Fertiliser Best Management Practice
Science, anecdotes & gaps

Dr Bill Cotching
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Fertiliser Best Management Practice

- Nutrient budget
- Soil sampling and analysis
  - spatial nutrient variability
  - interpretation of results
  - soil pH & liming
  - Soil constraints
- Nutrient application rates
  - timing of nutrient applications
  - avoiding nutrient losses
  - rates of soil nutrient decline
  - alternative soil amendments
- Planning & record keeping
“Liebig’s Law of the minimum”

Plant growth only occurs at the rate permitted by the most limiting factor.

A deficiency in any one of the 17 essential plant nutrients will reduce growth and production, even though the others may be abundantly available.

Sinclair 1998
“It is the rate of transfer from an unavailable to available nutrient form that is critical in organic systems, rather than the size of the available nutrient pool.”

Watson et al. 2008
Two main components to prepare a fertilizer management plan:

1. Whole farm nutrient budget

2. Interpretation of soil test results

Monaghan et al. 2007
Gourley et al. 2007
Nutrient budgeting tools

Examples: NutriMatch Budgeting Tool © OVERSEER®
Tasmanian Institute of Agriculture tools
Ellinbank Dairy Farm nutrient Balance tool

Account for:
- nutrient sources
- fertilisers
  - grain/pellets
  - fodder
  - effluent
- nutrient exports & losses
  - milk/meat/fibre/crop export
  - soil losses – leaching/fixation
  - laneways & yards
  - hay/silage sold or removed

Differentiate between ‘maintenance’ and ‘capital’ fertiliser required (or ‘mining’).
Nutrient budgets on Tasmanian dairy farms found:

Phosphorus balance ranged from deficit 37 to surplus 51 kg P/ha/year

51% of farmers had applied or brought in a net surplus of P,

Potassium balance ranged from deficit 32 to surplus 76 kg K/ha/yr

70% of farmers applied a net surplus of K

Cotching et al. 2017
Soil sampling & analysis

- Is the lab ASPAC accredited
- What soil tests to request
- Interpreting soil test results for soil type, & crop or pasture type
- What was the sampling depth (75, 100, 150 mm)  
  
  Coad et al. 2010

- What are optimum levels (science)
  
  Gourley et al. 2007

- What are the farmer’s desired levels
Olsen Phosphorus on 1700 dairy paddocks in Tasmania

Soil phosphorus - Olsen (mg/kg)

Optimum range

45%
Only 63 of the 1700 paddocks tested (3.7%) had nutrient levels in the optimum range for all of the four nutrient measures of pH, Olsen P, extractable K and S.
Reasons why soil nutrient levels are highly variable around the farm and within paddocks

1. Soil type
2. Paddock management:
   
   *Nutrient loading*

   *Less removal*
Reasons why soil nutrient levels are highly variable around the farm and within paddocks

1. Soil type

2. Paddock management:

   **Nutrient loading**
   - Cows standing near gate or at one end of paddock in wet weather
   - Silage / hay feeding out or harvesting
   - Grazing frequency (cow days /ha/yr)
     - Paddocks closer to the milking shed are more likely to be graze more frequently, and hence will have a higher dung load
   - Effluent application
   - Trees & hedgerows for cow shelter; clearing / burning
   - Fertiliser application

   **Less removal**
   - Poor growth due to pugging / dryness / wetness
   - Low productivity / less palatable species
   - Variable grazing frequency (dirty, smelly grass)

Aarons et al. 2015
Cotching et al. 2018
Interpreting soil test results

1. The sufficiency level of available nutrients (SLAN) concept is used in analysis of soil test results for conventional farming, where short-term nutrient availability is the primary concern and yields are often higher than they would be expected in organic farming.

2. The base cation saturation ratio concept (BCSR) is often used in analysis of soil test results for organic or ‘biological’ farmers.
Sufficiency level of soil nutrients

- Pasture growth limited by deficiency
- Pasture growth not limited by deficiency
Optimum soil nutrient values
Phosphorus

Gourley, et al. 2007
When soil test P is above the optimum range, adding fertiliser phosphorus will have no effect on pasture production.

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Optimum Range (Olsen P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All soils</td>
<td>&gt;9, &lt;11, &gt;15</td>
</tr>
<tr>
<td>PBI 0-15 (Very sandy)</td>
<td>&gt;30</td>
</tr>
<tr>
<td>PBI 15-35 (Sand, loam)</td>
<td>&gt;45</td>
</tr>
<tr>
<td>Volcanic clays &amp; loams</td>
<td>&gt;70</td>
</tr>
</tbody>
</table>

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Bolland et al. 2011
Burkitt et al. 2002

Baker & Gourley 2011
<table>
<thead>
<tr>
<th>Proportion of maximum pasture production %</th>
<th>Olsen P 0-75 mm depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>97</td>
<td>39</td>
</tr>
<tr>
<td>95</td>
<td>29</td>
</tr>
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</table>

400 kgN/ha applied

*Mackay et al. 2010*
Anecdote
“High fertility (nitrogen) pastures require higher levels of phosphorus”
<table>
<thead>
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<th>Nitrogen applied (kgN/ha)</th>
<th>Proportion of maximum pasture production (%)</th>
<th>Olsen P 0-75 mm</th>
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<tr>
<td>400 kgN/ha</td>
<td>95</td>
<td>29</td>
</tr>
<tr>
<td>0 kgN/ha</td>
<td>95</td>
<td>34</td>
</tr>
</tbody>
</table>

Mackay et al. 2010

Ryegrass-dominant pastures have a lower phosphorus requirement than clover-dominant pastures.

Bolland et al. 2011
The Base Cation Saturation Ratio concept (BCSR)

Desirable Levels:
- Calcium: 80%
- Potassium: 6%
- Magnesium: 12%
- Sodium: 1%

Measured Levels:
- Calcium: 64%
- Potassium: 4%
- Magnesium: 20%
- Sodium: 12%
Albrecht concluded that optimal plant growth will only occur in ‘balanced’ soils with ‘ideal’ base cation ratios. 

Albrecht’s work was confounded by changes in pH that he did not recognise. Plant growth is limited in acidic soils and additions of Calcium alone will not improve soil pH levels.

The data available today does not support the claims of the BCSR and a soil’s chemical, physical and biological fertility cannot be linked to nutrient ratios.

Plants are able to thrive over a range of cation ratios, if the nutrients are provided in a suitable amount.

The data are too sparse for conclusions or even speculation.
Nutrient balance and animal health

• Too much soil potassium can induce deficiencies of other nutrients, particularly magnesium & calcium, that can result in animal health issues, e.g. grass tetany & milk fever.

Grunes et al. 1970
Kronqvist 2011
Undersander 2018

Gap: research soil & plant nutrient balance & impacts on animal health
Anecdote
“Calcium addition increases soil pH”

\[
\text{CaCO}_3 + 2\text{H}^+ \rightarrow \text{Ca}^{++} + \text{H}_2\text{O} + \text{CO}_2
\]

It’s the ‘carbonate’ that increases soil pH
Soil pH change due to lime addition

Wyelangta, 1999
Crawford & Gourley 2001

Lsd = 0.181

Lime (t/ha)
Pasture response to lime application

Southern Vic & Tas dairy pastures on sandy loams, sandy clay loams & red clay loams

Lime rate: 2.5 – 20 T/ha

Pasture response averaged over 5 years: -10% to +13%

Crawford & Gourley 2001
Rowe 1982
Li et al. 2006

Phalaris based pasture on a sodosol in NSW

Lime rate: 3.3 - 4.1 T/ha & decrease of aluminium toxicity

Pasture response averaged over 5 years: +18%
Liming of pasture soils

✓ Sustained change in soil pH, but NOT pasture response

✓ Lime either increased, decreased or had no effect on soil extractable P and K

✓ Pasture production gains are seasonal & variable

✓ Mineral analysis of mixed pasture associated with lime application:
  Increase in: Ca, Mo
  Decrease in: P, Mg, Cu, Mn, Zn

✓ Earthworm activity increases with increasing pH up to $pH_{\text{water}}$ 6.5

Crawford & Gourley 2001
Edmeades et al. 1983

Springett & Syers 1984
Plants don’t eat, they drink
Plants drink, but they can’t swim!
Soil constraints

Drainable Porosity in some Tasmanian topsoils

Pores drained at field capacity (% vol)

Good

Hardie & Cotching in prep
The ‘green drought’ occurs when poor irrigation scheduling leads to soil water deficits and the application of irrigation water only keeps the grass green, but doesn’t result in optimum pasture growth rates.

Pasture growth rates were cut in half, from over 80 kg DM/ha/d to approximately 40 kg DM/ha/d. This was despite adequate irrigation water being applied to satisfy daily evapotranspiration demand.
Using fertiliser is about
right product,
right rate,
right time and
right place
for maximum profitability.
We like to keep it ‘real’.
Time fertilizer application to:

✓ Optimize plant growth

✓ Minimise runoff of nutrients to the environment
Anecdote
“Multiple P fertiliser applications are better than one per year”

Soils
Ferrosol (clay loam)
Derosol (silty clay)
Hyrdrosol (sandy loam)

Timing of fertiliser application at all sites:
Once in spring
Once in summer
Once in autumn
Three times in spring/summer
Twice in autumn
5 times (3 in spring + 2 in autumn)

Applying P fertiliser as a single annual application in summer did not compromise pasture production.

Burkitt, Donaghy, Smethurst 2010
Tasmanian nutrient loss rates to rivers from intensive agriculture are at the higher end of published values.

Irrigated pastures

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Rate</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Phosphorus</td>
<td>10 - 12</td>
<td>kgP/ha/yr</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>27</td>
<td>kgN/ha/yr</td>
</tr>
</tbody>
</table>

Broad & Corkrey 2011
When rainfall, runoff and fertilising coincide then there is the potential for significant nutrient loss.

The critical period over which fertiliser nutrients are susceptible to loss is somewhere between 1 and 3 days following application. Farmers should use the BOM 7 day forecasts for timing fertiliser application.

Holz 2010

The current BMP is to apply P fertiliser during drier conditions, when the risk of surface P runoff is generally lower.
Alternative soil amendments

- Biosolids
- Poppy mulch & seed waste
- Municipal green waste
- Compost, bedding straw
- Vegetable & fish processing waste
- Dairy effluent (green water & sludge)
- Chicken & pig manure
- Rock phosphate - most suitable to acid sandy soils in high rainfall areas
- Coal dusts and biochar
- Bacteria mixes/humates/compost teas/biodynamic preparations
When considering a new alternative product for your soil, some key considerations need to be made.

1. What soil constraints occur in your paddock? Have you done a recent soil test and what inherent issues occur with this soil type?

2. Have you information on the ingredients of the product and what the nutrient and organic matter content is?

3. Has there been any independent testing of the products and results produced?
Soil fertility management checklist

1. How often do you soil test?
2. Do you know what the optimum ranges for soil pH and nutrients are?
3. Are soil nutrient values different on different parts of your farm?
4. Is a nutrient budget (inputs & outputs) part of your fertiliser planning?
5. How often do you review your fertiliser plan, or do you apply the same product at the same rate each year?
6. Do your dairy cows suffer from grass staggers (tetany) from one month before to two months after calving?
7. Do you spread your dairy effluent over at least 5 ha per 100 cows milked?
References


Nitrogen fertilizer use on dairy pastures

✓ Only apply N when pasture is actively growing
  (No closer than 28 days apart)
✓ Apply 25 – 50 kg N/ha per application
  (1.0 – 1.5 kgN/ha/day depending on growth rate)
✓ Follow the cows, rather than apply over the whole farm at once
✓ Avoid high rates of N on wet soils
✓ Urea is the cheapest source of N
✓ In Tasmania, apply blend of urea/sulfate of ammonia in winter