Measuring Soil Health with practical examples

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WARD Laboratories, Inc.

Sources of Energy

- Nearly all living things obtain energy either directly or indirectly from the energy of **sunlight** captured during photosynthesis.

The sun is the source of energy for most living things.

Plants such as grass use energy from the sun to make their own food.

The zebra obtains energy by eating grass.

The lion obtains energy by feeding on the zebra.

Required Nutrient	*How nature provides it*
Carbon	 **Photosynthesis (CO_2 + Sunlight)**
Nitrogen	 **Atmospheric N_2 + N-fixing bacteria**
Mineral nutrients (macro, micro, and nano)	 **Microbial-facilitated release or from natural weathering**
Water	 **Rain, water infiltration, and storage capacity**

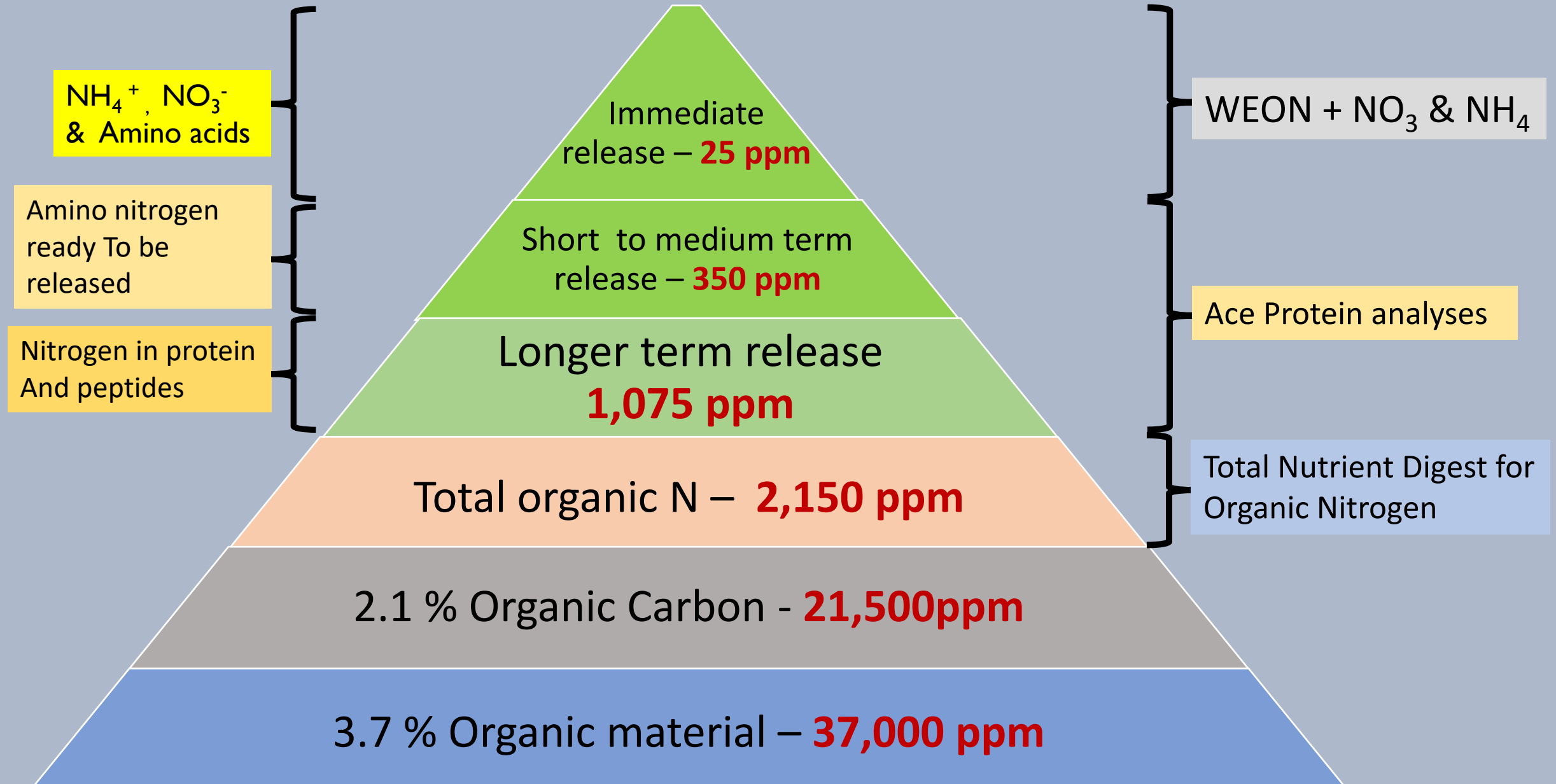
Photosynthesis capacity and rate measurements

- the amount of light intercepted by green leaves
- rate of conversion of light energy to sugars
- measured with a **refractometer**

The presence of mycorrhizal fungi can significantly increase photosynthetic rate

- Results in higher plant sugar and mineral content
- less prone to pests and diseases

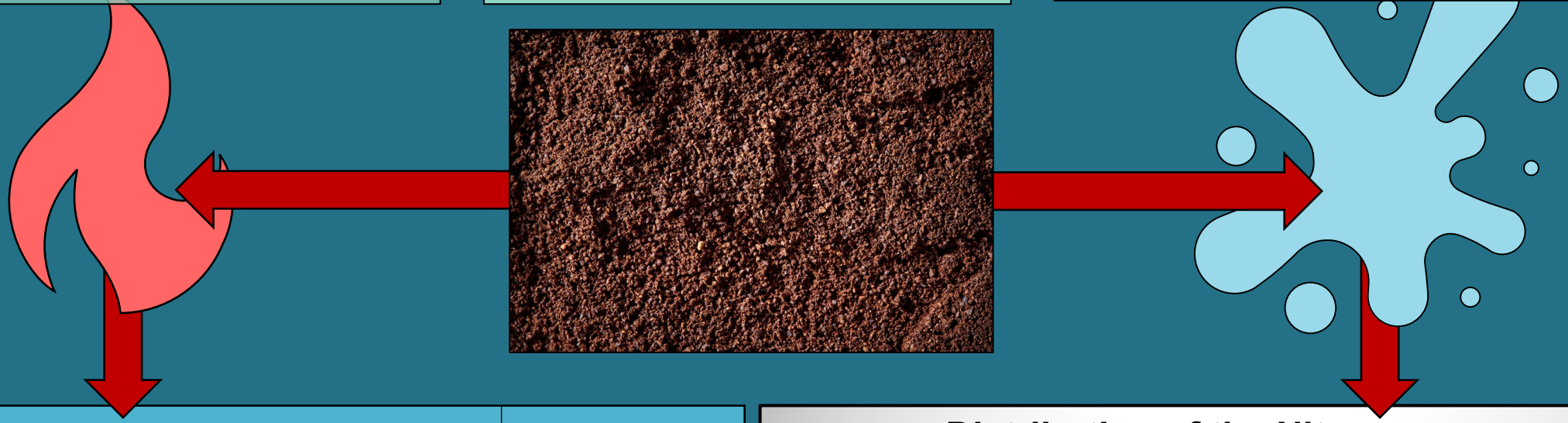
Natures nitrogen supply chain from Soil Organic Material

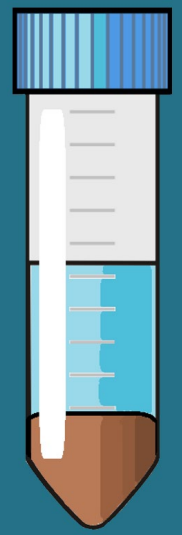


Measuring Nitrogen

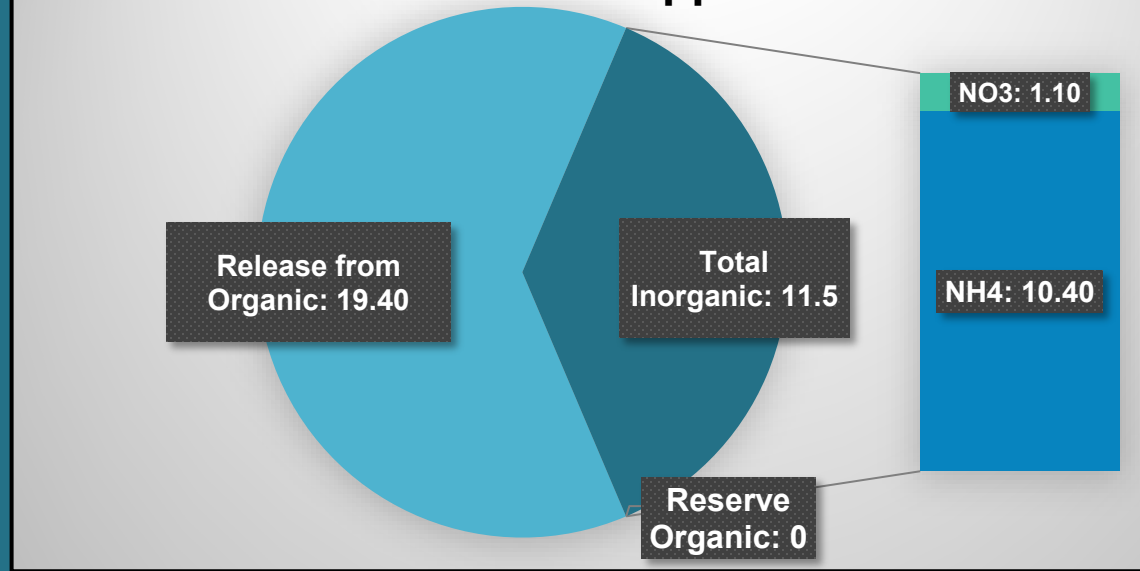
Total Soil Nitrogen: Combustion

Water Extractable Nitrogen: Organic, NO_3, and NH_4



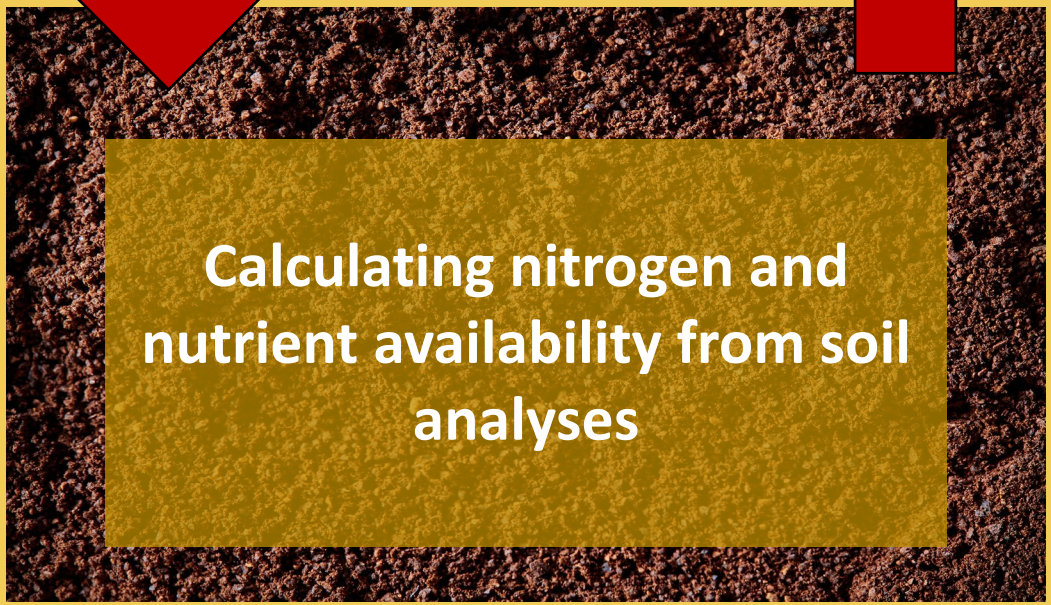


Total Nitrogen in Soil Organic Matter		N (lbs/acre)
Combustion Method (Ward lab): *68 farms from several states*	Average value	3075
	Median value	2949
	Highest value	6109
	Lowest value	478



Forage & Plant Analysis:

Nitrogen and nutrient content from cover crop



Calculating nitrogen and nutrient availability from soil analyses

Plant Biomass Total Nitrogen and Dry Matter

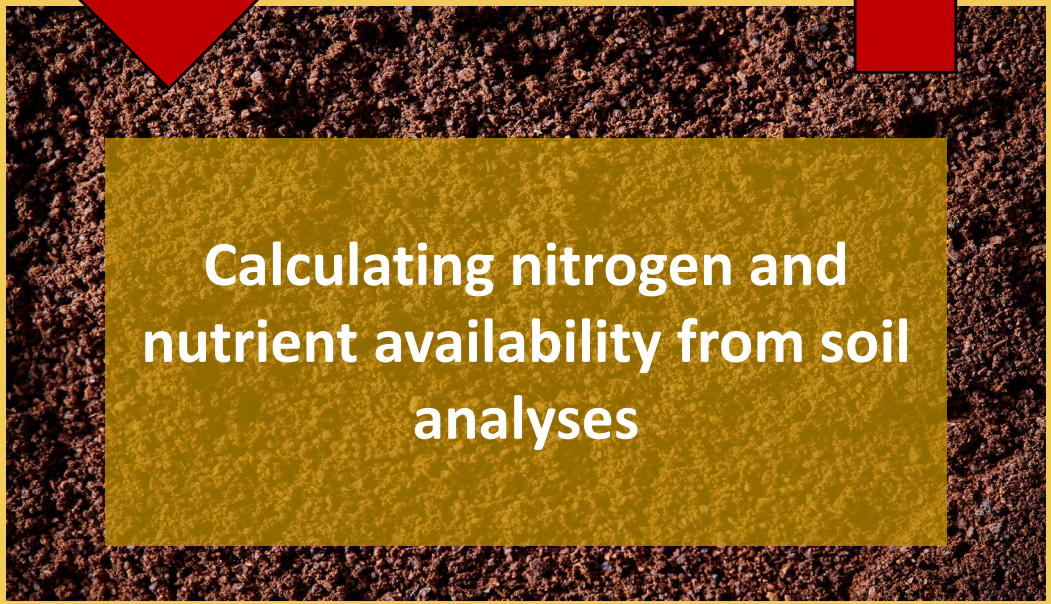
Crop	Total N (lb/acre)	Dry Matter (lb/acre/year)
Mustards	30 – 120	3,000 – 9,000
Radish	50 – 200	4,000 – 7,000
Rapeseed	40 – 160	2,000 – 5,000
Berseem clover	75 – 220	6,000 – 10,000
Cowpeas	100 – 150	2,500 – 4,500
Crimson clover	70 – 130	3,500 – 5,500
Field peas	90 – 150	4,000 – 5,000
Hairy vetch	90 – 200	2,300 – 5,000
Medics	50 – 120	1,500 – 4,000
Red clover	70 – 150	2,000 – 5,000
Subterranean clovers	75 – 200	3,000 – 8,500
Sweetclovers	90 – 170	3,000 – 5,000
White clover	80 – 200	2,000 – 6,000
Woollypod vetch	100 – 250	4,000 – 8,000

From *Managing Cover Crops Profitably, 3rd Edition. SARE Outreach* 2007

Forage & Plant Analysis:

Nitrogen and nutrient content from cover crop

From UNL-Extension



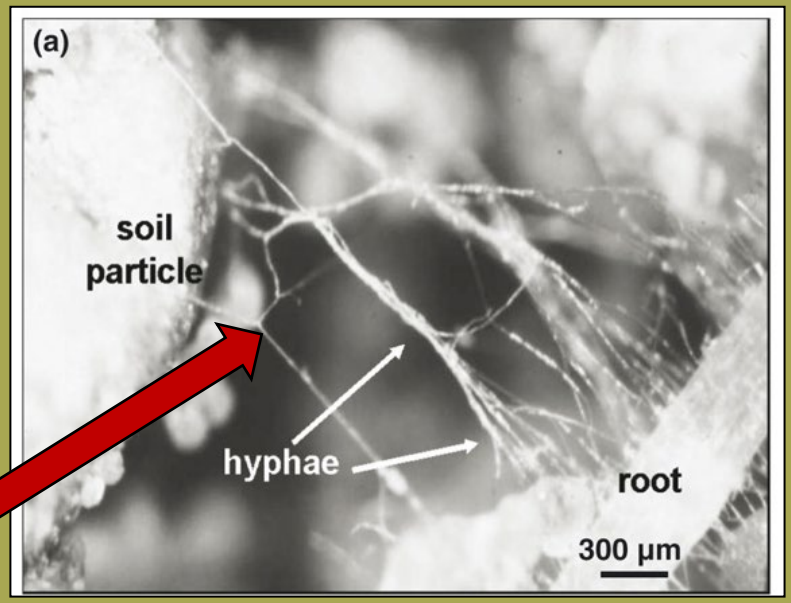
Calculating nitrogen and nutrient availability from soil analyses

- Gather plant cover in known quadrant area (25 x 25 cm, 50 x 50cm or 1 x 1 m)
- Place in PAPER back and ship to lab for analysis
- If microbial biomass (PLFA) or activity (CO_2) is in optimal range, assume 50% available N in the full first year (roughly apprx)

Minerals containing non-available nutrients.

Neutral Lipid Fatty Acid (NLFA) analysis

- quantifies root-colonized fungal colonies ***that bring non-available nutrients to roots***



Lambert et al., 2008

Total Mineral Content (lbs/acre)												
Total Nutrient Digest (Ward Lab) from 68 farms across several states	**Element**	**P**	**K**	**Ca**	**Mg**	**S**	**Zn**	**Fe**	**Mn**	**Cu**	**B**	**Mo**
	Average Value	**878**	**3735**	**8617**	**4418**	**431**	**90**	**22060**	**974**	**21**	**26**	**1**
	Median Value	**825**	**3599**	**5333**	**4443**	**375**	**85**	**22037**	**665**	**21**	**9**	**1**
	Highest	**2404**	**9354**	**70676**	**9956**	**1703**	**235**	**39559**	**5268**	**46**	**137**	**3.5**
	Lowest	**281**	**666**	**1076**	**647**	**51**	**10**	**1889**	**47**	**2**	**2**	**1**

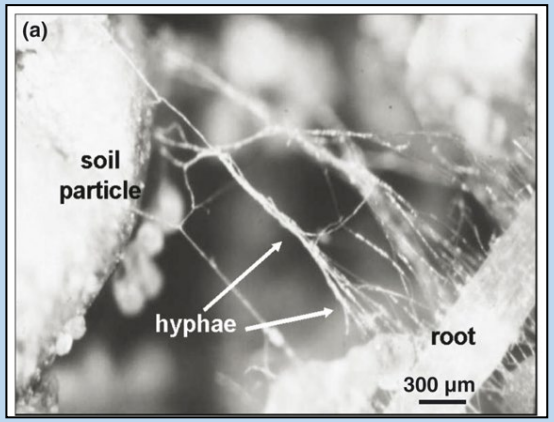
Also, these plus 40 other micro and nano-nutrients

Are mycorrhizae fungi present and are they colonizing the root?

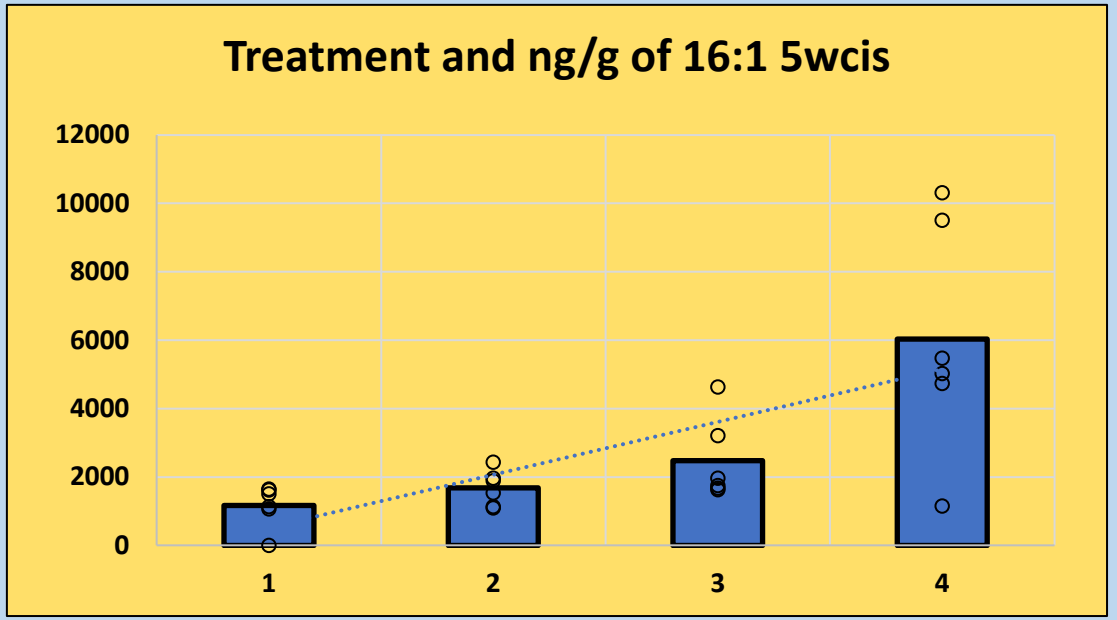
PLFA provides quantified evidence of mycorrhizae in ***BULK soil***

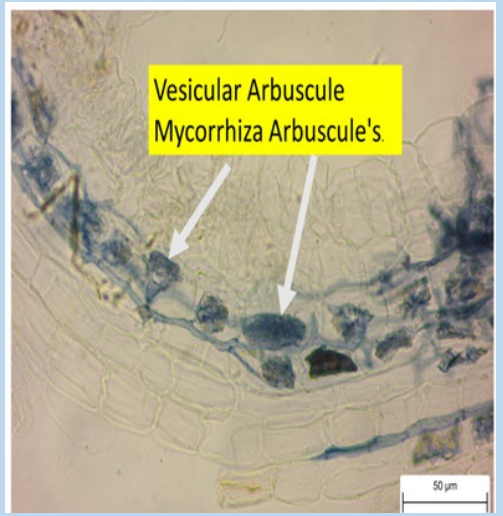
NLFA targets ROOTS and provides quantified evidence of mycorrhizae colonization

Root Colonization: Mycorrhizae evaluation



Correlation between NLFA and % colonization





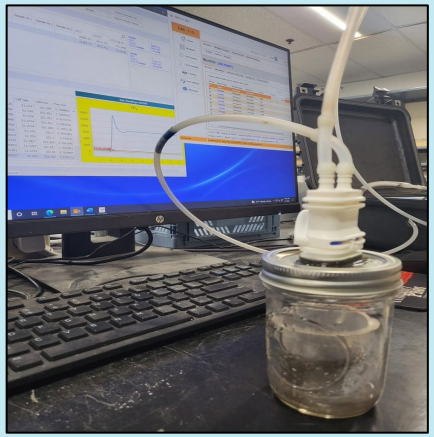
Mycorrhizae arbuscles in roots

Measuring Microbes in Bulk Soil – type, amount, and relationships

Broad, Qualitative Approach: 24-hour CO_2 Soil Respiration Method

Measuring the CO_2 release over a 24-hour period:

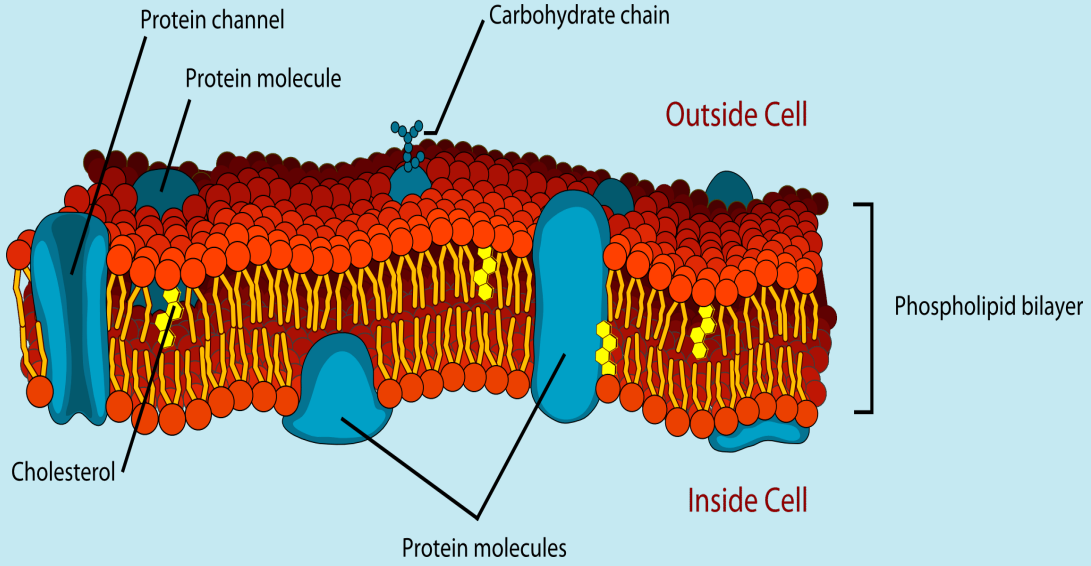
Relates microbial respiration to the total activity



Targeted Approach: PLFA (Phospholipid Fatty Acid) analyses

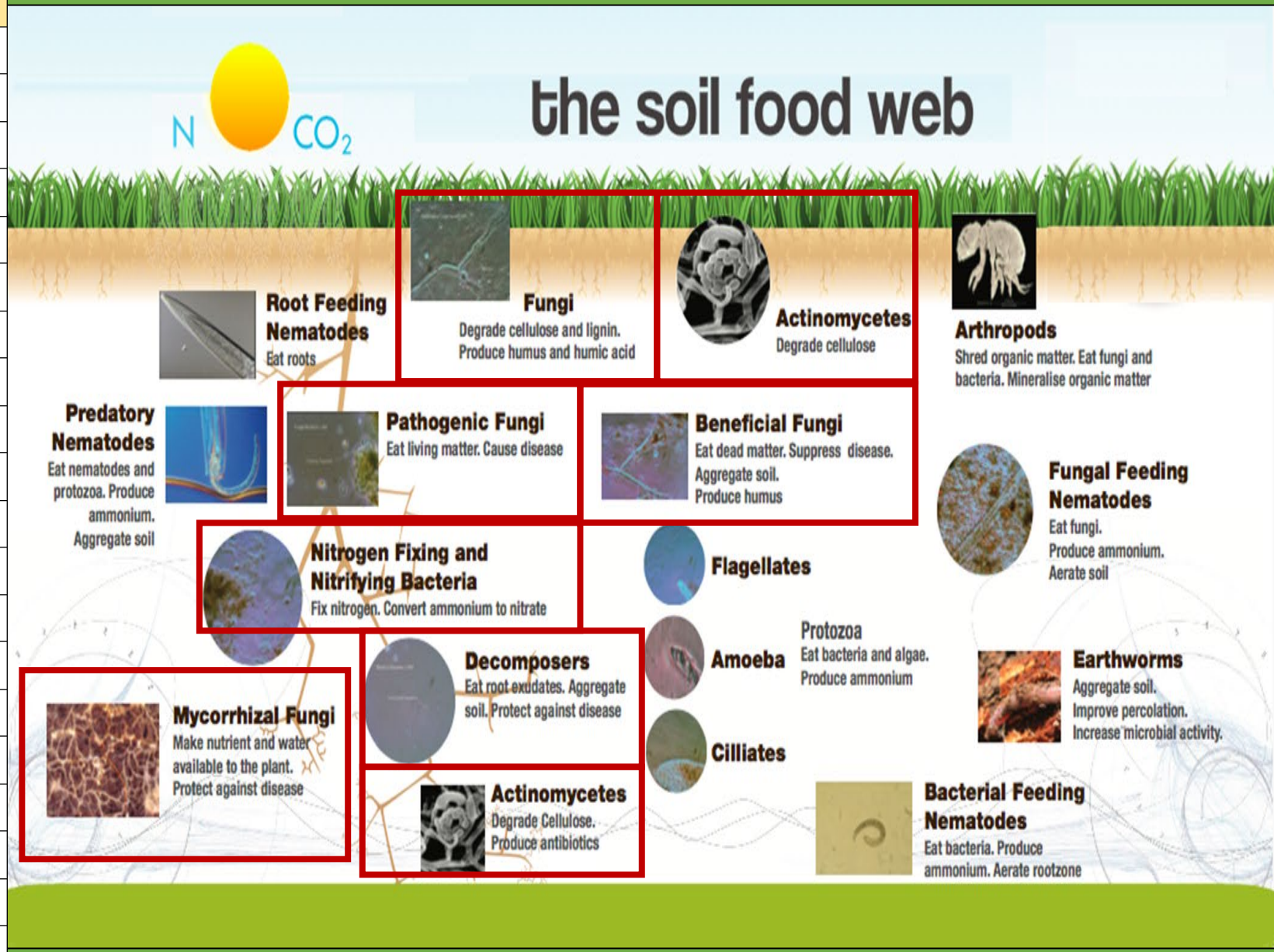
Quantifies microbes from the most important functional groupings of the Soil Food Web:

- Bacteria (gram+/-)
- Fungi (Saprophytes & Mycorrhizae)
- Actinomycetes Rhizobia bacteria
- Protozoa
- Total Microbial Biomass



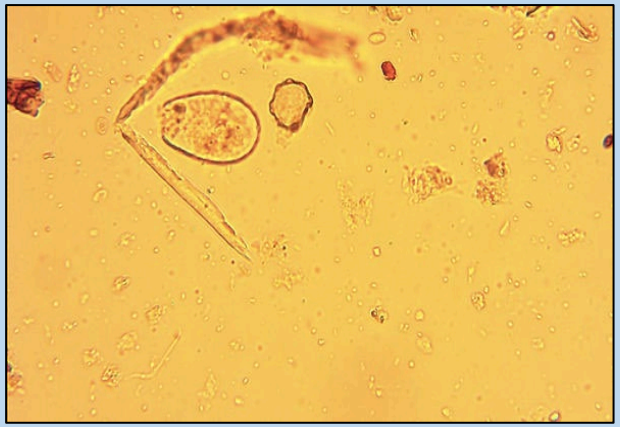
Phospholipid fatty acid analyses (PLFA)

Sample ID	BC 27
Total Microbial Biomass ng/g	5037.93
Diversity Index	1.446
Bacteria %	47.7
Total Bacteria Biomass	2403.09
Actinomycetes %	5.94
Actinomycetes Biomass	299.23
Gram (-) %	22.23
Gram (-) Biomass	1120.09
Rhizobia %	0
Rhizobia Biomass	0
Total Fungi %	12.8
Total Fungi Biomass	644.72
Arbuscular Mycorrhizal %	5.03
Arbuscular Mycorrhizal Biomass	253.27
Saprophytic %	7.77
Saprophytes Biomass	391.45
Protozoan %	0.17
Protozoa Biomass	8.5
Gram (+) Biomass	1283
Gram (+) %	25.47

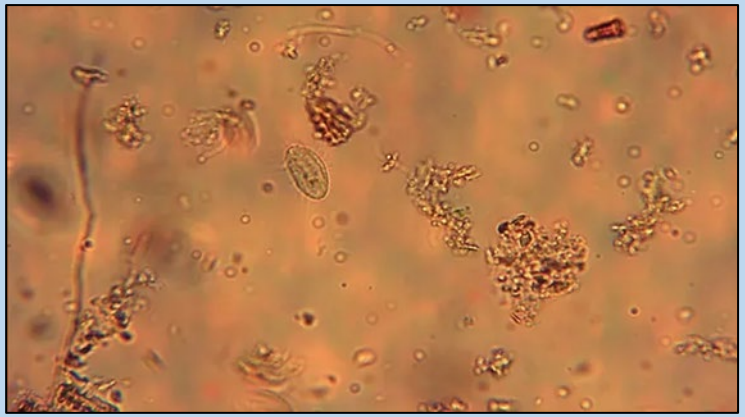


Real view of some of the “critters” in the soil microbiome not yet identified with the PLFA.

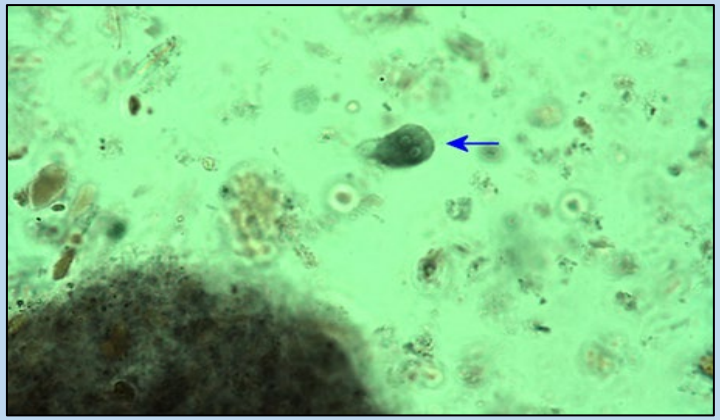
Protozoa species



Amoeba



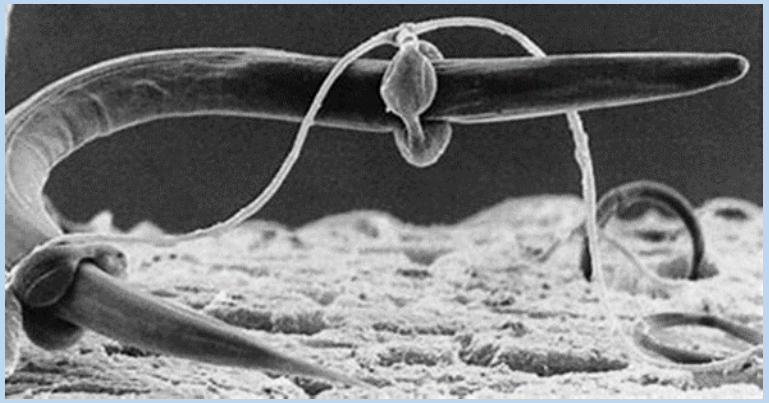
Ciliates



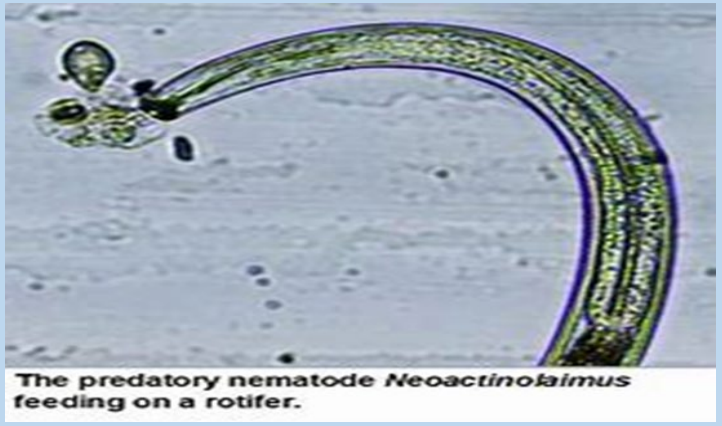
Flagellates

Nematodes

Bacterial feeders



Fungal feeders



Predators

Water infiltration and holding capacity

Soil aggregate stability is probably the most important soil condition for the maintenance of soil health.

The effects of different soil management on similar soils:
fewer aggregates in the tilled soil

tilled grain rotation	meadow soil with > 5 year fallow	forest soil

There is a strong correlation between the aggregate stability and the water infiltration and water holding capacity.

Soil Health test packages overview from Ward Laboratories.

WHAT DO THE TESTS MEASURE	**Microbial functional group evaluation, total microbial biomass, bacteria, fungi (mycorrhizae & saprophytes), protozoa and important microbial ratios**						PLFA	**Plus** PLFA
	Total Nutrient mineral reserve assay analyses by Total Nutrient Digest analyses.					Total Nutrient Digest	Total Nutrient Digest	**Plus** TND
	Root exudate simulated nutrient extract, NO3, NH4, inorganic and organic P, plus Ca, Mg, K				Inorganic nutrients extracted with H3A	Inorganic nutrients extracted with H3A	Inorganic nutrients extracted with H3A	**Plus** Inorganic nutrients extracted with H3A
	Microbial food source supply plus C/N ratio, Organic Nitrogen released and retained, Haney SH Indicator number and Nitrogen profile			H20 extracted Organic C&N, NH4 &NO3	H20 extracted Organic C&N, NH4 &NO3	H20 extracted Organic C&N, NH4 &NO3	H20 extracted Organic C&N, NH4 &NO3	**Plus** H20 extra Organic C&N, NH4 &NO3
	Soil organic matter and soil organic carbon		Soil organic Matter and Soil organic C	Soil organic Matter and Soil organic C	Soil organic Matter and Soil organic C	Soil organic Matter and Soil organic C	Soil organic Matter and Soil organic C	**Plus** Soil organic Matter and Soil organic C
	Ability to resist erosion		Volumetric Aggregate Stability	Volumetric Aggregate Stability	Volumetric Aggregate Stability	Volumetric Aggregate Stability	Volumetric Aggregate Stability	**Plus** Volumetric Aggregate Stability
	Indication and extent of soil life	24 Hour CO2-C Respiration test	24 Hour CO2-C Respiration test	24 Hour CO2-C Respiration test	24 Hour CO2-C Respiration test	24 Hour CO2-C Respiration test	24 Hour CO2-C Respiration test	24 Hour CO2-C Respiration test
OFFERED TEST and EVALUATION		***Entry level soil health test***	***Basic Soil Health test***	***Standard soil health test***	***Progessive soil health test***	***Complete Haney/ Ward SH test***	***Advanced soil health evaluation***	***Comprehensive soil health evaluation***	
PRICE								

Newly incorporated soil Health tests

Test name	What it measures	Why are these tests important and what do they contribute to the Soil Health evaluation.
Soil Enzymes	(β-glucosidase (BG)	Provides an indication of cellulose decomposition; ie an indication of soil organic decomposition. Useful for evaluation of SOM degradation rate and thus nutrient cycling ability.
	N-Acetyl-β-glucosaminidase (NAG)	Enzymes that catalyze the hydrolysis of chitin which facilitates carbon (C) and nitrogen (N) cycling in soils participating in the processes whereby chitin is converted to amino sugars, N in soils.
	Arylsulfatase (ARS)	Soil arylsulfatase (ARS) is an important enzyme that controls the acquisition of organic sulfur and thus the soil sulfur cycling.
	Alkaline Phosphatase (AlkP)	Alkaline phosphatase (ALP), hydrolyzes organic phosphorus (P) into dissolved phosphorus in soils and is therefore vital for provision of soluble phosphorus for plant roots.
	Acid Phosphatase (AcP)	Acid phosphatase (ACP) enzymes are involved in the mobilization of soil phosphorus (P) and polyphosphate accumulated in the fungal tissues of ectomycorrhizal roots, thereby influencing the amounts of P that are stored in the fungus and transferred to the host plan
	Phosphodiesterase (PHD)	This enzyme is the alkaline enzyme version of AcP which is active in predominantly acidic soils, PHD has a pH optimum of 10 and therefore active in alkaline soils for P release.
POX - C	Permanganate oxidizable carbon (POXC) is a simple method for estimating Labile Organic Carbon	*This test in association with TOC% could serve as a more accurate methodology to calculate stable or sequestered carbon. *TOC% - POXC(extracted at an acceptable Molality that will measure most or all of the labile carbon components that is microbially decomposible) = Stable carbon. *Could be included as a component of the Advanced Soil Health Evaluation.
Ace Protein	Autoclaved Citrate Extractable (ACE) Protein Index an indicator of the amount of protein-like substances that are present in the soil organic matter	The pool of proteins extracted is a soil health indicator reflecting the primary pool of organic N in soil and thus as potentially available organic N through mineralization.
NLFA (Neutral lipid fatty acids) are mainly used to measure the abundance of Arbuscular Mycorrhizal Fungi (AMF). In development	Mycorrhizae root colonization measurement.	This is one of the most important components of Soil Health that confirms connectivity between crop plant and soil minerals and has to become a component of the Comprehensive Soil Health evaluation.