Organic amendments & soil organic matter: The what, the how and the when …..
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Organic amendment:

Any material which is rich in carbon (C), added to soil with the objective of improving the *chemical*, *physical* or *biological* properties of that soil.

Chemical: nutrient status, soil carbon content/form
Physical: soil structure (water infiltration and drainage)
Biological: stimulates microbial activity

C: N ratio – the amount of carbon (C) vs the amount of nitrogen (N) in a material

Manures

- Fresh or stockpiled material that has not been processed
- Manures from cattle and sheep have a higher C:N ratio than manure from pigs
- If C:N is too low, high odour, loss of N as gas
- Issues with odour and weed seeds
- Pathogen transfer (e.g. *E. coli, Salmonella, Listeria*) is an issue in the handling of manure, and uptake by plants
- Need to consider withholding periods before grazing
- High transport cost per unit of value (due to rapid decomposition rates)
- Manures are rapidly broken down, due to high N contents
- Ruminants (cattle, sheep) have a low efficiency of N utilisation, so high amounts of N are excreted
- Most of the phosphorus (P) in feed cannot be directly absorbed by animals, in the form of *phytate* (non-available form of P)
- Ruminants can break down *phytate* through bacteria in the rumen
- Non-ruminants cannot access *phytate* so have to overfeed P – increased P in manure
- Pig manure contains high salt contents due to inclusion of salt in diet
    - Risk of declining soil structure with regular applications

Manure	C:N ratio
Cattle manure	20:1
Sheep Manure	16:1
Pig Manure	12:1
Poultry litter	20:1
Sawdust	450:1
Wood chips	600:1

Mulches

- Mulches are a layer of material covering the soil surface – not incorporated
- Can be organic (e.g. greenwaste) or inorganic (e.g. plastic)
- Benefits:
    - Moisture retention
    - Weed suppression
    - Nutrient supply (limited)
- Limitations:
    - Variable quality and particle size (if sourced off-site)
    - *Nitrogen drawdown*
    - *Temperature insulation*

Composts

A compost is defined as *"a material that has undergone controlled biological and chemical decomposition (including a period of pasteurisation), resulting in a stable product free from pathogens".*

- The quality of a compost is dependent upon:
    - Source material
    - Balance of the C:N ratio across the feedstock (C:N 30:1)
    - Quality of the process

- Composting will reduce the volume of a pile by 50 – 65 %
  - Reduced transport costs
- Pathogens such as *E. coli*, *Salmonella, Listeria* were not detected after 3 days of composting at 55 °C (Grewal et al, 2006)
- After the heating phase of composting has subsided, let it sit to *'cure'* ,to remove issues such as N drawdown and phytotoxicity, and increase biological stability (AS4454 "mature compost")
- A compost can be applied as a 'mulch' on the soil surface, or incorporated into the soil as a soil conditioner or fertiliser
- If applying as a fertiliser, apply the compost at a rate to satisfy the plant requirement for Phosphorus (P), top up N and other nutrients with fertiliser (or other nutrient sources.)
- The Australian Standard for compost is AS4454
- The standard recognises that compost is produced from a wide range of materials of variable nutrient and carbon content (and pathogens)
- The standard sets guidelines to manage the variability in feedstock and health risk, in order to produce a product that is safe to use, and is beneficial for the plant system
- The standard advises that if manures used in compost, need to maintain the core temperature of pile at 55 °C or higher for 15 days or longer, during which time the pile/windrow should be turned at least five times (to ensure all parts of the pile are subjected to high temperatures for the required time.
- Maintaining temperatures of 55 °C requires 30:1 C:N ratio, 60% moisture content and good O2 levels
- If applying as a fertiliser, apply to satisfy P requirements, top up N and others

Biochar

- Biochars are C rich organic products produced by heating in the absence of oxygen (pyrolysis)
- Biochars are more stable than composts, but the stability, C content and nutrient levels are dependent upon the source material used.
- Biochars have been shown to:
- Increase plant production
- Have no effect
- Decreased plant growth
- Response is due to source material, method of production (temperature, duration) and interaction with soil type (clay, sandy soil)
- Social benefits through reduced organic waste to landfill, and associated energy production

Effect of source & process

Schefe *et al*, unpublished data

Parameters	PL raw	PL compost	PL char
Soil pH (H2O)	7.4	8.7	10.0
EC, dS/m	4.9	4.9	7.6
Total C, %	41	37	57
Total N, %	1.9	2.3	3.0
Total P, mg P kg-1	8336	12184	17943
Ammonium-N, mg kg-1	525	206	1.4
Nitrate-N, mg kg-1	0	21.0	1.3
C:N ratio	219	16.3	19.2
P (CaCl2)	996	1175	0.6

PL = Poultry litter
GW = Green waste

Biological stimulants & organic fertilisers

- Biological stimulants and organic fertiliser cover a broad range of products
- There is no regulation or agreed standard on what they should be comprised of (unless approved for use in organic/biodynamic farming)
- The efficacy of these products and the duration of effect are highly variable across soil types, production systems and seasons
- Products that add beneficial microbes to the soil may have a limited life as these microbes (assuming they are still viable) cannot compete with the native populations of microbes (exception being *rhizobial inoculants*)
- Need to evaluate the product using any information available.

- Questions to ask:
  - What is the material made from?
  - How was it processed?
  - Is it purely from organic sources, or is it 'boosted' with inorganic fertilisers?
  - What is the total C content (NOT organic matter)
  - What are the total- and available- nutrient concentrations?

Example: green waste compost (commercial supplier)	
pHCaCl = 8.2	Total P = 2900 mg P kg-1 (0.29% w/w)
EC = 3.4 dS/m	Soluble P = 0.01 mg P kg-1 (0.00035% of total P)

  - Is there any field trial data on these products?
  - If the product is aimed at increasing soil C, is there data over a number of years?
  - If rock phosphate is the source of P, is it suitable for my soil?
  - Rock phosphate only solubilises well in low pH, high rainfall environments
  - What effect am I likely to get in the first year, and is there a residual benefit over time?

Soil Organic Matter

- Soil organic matter in its broadest sense, encompasses all of the organic materials found in soils irrespective of its origin or state of decomposition.
- Included are living organic matter (plants, microbial biomass and faunal biomass), dissolved organic matter, particulate organic matter, humus and inert or highly carbonised organic matter (charcoal and charred organic materials).
- The functional definition of soil organic matter excludes organic materials larger than 2 mm in size. (Baldock and Skjemstad 1999) *Recent review: Murphy, B, W, (2014) Soil Organic Matter and Soil Function – Review of the Literature and Underlying Data. Department of the Environment, Canberra, Australia.*

Soil Organic Carbon

- Soil organic matter is made up of significant quantities of C, H, O, N, P and S.
- Most analytical methods used to determine the levels of soil organic matter actually determine the content of soil organic carbon in the soil.
- Conversion factors can be applied to the level of soil organic carbon to provide an estimate of the level of soil organic matter based on the content of carbon in the soil organic matter.
- The general conversion factor is 1.72, so the level of soil organic matter is ≈ 1.72 x the soil organic carbon. However this conversion factor does vary depending on the origin and nature of the soil organic matter from 1.72 to 2.0.
- **Method is important – stick to one method of measuring soil carbon**
  (Baldock and Skjemstad 1999)

Forms of Carbon

- Three basic functional forms of soil carbon:

1. Dissolved carbon – This is made up of soluble compounds, which influence microbial activity and nutrient availability (flow on effects to improved soil structure). High turnover
2. Labile carbon - This is made up of compounds that interacts readily with other soil components and provide a food source for microbes, resulting in increased nutrient cycling and availability. Moderate turnover
3. Stable carbon – This form of carbon is made up of compounds that are chemically stable, (generally larger, complex compounds) with only limited interaction with other components. Important for soil structure. Associated with **C sequestration**. Slow turnover

- Hard to quantify these pools
- Standard definitions of carbon fractions, as per the Soil Carbon in Agriculture Research Program (SCaRP)

1. Particulate organic carbon (POC) – Organic carbon > 52 mm in size, comprised of partially decomposed material
2. Humus organic carbon (HUM) - Organic carbon < 52 mm in size. This carbon is relatively stable, and is associated with clay particles. This is the carbon pool that is related to C sequestration.
3. Recalcitrant organic carbon (ROC) – Charcoal and other forms of carbon that is relatively inert.

Organic matter decomposition

- Plant/organic material contains:
  - Sugars
  - Amino acids
  - Proteins
  - Cellulose
  - Hemicellulose
  - Fats, starches and waxes
  - Lignin and tannins

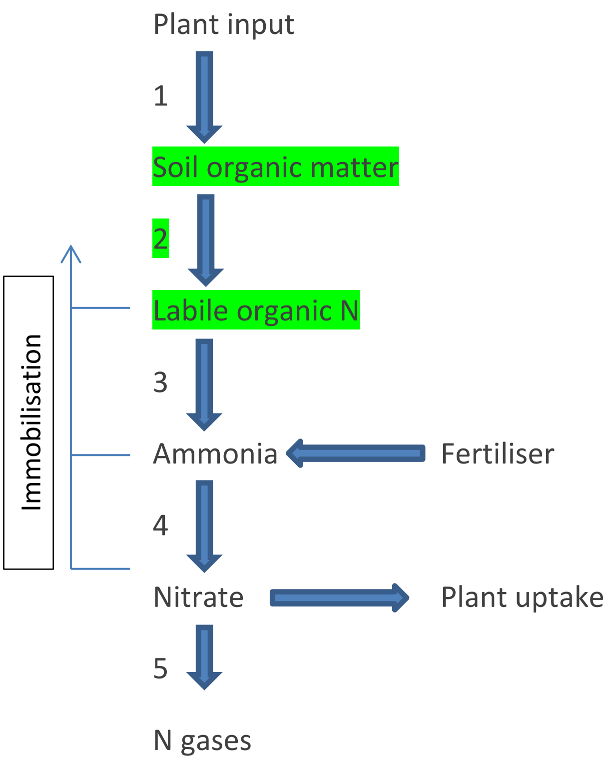
Increased resistance to decomposition

Require different microbial groups to decompose (bacteria vs fungi)

- Decomposition of these compounds results in the release of carbon dioxide (CO_2) and other greenhouse gases (e.g. nitrous oxide, N_2O)
- Products of microbial activity (and dead microbes) also contribute to organic matter production
  - Humus is largely derived from lignin decomposition and the products of microbial activity

Decomposition and Nitrogen supply

Step	Microbial groups	Target enzymes
1.Decomposition	Fungi, bacteria	Laccase, cellulase
2.Depolymerisation	Fungi, bacteria	Laccase; Aminopeptidase
3.Mineralisation	Fungi, bacteria	Aminopeptidase
4.Nitrifaction	Bacteria, archaea	Ammonium monoxxgenase; nitrite oxidoreductase
5.Denitrification	Bacteria	Nitrite reductase; Nitrate reductase; Nitrous oxide reductase



Benefits of soil carbon

- Generally accepted that for greatest benefits of soil C, need to maintain levels at or above
- Easier to do in a pasture system with permanent plant cover, than in a cropping system based on annual species.
- Not just above ground leaf matter that contributes to soil C, dead and decomposing root material also have a significant role in building soil C through the soil profile.
- Soil carbon (and soil organic matter) provides many different benefits; physical, chemical and biological.
- As described previously, not all forms of carbon are the same, with different forms of carbon contributing to different aspects of the soil.

Physical benefits of soil C

- Improves structural stability of soils, reducing dispersion and slaking
- Increases the water-holding capacity, infiltration through the soil surface, and drainage of water through the soil profile
- Improves the friability of the soil, decreases soil strength (and increases surface roughness)
- Improves aeration

Chemical benefits of soil C

- Contributes to the cation exchange capacity (CEC) of soil, (important in lighter, sandy soils)
- Increase the soil's ability to buffer against changes in pH
- Reduce the availability of aluminium (Al) in the soil solution (important in low pH soils)
- Increase availability of nutrients such as phosphorus (P), reducing the proportion of soil P that is fixed in unavailable forms
- Promote the binding of organic matter to soil minerals
- Interact with herbicides and pesticides (can assist in degrading persistent chemicals in the soil
- Carbon sequestration (to be expanded upon)

Biological benefits of soil C

- Provides a source of food, energy and habitat to microbes and other soil organisms
- This ‘safe’ place enables microbes to be supported across low input times, ready to act temperature and moisture conditions are favourable
- Serves as a large reservoir of nutrients which are slowly released to the plant (through biological decomposition)
- Can contribute to the biological control of disease organisms in the soil (through maintaining high levels of ‘beneficial’ microbes

Carbon sequestration

- “Soil carbon sequestration potential: A review for Australian agriculture”(2010) Sanderman, Farquharson, Baldock.
- Cropping:
  - Still playing catch-up from depletion due to initial years of cultivation.
  - Greatest gains were seen within the first 5 – 10 years of field trials, almost no change over 40 yrs
- Pasture:
  - Improvements such as liming, fertilising and sowing of more productive species have resulted in gains
  - Large gains were measured upon conversion of cultivated land to permanent pasture
- Issues in financially committing to sequestration due to the potential for large CO2 losses in short time frames, covenants on future management of land
- Issues in spatial and temporal variability of soil C across a farm.

Application of organic amendments to soil

Amendments:

- Manure
- Compost
- Biochar
- Biological stimulants

Questions:

- What benefits will it have
- How long will it last
- What might be a negative effect?

These will be the focus of a group discussion, based on what we have learnt throughout the presentation.

Surface or subsurface application?

- Optimal placement depends on what the issues are that you are trying to address, and the amendments available
- Surface application (with surface mixing) beneficial for:
  - Surface crusting
  - Poor infiltration
  - Improved biological activity
  - Improved nutrient cycling
  - Improved plant germination and establishment
- Subsurface application (through deep ripping, injecting) beneficial for:
  - Improved water flow through sodic subsoils
  - Dense subsoils, poor root penetration
- Logistics and economics of application are key drivers

Testing of soils and amendments

- Soil tests:
  - Agronomic tests are suitable, which determine the amount of available nutrients and other soil parameters such as pH, EC, CEC
  - Soil Carbon – different laboratories tend to have different tests to measure soil C, depending on what equipment they have.
  - Make sure you measure soil organic Carbon, and total soil Nitrogen (and mineral N)
- Find a laboratory that is NATA accredited (National Association of Testing Authorities)
- Use the same laboratory every time.
- Understand the detail behind how and when to take soil tests, and how to package the soil ready for transport
  - Lots of variation in analytical results can be traced back to poor sampling practice

Testing of soils and amendments

Amendment tests:

- Follow the requirements for the Australian Standard AS4454

Table 1: target parameters for sampling compost products. Tests to be conducted according to AS4454.

Parameter	Stage1, early maturation	Stage 2, advanced maturation
CO_2 respiration (mg CO_2-C per g OM per d)	<4	<2
Dewar self-heating (ºC)	N/A	<40
Ammonium N (mg/kg)	<200	<100
Root length bioassay (mm)	>60	>60
Ammonia gas (ppm)	<500	<100