Advanced Soil Biology: Nutrient Release, Disease Suppression and Support with Teas

EFAO, Ontario
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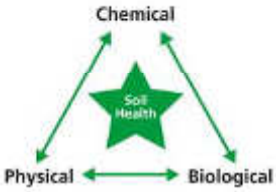
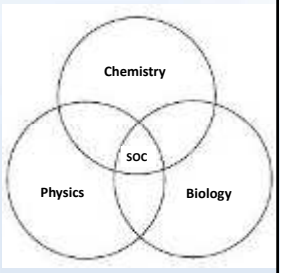
What is a healthy soil?

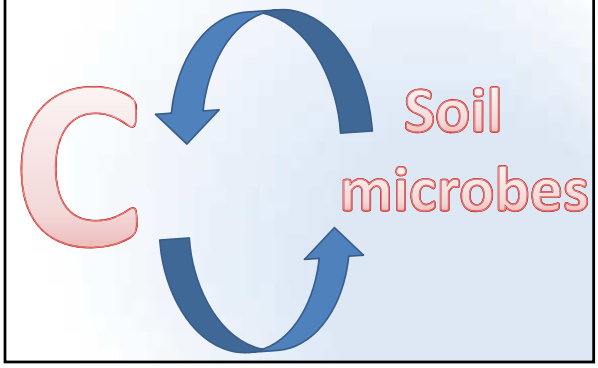


What drives a healthy soil?



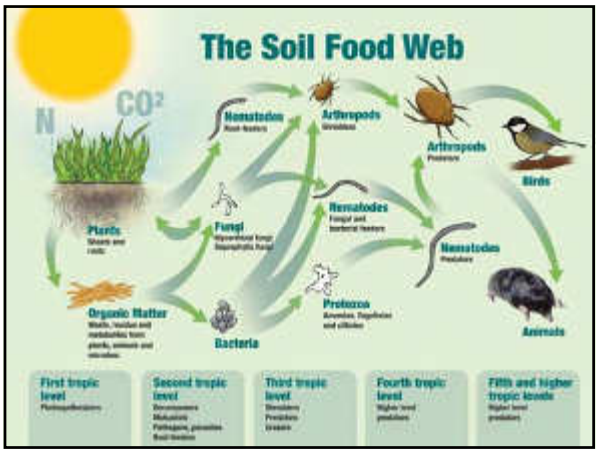
What drives soil organic carbon?

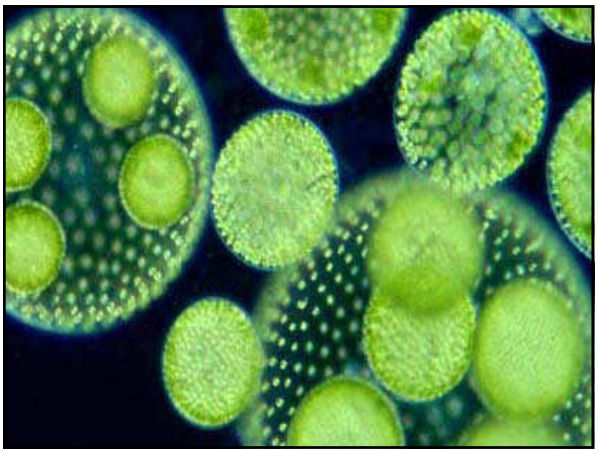
And what drives soil microbes?

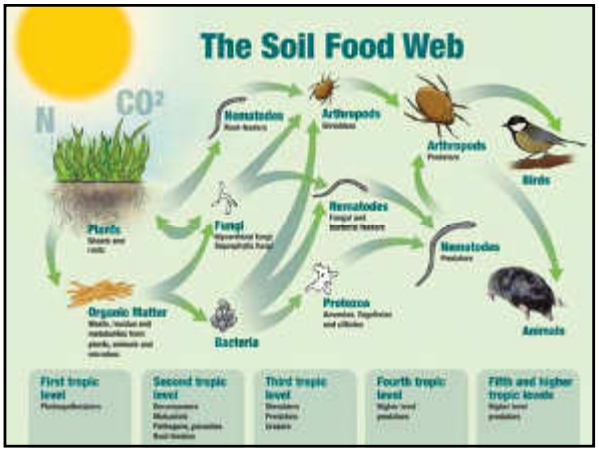


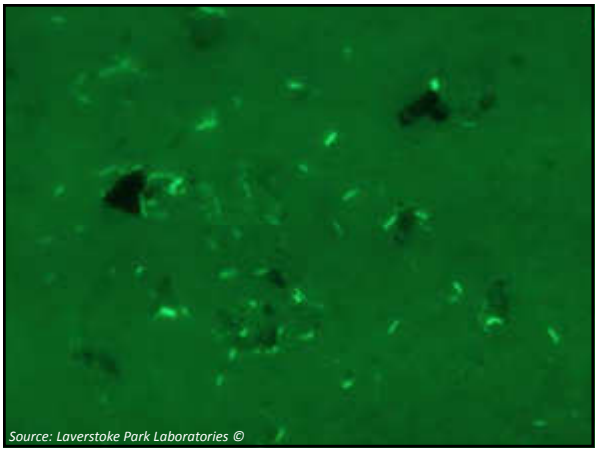
Soil Biology

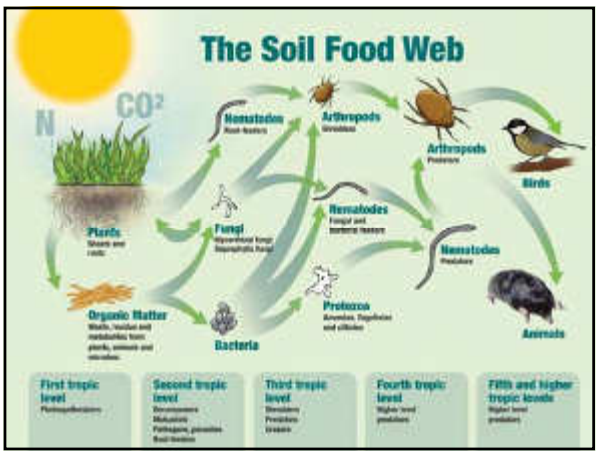
- Beneath the soil surface contains an immense number of living organisms.
  - Algae
  - Bacteria
  - Fungi
  - Protozoa
  - Nematodes
  - Micro and Macro Arthropods
  - Insects
  - Earthworms

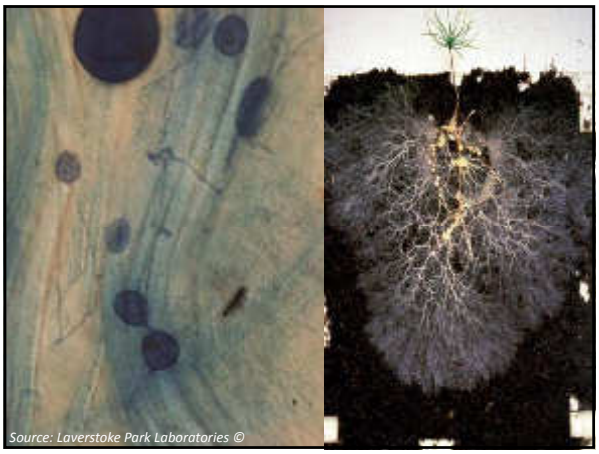




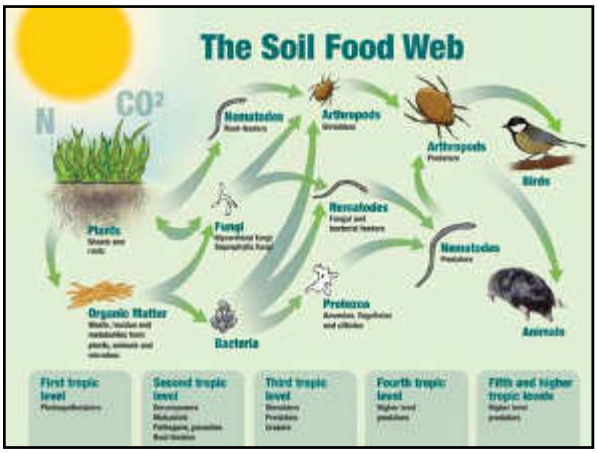


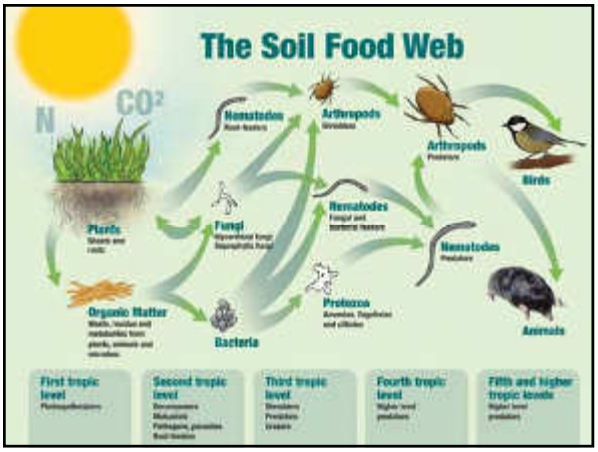


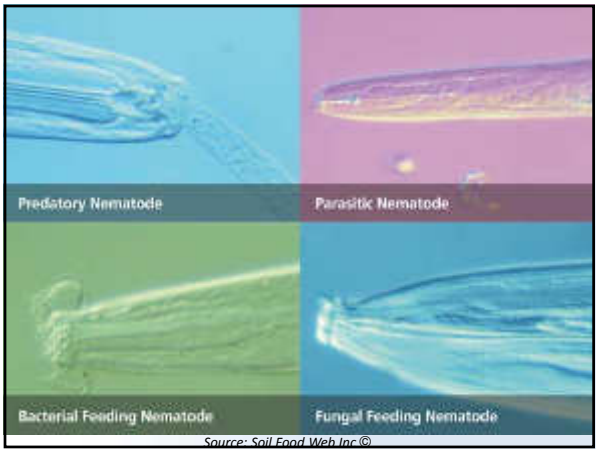




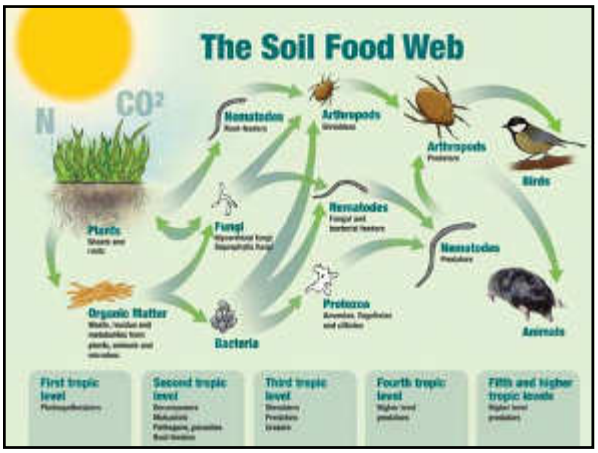
Source: Laverstoke Park Laboratories ©





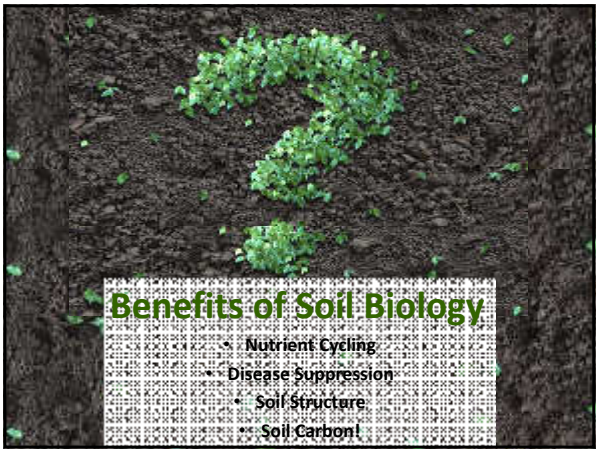


Source: Soil Food Web Inc ©



Why Microbes?

- A healthy and balanced soil micro biota will:
  - Digest and cycle organic matter
  - Improve soil structure and rooting depth
  - Recycle, solubilise and retain nutrients
  - Decompose toxins
  - Increase water and nutrient holding capacity
  - Produce by-products that promote plant growth
  - Protect the plant from disease
  - Sequester carbon



Nutrient Cycling

- Soil microbes **solubilise** insoluble nutrients (reserves and applied) by exuding:
  - Organic acids
  - Enzymes
  - Carbohydrates
- Decomposer organisms also **breakdown** soluble and insoluble organic matter **liberating nutrients** for subsequent plant uptake.

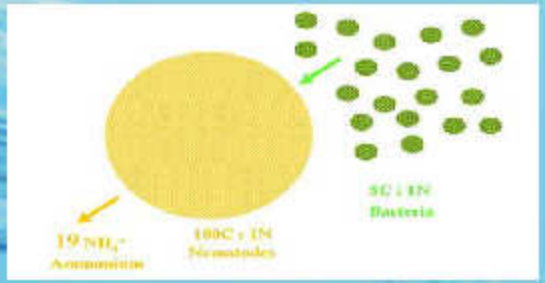
Nutrient Cycling

- Nutrients are made available for plant growth when:
  - A microbe **dies** and its body decomposes releasing nutrients that are stored in its biomass.
  - A microbe is **consumed** by a higher trophic level predator and waste products are **excreted** from the predator.

Organism Group	C:N
• Bacteria	5:1
• Fungi	20:1
• People	30:1
• Green Leaves	30:1
• Protozoa	30:1
• Nematodes	100:1
• Brown plant material	150–200:1
• Deciduous wood	300:1
• Conifer wood	500:1

Protozoa

Nematodes



Nutrient and Moisture Access

- AMF are well documented to access soil reserves of P beyond the root zone.
- They also assist other macro nutrient access – Ca, Mg, K and N.[4]
- And micro-nutrients – Zn, Cu, Fe.[4]

From Nutrients to Disease

- The army of microbes hording around plant roots not only access soil nutrient reserves, but they also form a biological barrier between the plant and potential pathogens.

Biology

- Microbes play an equally important role in controlling diseases.
- Direct Action
  - Pathogen antagonism
- Indirect Action
  - Modification of soil physiochemical properties which can also enhance plant health

Disease Prevention

- Competitive Exclusion
  - Competition for space, food sources, nutrients etc
- Antagonism/Antibiosis
  - Production of antibiotic, antifungal and other inhibitory compounds
- Predation/Parasitism
  - Direct predation of disease causing organisms
- Induced Resistance

AMF and Disease

- AMF colonise root cells excluding pathogens.
- AMF release antibiotic substances into the mycorhizosphere.
- AMF assist the plant to mount defence chemicals faster.
- Improved nutrition changes root exudate profile leading to changes in micro communities.

Manipulating native organisms

- Organic amendments increase soil suppressiveness.
  - Feed and promote beneficial native organisms
  - Compost, manure, residues, biostimulants = carbon
- Long term experiments show us that organic farming systems have higher microbial biomass and diversity (due to regular applications of these organic amendments).

Inoculation

- Apply **new populations** of microbes
  - Compost
  - Compost extracts
  - Commercial inoculums

Liquid Compost Solutions

- Many different types and permutations.
- Liquid compost solutions contain:
  - micro-organisms (bacteria, fungi, protozoa)
  - soluble nutrients (macros and micros)
  - other soluble organic compounds (humic substances)
  - all extracted from the compost.
- This solution can then be applied to soil, compost or leaf surfaces or used to brew compost tea.

Terms and Definitions

- **Compost Extract (CE)**
  A compost/water mixture, extracted and used immediately.
- **Non-Aerated Compost Tea (NACT)**
  Compost/water mixture often left for many days to ferment.
- **Aerated Compost Tea (ACT)**
  Compost/water mixture is actively aerated during the extraction with the addition of specific food sources and left to brew for several hours.

- **Aerobic** – with air (oxygen)
- **Anaerobic** – without air (oxygen)

Terms and Definitions

- Compost teas are not to be confused with:
  - **Plant Teas**
    Liquid extracts from plants (comfrey, horsetail, nettles)
  - **Manure Teas**
    Animal manure/water mixture

Plant Teas

- Processing (often soaking) plant material to make a liquid extract (oil or water).
- Contains minerals (nutrition), carbon chains (food source) and phyto-compounds (pest and disease mgmt) = ideal plant and microbe food.
  - Aloe vera
  - Comfrey
  - Nettle
  - Lucerne/Alfalfa
  - Rosemary
  - Garlic
  - Anything!

Plant Teas

- Plant extracts can additionally be fermented to:
  - pre-digest plant matter
  - release phyto-active compounds
  - inoculate beneficial microorganisms
- Adding EM is ideal here

Compost Extract

- Compost extract is a liquid solution made from mixing compost with water.
- Typically agitation is required to wash (extract) organisms off the compost into solution.
- Usually extracted only for a few hours (1-6h) and applied immediately.
- No additional food sources added (can be added at time of application).
- Positives – quick and easy to make; small initial investment.
- Negatives – more compost required than CT.
  - 10% compost (10 kg per 100 L of water)

Non-Aerated Compost Tea

- A compost extract that is left to ferment with no additional aeration (anaerobic).
- Can be left for 1 – 30 days before application.
- Food sources can be added or omitted.
- Positives – quick and easy to make; small initial investment.
- Negatives:
  - Anaerobic conditions potentially more favourable to pathogens.
  - Ferment or putrefy.
  - Addition of foods increases risk of pathogens so best omitted.

Aerated Compost Tea

- A compost extract that is actively aerated to remain aerobic.
- Typically brewed for 24-48 hours.
- Additional food sources added.
- Positives:
  - Low compost used: 1% compost (1 kg per 100 L of water)
- Negatives:
  - 'Specialised' gear required; higher initial investment.

What happens during brewing?

- Active organisms grow/multiply and increase total microbial biomass.
- Dormant microbes can become active (if conditions suitable).
- Active organisms <u>also</u> produce a host of by-products (biochemicals) that are released into the brew (*antimicrobial and plant growth promoting compounds etc*)

Total and Active Biomass?

- Total Biomass
  - The total biomass of the whole population (bacteria or fungi).
- Active Biomass
  - The percentage of the total biomass that is actively feeding, growing, respiring, reproducing, protecting etc.

Oxygen

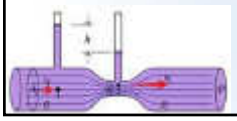
- Why all the fuss about aerating compost extracts?
  - Good quality compost production is an aerobic process (*in fact compost by definition is '<u>aerobic decomposition</u>' of organic materials into humus*).
  - Well structured agricultural soils allow oxygen to diffuse into the soil keeping the soil environment aerobic.
  - So both composts and soils are aerobic environments. In order to culture aerobic organisms in the compost extracts/teas, aeration is required to select for these oxygen loving organisms.

Aerating Compost Tea

- Aerating CT is important to:
  - Supply and meet the demand for oxygen by the aerobic microbes during the <u>entire</u> brewing process.
  - To minimize the chances of pathogen introduction (many pathogens are anaerobic organisms). Keeping the brew oxygenated helps the aerobic organisms out compete the anaerobes.
  - Minimum of 6 mg/L (ppm) of dissolved oxygen is necessary. This can be measured with a dissolved oxygen meter.

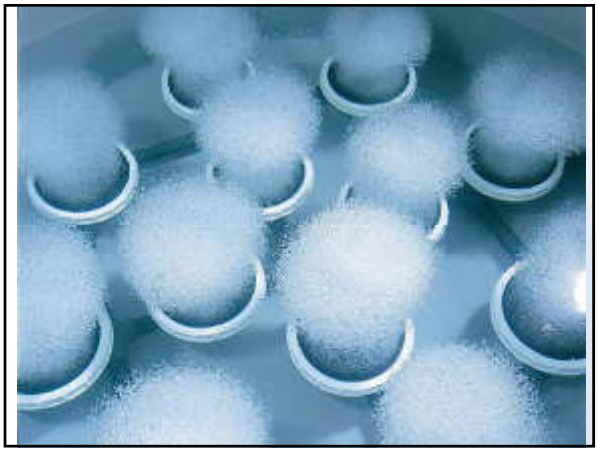
Aerating Compost Tea

- Aeration can be achieved via:
  - Air Blowers
  - Venturi Pumps (venturi effect)
  - Circulation/Flowform



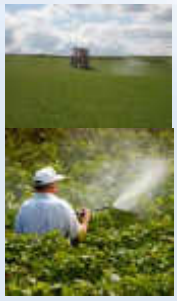
Aerating Compost Tea

- Be aware, circulation pumps (with or without venturi fitted) can potentially damage microorganisms as liquid passes through impeller.
- Diaphragm or piston pumps are preferable over centrifugal pumps.
- All pumps must be tested to ensure they do not damage biology (sample tea before and after).
- Air blowers are beneficial to avoid this problem.



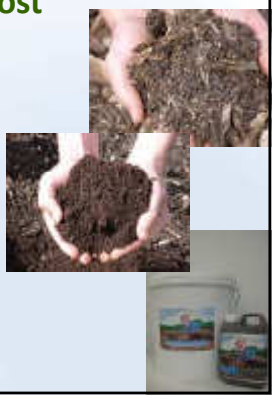
Producing CT

- Fill brew tank with water.
- Aerate water for 1 hour if chlorinated water is used.
- Dilute food sources in additional water to ensure fully solubilised and add to brew.
- Place compost into a fine mesh tea bag and submerse into the water.
- Leave for 24-48 hours.



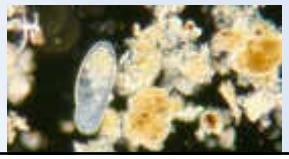
Compost

- Premium quality with <u>maximum</u> total and active microbial biomass required.
- Mediocre compost is not suitable for tea production *(suitable for soil application).*
- Compost quality is key to compost tea quality.
- Used at a rate of 1% (1kg per 100 L of water).



Food Sources

- Matching food supply to the oxygen demand of the microbial population is critical.
- If over fed, often bacteria will boom at the expense of fungi and utilise all oxygen. High risk of brew going anaerobic .
- Food Sources – 0.1 – 1% (100mL-1L per 100L water)

Feeding Micro-Organisms

- Bacterial Foods
  - **Simple** sugars and carbohydrates
  - Molasses, Sugars, Fulvic acid
  - Fish Emulsions
  - Seaweed/Kelp Extracts
- Fungal Foods
  - **Complex** carbohydrates and complex organic molecules
  - Fish Hydolysate, Fish Oils
  - Seaweed/Kelp Extracts
  - Humic acid
- Protozoa Foods
  - Bacteria


Compost Tea Environment

- Water Quality – rain water is preferable.
- Water Temperature – many microbes grow best at 20-25°C however it is best to match brew temp to ambient temp.
  - Air blowers are useful for this.
- Brew pH should also match soil pH.

Brewing Time

- Short brew times do not give the microbes sufficient time to multiply or increase in activity.
- If brew left too long, microbes can run out of food and go dormant.
- Protozoa are more likely to dominate the longer the brew. B and F start, P take over, consume all B and F, brew is left with mainly P.
- Typically: Summer 24 hours
  Winter 24-48 hours

Transferring Tea

- Ideally, position brew tank on high ground to gravity feed into spray tank.
- If transfer pump required, then diaphragm or piston pumps are preferable over centrifugal pumps.
- Filter if necessary no finer than 200 micron *(larger the better)*.
- If diluting with mains water add it to the tank the day before to give chlorine time to dissipate before adding the compost tea.


What happens when tea is applied?

- The increase in microbial biomass on leaf surfaces
  - Protects the plant
  - Feeds the plant (N-fixation etc)
  - The plant feeds the microbes
- Induced resistance
  - Microbes release compounds that turn the plants immune system on strengthening its disease resistance.

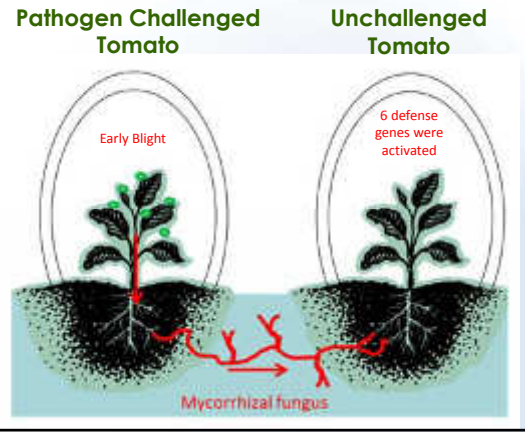
Microbe Brewing

- Similarly to compost tea, microbial blends of lab cultured strains, can be mixed with water and brewed.
- **Advantage**: often very specific strains performing very specific functions. Can be ideal if need for example:
  - A nitrogen boost = apply N fixers
  - Disease suppression = apply antagonists
  - Stubble digestion = apply cellulose digesters
- **Disadvantage**: lacking diversity of CT as only a few species compared to a few thousand.

AMF and Plant Resistance

- Plants are well known to communicate to each other via airborne signalling molecules.
- These molecules can alert other plants (often miles away) of an impending attack (disease or insect).
- More recently, AMF networks underground have been show to also act as transporters of plant signals.
- Tomatoes infected with *Early Blight* can trigger the immune systems of neighbouring tomatoes via the underground AMF network.

* Song YY, Zeng RS, Xu JF, Li J, Shen X, et al. (2010) Interplant Communication of Tomato Plants through Underground Common Mycorrhizal Networks. PLoS ONE 5(10): e13324.



Biological Disease Management

- A combination of:
  - Nutrition
    - Balanced nutrient supply
    - Management of key 'disease fighter' nutrients
  - Biology
    - Viable, active and diverse population
    - Key antagonistic species
  - Crop Management
    - Inducing resistance
      - nutrition and biology

Nutrition

- Plants require a balanced supply of **all** mineral nutrients.
- **Macro** and **micro** nutrients are equally important.
- Nutrients are the catalyst for photosynthesis – the process by which the plants immune system is fuelled.

Disease Fighters

- Although a balanced nutrient supply is necessary, key 'disease fighting' nutrients can also be specifically and intentionally managed:
  - Silicon
  - Calcium
  - Potassium
  - Copper
  - Nitrate (excess)

Photosynthesis

$6CO_2 + 6H_2O$ ----------> $C_6H_{12}O_6$ (sugar) + $6O_2$

minerals/enzymes

$C_6H_{12}O_6$ (sugar) ----------> minerals/enzymes

- Complex sugars
- Carbohydrates
- Amino Acids
- Proteins
- Fats & Oils
- Hormones
- Vitamins
- Phytonutrients
- Protective Compounds

Root Exudates in the Rhizosphere

- Diverse (more complex) root exudates (higher brix) encourage and recruit a more diverse micro flora around the plant root system.

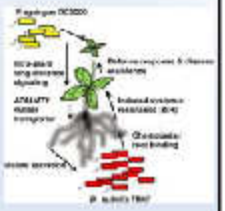
$C_6H_{12}O_6$ (sugar) ----------> minerals/enzymes

- **Complex carbs**
- **Proteins**
- **Phytonutrients**
- **Protective Compounds**

= Diverse Foods for bugs!

Biology and Disease

- Plants can 'pick and choose' different microbes species they need around root systems.
- Plants under foliar pathogen attack have been shown to release the root exudate, **malic acid** – a known food source for ***Bacillus subtilis***.
- *B. subtilis* then colonises the root system and triggers the **plants immune system** further to aid the attack against the foliar pathogen.

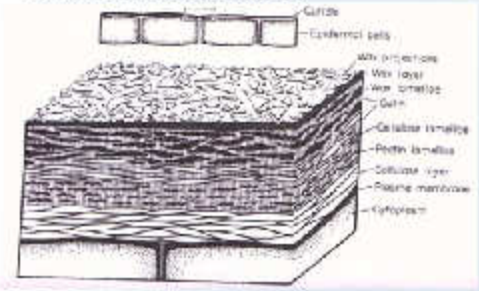


Photosynthesis and Plant Defence

- Nutrients catalyse photosynthesis.
- Photosynthesis fuels the plants own protective defence systems.
- Passive Defences – physical
- Active Defences – biochemical

Passive Defence

- Physical barriers – spines, hairs, thorns, thickness of epidermis etc



Active Defence

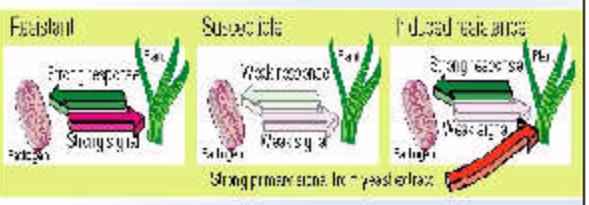
- Involves **bio-chemical pathways** plants use to respond to environmental signals.
- The process relies on an **external cue** (eg: presence of disease causing organism)
- The right cue triggers the production of a **cascade of specific biochemicals** that actively inhibit, deter or **kill** an invading pest.

Immune Responses

- SAR: **Systemic** Activated Resistance.
  - Natural response to pathogen infection.
  - Presence of pathogen triggers plant immune system.
- ISR: **Induced** Systemic Resistance.
  - When the immune response is induced by an external stimuli (non pathogenic).
  - Involves tricking the plant into responding.
  - Kelp, silicon, botanical extracts, some beneficial microbes.

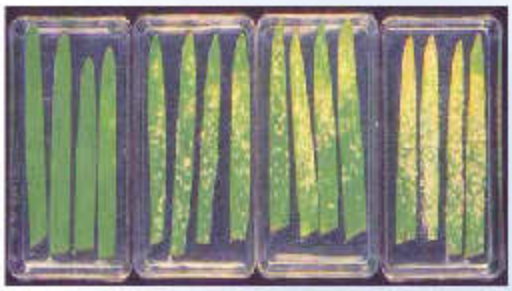
Induced Resistance - How it Works

SAR ISR



A weak signal or lack of energy to respond to pathogen signal causes infection.

Barley sprayed with ISR elicitor (yeast derved). Far right = control, left 3 sets treated with different elicitor formulations



How do we 'Induce' Systemic Resistance?

- **Kelp** - cytokinins involved in ISR
- **Silicon** – promotes accumulation of phenolics in infected host epidermal cells & increases number of cells that respond.
- **Promote soil life diversity** - many ISR responses happen at the root/soil interface with specific microbes such as:
  - *Bacillus sp*
  - *Trichoderma sp*
  - *Pseudomonas sp*
  - Compost teas – species & exudate variety

The Argument against Chemical Pest Control

- By using a chemical to control a pest, the **rich suite of biological compounds** that the plant would have naturally synthesised in order to protect itself will ***not*** be produced.
- Therefore **flavour, nutritional & medicinal properties** of produce will be compromised.

The beneficial bio chemicals are replaced by potentially toxic man made chemicals. You are in essence ***restricting the full expression*** of the plant's potential.

Sustainable Agriculture

- A quote to summarise:

"The achievement of sustainable agriculture was 'let down' in the 20th century when research focused strongly on soil chemical and physical factors, and neglected biological factors"

- Lets not waste anymore time!