Understanding Nitrogen Fertiliser Use in Dairy Systems

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Nitrogen use on Tasmanian Dairy Farms

Average 185 kg N/ha
10th Percentile 31 kg N/ha
25th Percentile 89 kg N/ha
50th Percentile 151 kg N/ha
75th Percentile 255 kg N/ha
90th Percentile 351 kg N/ha

Source (DBOY 2006-2010, RedSky analysis)
Nitrogen use on Tasmanian Dairy Farms

\[ y = -3E-05x^2 + 0.0237x + 7.0162 \]

\[ R^2 = 0.3755 \]
Nitrogen use on Tasmanian Dairy Farms

\[ y = -0.0053x^2 + 4.9493x + 569.87 \]

\[ R^2 = 0.0849 \]
The Role of Nitrogen

• All living organism require Nitrogen (N)
  – Essential constituent in chemical structure of proteins and nucleic acids

• Essential for pasture growth
  – Generally between 2.5 and 4.0% in ryegrass pastures

• For pasture N must be in the form of either ammonium of nitrate

• Generally speaking intensive farming system rely on the provision of additional N

• It takes about 600kg N to grow 12t DM/ha regardless of where the N comes from
Nitrogen Cycle

Photo Courtesy of UW Nutrient and Pest Management Program.
Source http://fyi.uwex.edu/discoveryfarms/page/7/

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Nitrogen Cycle

• Soil nitrogen exist in three general forms – organic nitrogen, ammonium ($\text{NH}_4^+$) ion and nitrate ($\text{NO}_3^-$) ions.

• Nitrate and ammonium ions are taken up the plant roots but they differ in their mechanism.
  – Nitrate is an anion, is not adsorbed by the colloidal material and is therefore mobile in solution. It is easily accessible but also susceptible to leaching and denitrification.
  – Ammonium is a cation and is retained by cation exchange on the clay and organic matter. Less mobile, less accessible and less susceptible to loss than nitrate. However ammonium is progressively converted to nitrate (nitrification).
Nitrogen – Where does it go to?

Ammonia

Nitrogen

Nitrous oxide

Gas

Harvested

Milk, meat, wool

Hay, silage

Runoff

15-50% of ‘new’ N

Drainage

Nitrate

Organic

Only 30 to 40% of total N is fully recycled!

Source Eckard 2004
Nitrogen Response Efficiency

- Nitrogen response efficiency is expressed as the amount of additional pasture grown divided by the amount of N applied.
  - For example:
    - Apply 50Kg N/ha and produce 1500 kg DM/ha.
    - Apply no nitrogen and produce 1000 kg of DM/ha
    - Additional growth due to Nitrogen is 500kg DM (1000 – 500).
    - N response efficiency is additional growth divided by the amount applied. That is 500 kg DM/50kg N =10 kg DM/ kg N
    - At $1.50 per kg N to apply the cost of additional pasture is
      - $1.50/ 10 kg DM = 15c per kg DM or $150 per t DM.
Factors affecting response to Nitrogen

• Soil Temperature
  – Pasture will respond to nitrogen as long as soil temperature are above 4°C. General rule is if the pasture is growing you will get a response to nitrogen

• Soil Moisture
  – If soil moisture is depleted this will limit pasture growth an in turn limit responses to N fertiliser

• Basal Fertility and Species Composition
  – For pasture to respond well to N, other soil nutrient and pasture composition must not be limiting

• Current soil N status
Nitrogen research

Hypothesised that:

a. part of the variability in the response of pastures to the application of nitrogen can be attributed to the soil inorganic N status prior to the application of mineral fertilisers and

b. then it may be possible to determine optimum N application rate based on current soil N status.

Also Hypothesised that:

a. That timing of N fertilise application during winter does not influence the efficiency of nitrogen response rate.
Study design

– experimental area grazed over the Autumn/winter period.
  • 29\textsuperscript{th} April, 4\textsuperscript{th} June, 20\textsuperscript{th} July and 1\textsuperscript{st} September

– Three nitrogen application rates applied immediately following each of the first three grazing events to each main plot
  • 0 (total N applied 0 kg N/ha)
  • 50 (total N applied 150 kg N/ha)
  • 100 (total N applied 300 kg N/ha)

– Each main plot was divided into six sub-plots. Following grazing on 1\textsuperscript{st} September application rates (0, 20, 40, 60, 80 or 100 kg N/ha) was then randomly allocated to each subplot

– The experiment was then allowed to grow to 2.5 to 3 leaves then was grazed and then allowed to grow to 2.5 to 3 leaves again.

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Soil N status and pasture sap NO$_3$ concentration after the application of winter N treatments and prior to the application of spring N treatments.

<table>
<thead>
<tr>
<th>Depth (mm)</th>
<th>Total soil inorganic N (kg/ha)</th>
<th>Sap NO$_3$ (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter N (kg N/ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>10.5 (0.9)</td>
<td>445 (112)</td>
</tr>
<tr>
<td>150</td>
<td>21.9 (1.3)</td>
<td>517 (111)</td>
</tr>
<tr>
<td>300</td>
<td>54.6 (14.0)</td>
<td>675 (78)</td>
</tr>
<tr>
<td>P value</td>
<td>&lt;0.05</td>
<td>ns</td>
</tr>
</tbody>
</table>

Values in parentheses are the standard errors around the mean
Results

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Results

0.9 of y max occurs when x (plant available N) = 54 kg N/ha
What about plant N concentration?

Relation between Kjeldahl-nitrogen concentration in shoots and relative dry matter yield of perennial ryegrass. Source: Smith et al. (1985).
Study design

- Two locations.
  - Elliott and Mella
- Nitrogen applied at leaf stage (main plots)
  - 0, 0.5, 1, 1.5 and 2 leaves
- Each main plot was divided into six 5 sub-plots for nitrogen fertiliser application rates
  - 0, 25, 50, 75 and 100 kgN/ha
- The experiment was allowed to grow to 3 leaves for two growth periods
## Study design

### Soil test results for the experimental sites

<table>
<thead>
<tr>
<th></th>
<th>Units</th>
<th>Mella</th>
<th>Elliott</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate Nitrogen</td>
<td>mg/Kg</td>
<td>82</td>
<td>1.4</td>
</tr>
<tr>
<td>Phosphorus Olsen</td>
<td>mg/Kg</td>
<td>43.6</td>
<td>13.4</td>
</tr>
<tr>
<td>Potassium Colwell</td>
<td>mg/Kg</td>
<td>210</td>
<td>150</td>
</tr>
<tr>
<td>Sulphur</td>
<td>mg/Kg</td>
<td>9.3</td>
<td>25</td>
</tr>
<tr>
<td>Organic Carbon</td>
<td>%</td>
<td>5.4</td>
<td>6.0</td>
</tr>
<tr>
<td>pH Level (CaCl2)</td>
<td>pH</td>
<td>5.0</td>
<td>5.3</td>
</tr>
<tr>
<td>pH Level (H2O)</td>
<td>pH</td>
<td>5.6</td>
<td>5.9</td>
</tr>
</tbody>
</table>
Results – 2011

Elliott – total yield (two harvests)
Results – 2011

Mella – total yield

Yield (kg DM/ha)

Leaf stage at N application

- 0 kg N/ha
- 25 kg N/ha
- 50 kg N/ha
- 75 kg N/ha
- 100 kg N/ha

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Results – 2011

<table>
<thead>
<tr>
<th>Factor</th>
<th>Elliott</th>
<th>Mella</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf stage</td>
<td>0.216</td>
<td>0.671</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Leaf stage x Nitrogen</td>
<td>0.276</td>
<td>0.257</td>
</tr>
</tbody>
</table>

Total Yield

<table>
<thead>
<tr>
<th>Location</th>
<th>0kg N/ha</th>
<th>100 kg N/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elliott</td>
<td>2159&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3425&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mella</td>
<td>2880&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3366&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

What is the nitrogen response efficiency here for the two sites?
Results

Nitrogen response rate (kg DM/kg N)

Nitrogen rate (Kg N/ha)

- 25 kg N/ha
- 50 kg N/ha
- 75 kg N/ha
- 100 kg N/ha

Blue bars represent Mella, and red bars represent Elliott.
Lessons so far

• Anecdotal evidence that N soil status may provide some indication of N response rate and that the response rate to nitrogen is influenced by current soil status.

• In the two environments examined, the timing of N application during winter did not influence N response rate so long as sufficient time (at least 1-leaf regrowth period) is provided. This provides flexibility to winter N applications.
  • But be careful, elevate N concentration in pasture at grazing likely when applied between the 1 and 2 leaf regrowth compared to between 0 and 1 leaf regrowth stage.

• The optimum N response rate coming into spring is 50 to 60 kg N/ha of available soil N and that diagnostic assessment of N availability prior to spring may provide some indication of N required.

• Reliability and accuracy of soil N tests requires further research and development.

• Development of N response calculator.
Development tools

Predictive N fertiliser response rate calculator

Predict your N fertiliser response rate based on your soil temperature, soil moisture content and N fertiliser application rate.

To activate this calculator, the macro setting needs to be enabled. Consult MS Excel help if unsure how to do this.

Launch Calculator
Development tools

Nitrogen Response Calculator

ENTER:

- Soil Temperature (Degrees C.)
- Soil Moisture (FMP=0, FC=100)
- Total Inorganic Nitrogen (0-30cm deep, Kg N/ha.)
- Urea Price ($/tonne)
- Forage Price ($/tonne)

ESTIMATES:

- Estimated Economical Fertiliser Application Rate (Kg N/ha)
- Estimated Response Rate (Kg DM/Kg N applied)
- Estimated Cost per Kg DM ($/Kg DM)

CALCULATE

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Development tools

Nitrogen Response Calculator

ENTER:
- Soil Temperature (Degrees C.)
- Soil Moisture (FWP=0, FC=100)
- Total Inorganic Nitrogen (0-30cm deep, Kg N/ha.)
- Lucerne Price ($/tonne)
- Forage Price ($/tonne)

ESTIMATES:
- Estimated Economical Fertiliser Application Rate (Kg N/ha)
- Estimated Response Rate (Kg DM/Kg N applied)
- Estimated Cost per Kg DM ($/Kg DM)

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Dairy Nitrogen for Greater Profit

Cameron Gourley

Ivor Awty, Murray Hannah, Kohleth Chia, Bill Malcolm, Kerry Stott, Matt Cox, Oliver Lardner, Jenny Collins, Donna Gibson, Richard Rawnsley, Keith Pemberton, Jeff Kraak, Aaron Gosling, Lee Menhenett, David James, Mark Jago.
Standardise and improve nitrogen fertiliser decisions

“…..help determine how much N to apply to a particular pasture, at a particular time of the year, in a particular region, that will maximise profitability.”

National, simple, relevant, widely accessible, web-based, flexible, instantaneous, ..........

• Use the best scientific information available
• Provide credible economic outcomes

Source Gourley 2014, Dairy Nitrogen for Greater Profit
Diminishing DM Responses to Extra Inputs of N

Source Malcolm 2014, Dairy Nitrogen for Greater Profit
Tasks and activities

1. Improve predictive capacity of Pasture DM yield responses to applied N fertiliser
   - Collation of national N fertiliser experiments
   - Detailed meta-analysis of existing data
   - Validation with ‘on-farm’ N experiments

2. Improve the determination of economic returns from N fertiliser inputs
   - based on estimates of production and profitability

3. Build a web-based tool ‘Dairy Nitrogen Fertiliser Advisor’

4. Delivery enhanced information, knowledge and tools to industry

Source Gourley 2014, Dairy Nitrogen for Greater Profit
Tasks and activities

5,959 Partitions

Source Gourley 2014, Dairy Nitrogen for Greater Profit
Tasks and activities

Source Gourley 2014, Dairy Nitrogen for Greater Profit
Pasture DM responses to applied urea fertiliser.

- Red or blue squares are raw DM yield measures with black ‘line of best fit’.
- Red curve is independent model prediction from meta-analysis.

Source: Gourley 2014, Dairy Nitrogen for Greater Profit
Profit maximisation MR=MC

- last unit of input produces enough revenue to just cover the cost of the input
- MR = marginal unit of output (marginal product) multiplied by the price of the output.
- MC = cost of the extra unit of input also expressed as:
  - MP=Pₓ/Pᵧ
  - where Pₓ = cost of N Pᵧ = price of DM
  - solved for the input x (N fertiliser) to determine the optimum amount of N to use.

Source: Malcolm 2014, Dairy Nitrogen for Greater Profit
Dairy Nitrogen Fertiliser Advisor

The Dairy Nitrogen Fertiliser Advisor allows dairy farmers with their advisors to examine the profitability of nitrogen fertiliser applications to pasture. Predicted pasture responses, based on nearly 6,000 nitrogen fertiliser experiments undertaken across Australia, are calibrated to account for prevailing conditions facing individual farms. Profitable nitrogen fertiliser recommendations consider the fertiliser costs and the value of extra pasture consumed for each incremental increase in fertiliser use.

Select your season and region
Select the most likely pre and post-grazing DM for the current position, and the amount of Nitrogen you would normally use (if any) to achieve these outcomes
Provide your estimate of the 'as spread' cost of nitrogen and the market value of the extra pasture consumed (based on the market price for substitute ME)

![Graph showing pasture dry matter consumption and nitrogen application](image_url)
How it works
Sensor

\[ \text{NDVI} = \frac{\text{NIR} - \text{VIS}}{\text{NIR} + \text{VIS}} \]
Smart N Boom
Nitrogen application

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Results

Nitrogen application

Pasture growth

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Greenseeker technology

For every Kg of N fertiliser applied have an Emission Factor (EF) of 6.2 kg CO₂-e.
- Direct N₂O losses from denitrification (EF 1.9)
- Indirect N₂O losses from leaching & volatilisation (2.3 EF)
- Embedded emissions in production (EF 2.0)

- N leaching losses decreased from 88.5 to 73.5 kg N/ha.year (15/52 = 29%)
- Simulated average N volatilisation losses decreased from 46.7 to 40.5 kg N/ha.year (6.2/52 = 12%).
- Results consistent with NGGI.
  - The leach fraction and volatilisation fraction are 30 and 10%, respectively.
- Modelling indicates that EF of 1.8 for leaching, 0.5 for volatilisation (2.3 for indirect N₂O losses) can be applied to the Smart-N™ Greenseeker® technology.
- However there was little change in denitrification rate. Why?

Source: Action on the Ground project: AOTGR1-124 “Lowering nitrous oxide emissions in intensively grazed pasture systems”

Simulated annual N fertiliser inputs with or without the adoption of the Smart-N™ Greenseeker® technology was 322 and 270 kg N/ha.year, respectively (52 kg N/ha saving). This represents a 16% reduction in N usage.
Nitrous oxide

– Global warming ~300 x CO₂
– Denitrification
  • Warm, water-logged soils
  • Excess NO₃ in soil
– Inefficient use of nitrogen
  • Ruminants excrete 75 to 95% of N intake
  • >60% lost

Source Eckard 2010
Nitrous oxide

Measuring nitrous oxide

Automatic Chambers

Micromet system

Source Eckard 2010
Nitrous oxide

• Approaches to reducing N$_2$O emissions
  – Nitrogen Fertiliser
    • Rate, source, timing, placement
    • Formulation
  – Water management
    • Drainage, irrigation
  – Soil Management
    • Reduced tillage
  – Animal Management
    • Stocking density, diet, hot spots

• Short term mitigation
  – Feed
    • Balancing ME:CP
    • Tannins
  – Inhibitors
    • Enhanced efficiency fertilisers (EEFs) containing the N inhibitors

• Longer term mitigation options
  – Breeding
    • Improved animal FCE
    • Improvement plant ME:CP

Source Eckard 2010
Thank You

Questions?