Improving profitability from nitrogen fertiliser on Australian dairy farms

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Introduction

Dairy production in Australia has continued to intensify, as measured by the volume of milk produced per hectare of forage area. There is an ongoing trend for fewer, but larger, more capital intensive operations, with increased stocking rates. The number of dairy farms in Australia has declined by around 70% over the past 25 years, but average farm herd size and milk production per cow have increased, with national cow numbers remaining roughly the same (Dairy Australia 2011). Associated with these increases in intensity and production is a reliance on greater inputs of fertiliser and feed. The cost of manufacturing nitrogen (N) fertilisers, principally associated with the cost of fossil fuels, is expected to rise substantially in real terms in coming decades and consequently fertiliser N use will become a larger part of dairy farm operating costs.

Increasing dairy production intensity also exacerbates nutrient surplus at the paddock and farm scale (Gourley et al. 2012; Gourley and Weaver 2012). Nitrogen is not significantly buffered by soils, and where N is applied in high concentrations such as in dung, urine or fertiliser, losses through volatilization and leaching can be high. The challenge of optimising the production potential and profitability of N inputs on dairy farms while reducing negative environmental effects is faced by most industrialized countries including Australia (Steinfeld et al. 2006, OECD 2008).

Nitrogen inputs, efficiency of use and surplus on Australian dairy farms

Prior to the 1940s, agriculture largely depended on naturally available soil nutrients, nutrient recycling from animal manure or biological-N fixation by legumes. Innovations in fertiliser manufacturing after the second world war, as well as a continuing trend for declining fertiliser and feed costs relative to other inputs such as labour and land, and the ability to transport agricultural inputs and outputs cheaply and extensively, has led to rapid adoption of inorganic fertiliser use and a spatial disconnect between nutrient flows required for livestock production systems (Vitousek 1997).

Currently, N fertiliser is primarily used in dairy grazing systems at average rates of around 220 kg N ha\(^{-1}\) yr\(^{-1}\) (Dairy Australia 2011). However, these average figures can misrepresent the actual rates applied at the farm and paddock scale. For example Gourley et al. (2012) found N fertiliser rates ranging from no fertiliser use to >400 kg N ha\(^{-1}\) year\(^{-1}\), on contrasting dairy farms in Australia.

The utilisation of nitrogen applied to pastures and crops into milk, meat and wool are often low and consequently N inputs frequently exceeds outputs (Powell et al. 2010). For example, a national Australian study of nutrient use on dairy farms (Gourley et al. 2012) found that whole-farm N surplus (the difference between total N imports and total N exports) ranged from 47 to 601 kg ha\(^{-1}\) yr\(^{-1}\) and N use efficiency (the ratio of total N exported in product divided by total N imported at the farm scale) ranged from 14 to 50%. While they found a strong correlation between total N imported and milk production per ha (Fig. 1a), N surplus was also strongly related to milk production (Fig. 1b) with the slope of this linear relationship (0.0121; SE = 0.0015) providing an estimate of the productivity N surplus, equivalent to 12.1 g N litre\(^{-1}\) milk produced. Similar ranges in N surpluses and use efficiencies have been reported on commercial dairy farms in south-west Western Australia (Ovens et al. 2008) as well as New Zealand (Ledgard et al. 2004), the USA (Hristov et al. 2006), and Western Europe (Treacy et al. 2008).

Understanding nitrogen loss pathways

Nitrogen loading rates at the paddock scale are often high and heterogeneous, irrespective of the intensity of the dairy operation. In addition to N fertiliser applications, N loading rates (as well as P and K) are also driven by animal excreted N, which in turn is influenced by stocking density, feeding strategies and N intake and frequency of effluent applications. Holding paddocks and feeding areas may have N loads from animal excreta in excess of 1000 kg N ha\(^{-1}\) year\(^{-1}\) (Gourley et al. 2011).
Figure 1. Relationships between milk production and (a) whole-farm nitrogen inputs and (b) nitrogen surplus for 41 contrasting dairy farms across Australia. Unshaded symbols represent organic dairy farms.

Applied fertiliser or manure N is not generally fixed by soils and excess N may be lost from the soil relatively quickly, making the rates and timing of land applications critically important. Fertiliser and manure N applied to wet and cold soil conditions will have reduced plant uptake and enhanced leaching processes can lead to losses of 20 - 80% (Ledgard 2001). Losses of N through ammonia volatilization can occur in grazed pasture systems, particularly on moist soils with a high pH (Monaghan et al. 2007). Volatilised ammonia contributes to haze through the formation of particulates, and is then redeposited to cause acidification and waterway eutrophication. Volatilisation from surface applied urea can typically range between 5 - 25%, but is generally between 5 - 10% from di-ammonium phosphate and < 3% from ammonium sulphate and ammonium nitrate (Monaghan et al. 2007). Ammonia volatilization from urinary excreted N is also a significant loss pathway (up to 50%) in animal production systems, particularly where animals are confined (Hristov et al. 2011). While losses of N through denitrification constitute only a small percentage (2-5%) of applied N, N2O contributes significantly to greenhouse gas emissions and ozone depletion. Particular management strategies are often directed to reduce N losses in particular forms, i.e. nitrate (Ledgard et al. 2004), nitrous oxide (De Klein and Eckard 2008) and ammonia (Hristov et al. 2011), and while these may assist in meeting particular environmental targets, they may also result in pollution ‘swapping’ (Stevens and Quinton 2008), i.e. a decrease in one loss pathway may increase another. This is particularly so when these strategies are not accompanied by attempts to improve the overall nitrogen use efficiency of the farming system.

Production gains from fertiliser inputs

The current focus on increasing pasture production from nitrogen fertiliser inputs, regardless of marginal cost and benefit, has often led to the false ‘more is better approach’ to N use decisions on many dairy farms. Currently dairy farmers may use excessive N because they, and their advisors, do not know enough about nitrogen-pasture response functions. Uncertainty about expected responses to N applications creates incentives for excessive use of nitrogen, with the associated problems of increasing farm and environmental costs. Farm profit is reduced and the surrounding natural environment adversely affected.

Recent research across Australia, including the ‘Greener Pastures’ project in WA, ‘Profitable N’ in Tasmania and the national ‘Accounting for Nutrients’ project have all demonstrated that the efficiency of use of N from fertiliser applications is variable and often low. For example, half the dairy farmers in WA were using more N than the agronomic optimum. With further anticipated increases in N fertiliser prices, continued over application of N fertiliser Australia wide, will challenge the on-going profitability and sustainability of many dairy farm businesses. A recent study involving 41 commercial dairy farms nationally (Gourley et al. 2012), found that the relationship between N fertiliser inputs and milk production from home-grown pasture was poor (Figure 2a), demonstrating that farms operate on different response functions and that substantial improvements in N fertiliser decisions could be achieved on many of these farms. The relationship improved slightly when additional N from the fixation of atmospheric nitrogen by pasture legumes was included (Fig. 2b).
Comparisons across farms in WA has also demonstrated that there is no consistent relationship between farm operating profit and N fertiliser use; farms can have high profit with low N use and low profit with high N use, and vice versa (Figure 3).

Greater knowledge of the likelihood of particular N-pasture response functions applying in different dairy systems should enable improved decision-making about efficient, profitable levels of N application in these dairy systems. Within seasons, the constraints are likely to include existing available soil N levels, soil type, soil moisture and temperature status, soil fertility (P, K, S), acidity limitations, pasture species, and management of grazing/defoliation.

Response in pasture production can also be moderated by grazing & feeding management practices. Increased precision of N fertiliser use in the different situations of different systems will reduce the current widespread waste from excessive, inefficient and unprofitable N application, and reduce the adverse implications of waste nitrogen on dairy farm profit and the health of the wider natural environment.

Recent work has reviewed and utilized many hundreds of N fertiliser - pasture yield experiments undertaken across Australia from published and unpublished sources (Fig. 4). The analysis of comprehensive N fertiliser response data (meta-analysis) and the associated meta-data for the site conditions has been used to define...
improved seasonal response functions (including variation) when constraints imposed by soil-based factors or grazing management are removed.

These new response curves will be further developed in terms of total DM response, average response to N and marginal response to additional increments of N fertiliser applied. The unique aspect of this current project is therefore bringing economics, and profit (marginal return over marginal cost, to the fore; linked to improved predictions about pasture responses to N fertiliser applications. The final stage of this work will be to develop a simple N fertiliser decision calculator; based on the potential pasture DM response (including variation) and profitability (including variation) of N fertiliser decisions, at the individual farm and paddock scale.

![Sub-set of the experimental data used to develop improved relationships between N fertiliser input and pasture yield response.](image)

**Figure 4.** Sub-set of the experimental data used to develop improved relationships between N fertiliser input and pasture yield response.

**Conclusions**

The quantity of N imported onto dairy operations varied markedly, with feed and fertiliser generally the most substantial imports. While N fertiliser input is clearly a driver of milk production from home-grown pasture and crops, there continues to be a high degree of uncertainty around production gains from N fertiliser use. Studies suggest that there are opportunities on many dairy farms to make more efficient use of their fertiliser inputs. Where N fertiliser applications are warranted, appropriate rates and blends of fertiliser applied when soil and pasture growth conditional are optimal for plant utilisation, should ensure profitable increases in pasture and crop productivity. In the future, more sophisticated approaches will likely be required which quantify N flows through the continuum of feed, milk production and manure; increase the capture and storage of excreted manure N; determine N loading rates in areas across the farm; and target fertiliser application rates for optimum plant uptake.

**References**


