Summary

- Keep soil covered – carbon flow
- Minimise soil disturbance
- Inoculate or support AMF

Future Research

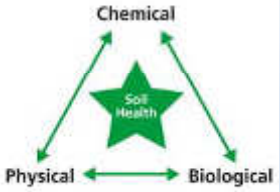
- What are the most suitable methods to:
  - Optimise microbial abundance in agro-ecosystems?
  - Optimise sequestration of plant biomass and/or root exudates into the stable carbon pool?
  - Optimise microbes' ability to acquire and supply nutrients?
- What are the optimum soil characteristics that shift microbial communities toward these processes (chemistry, physics, biology)?
- What are the key microbe groups that are most efficient for these processes and how best to use them in agro-ecosystems?

Making the Most of Your Soil: Getting higher quality and yield with fewer inputs

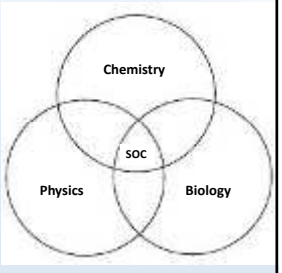
EFAO, Ontario
6th Dec 2014

Joel Williams
BioLife Agricultural

What is a healthy soil?

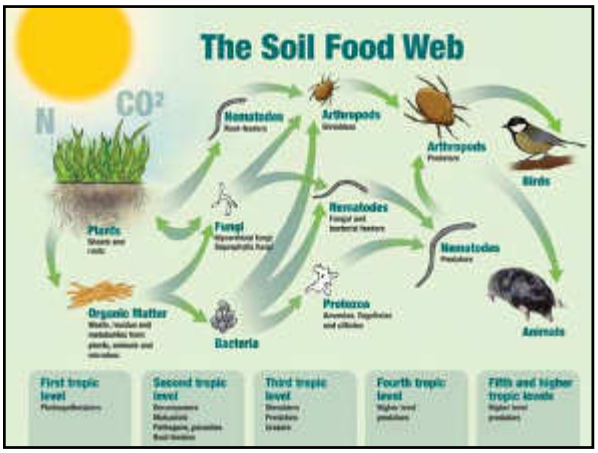


What drives a healthy soil?



Soil Biology

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



Why Microbes?

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

Access Soil Reserves

The Soil Environment

- Soil biology can modify the **soil environment** thereby improving plants to access soil nutrients
  - Soil structure
  - Aeration
  - Root exploration
  - Mycorrhizal fungi

Plant Morphology

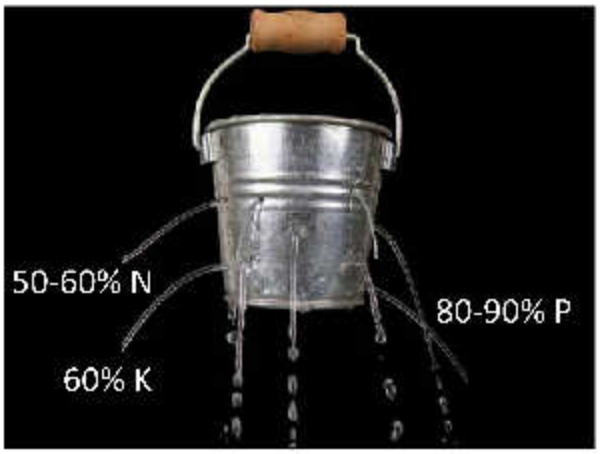
- Soil biology can modify the plants **growth habit** to improve nutrient access
  - Rate of root growth
  - Root length
  - Root branching
  - Root surface area
  - Root hair abundance and distribution

Do Plants Really Need Biology?

- Plants can extract their own nutrients from the soil BUT microbes do it better!
- Research has highlighted that within a grassland:
  - 5-20% of plant N comes from N-fixing bacteria
  - 75% of plant P comes from mycorrhizal fungi
  - 72% of grass sp would not survive without AMF
  - 25% of grass sp would not survive without N-fixers

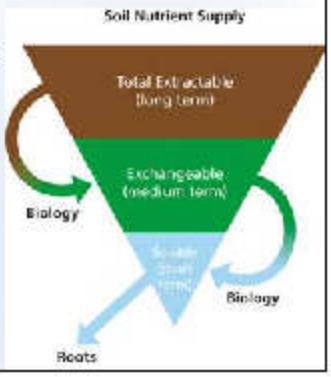
Nutrient Efficiency

- How efficient are we at delivering nutrients to crops?
- How much of our applied nutrients are actually being taken up by plants?
  - N - 40 50% of applied N [1,2]
  - P - 10 20% of applied P [1,2]
  - K - 40% of applied K [1]



Soil Chemistry

- Soil microbes release organic acids and enzymes that solubilise nutrient reserves.
- Without adequate biological activity, nutrient cycling and subsequent plant growth is limited.



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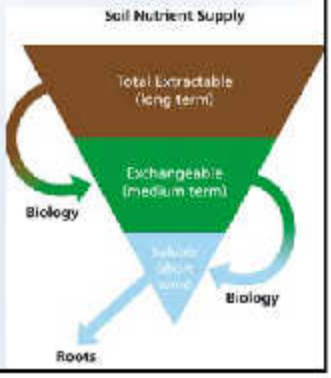
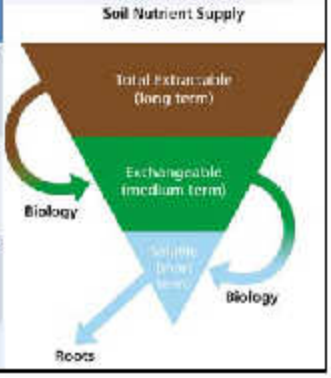
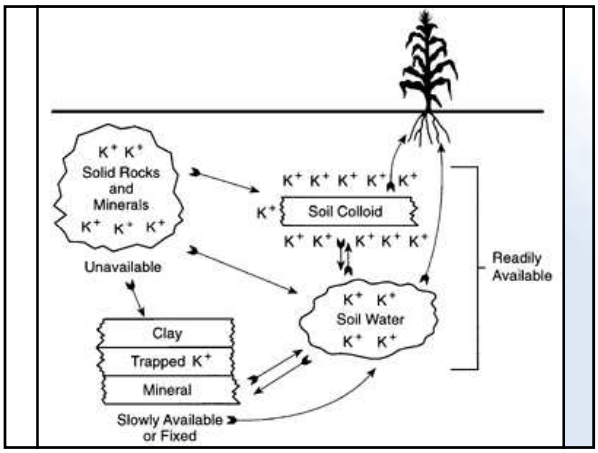


Soil Chemistry Data

P	K	Mg	B	Zn
1019	2920	1685	11.8	151
417	2107	491	2.82	63.1
103	782	141	1.92	6.72





Protect Soil Life

Nutrients and Carbon

- **Every single time** any nutrients are applied, they should be **combined** with a carbon source (liquid or dry).
- The carbon **binds** to the nutrients **chelating** and **complexing** them, **stabilising** them, **buffering** them and improving **uptake** by plants.

Carbon Protects Biology

- Research findings investigating soil life recovery after:
  - Fumigant application vs
  - Fumigant + composted manure
- Fumigant: **12** weeks later = **little recuperation** of soil function.
- Fumigant + compost = **normal** biological activity observed within **8-12** weeks.

* Dungan, R.S., Ibekwe, A.M. And Yates, S.R. (2003). Effect of propargyl bromide and 1,3-dichloropropene on microbial communities in an organically amended soil. *FEMS Microbiology Ecology*. 42: 75-87.

Fertilisers – Organic vs Inorganic

- 200 kg/ha of nitrogen was added to the soil in the form of:
  - Ammonium nitrate, or
  - Dairy manure
- Soil respiration and enzyme activity were higher in the organically amended soil*.
- Increasing carbon in your fertiliser program will increase microbial health irrespective of nutrient content.

* Marinari, S., Masciandaro, G., Ceccanti, B. and Grego, S. (2000) Influence of organic and mineral fertilisers on soil biological and physical properties. *Bioresource Technology*. 72: 9-17.

Nutrients and Biology

- **Excess** nutrients can interfere with healthy soil biological function.
- Nutrients should be applied in a **timely** and **appropriate** fashion to ensure surplus nutrition is not flushing through the system having a negative impact on soil life.

Organic and Inorganic

- Organic inputs buffer Inorganic inputs.
- The message is simple:
- Increasing **carbon** in your **fertiliser** programs will increase nutrient efficiency and microbial health no matter what production system you use!
- **Just combine it with Carbon!**

Carbon Sources

- Liquid Carbon
  - –Molasses
  - –Fulvic acid
  - –Fish Emulsions
  - –Seaweed/Kelp Extracts
  - –Plant Teas
- Dry Carbon
  - –Compost
  - –Raw Humates
  - –Humic + Fulvic granules/powder
  - –Green Manures

Mining Minerals with Plants (and microbes)

Accessing Nutrients via Plants

- Use plants root exudates to solubilise soil minerals
- Plant diversity important
  - –Different exudates
    - Lactic acid, acetic acid, oxalic acid, Gallic acid
  - –Different rooting depths

Accessing Nutrients via Plants

- Legumes (particularly lupins and cowpea) have stronger root exudates
- Lupins increase available P for subsequent crop
- Buckwheat also a great nutrient scavenger

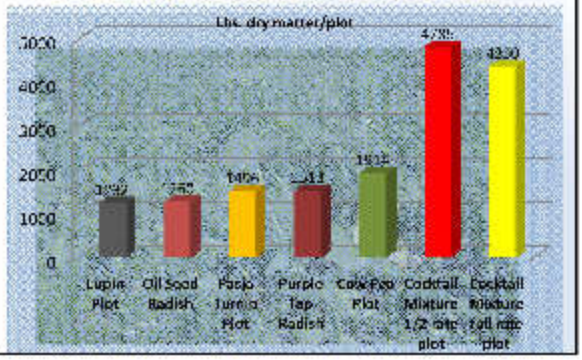
Increasing Plant Diversity

- Cash crops
- Cover crops
- Rotational crops
- Inter-crops
- Summer/Winter
- Annuals
- Perennials

Green Manures

- Green manures are an important means to feed soil life.
- Add Organic Matter
  - Grasses
    - Adds bulk/fine root mass
  - Oats
    - Quick establishment for barley wheat crops
  - Lupins/Legumes
    - Add nitrogen/root exudates
  - Brassicas
    - Biofumigation

The power of diversity: *Collaboration* is more apparent than *Competition*



Digesting Green Manures

- Incorporate the crop when mature
  - Green or brown?
  - Bacteria or fungi?
  - C:N Ratio
- Leave enough time for it to break down before planting next crop
- Don't bury it.
- Don't leave it all on top - oxidation = loss of C
- Somewhere in between these two is ideal - a very light, mild scarification, or very shallow incorporation, slashing, rolling.

Digesting Green Manures

- Use commercial decomposing **inoculums** to speed up the process.
- The **quicker** we can incorporate the carbon into the biology, the less left over there will be to loose as CO_2.
- Apply **nitrogen** during incorporation (eg: spray foliage with fish)

Plant Breeding

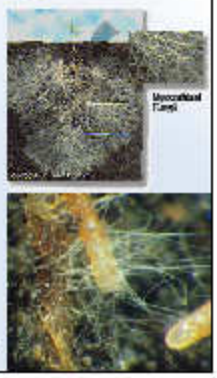
- Current varieties bred in:
  - Fumigated soils
  - Luxurious nutrients
  - Plentiful water
  - Biologically compromised soils
  - (to minimize G x E interactions)
- We must select nutrient scavenging traits
- Varieties that can easily access organic and mineral reserves along with functional microbes and move away from soluble, inorganic dependency

Digesting Green Manures

- Living soil cover keeps **root exudates** flowing into the system feeding microbial biomass (particularly mycorrhiza).

Mycorrhizal Fungi

- A group of fungi that form a symbiotic relationship with plants.
- Plants translocate carbohydrates to the fungi in exchange for nutrients, moisture and protection.
- 80% of all land plants form these associations (90% of our agriculturally important plants).*



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.*
- And micro-nutrients – Zn, Cu, Fe.*
- AMF also increase drought resistance by accessing moisture in soil micro-pores that roots cannot access.*
- AMF can also increase tolerance to salinity and heavy metals.*

Organic and Conventional

- Research has highlighted when compared to conventional soils, organically farmed soils have:
  - Higher AMF spores
  - Higher AMF abundance
  - Higher AMF diversity
  - Higher AMF colonisation of plant roots
- This trend has been identified in numerous research papers in a range of climates, soil types and cropping scenarios.

Is Diversity Important?

- There is good evidence suggesting different AMF species often perform very specific tasks.
- Some species are better than others at providing:
  - Nutrients
  - Moisture
  - Disease protection
  - Soil aggregation
  - Carbon sequestration
  - Or all of the above but at different times of the year!!
- **Diversity** is key in accessing the full range of benefits.

Using the right inputs

Soil Amendments

- "To every action there is an equal and opposite reaction" Newtons 3rd law
- Every management decision will impact soil health in either a positive or negative way.
- Soil life are an ideal way to asses this.
- Guiding Philosophy: *Does an input or practice increase or decrease soil biological health?*

Inputs

Biostimulants
- Humates
- Humic Acid
- Fulvic Acid
- Seaweed Extracts
- Liquid Fish
- Molasses/sugars
- Plant Teas
- Green Manures
- Cover Crops

Biofertilisers
- Compost
- Liquid Compost Extracts
- Microbial Inoculants
- Manures

Chemical Inputs
- Fertilisers
- Pesticides

Humates

- What are humates?
- Humates are derived from prehistoric plant matter.
- Humates have been compressed and preserved as brown coal.
- Also called lignite and leonardite.

Humates

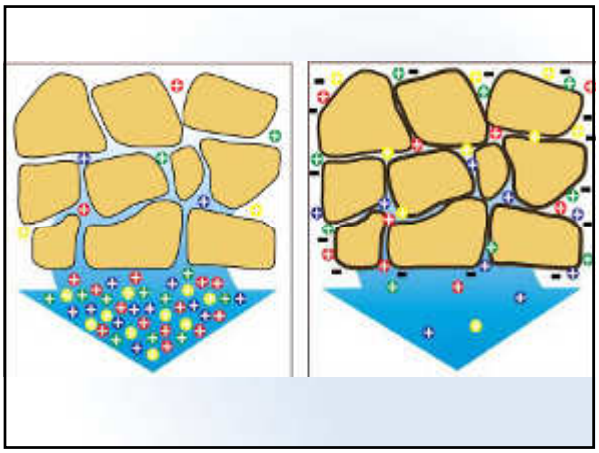
- Contain a huge diversity of carbon compounds including:
  - Humic Acids (alkaline soluble)
  - Fulvic Acids (acid and alkaline soluble)
  - Humins (insoluble fraction)
- Raw humates (brown coals) can be applied at a rate of ~200 kg/ha up to 5 T/ha as long term soil amendment.

Benefits of Humates

- The benefits of humates are numerous and they directly and indirectly improve soil biological health by:
  - Increasing CEC: moisture and nutrient retention
  - Buffering pH extremes
  - Chelating and increasing nutrient availability
  - Buffering excess elements (eg.Na) and heavy metals
  - Detoxifying soil
  - Plant growth stimulation (root exudates)

Humic Acid

- A biologically active fraction of humates.
- Higher molecular weight than fulvic acid.
- Larger sized molecule so it is more stable/resistant in the soil environment.
- Structurally complex nature and high bioactivity means it is a fantastic fungal food source.
- Ideal for soil application.
  - Can be used as a foliar application though in some instances (with alkaline inputs).



Using Humic Acid

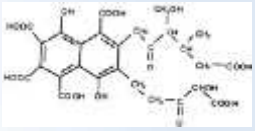
- Alkaline extracted (high pH) so it can be fussy on compatibility with acid fertilisers and chemicals.
- Incompatible with many sulphates, nitrates and phosphates when in liquid form.
- Check compatibility first!
- Application rates:
  - Liquid: ~2 L to 20 L/ha
  - Solid (K-humate): ~2 kg to 5 kg/ha.

Fulvic Acid

- Another biologically active fraction of humates.
- Lower molecular weight than humic acid.
- Smaller sized molecule.
- Structurally simpler nature and high bioactivity means it is a great bacterial food.
- Ideal for foliar applications (powerful chelator)
  - Small molecular size, high exchange/surface area.
  - Still commonly used for soil application though.

Using Fulvic Acid

- Soluble in both acid and alkaline conditions.
- More versatile than humic acid as less compatibility issues.
- Application rates (check product labels):
  - Liquid: ~2 L to 20 L/ha
  - Solid (fulvic powder): ~100g to 3 kg/ha.



Humates

- Humates, Humic Acid and Fulvic acid improve uptake efficiency of whatever they are combined with.
- This reduces the need/dependency on inputs.
- Their effect also extends to dormant nutrients in the soil improving nutrient cycling.

Seaweed Extracts

- As kelp comes from the sea, it contains broad spectrum trace minerals, enzymes and vitamins.
- Also renowned for a wide array of different carbohydrates it produces (both bacterial and fungal foods).
- Contains mannitol – a powerful chelating agent and microbial stimulant.

Seaweed

- When compared to an unamended control, research has highlighted seaweed can significantly:
  - Increase soil pores.
  - Increase aggregate stability.
  - Increase soil microbial biomass.
  - Increase microbial activity.

* Haslam, S.F.I. & Hopkins, D.W. (1996) Physical and biological effects of kelp (seaweed) added to soil. Applied Soil Ecology. 3 (3): 257-261

Liquid Fish

- Fish Hydrolysate
  - Enzymatically digested.
  - Not heat treated (max 50°C).
  - Higher presence of complex carbon chains due to less physical processing.
  - Higher oil content.
  - Fungal food.
- Fish Emulsion
  - Heat treated so complex carbon chains are denatured and broken down.
  - Bacterial food.

Plant Teas

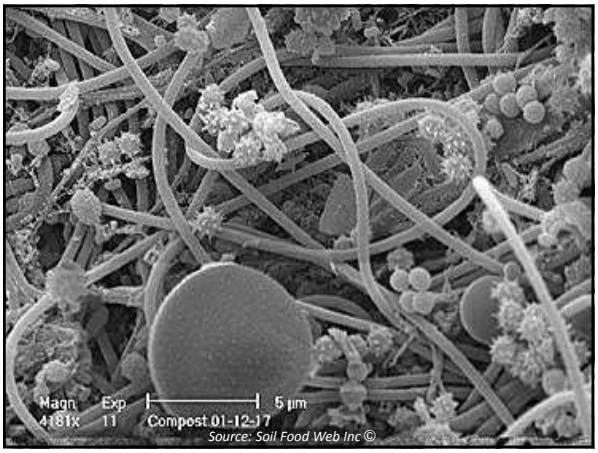
- Processing (often soaking) plant material to make a liquid extract (oil or water).
- Contains minerals (nutrition), carbon chains (food source) and phyto-compounds (pest and disease mgmt) = ideal plant and microbe food.
  - Aloe vera
  - Comfrey
  - Nettle
  - Lucerne
  - Rosemary
  - Garlic
  - Anything!

Feeding Soil Microbes

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

Biofertilisers

- Apply **new** populations of soil organisms
  - Composts
  - Liquid Compost Extracts
  - Commercial inoculums
  - Manures



Long Term Soil Balance and Short Term Cropping

Remineralising, balancing and building carbon in soils is a long term goal. Short term crop management is also required in tandem and optimal crop management (year after year) will simultaneously contribute to building soil fertility.

The Role of a Foliar

- Foliar applying nutrients is more efficient than soil applied:
  - Bypass soil imbalances
  - No nutrient antagonism (competition)
  - No leaching, no volatilisation
  - Less fertiliser required
- Nutrients are targeted directly onto plant surfaces for subsequent absorption

Foliar Applications

- When foliar applying consider:
  - Time of day
  - Spray pH
  - Spray EC
  - Chelation
  - Wetter/stickers
  - Nutrient synergists

The Biological Link to Foliar Applied Nutrition

- Foliar applied nutrients is actually all about microbial stimulation.
- When calculated back, the amount of nutrient applied via foliar applications is very small.
- But those small amounts stimulate photosynthesis and hence sugar production.
- Those sugars etc are sent to the roots and exuded to feed soil microbes.
- Soil microbes in return, solubilise much more nutrient from the soil and feed the plant.

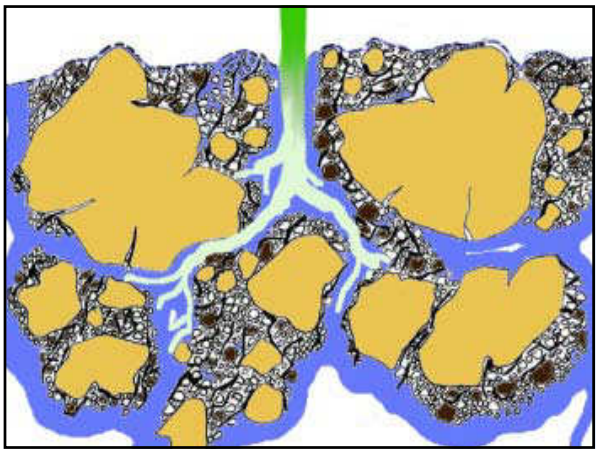
Photosynthesis

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

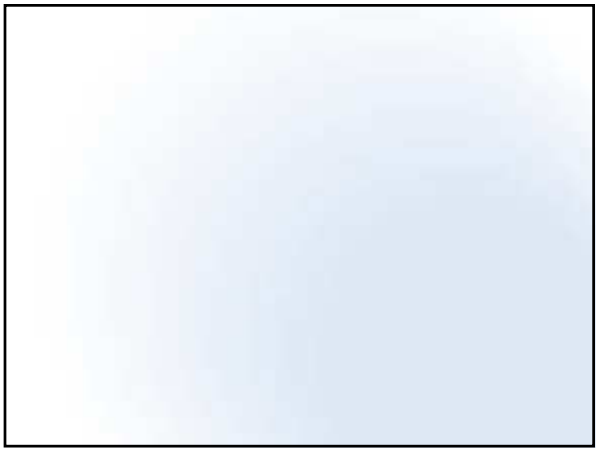
minerals/enzymes

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

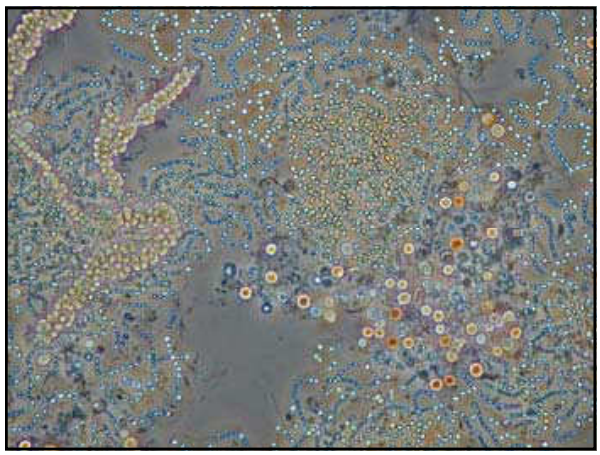
- Complex sugars
- Carbohydrates
- Amino Acids
- Proteins
- Fats & Oils
- Hormones
- Vitamins
- Phyto-nutrients
- Protective Compounds




A targeted foliar program to optimise plant health will further improve nutrient access (efficiency) from the soil.




Diversity and Dormancy
Source: Laverstoke Park Laboratories ©



FEEDING THROUGH THE FOLIAGE

- Foliar feeding has been estimated to be 8 to 20 times more efficient than root feeding.
- 80% of foliar nutrients reach their mark compared with 10 - 30% soil applications.
- It has taken a long time to gain mainstream acceptance and adoption of the philosophy.
- Many previous trials have produced mixed results.
- An understanding of the technology & appropriate application methods should limit variations in response.

Role of Nutrients

- N – Chlorophyll, AA, P
- P – Energy, root development
- K – Enzyme production, sugar movement, N utilisation
- Ca – Cell wall strength
- Mg – Chlorophyll
- S – N utilisation, root development
- B – sugar translocation, reproductive processes
- Cu – disease protection
- Zn – auxin production, leaf size
- Mn – reproductive processes
- Fe – chlorophyll production
- Mo – N utilisation
- Si – cell wall strength

MOBILITY OF NUTRIENTS

All nutrients are readily absorbed into the leaves, however some are more readily translocated within the plant than others.

Good Mobility:
- Nitrogen
- Phosphorus
- Potassium
- Magnesium
- Manganese

Poor Mobility:
- Calcium
- Boron
- Zinc
- Copper
- Iron
- Molybdenum
- Silicon

Testing the older leaves may help give a true indication of mobile nutrient deficiencies

Foliar Programs

- Leaf Test Monitoring
  - Crop specific
  - Weekly to monthly intervals
  - Target fertiliser $
  - Apply exactly what is required

Foliar Programs

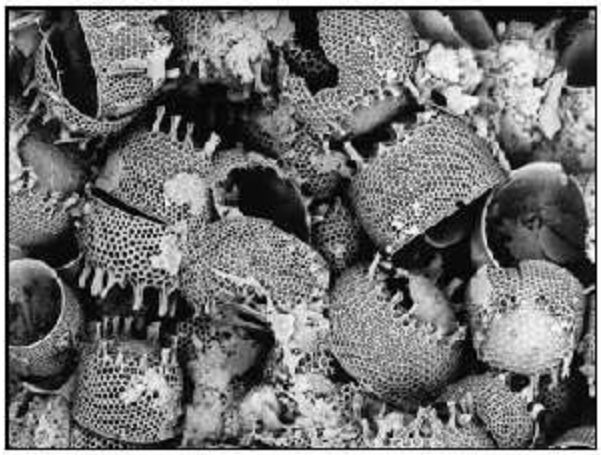
- Vegetative vs Reproductive
  - Vegetative Nutrients – nitrate
  - Reproductive Nutrients – ammonium
  - Cell division – calcium

Foliar Programs

- Crop Stage Programs
  - Germination – Mn, Zn, traces
  - Early root Growth – P
  - Vegetative Structure – N, Mg
  - Pre-flowering – B
  - Fruit Set – Ca
  - Fruit/Seed Fill – K

Silicon

- Classically speaking, not an essential element, but beneficial.
- However, silicon is the "essential non-essential" in ecological production systems.
- Si enhances Ca uptake.
- Both Si and Ca are deposited in cell walls.
- Si is an inducer of the plants immune system boosting resistance against insects and disease.
- Improves frost, heat, drought, salinity, sodium and heavy metal resistance.



Calcium

- Ca is the trucker of all minerals.
- Ca is deposited in cell walls and improves nutrient uptake of all elements into the cells.
- Highly immobile.
- Ca is a cell strengthener (along with Si) improving pest and disease resistance.
- Ca improves quality of all crops.
- Role in regulating sap pH.
- Requires B to bring its benefit.

Potassium

- Important for sugar translocation – sizing up fruit.
- Improves flavour and quality.
- Crucial role in regulating sap pH.
- Important for protein synthesis – brix/quality.
- Highly mobile.
- Use sap meter on young and old leaves.

Synergism

- Always apply **carbon** with **nutrients.**
- Always apply **B** with **Ca.**
- Even better, combine **Si** with **B** and **Ca.**
- Include **Mg** with **P** applications.
- Include **Mo**, K, **S** with **N** applications.

Photosynthesis

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

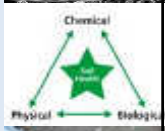
minerals/enzymes

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

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

Sustainable Agriculture

- Although there is much to learn and we do not know the full long term impacts of all inputs; remember:
- "To every action there is an equal and opposite reaction"
- Guiding Philosophy: *Does an input or practice increase or decrease soil biological health?*



Questions and Summary?

Thank you

EAFO

Especially to Alexander English and Harris Ivens

biolifeag@gmail.com