Soil Biology Masterclass

18 August 2021

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Nitrogen availability

Integrated Crop Protection
PROTECTING CROPS

Soil Wealth
NURTURING CROPS

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Mineralisation - Biology Drives the System

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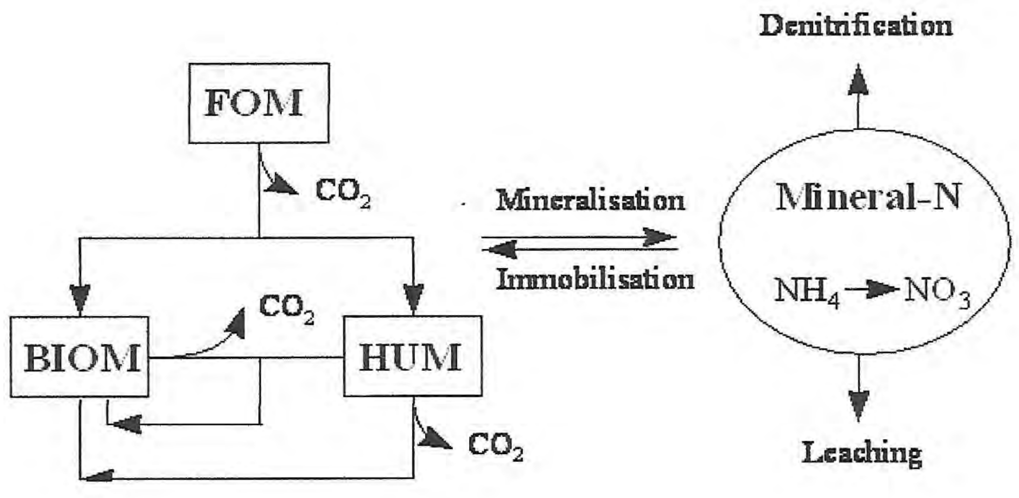
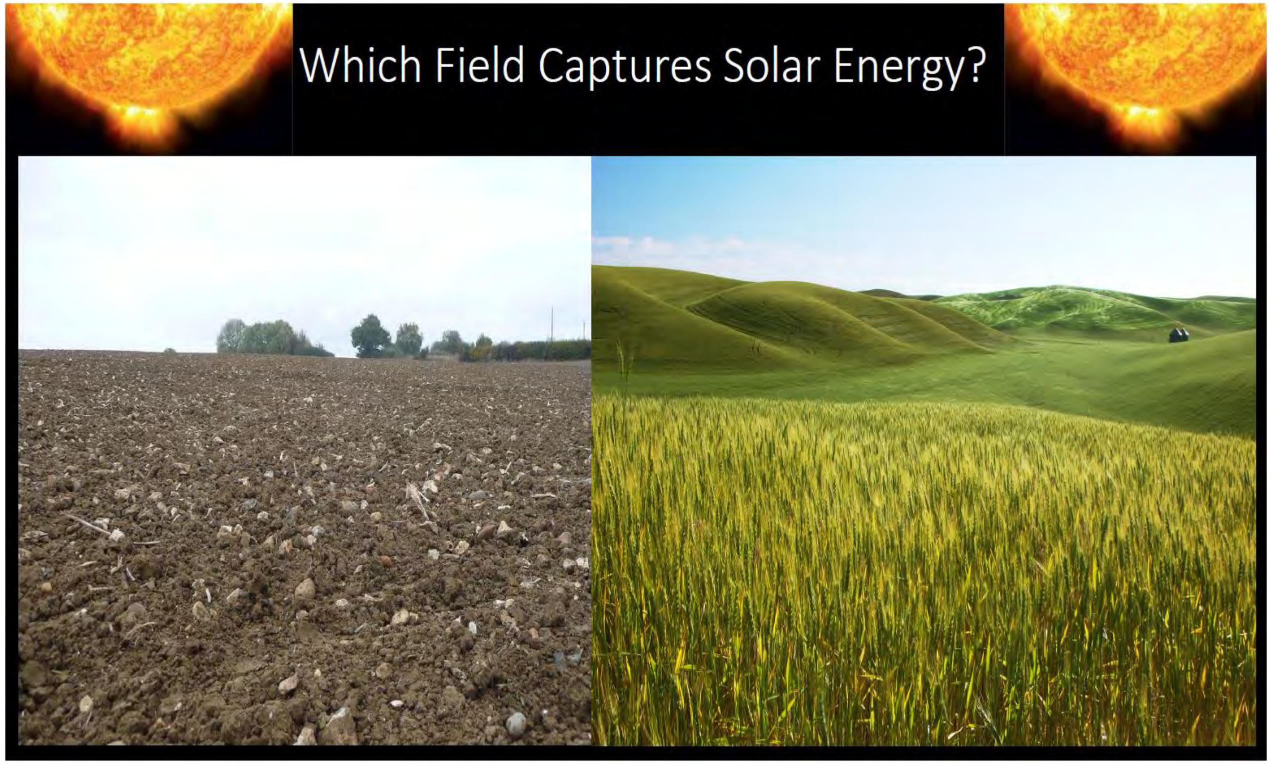


- FOM – Fresh Organic Matter (stubble, compost)
- BIOM - Labile Fraction
- HUM – humus
- Note the evolution of CO_2 when decomposing fresh OM and labile OM to humus.
- Balance act of N additions and losses

Nutrient Cycling



- Crops, Cover Crops & Crop residues feed the soil

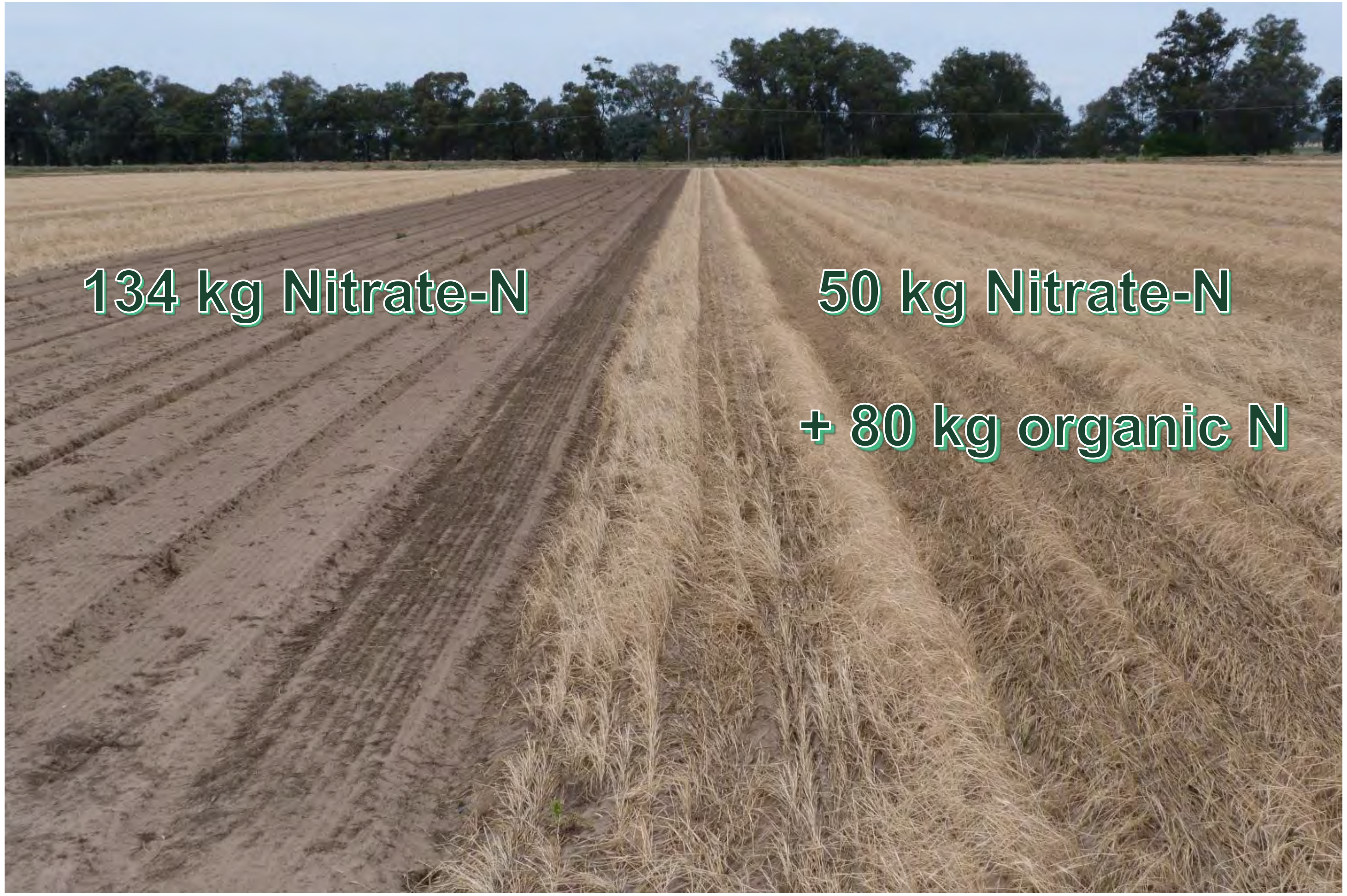
Nutrient Cycling

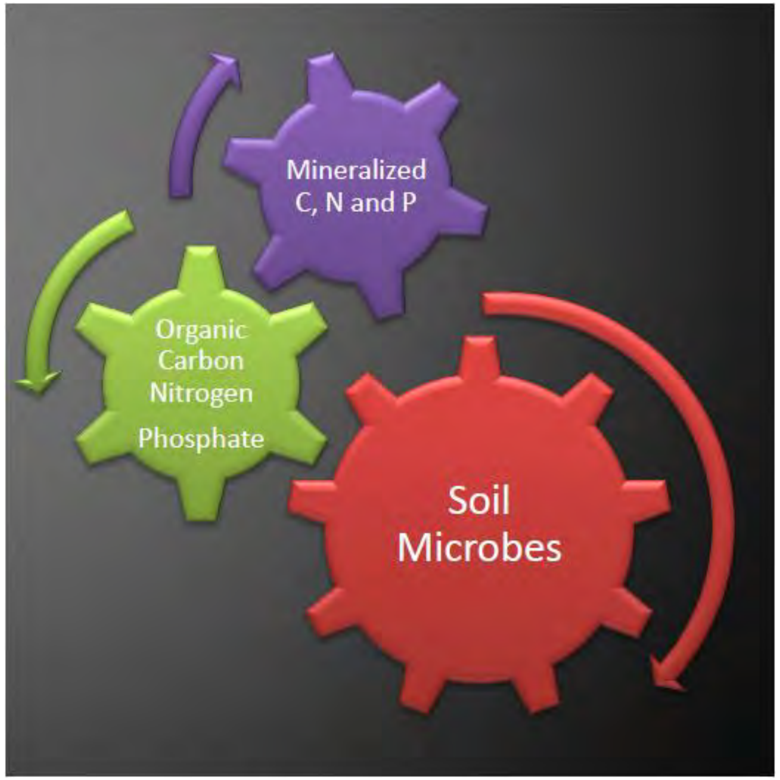
N – P – K – S Ca Mg + micros

- Organic nutrients in crop residues will equal "fertiliser removal rates" for specific residue.

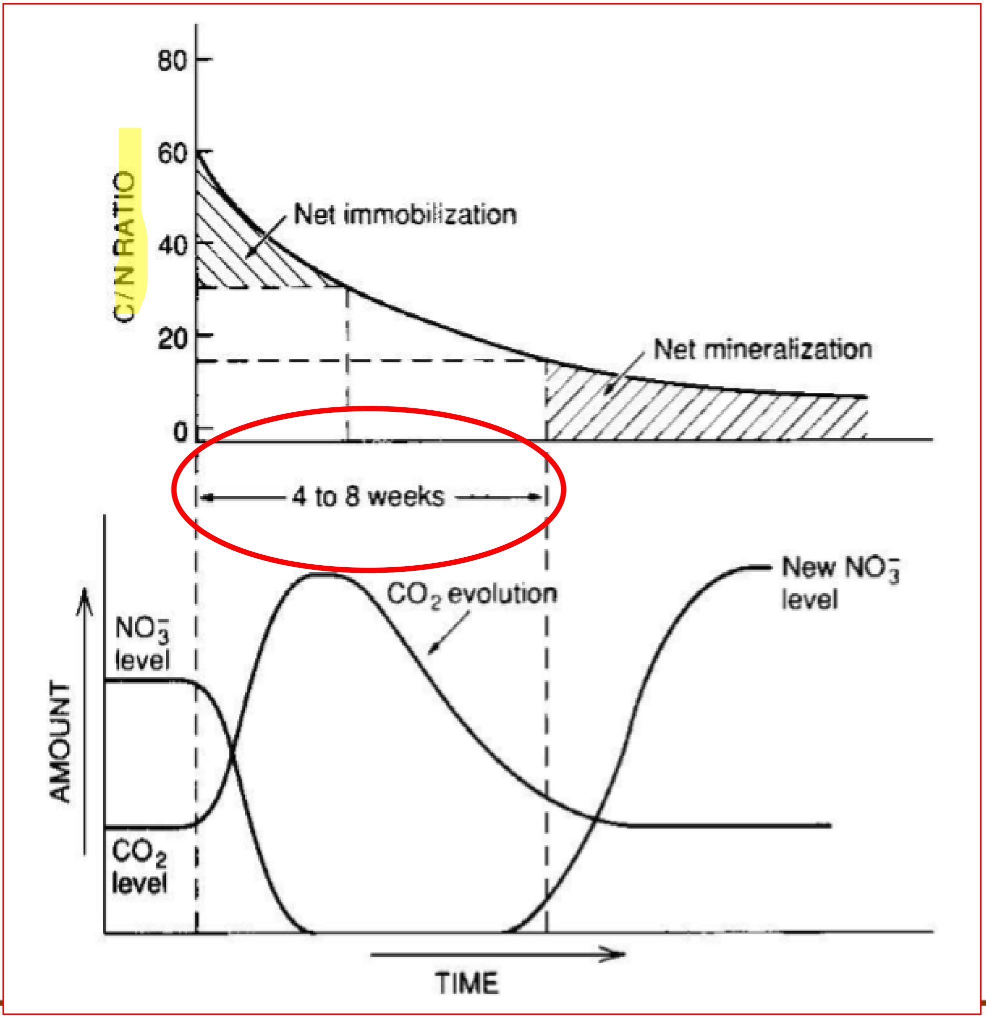
Ryegrass per tonne dry matter	
Nutrient	**Units (Kg)**
Nitrogen	20
Phosphate	3
Potassium	18
Sulphur	2

Inorganic & Organic





Mineralisation of organic matter



- Immobilisation & Mineralisation happen continuously and simultaneously. They are driven by soil biology.
- C:N stubbles above 25:1 will initially tie up (immobilise) nitrogen.
- CO2 evolution (soil respiration) is **microbial activity** and mineralisation of soil organic matter

- Fungi hyphae on oat stubble

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N budget following ryegrass cover crop

- Ryegrass 2.5 t/ha dry matter X 4% N (mid jointing stage) C:N ~ 20:1
- Vegetable crop planted 15 days post termination of cover crop using strip till
- Cowra NSW: Oct Nov Dec … Overhead irrigation – 200 mm
- Crop Removal (75 day crop 45 t/ha x 3.3 kg N per tonne) 150 kg N
- Harvest Index (nitrogen) = 90% **170 kg N**
- Bulk density = 1.1 O.C. = 1% pH = 5.5 CEC = 7
- Soil test N post CC: 0 – 15 cm = 10 mg/kg 15 – 30 cm = 5 mg/kg 25 Kg N

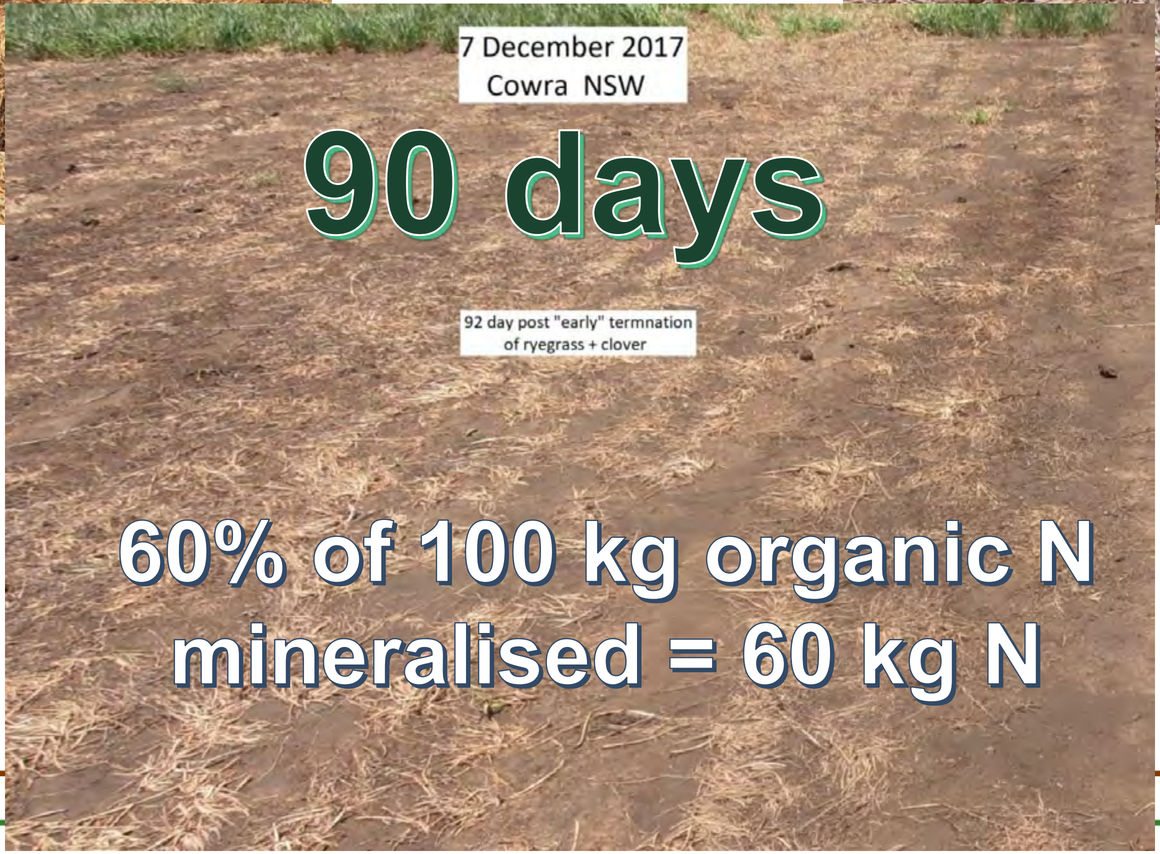
- **N budget ?**

RYEGRASS

C:N = 20:1

Warm temps

200 mm rain



N budget following ryegrass cover crop

- Total N requirement — 170 kg N/ha
- Soil test (rooting depth of crop) — 25 kg N/ha
- **Mineralisation estimate (.5 kg/day X 70 days) — 35 kg N/ha**
  Ryegrass recycled N (2500 kg X 4% X .6) — 60 kg N/ha

- N budget **170** – 25 – 35 - 60 = **50 kg N/ha** (inorganic N = NO3 / NH4)

  Apply early - - - **50 - 60 kg N/ha**

Residual soil nitrogen should be less than 50 kg/ha following vegetable crops

Tillage

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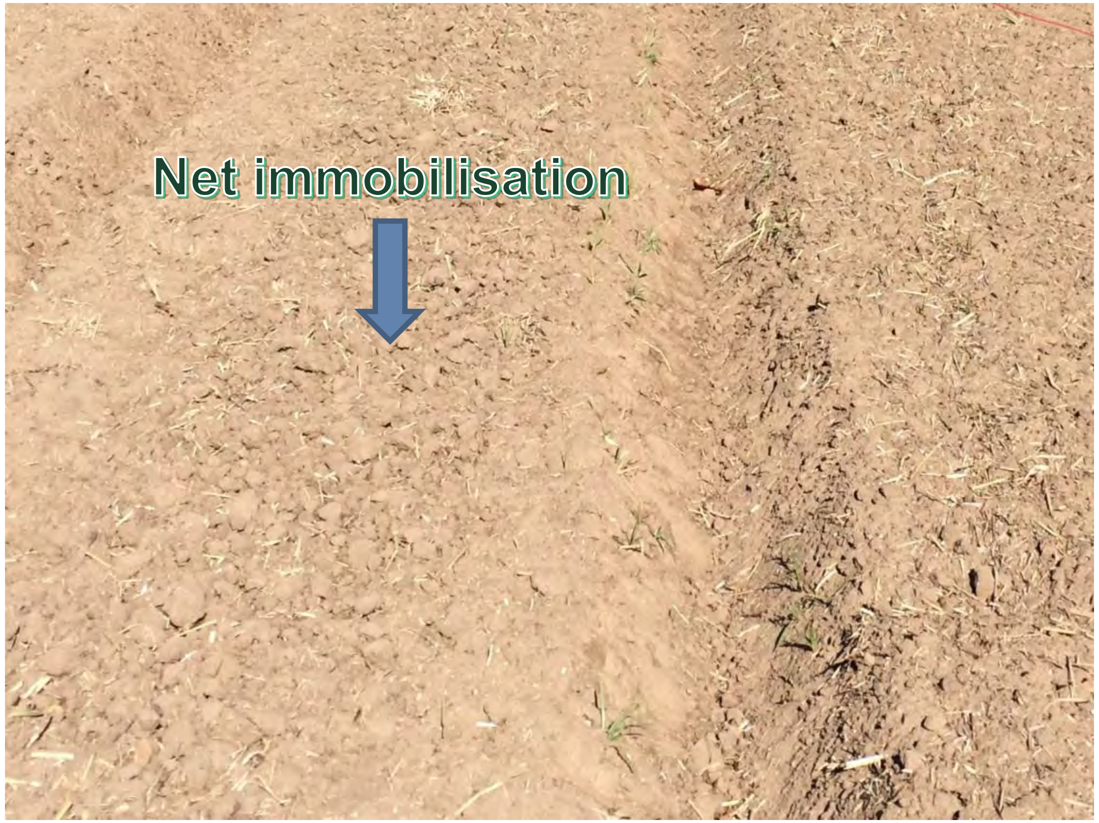
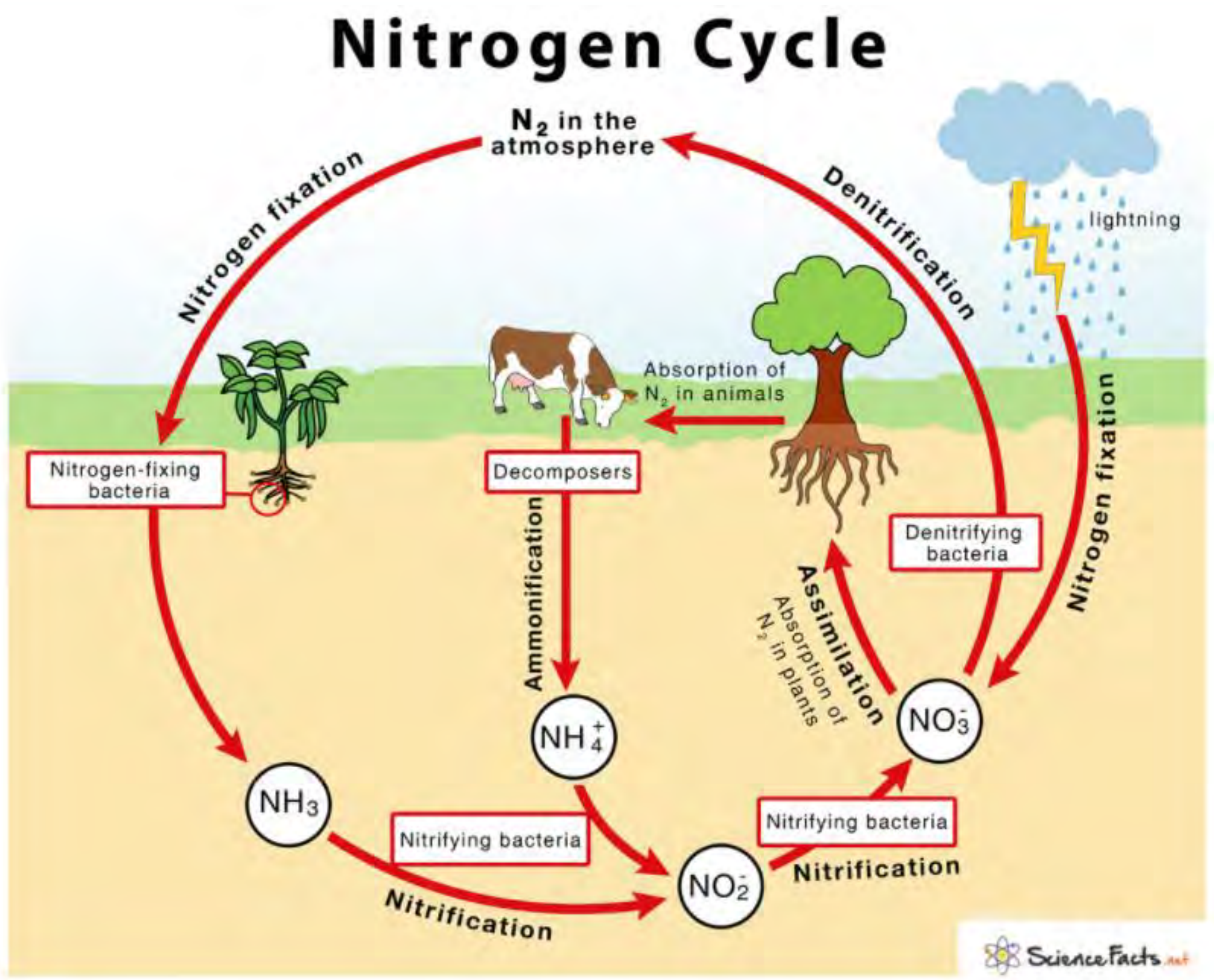
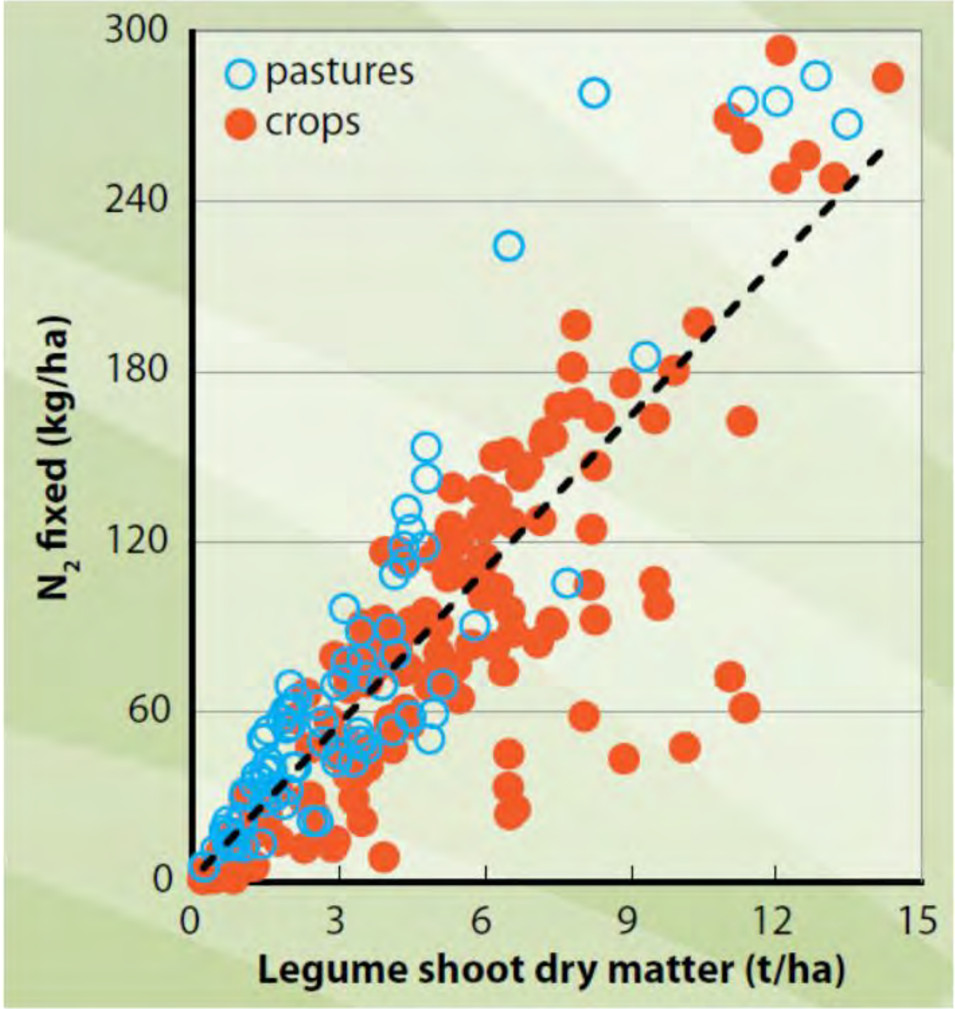


Nitrogen Availability - Biology Drives the System



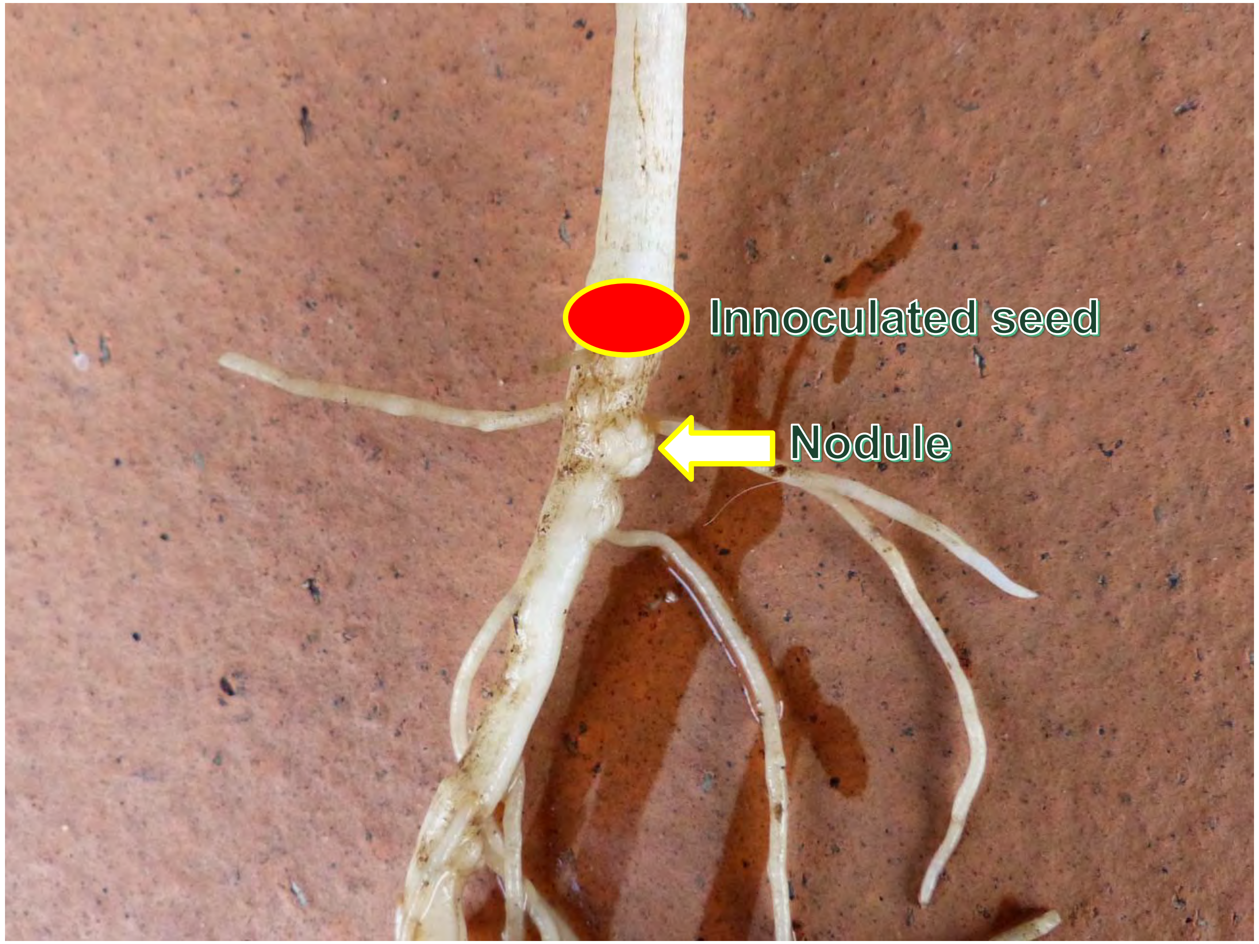
- Legumes
- Denitrification & Nitrification

Legumes = net mineralisation



- *Roughly* 20 kg of N is fixed per tonne of dry matter (does NOT include root N which might contribute another 30% - 50%).
- If grain (seed) is harvested, 30 – 40% of N is removed or exported from paddock
- A slow release of N compared to inorganic fertiliser
- Legume species, Soil pH, Rhizobia, soil N status all effect actual result!

"Mutualistic" bacteria – form partnership with plants



- For most legumes, acid soils will reduce N fixation.
- Soil plant available N above 35 kg/ha (20 ppm) will reduce legume N fixation by a similar amount.
- Root hairs curl around the rhizobia forming a "pocket" which begins the process of nodulation

Rhizobia – very important to innoculate seed

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Legume	Group	Strain No.	Genus/species
Lucerne	AL	RRI128	Sinorhizobium meliloti
Faba, Peas, Vetch	F	WSM1455	Rhizobium leguminosarum bv. viciae
Narrow leaf Lupin	G	WU425	Bradyrhizobium sp.
Soybean	H	CB1809	Bradyrhizobium japonicum
Lab Lab	J	CB1024	Bradyrhizobium spp.
Sunnhemp	P	NC92	Bradyrhizobium spp.

- Commercially available: Billions of **live** cells per gram
- Legume species release specific chemical compounds & rhizobia excrete their own chemical "message"
- Resources: Soil Wealth website (Cover Crop Agonomy Chart) & GRDC website

Non-symbiotic N_2 fixing bacteria

- *Azospirillum spp*. – aerobic, but can also function under low oxygen conditions

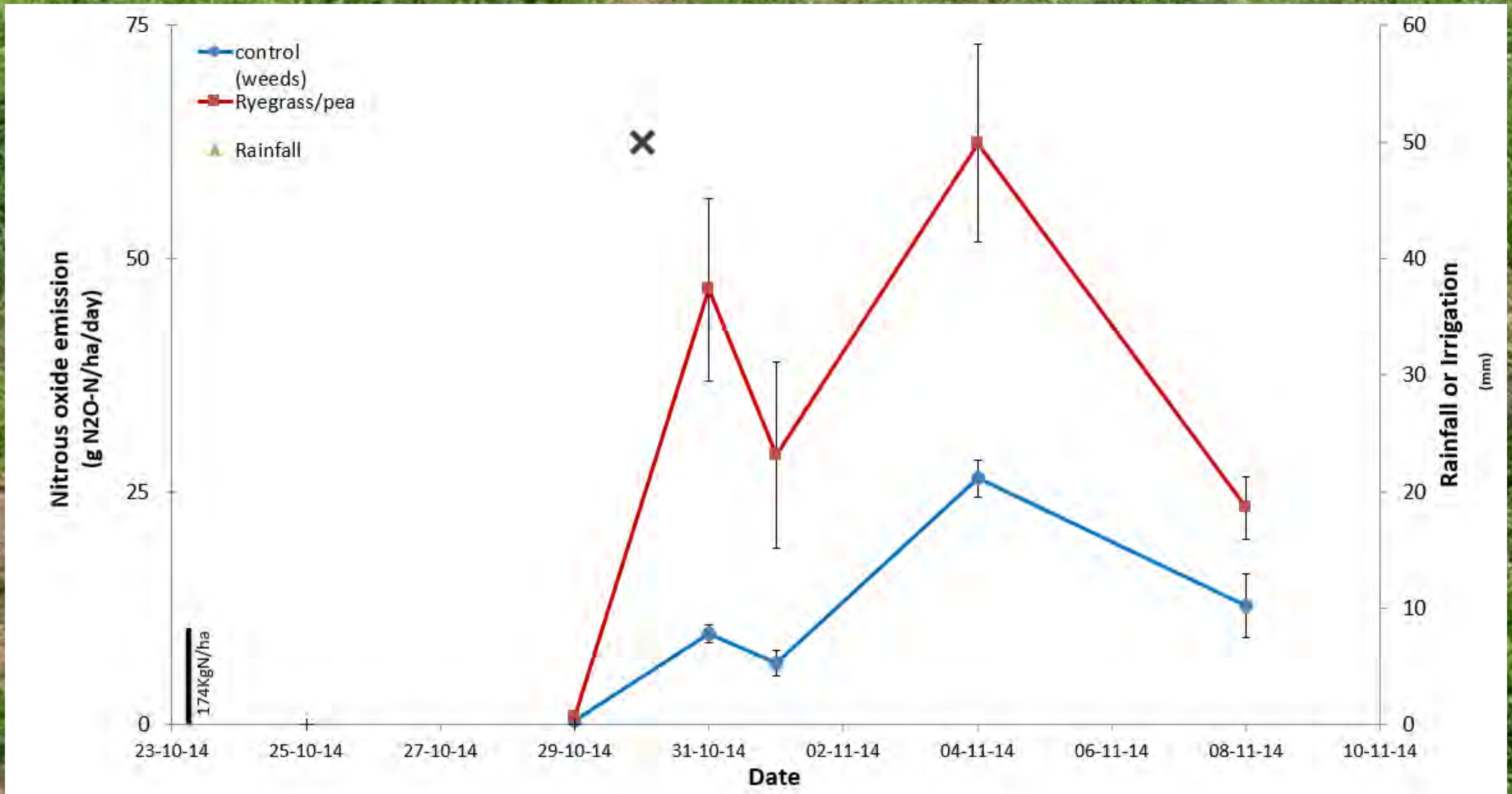
  - colonise roots & excrete plant hormones (PGPR)
  - competes with pathogens on roots; reduces plant disease
  - how much N contribution via biological fixation is unknown (estimations are 10 – 50 kg N / Ha / year)
  - Ideal = 30C   7 pH   (Range: 5C – 42C   5 – 9 pH)

DE-nitrification (waterlogging)

- Soil oxygen becomes limited (30% – 5% oxygen: varies with temperature of the soil) mainly heterotrophic bacteria use organic carbon and the oxygen in nitrate (NO_3) to oxidise the carbon which leads to the creation of nitrogen gas N_2 (atmospheric N).
- Less denitrification occurs in deeper soil profiles (lower organic carbon).

Bacterial Nitrogen driven transformation –nitrous oxide following a cover crop

Ryegrass & peas



Control (weeds)

- **Cover crop = food =** bacteria "party" drives soil anerobic
- Bacteria used oxygen from nitrate – loss of N from nitrous oxide emissions
- Adding biomass increases risk of denitrification – leave 1-2 weeks after incorporating before adding nitrogen

Nitrification (convert NH_3, NH_4 to NO_2 or NO_3)

Conversion Time	
Soil	**50% conversion**
Temperature	**Ammonium - Nitrate**
5	6 weeks
8	4 weeks
10	2 weeks
20	1 week

- Mostly **aerobic** bacteria, chemoautotrophs, often sensitive to pH (ideal = 7)

- Nitrobacteraceae family

  - ***Nitrosomonas***, *Nitrosococcus, Nitrosospira*

    (NH3 - NO2)

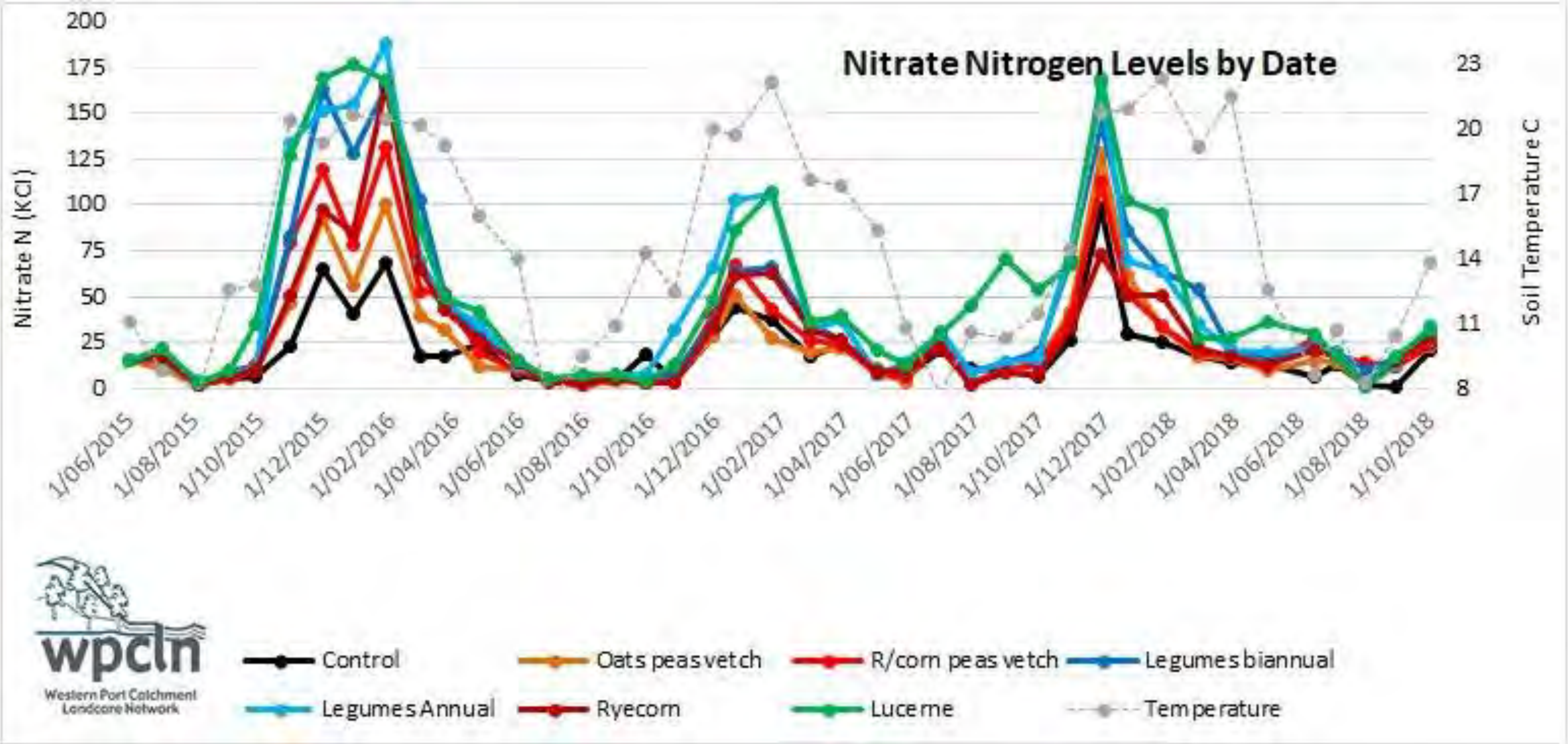
  - ***Nitrobacter***, *Nitrospina, Nitrococcus, Nitrospira*

    (NO2 - NO3)

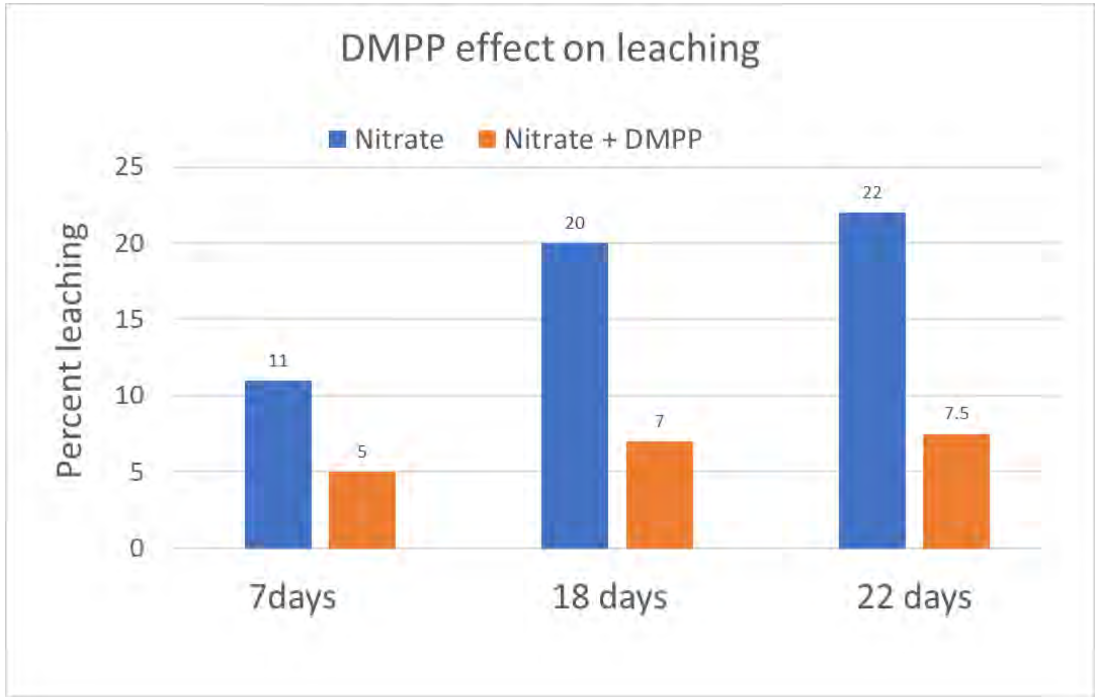
Seasonal temperature influence on mineralisation

3 year study in Victoria

December – March = “peak” times



Ammonium Stabilisers - biological



- Nitrapyrin (N-Serve) – 1962 - *bactericidal*
- Dicyandiamide (DCD) – 1978 - *bacteristatic*
- DMPP (pyrazoles) – 1994 - *bacteristatic*

- Slow Release (urea + formaldehyde) = chemical
- Controlled Release (polymer coated) = physical
- **Stabilised Release** (entec, eNpower) = **biological**

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Soil Organic Matter Fractions

- **Soil Organic Matter** is organic material produced by the decomposition of plant and other forms of organic material (largely particulate) by the action of soil biota and microbes
- **Four soil organic matter pools:**
  - **Fresh organic substances** – plant residues, organic fertiliser, compost
  - **Fast decomposable** - particulate organic matter – labile fraction
  - **Slow decomposable** – humus – stable fraction and major N source

- **Inert** – unavailable SOM eg. Charcoal, calcium carbonate concretions/nodules or as diffuse carbonate. Also mafic parent materials (limestones, basalts) and dolomite or magnesium carbonate.

Biological - Fungi : Bacteria ratio

- Bacteria tend to dominate in systems with fewer organic inputs (cover crops, crop residues, compost) leading to lower C:N ratios.

- Bacteria are more prominent in cooler seasons

- Bacteria are important in the soil ecosystem, but **fungi** are desired and more often considered indicators of good soil health.

- Fungi are more tolerant of acid conditions than bacteria. Fungi (saprophytes) are mainly responsible for initial breakdown of organic matter, then bacteria required to make humus.

Soil Microbiology

- Populations of soil ***bacteria*** change rapidly depending on moisture, time of year, type of crop & hosts (weeds, stubble, organic matter).
- The activity is greater in neutral rather than acid soils.
- Application of high rate of trace elements can be toxic and inhibit mineralisation
- Mineralisation is more rapid in sandy soils compared to loam or clay loam soils – clay minerals absorb organic compounds
- Soil macrofauna accelerate N mineralisation as they provide excreta, increase the surface area of litter and redistribute litter in the soil
- HEALTHY populations of soil bacteria AND fungi are encouraged by REDUCED TILLAGE, GROUND COVER & ORGANIC MATTER

Protozoa:Bacteria = Predator:Prey ratio

- Protozoa feed on bacteria which helps release nutrients, especially nitrogen.
- A higher ratio indicates an active community where nutrients are sufficient to support more predators.
- This ratio will always be a low number. The prey will always greatly outnumber the predators.

Protozoa : Bacteria	
Scale	**Rating**
<0.002	Very Poor
0.002 - 0.005	Poor
0.005 - 0.008	Slightly Below Average
0.008 - 0.01	Average
0.01 - 0.013	Slightly Above Average
0.013 - 0.016	Good
0.016 - 0.02	Very Good
>0.02	Excellent