Soil Fertility – Choices and Solutions for Organic Crops

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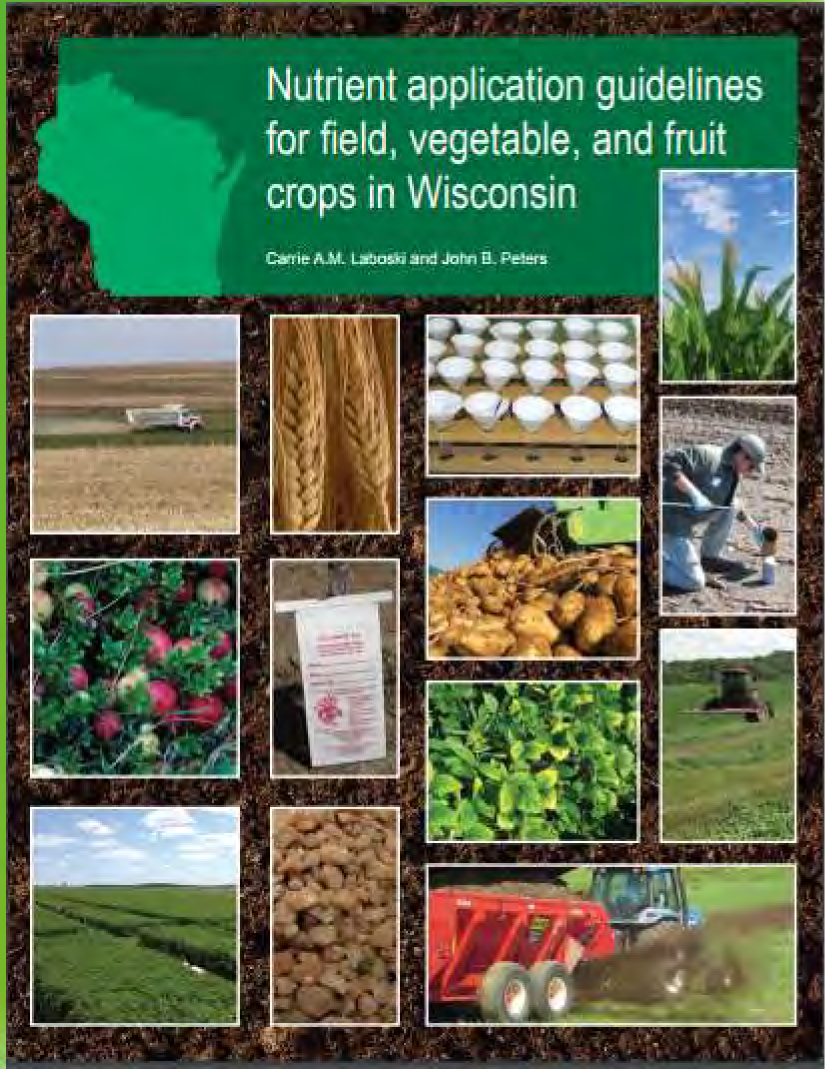
Presentation Description

- Basic overview of:
  - Soil fertility concepts
  - Soil testing
  - Soil health
  - Short and long-term options for improving nutrition through soil building strategies



http://learningstore.uwex.edu/assets/pdfs/A2809.pdf

Soil Fertility Concepts –

Supply and Acquisition

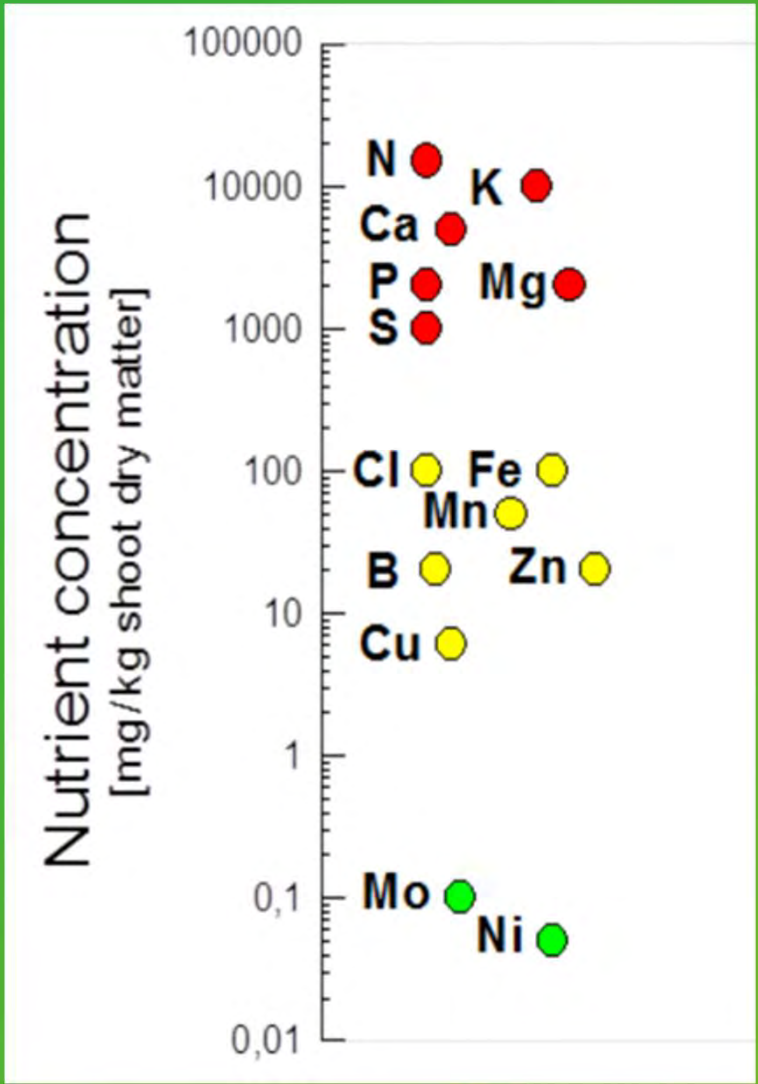
18 Plant Essential Nutrients

- Essential nutrients
  - Required to complete the plant's life cycle
  - Nutrient is not replaceable by another nutrient
  - An essential metabolite or required for enzyme activation

C HOPKNS CaFe Mg

B Mn CuZn MoCo NiCl

C HOPKNS CaFe



http://plantsinaction.science.uq.edu.au/book/export/html/231

Nutrient	Macro/micro	Uptake form
Carbon	Macro	CO_2, H_2CO_3
Hydrogen	Macro	H^+, OH^-, H_2O
Oxygen	Macro	O_2
Nitrogen	Macro	NO_3^-, NH_4^+
Phosphorus	Macro	HPO_4^{2-}, $H_2PO_4^-$
Potassium	Macro	K^+
Calcium	Macro	Ca^{2+}
Magnesium	Macro	Mg^{2+}
Sulfur	Macro	SO_4^-
Boron	Micro	H_3BO_3, BO_3^-
Copper	Micro	Cu^{2+}
Iron	Micro	Fe^{2+}, Fe^{3+}
Manganese	Micro	Mn^{2+}
Zinc	Micro	Zn^{2+}
Molybdenum	Micro	MoO_4^-
Chlorine	Micro	Cl^-
Cobalt	Micro	Co^{2+}
Nickel	Micro	Ni^{2+}

Plant Available Nutrient Supply

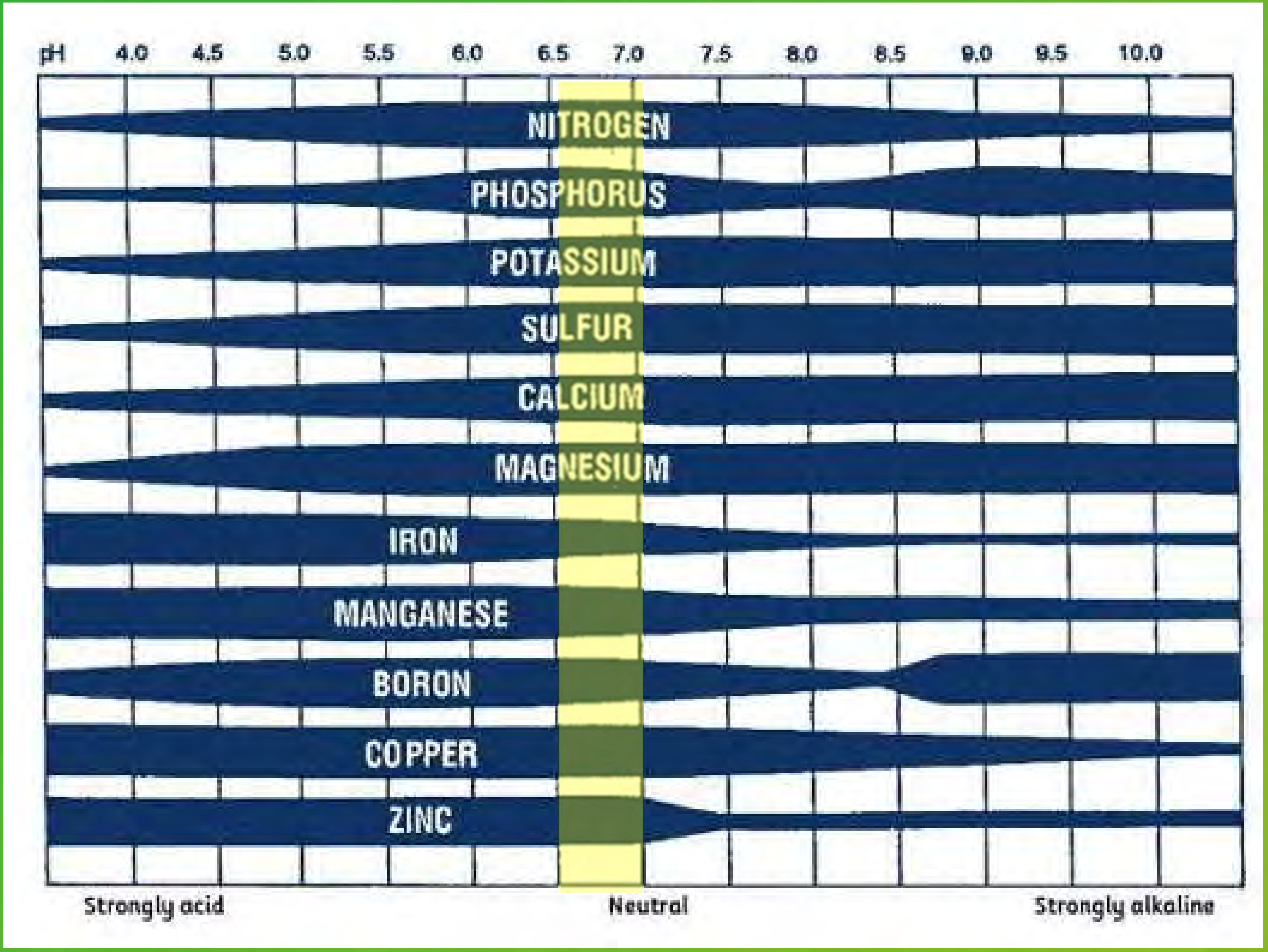
Additions

- Weathering
- Mineralization
- N Fixation
- Atmospheric deposition
- Fertilization

Losses

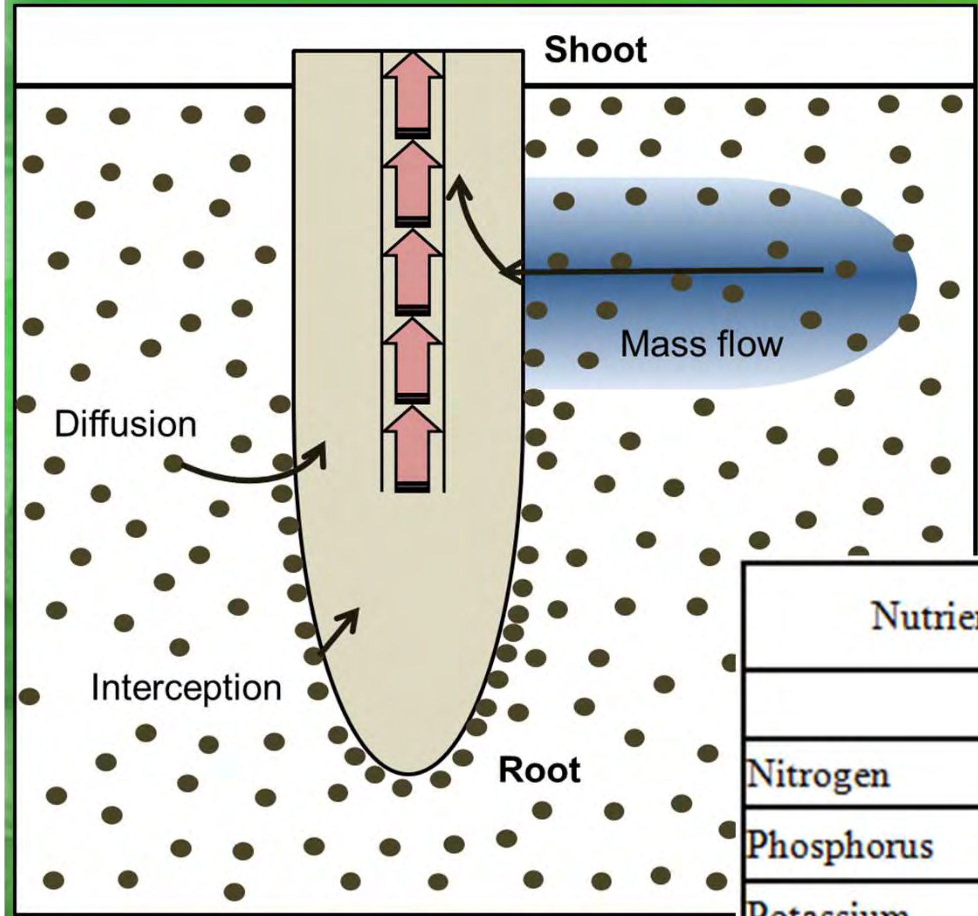
- Leaching
- Runoff
- Immobilization
- Sorption
- Transformation
- Harvest

Soil pH



http://sfbfp.ifas.ufl.edu/articles/article_2013_february.shtml

Plant Nutrient Acquisition



Nutrient		Root interception	Mass Flow	Diffusion movement
Pecentages in Supply				
Nitrogen	N	1	99	0
Phosphorus	P	2	4	94
Potassium	K	2	20	78
Calcium	Ca	12	88	0
Magnesium	Mg	27	73	0
Sulphur	S	4	94	2

http://plantsinaction.science.uq.edu.au/book/export/html/231
http://www.tankonyvtar.hu/en/tartalom/tamop425/0010_1A_Book_angol_02_tapanyaggazdalkodas/ch03s02.html
http://apps.cdfa.ca.gov/frep/docs/Corn.html

Routine Soil Tests –

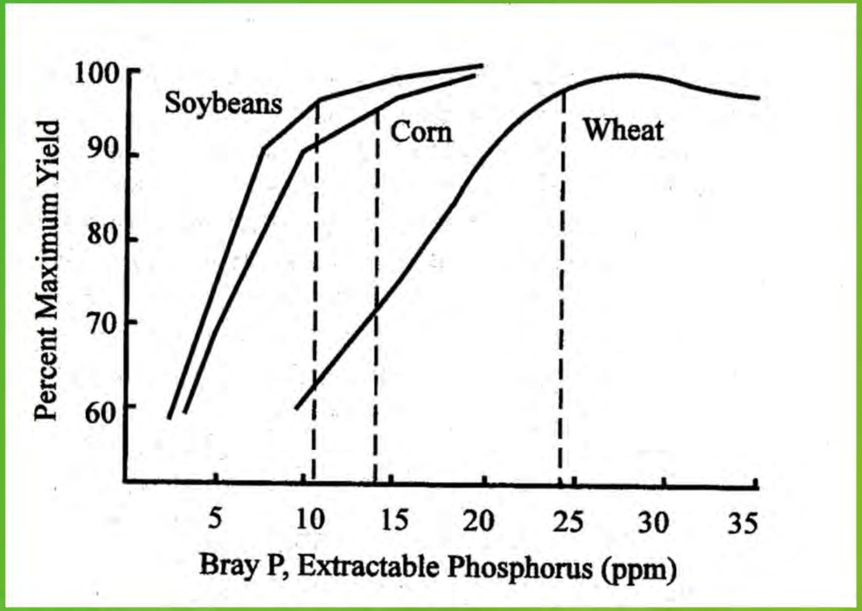
A Gauge of Supply

Soil Testing

- Based on extensive field and laboratory research on a wide range of soils
- Identifies responsive and non-responsive soil test levels
- Predicts nutrient application rate

Nutrient Extraction

- Chemical method to predict the available “pool” of nutrient
  - Must be a **correlation** between the amount extracted and the amount of nutrient taken up by the plant
  - Numbers are indices and often have no absolute meaning



http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1130447046&topicorder=10&maxto=11

Soil Test Calibration

- Laboratory nutrient values must be **calibrated** with crop yield response across many growing conditions
  - **Region, soil type, and crop specific**
- Predict the supplemental nutrient needed to achieve maximum **economic** yield

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---------Category-------			
Name	**Symbol**	**Description**	**Probability of a yield increase to applied nutrients** (%)
Very low	VL	Substantial quantities of nutrients are required to optimize crop yield. Buildup should occur over a 4- to 8-year period. Response to secondary or micronutrients is likely or possible for high or medium demanding crops, respectively.	>90
Low	L	Somewhat more nutrients than those removed by crop harvest are required. Response to secondary or micronutrients is possible for high demanding crops, but unlikely for medium or low demanding crops.	60-90
Optimum	O	This is economically and environmentally the most desirable soil test category. Yields are optimized at nutrient additions approximately equal to amounts removed in the harvested portion of the crop. Response to secondary or micronutrients is unlikely regardless of crop demand level.	30-60
High	H	Some nutrients are required, and returns are optimized at rates equal to about one-half of nutrient removal by the crop.	5-30
Very high	VH	Used only for potassium. Soil tests are above the optimum range and gradual drawdown is recommended. Approximately one-fourth of nutrient removal is recommended.	2-5
Excessively high	EH	No fertilizer is recommended for most soils since the soil test level will remain in the non-responsive range for at least two to three years. On medium- and fine-textured soils, a small amount of starter fertilizer is advised for some crops (for more detail, see Chapter 10: Starter fertilizers).	<2

Table 7.1. Soil test phosphorus (P) interpretation categories. Choose the highest demanding crop in your rotation to set the soil test interpretation categories for the rotation. If the desired crop is not listed on the table, consult Table 4.2 to determine its demand level.

	Soil test category				
	Very low (VL)	Low (L)	Optimum (O)	High (H)	Excessively high (EH)
Soil group[a]	soil test P ppm[b]				
Demand level 1: corn grain, soybean, clover, small grains (but not wheat), grasses, oilseed crops, pasture					
Loamy	< 10	10–15	16–20	21–30	> 30
Sandy, Organic	< 12	12–22	23–32	33–42	> 42
Demand level 2: alfalfa, corn silage, wheat, beans, sweet corn, peas, fruits					
Loamy	< 12	12–17	18–25	26–35	> 35
Sandy, Organic	< 18	18–25	26–37	38–55	> 55
Demand level 3: tomato, pepper, brassicas, leafy greens, root, vine, and truck crops					
Loamy	< 15	15–30	31–45	46–75	> 75
Sandy, Organic	< 18	18–35	36–50	51–80	> 80
Demand level 4: potato					
Loamy	< 100	100–160	161–200	> 200	
Sandy, Organic	< 30	30–60	61–90	91–120	> 120

[a] See Chapter 4: Soil and crop information for more details on soil groups.

[b] ppm (wt/vol; g/m^3)

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Table 7.4. Phosphorus (P) and potassium (K) fertilizer application rate guidelines.

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Crop name	Yield goal (per acre)	P_2O_5 rate guidelines					K_2O rate guidelines					
		VL	L	O	H	EH	VL	L	O	H	VH	EH
		---lb P_2O_5/a to apply[a]---					---lb K_2O/a to apply[b]---					
Alfalfa, seeding	1.5–2.5 ton	65	55	25	15	0	160	145	105	55	25	0
Alfalfa, established[c]	2.6–3.5 ton	80	70	40	20	0	235	220	180	90	45	0
	3.6–4.5 ton	90	80	50	25	0	295	280	240	120	60	0
	4.6–5.5 ton	105	95	65	35	0	355	340	300	150	75	0
	5.5–6.5 ton	120	110	80	40	0	415	400	360	180	90	0
	6.6–7.5 ton	130	120	90	45	0	475	460	420	210	105	0
	7.6–8.5 ton	145	135	105	55	0	535	520	480	240	120	0
	8.6–9.5 ton	155	145	115	60	0	595	580	540	270	135	0
Apple, establishment[d]	all	200	150	—	—	—	275	200	—	—	—	—
Asparagus	2,000–4,000 lb	90	65	10	5	0	120	90	20	10	5	0
Barley, grain	25–50 bu	55	45	15	10	0	60	45	15	10	5	0
	51–75 bu	65	55	25	15	0	65	50	20	10	5	0
	76–100 bu	75	65	35	20	0	75	60	30	15	10	0
Barley, grain + straw[e]	25–50 bu	75	65	35	20	0	120	105	75	40	20	0
	51–75 bu	85	75	45	25	0	130	115	85	45	20	0
	76–100 bu	95	85	55	30	0	140	125	95	50	25	0
Bean, dry (kidney, navy)	10–20 cwt	60	50	20	10	0	80	65	25	15	5	0
	21–30 cwt	70	60	30	15	0	95	80	40	20	10	0
	31–40 cwt	80	70	40	20	0	110	95	55	30	15	0

So, what?

- Different states use different extractants to make fertilizer recommendations
  - Plant available phosphorus extractants
    - Bray I, Mehlich I, Mehlich III, Morgan, Modified Morgan, Olsen Bicarbonate, H3A-1
  - Plant available potassium extactants
    - Bray I, Ammonium acetate, Mehlich I, Mehlich III
- Choose your lab carefully!
  - Different labs use different extractants
  - Different states often have different fertilizer recommendations based on same or different extractants
  - May or may not work with your state's recommendations or regulations

Table 3.1. Analytical procedures for soil tests performed at University of Wisconsin laboratories and Wisconsin DATCP-approved private laboratories.

Soil Test	Procedures[a]
Soil pH	Prepare a 1:1 soil to water mixture and measure the pH with a glass electrode.
Buffer pH (BpH)	Prepare a 1:1:1 soil to water to Sikora buffer mixture and measure the pH with a glass electrode.
Phosphorus (P)	Extract with Bray 1, develop color, and measure colorimetrically using a spectrophotometer.
Potassium (K)	Extract with Bray 1 and measure with atomic absorption, flame photometer, or ICP-OES.
Organic matter (OM)	Loss of weight on ignition at 360°C for 2 hours. OM = 0.07 + 0.89 (LOI)[b]
Calcium (Ca), magnesium (Mg), sodium (Na)	Extract with neutral 1 N[c] ammonium acetate and measure with atomic absorption, flame photometer, or ICP-OES.
Sulfur (S)	Extract with 500 ppm phosphorus in acetic acid, develop turbidity, and measure with a photoelectric nephelometer.
Boron (B)	Extract with hot water, develop color, and measure colorimetrically using a spectrophotometer.
Manganese (Mn)	Extract with 0.1 N phosphoric acid and measure by atomic absorption or ICP-OES.
Zinc (Zn)	Extract with 0.1 N hydrochloric acid and measure by atomic absorption or ICP-OES.
Nitrate-nitrogen (NO_3-N)	Extract soil with 2 N KCl and analyze colorimetrically using a spectrophotometer.
Physical analysis (% sand, silt, clay)	Prepare 50 or 100 g soil with dispersing solution and measure with hydrometer.
Soluble salts	Prepare 1:2 soil to water mixture and measure with conductivity bridge.

[a] Detailed descriptions of the procedures can be found at uwlab.soils.wisc.edu/

[b] LOI = percent weight loss on ignition

[c] N = normal solution

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Soil Testing and Plant Diagnostic Services

Soil test procedures

- Soil pH_s (1:1 solution:soil suspension). Solution is 0.01M $CaCl_2$
- Lime requirement (neutralizable acidity) uses the Woodruff buffer solution
- Organic matter percentage by loss on ignition
- Extractable phosphorus (Bray-1 P)
- Exchangeable potassium (ammonium acetate extraction)
- Exchangeable calcium (ammonium acetate extraction)
- Exchangeable magnesium (ammonium acetate extraction)
- Cation exchange capacity (estimated from exchangeable potassium, calcium, magnesium and neutralizable acidity)
- Extractable zinc (DPTA extraction)
- Extractable sulfur (calcium phosphate in acetic acid extraction)
- Extractable iron, manganese and copper (DPTA extraction)
- Exchangeable sodium (ammonium acetate extraction)
- Hot water extractable boron (0.1 percent $CaCl_2$. H_20)
- Nitrate-nitrogen and ammonium-nitrogen (2 M KCl extraction)
- Soluble salts (electrical conductivity in a 1:1 soil:water saturation e
- Particle size analysis (hydrometer method)

Recommended Chemic

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Sulfur (S)	Extract with 500 ppm phosphorus in acetic acid, develop turbidity, and measure with a photo-electric nephelometer.
Boron (B)	Extract with hot water, develop color, and measure colorimetrically using a spectrophotometer.
Manganese (Mn)	Extract with 0.1 N phosphoric acid and measure by atomic absorption or ICP-OES.
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WI DATCP Certified Labs

The following soil testing laboratories are Wisconsin DATCP certified.

UW Soil & Forage Lab
2611 Yellowstone Dr
Marshfield, WI 54449
(715)387-2523
https://uwlab.soils.wisc.edu/
MAP participant

A & L Great Lakes Laboratories, Inc.
3505 Conestoga Dr.
Fort Wayne, IN 46808
(219)483-4759
rwarden@algreatlakes.com
MAP participant

AgSource Laboratories
106 N. Cecil Street
Bonduel, WI 54107
(715)758-2178
speterson@agsource.com
bonduel@agsource.com
MAP participant

Dairyland Laboratories
709 W Meadow St
Stratford, WI 54484
(715)-687-9997
info@dairylandlabs.com

MAP participant
217 E. Main Street
Arcadia, WI 54612
(608)323-2123

Rock River Laboratory
710 Commerce Drive
PO Box 169
Watertown, WI 53094
(920)261-0446
dustin_sawyer@rockriverlab.com
MAP participant

Minnesota Valley Testing Laboratories, Inc (MVTL)
1126 N Front St PO Box 249
New Ulm, MN 56073
(800) 782-3557
bhansen@mvtl.com
MAP participant

Midwest Laboratories Inc.
13611 B Street
Omaha, NE 68144
402-334-7770
jp@midwestlabs.com
MAP participant

https://datcp.wi.gov/Documents/NMSoilManureLabs.pdf

Take Home –
Soil Test – Nutrient Supply

- Soil testing is proven method for identifying potential fertilizer requirements of crops
  - **Good sample, right procedure, right interpretation**

- No matter the fertilizer used
  - 4Rs
  - **Right source, right rate, right time, right place**

Soil Health–

Supply and Acquisition

What is Soil Health?

…the **continued capacity** of soil

to **function**

as a **vital living ecosystem**

that sustains plants, animals, and humans.

https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/

Soil Health

- Good soil tilth
- Sufficient depth
- Good water storage and drainage
- Large population of soil organisms
- Small population of pathogens and pests
- Sufficient, but not excess, nutrients
- Low toxins
- Resistant and resilient

https://soilhealth.cals.cornell.edu/files/2015/03/02_CASH_SH_Series_What_Is_Soil_Health_122016-15bp

Measuring Soil Health

Functional Approach

- Sensory
    - Visual, Feel, Smell
- Profitability
    - Yield vs Inputs
- Cornell Soil Health Test
    - Fertility, Active Carbon Aggregate Stability, Respiration, AWC, Hardness

Detailed Approach

- Tier One Measures – Soil Health Institutes
    - Organic carbon, water-stable aggregation, texture, penetration resistance, bulk density, available water holding capacity, infiltration rate
    - pH, nitrogen, phosphorus, potassium, micronutrients, CEC, EC, base saturation
    - Carbon mineralization, nitrogen mineralization
    - Erosion rating, crop yield

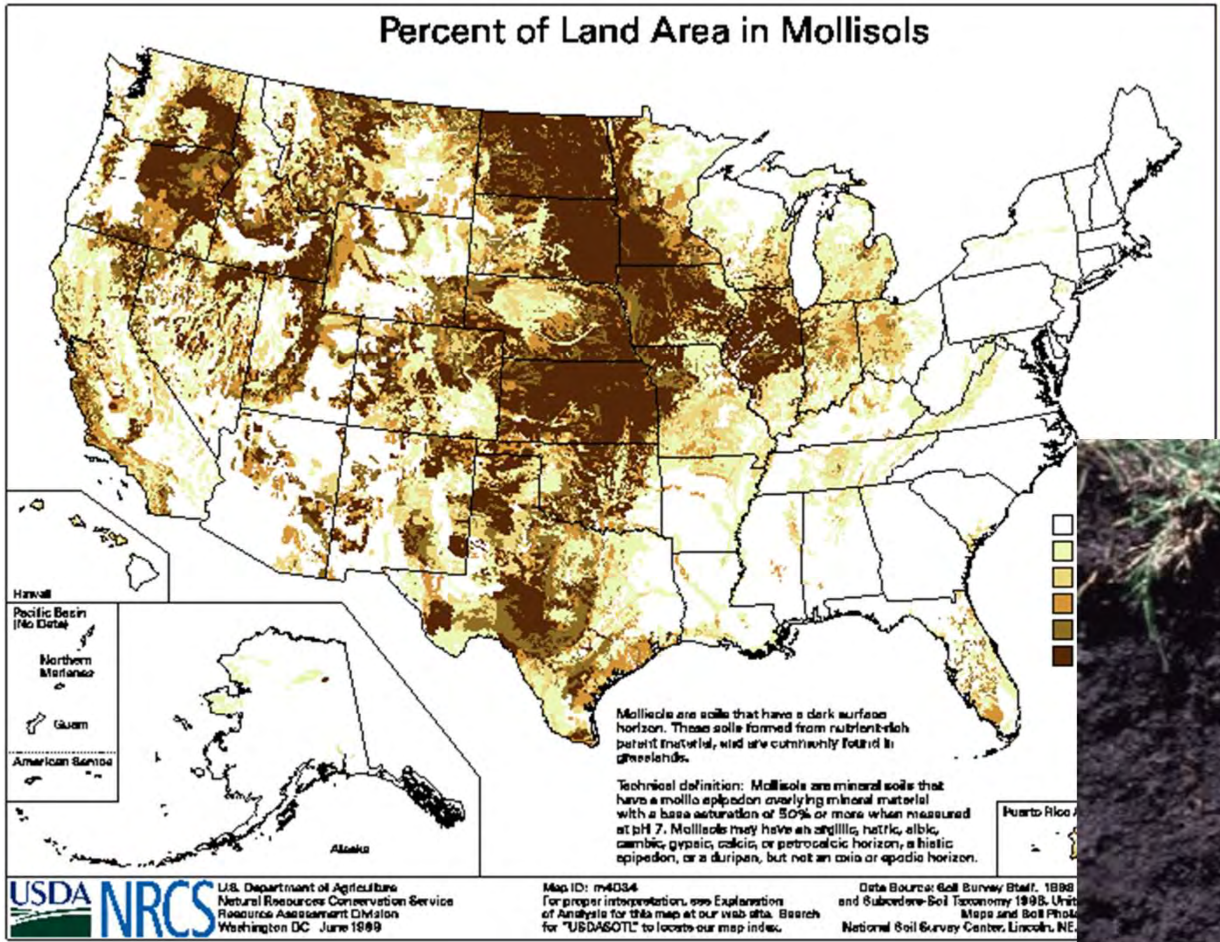
Nutrient Supply

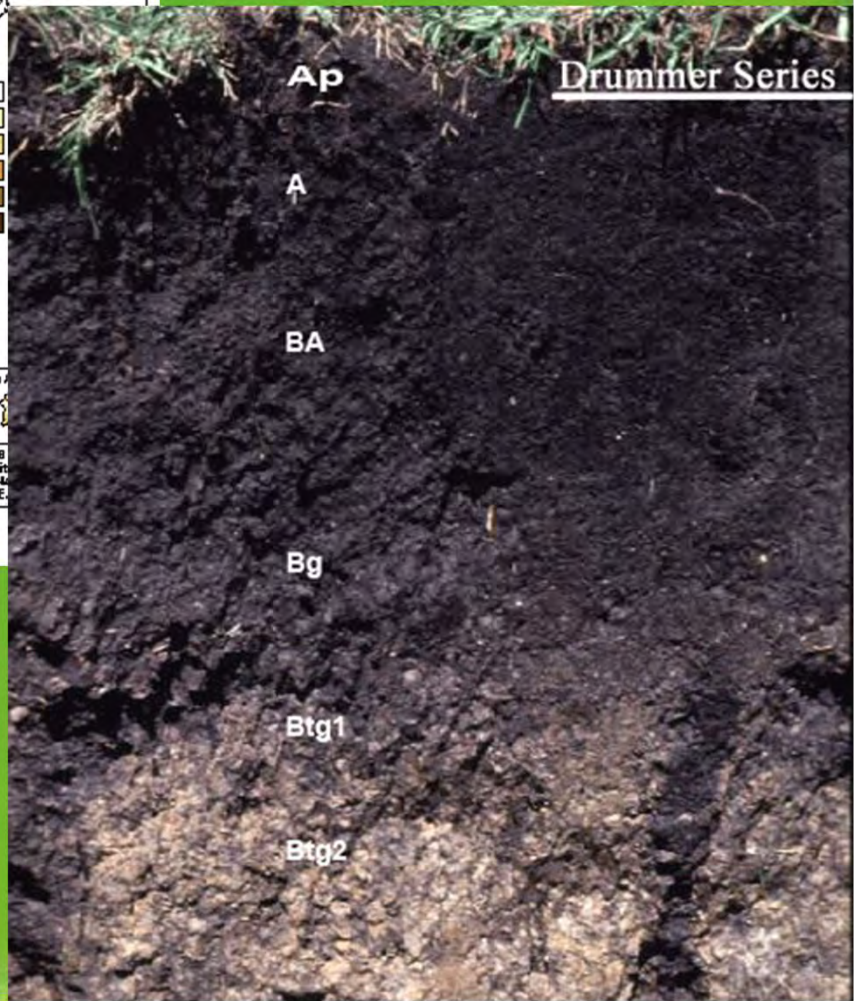
- 1% SOM
  - Estimated to contain –
  - 1000 lb N
  - 100 lb P
  - 100 lb K
  - 100 lb S

C HOPKNS CaFe Mg B Mn CuZn
Mo NiCl

- …CEC, aggregation, water holding capacity, etc..
- Legume credits

UNDERSTANDING SOIL MICROBES AND NUTRIENT RECYCLING
James J. Hoorman, Rafiq Islam, http://ohioline.osu.edu/factsheet/SAG-16


Percent of Land Area in Mollisols
Hawaii
Pacific Basin (No Data)
Northern Marianas
Guam
American Samoa
Alaska
Mollisols are soils that have a dark surface horizon. These soils formed from nutrient-rich parent material, and are commonly found in grasslands.
Technical definition: Mollisols are mineral soils that have a mollic epipedon overlying mineral material with a base saturation of 50% or more when measured at pH 7. Mollisols may have an argillic, natric, albic, cambic, gypsic, calcic, or petrocalcic horizon, a histic epipedon, or a duripan, but not an oxic or spodic horizon.
USDA NRCS
U.S. Department of Agriculture
Natural Resources Conservation Service
Resource Assessment Division
Washington DC June 1999
Map ID: m4034
National Soil Survey Center, Lincoln, NE.


Drummer Series
Ap
A
BA
Bg
Btg1
Btg2

Larry G. Bundy
Dept. of Soil Science
Univ. of Wisconsin

Contribution of Soil N to Yield

State	CC	SC
	-------- % 1/ --------	
Illinois	54	64
Iowa	45	75
Minnesota	60	76
Wisconsin	71	77
Mean2/	56	70

1/ Yield with zero N as % of yield at EONR.

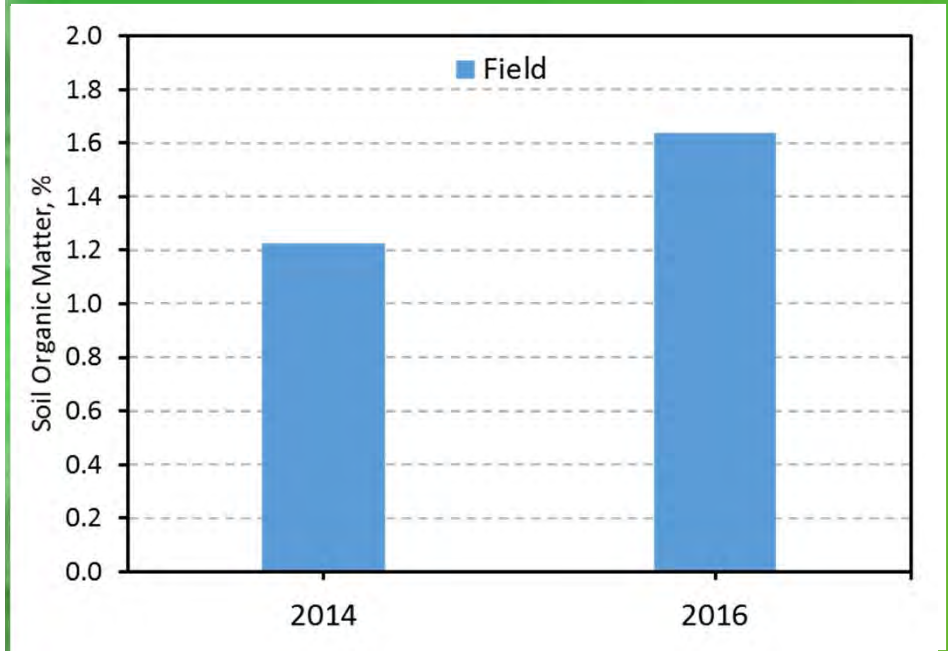
2/ Mean of 271 CC and 427 SC sites. Sawyer et al., 2005.

What is Your SOM?

NRCS Baseline SOM Project – NE WI

Soil Organic Matter (%)						
County	**n**	**Mean**	**StDev**	**Median**	**Max**	**Min**
Brown	45.0	8.2	2.7	7.9	15.5	4.3
Kewaunee	18.0	10.4	5.0	9.4	25.9	4.5
Outagamie	9.0	9.5	5.9	7.8	20.7	3.5
Shawano	35.0	5.8	1.9	5.4	10.1	2.6

Soil Organic Matter Accumulation



3 year cover crop project – Manawa

At current organic carbon accumulation rates, it would take:

- 1.7 years to reach a SOM of 2%
- 6.6 years to reach a SOM of 3%

Francisco Arriaga, UWEX Soil Management Specialist – 2016 – Manawa, WI Field Site

Results

Soil organic matter, total organic C and organic N

Organic matter and total organic C were not affected by the cover crop at any of the locations. Detectable changes in soil C fractions can take many years

Maintain Realistic Expectations!!!

http://www.practicalfarmers.org/farmer-knowledge/research-reports/2016/winter-cereal-rye-cover-crop-effect-soil/

Can I Increase SOM 1% This Year?

- 2,000,000 lbs soil * 1% = 20,000 lbs OM or 11,600 lb of carbon
- 10 to 20% plant residue conversion rate…let's go with 20%...100,000 lbs OM or 58,000 lbs carbon

- He states 0.1% would be superb
- 20 T/A/yr of solid dairy manure would increase organic matter content 0.065% per year

http://agfax.com/2018/01/16/pennsylvania-soil-health-can-i-increase-organic-matter-by-1-this-year/
Sjoered Willem Duiker, Pennsylvania State University Extension Soil Specialist

Mineralization

Woodland

CS, tillage, no manure

CS, tillage, manure

CS, no-till, no manure

Unfortunately, nutrient cycling is a very complicated process mediated by environmental factors and microbial activities and seldom can be determined using simple "accounting" methods. (B. Roberts, State Agronomist, Illinois.)

Manure Impacts on Microbial Activity

- Published literature tells us
  - "Bacterial abundance was significantly greater in manured soil than in fertilized and untreated soils. Bacterial abundance indicates that the 4 year cumulative effect of manure was detectable for at least two growing seasons after applications cease."

Responses of the bacterial and fungal biomass in a grassland soil to multi-year applications of dairy manure slurry and fertilizer. 2005. Forge, TA, S. Bittman, CG Kowalenko. Soil Biology and Biochemistry, 37(4) 613-623

Manure Impacts on Microbial Activity

- Published literature tells us
  - "Protozoa, bacterivorous nematodes, and fungivorous nematodes were consistently more abundant in soil treated with manure…than in fertilized and untreated soil, indicating that microbial turnover and flux of nutrients through the soil food web was enhanced in manured soil relative to fertilized or untreated soil."

Responses of grassland soil nematodes and protozoa to multi-year and single-year applications of dairy manure slurry and fertilizer. 2005. Forge, TA, S. Bittman, CG Kowalenko. Soil Biology and Biochemistry, 37(10) 1751-1762

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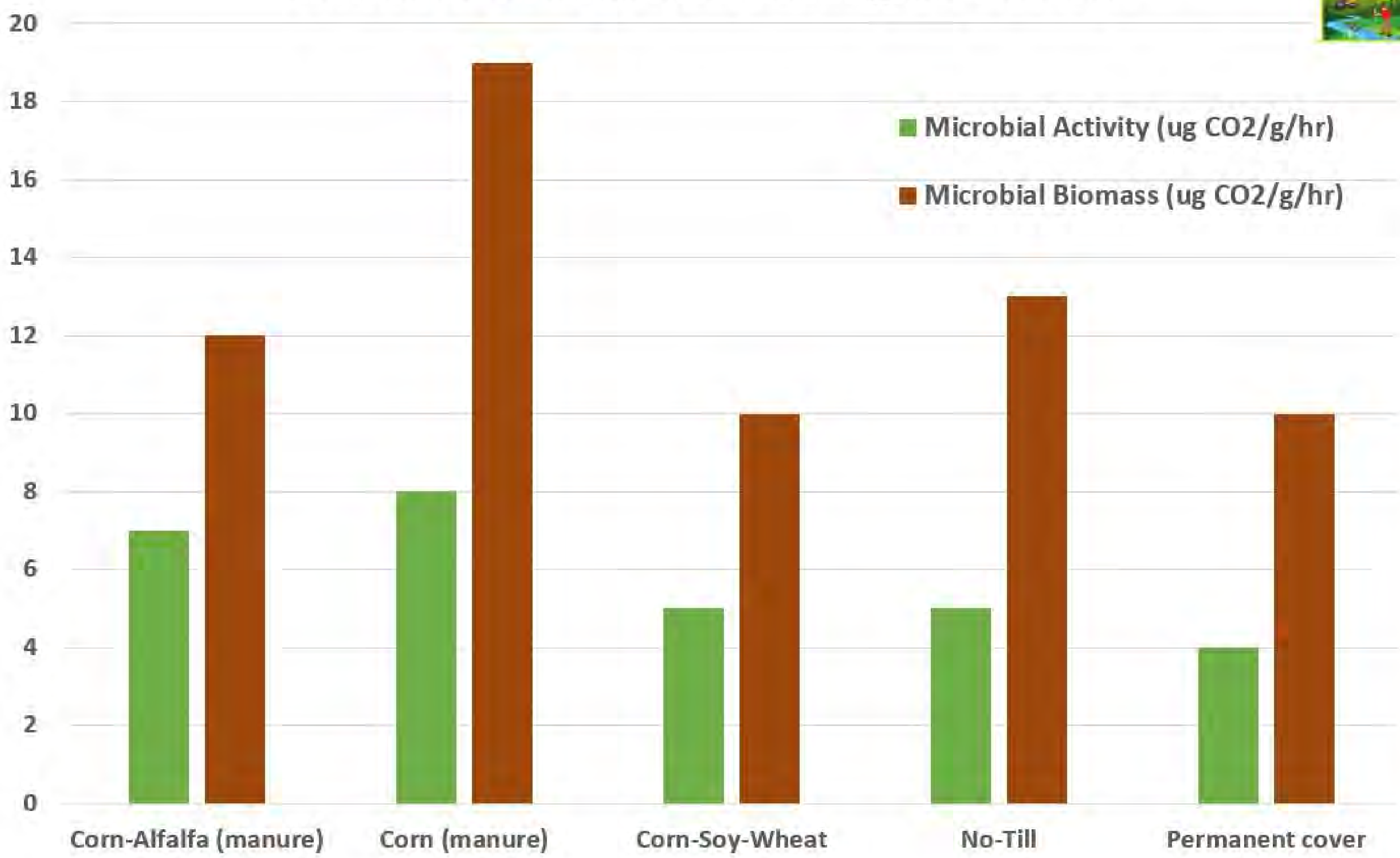
GREEN BAY

Demonstration Farms - Biological Factors



Soil Fertility and Biodiversity in Organic Farming

Paul Mäder,[1*] Andreas Fließbach,[1] David Dubois,[2] Lucie Gunst,[2] Padruot Fried,[2] Urs Niggli[1]

An understanding of agroecosystems is key to determining effective farming systems. Here we report results from a 21-year study of agronomic and ecological performance of biodynamic, bioorganic, and conventional farming systems in Central Europe. We found crop yields to be 20% lower in the organic systems, although input of fertilizer and energy was reduced by 34 to 53% and pesticide input by 97%. Enhanced soil fertility and higher biodiversity found in organic plots may render these systems less dependent on external inputs.

Mycorrhizae as members of the soil community ameliorate plant mineral nutrition and contribute to soil aggregate formation (*16*). Root length colonized by mycorrhizae in organic farming systems was 40% higher than in conventional systems (*7*) (Fig. 2C).

Biomass and abundance of earthworms were higher by a factor of 1.3 to 3.2 in the organic plots as compared with conventional (*17*) (Fig. 2D). We also investigated epigaeic arthropods that live above ground, because they are important predators and considered sensitive indicators of soil fertility. Average activity density of carabids, staphylinids, and spiders in the organic plots was almost twice that of the conventional plots (*18*) (Fig. 2D).

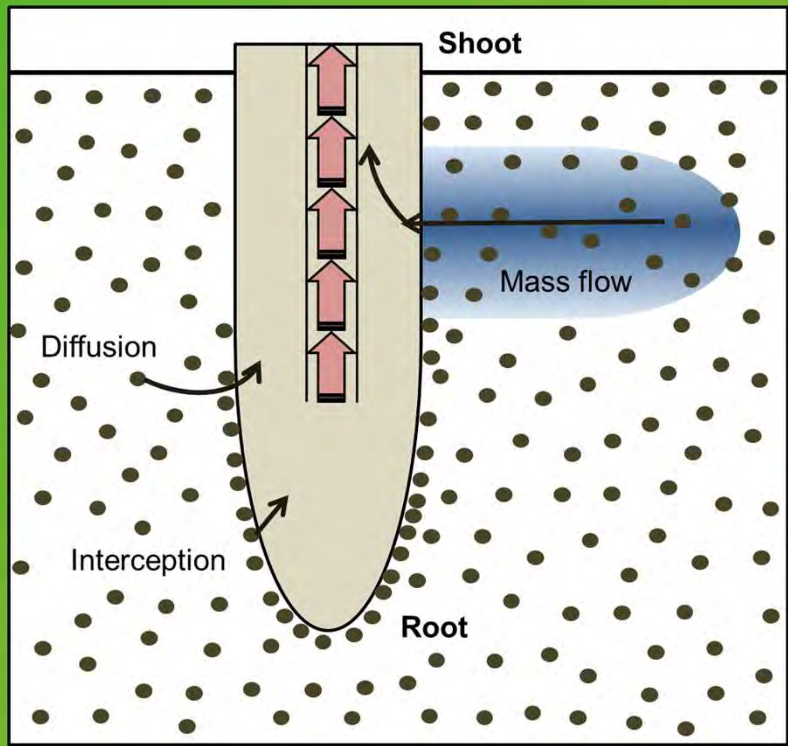
Healthy ecosystems are characterized by high species diversity. The DOK trial shows that organic farming allows the development of a relatively diverse weed flora. Nine to 11 weed species were found in organically managed wheat plots and one species in conventional


Supply?

Soil Health – Nutrient Supply

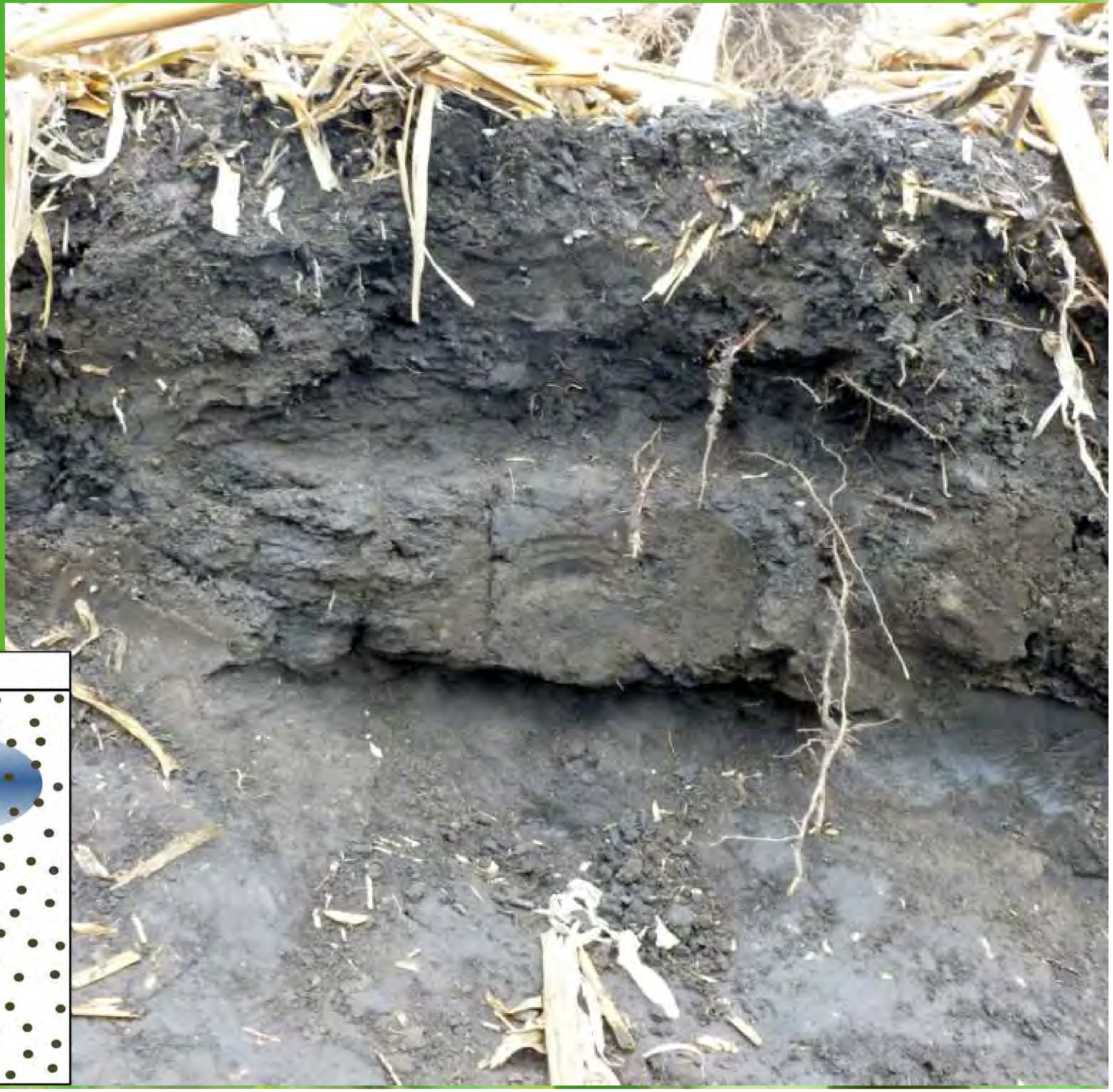
- Increase soil organic matter
  - Cover crops, manure, compost, meals, maintain adequate N levels, crop biomass, reduce tillage, reduce erosion, perennial crops…
- Increase biological activity
  - Cover crops, manure, composts, crop biomass, reduce tillage, crop rotations/diversity, maintain pH and fertility, maintain good tilth…

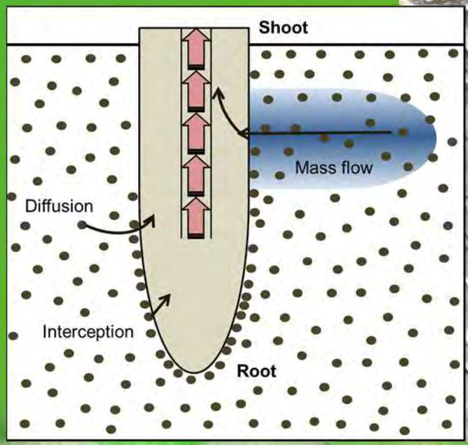
Nutrient Acquisition



Compaction

- Compaction can cause 25 to 50% yield loss
- 150 bu/A * 25% * $10/bu = $375/A

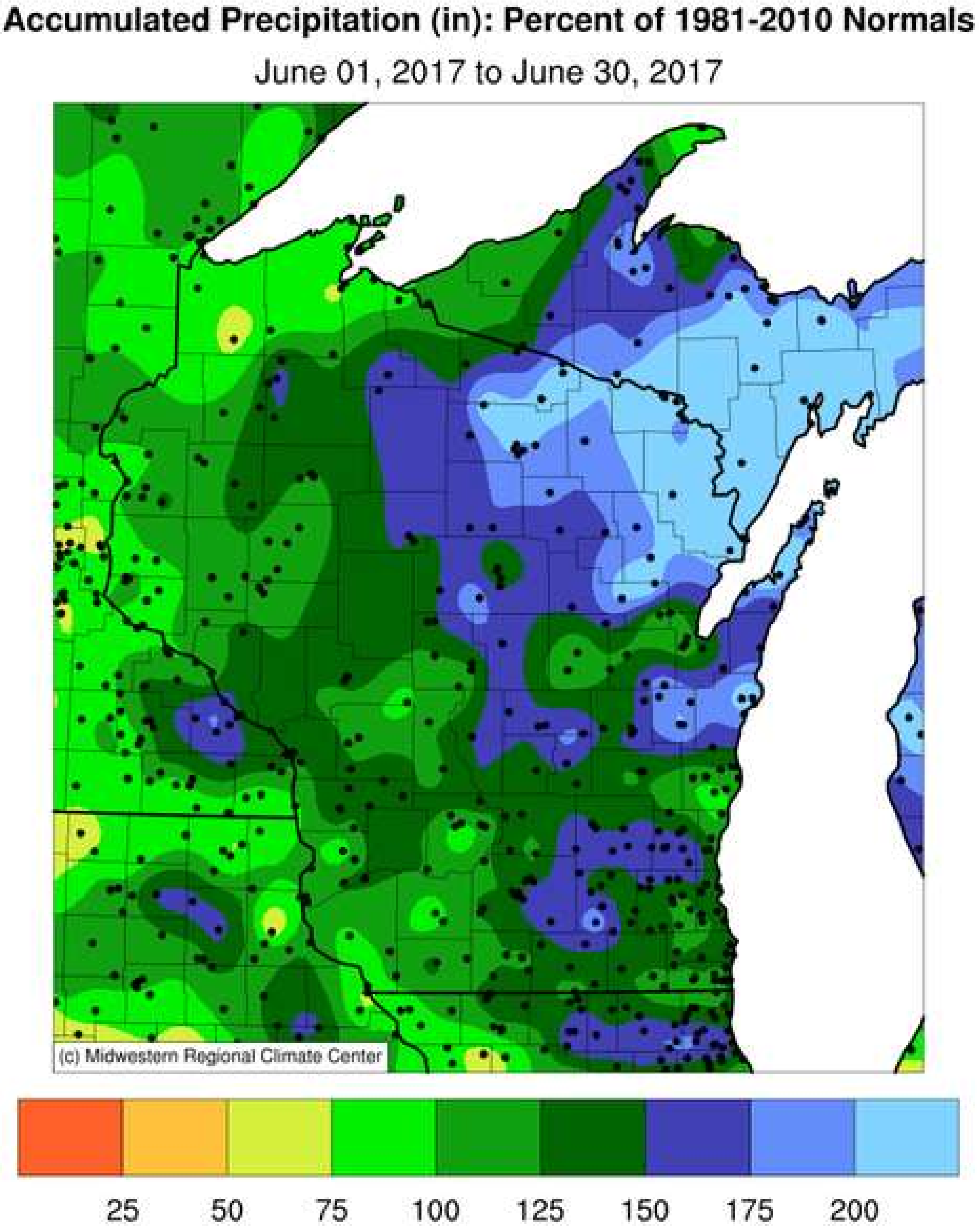




Raghavan, GSV, Alvo, P, and McKyes, E. 1990. Soil Compaction in Agriculture: A View Toward Managing the Problem. In: Advances in Soil Science: Soil Degradation. Lal, R and Stewart, BA, editors. Springer, NY

So, what's the problem with a little compaction?

http://www.aos.wisc.edu/~sco/clim-watch/index.html



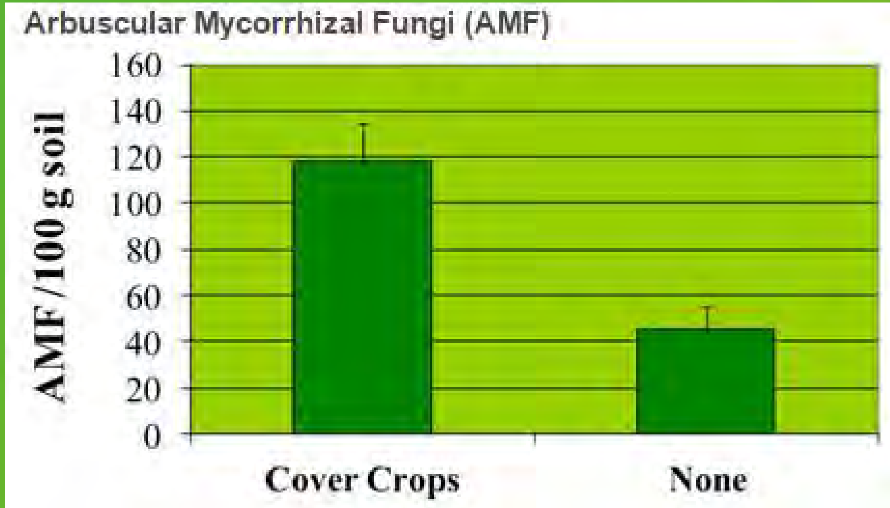


Photos courtesy of Brad Reybki

Increased Microbial Activity

Mycorrhizae and their exudates…

- Glue up to 90% of surface aggregates
- Increase soil exploration by plant system…up to 700x
- Can contribute up to 80% of P, 10% of K, 25% of Zn and 60% of Cu and 25% of plant N
- Connect plant systems for nutrient and sugar transport



A five-way cover crop mix (winter wheat-clover-vetch-turnip-radish) significantly increased AMF.

Fall Cover Crops Boost Soil Arbuscular Mycorrhizal Fungi Which Can Lead To Reduced Inputs

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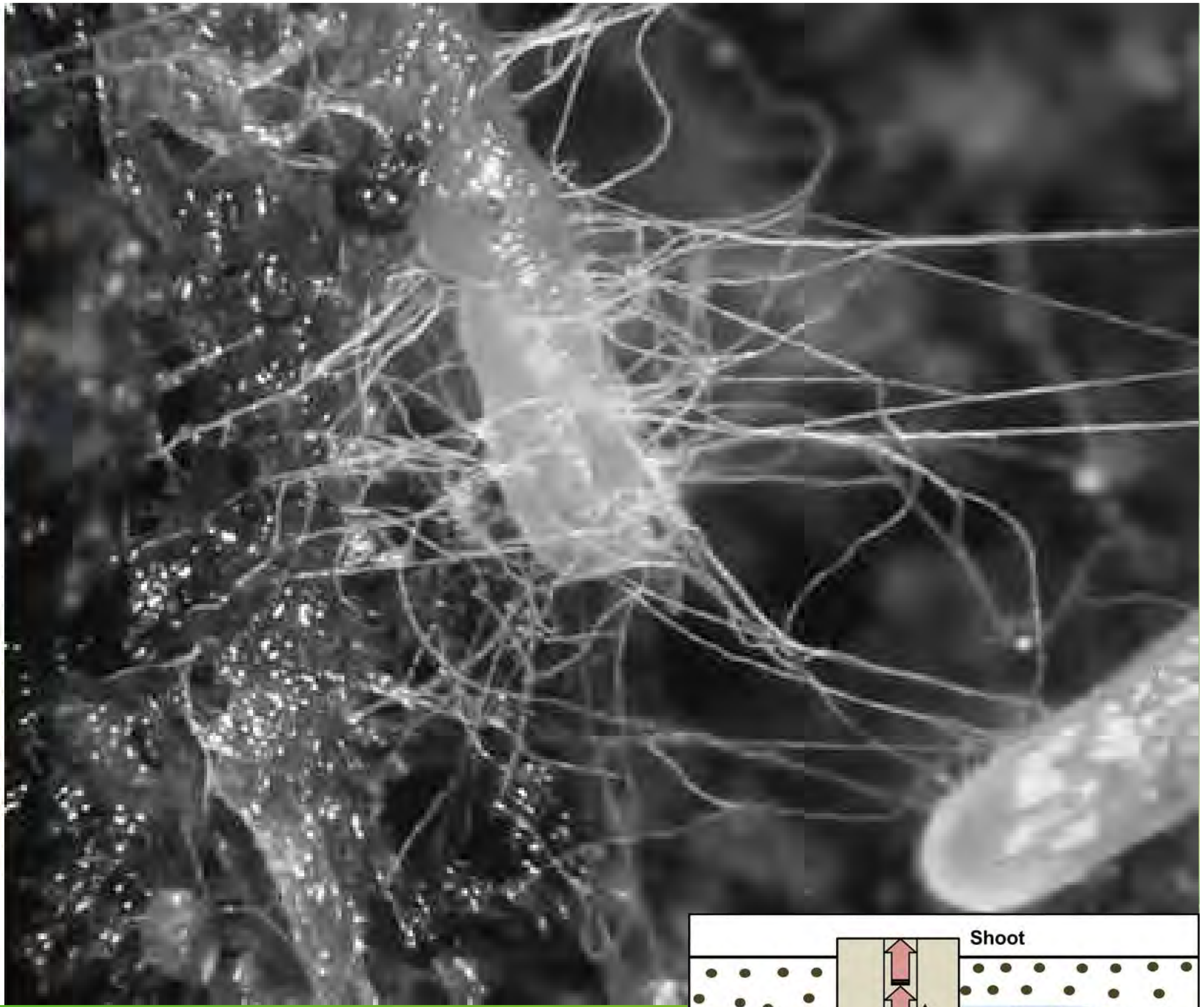
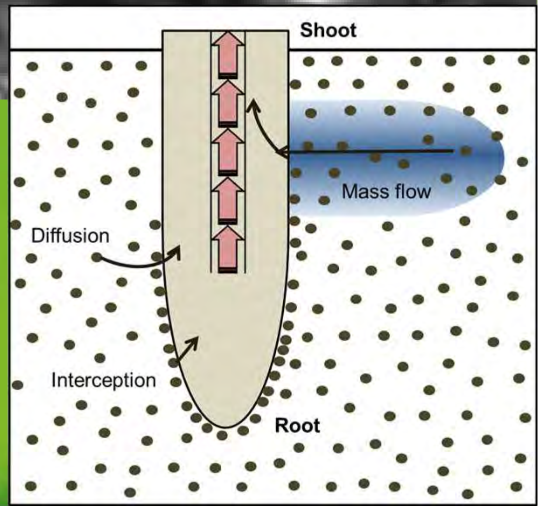
Michael Lehman – 6/10/2013

This work is a collaborative effort between Dr. Michael Lehman (Research Microbiologist), Dr. Shannon Osborne (Research Agronomist), and Dr. Wendy Taheri (post-doctoral research associate) who are all affiliated with the USDA-ARS North Central Agricultural Research Laboratory (NCARL) in Brookings, SD. Additional support for this work was provided by the South Dakota Corn Utilization Council.

https://agresearchmag.ars.usda.gov/2002/sep/soil
Annu. Rev. Phytopathol. 2003. 41:271–303





https://drearth.com/learning-center/the-technology/mycorrhizae/


Roots are not passive players!!

Soil Health – Nutrient Supply

- Maintain aggregates/reduce compaction
  - Cover crops, manure, compost, meals, maintain adequate N levels, crop biomass, reduce tillage, reduce erosion, perennial crops…
  - Sodium is a dispersant
- Increase biological activity
  - Cover crops, manure, composts, meals, crop biomass, reduce tillage, crop rotations/diversity, maintain pH and fertility, maintain good tilth…

Questions?

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