

**Soil Fertility**
If any other nutrients (P, K, lime) are limiting growth this could limit the response to N. Data from a cutting trial imposed on the Phosphorus farmletts at Ellinbank (C. Gourley, Unpublished data) suggest that pasture responses to N will be limited at soil P levels below 14 ppm Olsen P (Figure 6). It makes sense therefore to target N applications to high fertility paddocks to ensure the most efficient response.

![Figure 6.](image)

**Figure 6.** The response of a perennial ryegrass pasture to increasing rates of soil Olsen P with 80 kg N fertiliser applied (C. Gourley, Ellinbank, Unpublished data).

**Positive effects on pasture and soil**

*Pasture vigour*

The time taken to 3-leaf emergence is not affected by N fertiliser regime. Figure 7 shows perennial ryegrass leaves grown for the same period, but under either a high or low N regime, showing longer and wider leaves with higher N.

Nitrogen fertiliser has also been shown to increases tiller density in pastures, but this does depend on our grazing management (Eckard 1998). If the animals do not keep up with the higher growth rates, shading restricts light reaching down into the pasture and restricts the growth of new tillers. However, with good grazing management, high utilisation and the right rotation, N fertiliser will increase the pasture density by increasing tiller numbers. High tiller numbers are essential for long-term perenniality of pastures.

![Figure 7.](image)

**Figure 7.** Perennial ryegrass grown to 3-leaf emergence with either no N or 50 kg N fertiliser applied following the previous grazing
Negative effects of nitrogen fertiliser use

Environmental Implications

The regular use of high rates of N fertiliser have been criticised world wide due to their potential environmental impact and inefficiency. Numerous studies have demonstrated that as N fertiliser rate is increased beyond the capacity of the soil-plant systems capacity to utilise the surplus N, an increasing proportion of the N applied is susceptible to loss, either as leaching, denitrification or volatilisation as ammonia gas as shown in Figure 8 (Eckard 1998; Eckard et al. 2004a; Eckard et al 2006).

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y = 0.0006x^2 + 0.0286x + 33.978
\]

\[
R^2 = 0.9278
\]

**Figure 8.** The relationship between increasing annual N fertiliser rates and total N losses from a grazing pasture as predicted by the DairyMod model (Eckard et al. 2006).

Soil acidification

All inputs of N to the soil will contribute to acidification, regardless if the N was sourced from legumes, the atmosphere or from N fertiliser. However some sources of N fertiliser acidify the soil more than others. Regular use of Ammonium Sulphate acidifies the soil substantially more than Urea, which in turn acidifies marginally more than Calcium Ammonium Nitrate (Eckard 1990a). However, the application of one or two strategic applications in a year will not acidify the soil notably and certainly not as much as the acidifying effect of a high clover pasture.

Animal Health

The excessive use of N fertiliser on annual ryegrass pasture has been implicated in reduced fertility in animals, appetite suppression, grass tetany, lower dietary fibre and isolated cases of nitrate or ammonia toxicity (ammonia or free gas bloat). Most of these cases are linked to high rates of N fertiliser in excess of those advocated, coupled with the season of the year (spring or autumn), abnormal weather conditions (long periods of warm, yet overcast weather in spring or autumn) and, worst of all, hungry animals (Eckard 1990b).

It is important to note that it is seldom nitrate toxicity, but more commonly a chronic or sub-clinical ammonia toxicity or even ammonia bloat (free gas bloat) that may affect animals on highly N fertilised pasture (Eckard and Dugmore 1994). The problem here is that high quantities of N are being released in the rumen while the energy required by the microbes and the animal to utilise this N is in short supply. However, animal health problems associated with N fertiliser are
less common on perennial ryegrass, cocksfoot and tall fescue pastures, as these species accumulates less nitrate and protein.

Further information, including a summary list of recommended management practices for N fertiliser use on pastures can be found at www.nitrogen.unimelb.edu.au.

References: