Fundamental Concepts in Organic Agriculture

Soil Fertility Workshop
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Outline

- Definition
- Historical Development and Philosophy
- Principles
- Nutrient Cycles -Soil Biology
- Tools and Practices

Definition

"..an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony."

National Organic Standards Board

Origins

- J.I. Rodale coined the word “organic” (1940’s) and principal figure in U.S. organic agriculture.
- Rodale’s concepts drawn primarily from British agronomists Albert Howard
    - -“An Agricultural Testament” (1943)
    - - “The Soil and Health” (1947)
        - - Natural approach to building soil fertility, return wastes to the soil
- Lady Eve Balfour, “The Living Soil” (1948)
    - - Ecological farming
- Rachel Carson, “Silent Spring” (1962)

Philosophy

- Human health tied to the health of the environment
- A healthy soil is the foundation
- "Feed the soil to feed the plant"

Guiding Principles

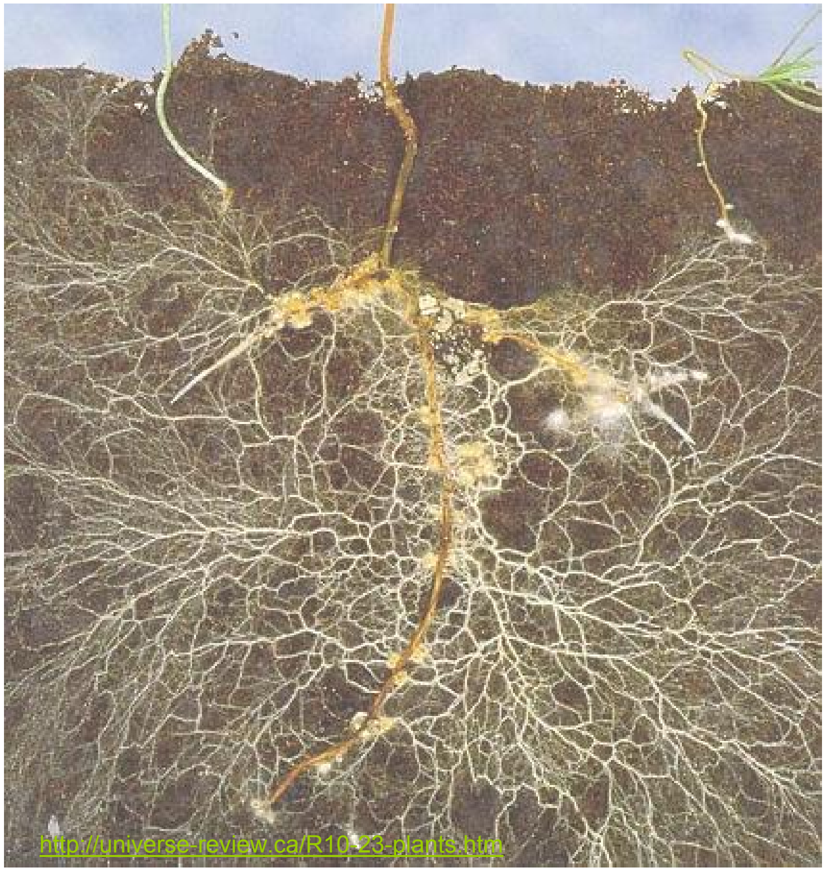
- Biodiversity
  - Mimic nature, improve nutrient cycling, disease suppression, tilth, and N fixation
- Diversification and Integration
  - Integrating crop and livestock operations
  - Perennial and annual cropping systems
- Sustainability
  - Reduce off-farm inputs
  - Enhance soil resource
- Natural Plant Nutrition

Guiding Principles

- Natural Plant Nutrition
  - Manage nutrients by managing soil organisms
  - Build the soil
- Natural Pest Management
  - Pests are indicators of "…how far a system has strayed from the natural ecosystem it seeks to imitate."
  - Natural predators and the maintenance of a complex agro ecosystem
- Integrity
  - Protecting organic products from contamination and commingling with non-organic products

Feed the Soil?

- Feed the bugs!
  - Microorganisms
    - Bacteria
    - Fungi
    - Actinomycetes
    - Protozoa
    - Algae
  - Nematodes
  - Macrofauna
    - Earthworms



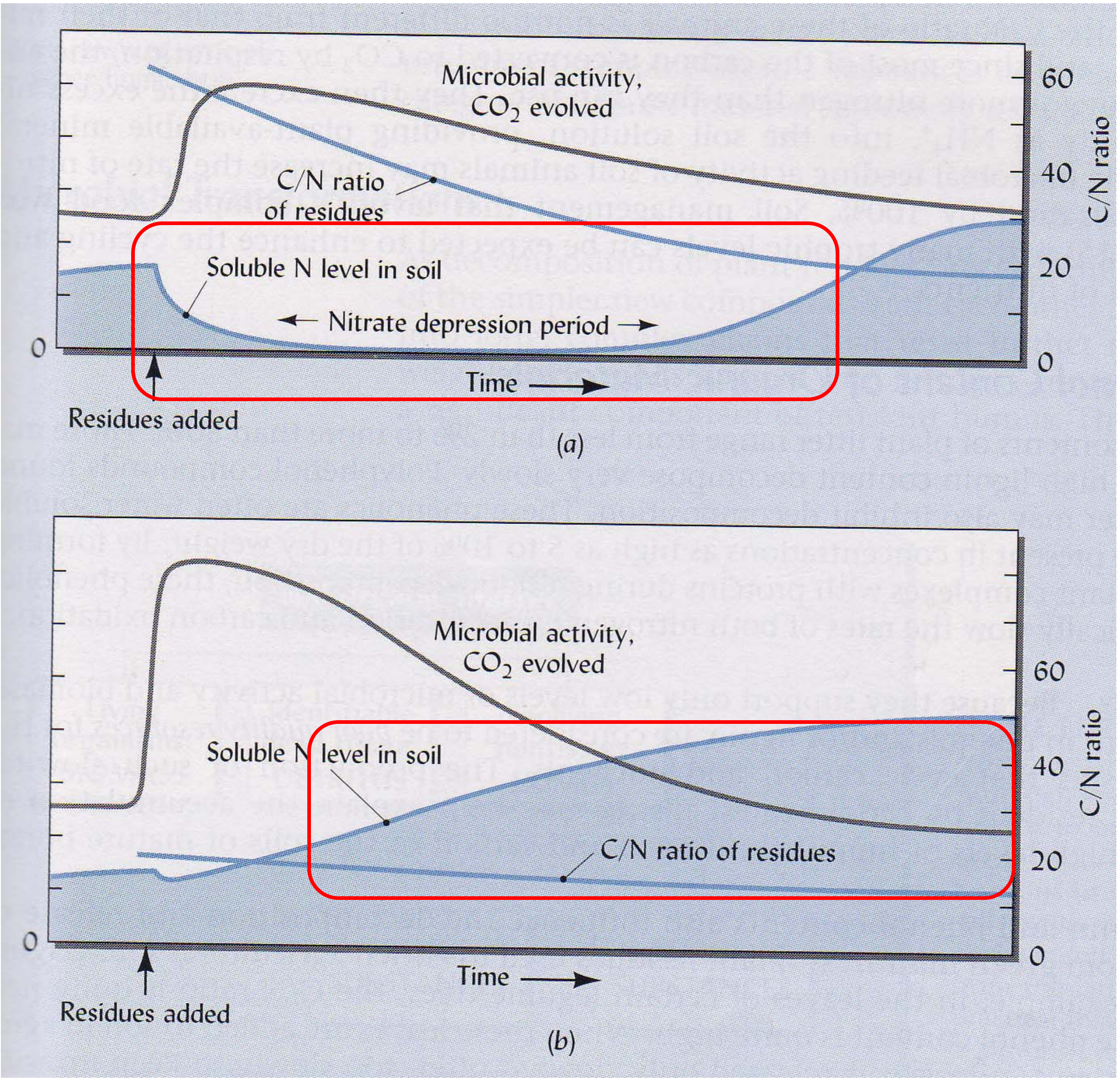
"The plow is one of the most ancient and most valuable of man's inventions; but long before he existed the land was I fact regularly ploughed, and continues to be thus ploughed by earthworms."

Charles Darwin, 1881

Nutrient Cycling

- Soil microorganisms mediate nutrient cycles through decomposition of organic residues
  - Microorganisms ‘feed’ on the residues
  - Biochemical by-products are plant nutrients (N,P,S) and other beneficial compounds like humic acid
- Mineralization
  - Microbial conversion of organic N P and S into ammonium, phosphate, and sulfate
  - Nutrients become available
- Immobilization
  - Microbial assimilation of inorganic N, P, and S
  - Nutrients temporarily tied up in microbial biomass

Mineralization/Immobilization



C:N ratio>25-30

net immobilization

N deficiency

C:N ratio < 25

net mineralization

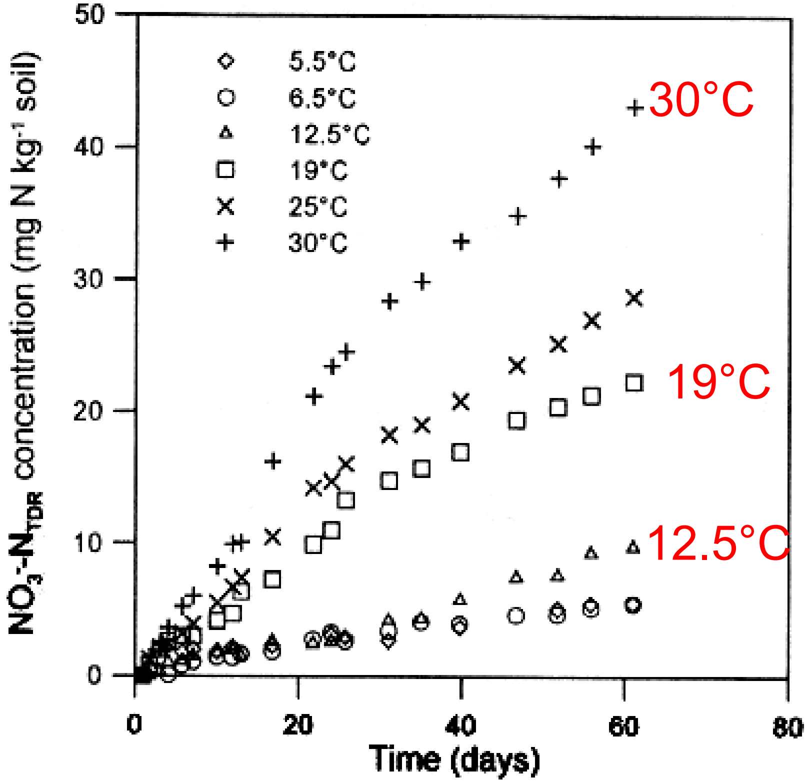
Source of plant N

Brady & Weil, 2004, Elements of the Nature and Properties of Soils

Factors Affecting Mineralization

1. Temperature

- Reaction rates double with every 10°C increase

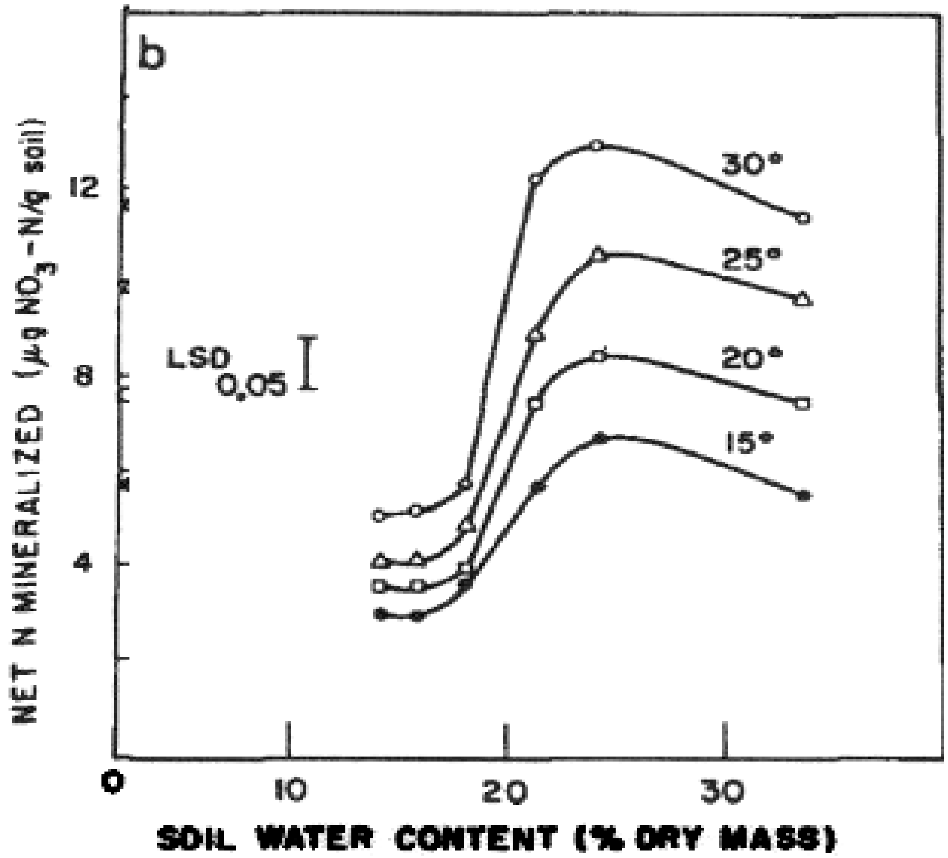


De Neve et al., 2002

Factors Affecting Mineralization

2. Moisture

- Mineralization low under dry conditions
- Increase to optimum under moist conditions
- Decrease as soil becomes saturated



Source: Cassman & Munns, 1980

Microbial Functional Groups

- Bacteria
  - decomposers, primary players in NP and S cycling
  - Actinomycetes act on more complex compounds to form humus
- Fungi
  - Decomposers, attack lignin
  - Nutrient acquisition (mycorrhiza)
- Protozoa and Nematodes
  - Consume bacteria and fungi releasing plant nutrients (N)
  - Activity increases decomposition rates

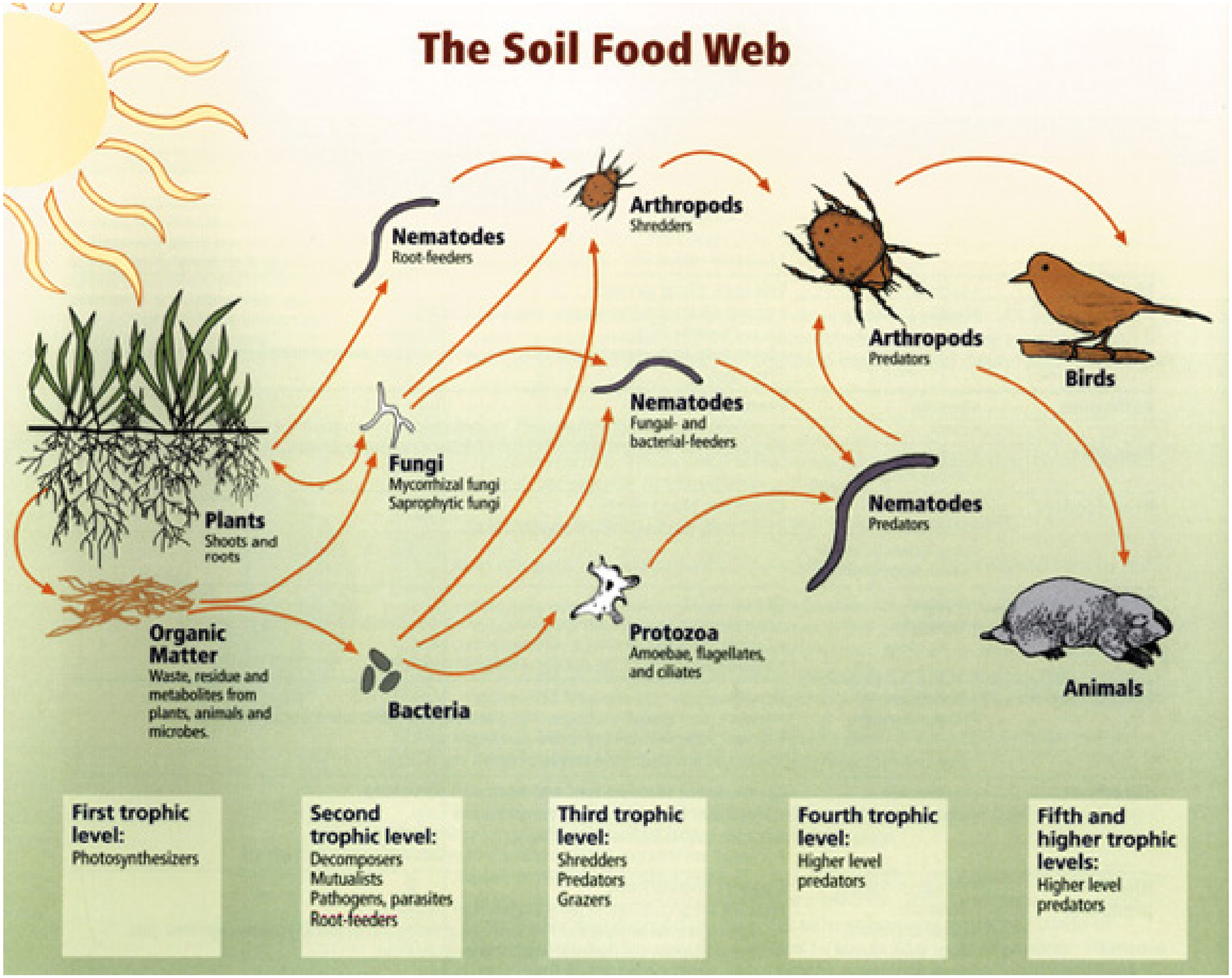
Factors Affecting Microbial Populations

- Moisture
  - Microorganisms need water to survive
- Oxygen
  - Bacteria both aerobic and anaerobic
  - Fungi, protozoa and nematodes aerobic
- Temperature
  - Adaptable
  - Activity generally increases as temperature rises
- Soil pH
  - Bacteria sensitive to acidity
  - Fungi function at low pH
- Organic Matter
  - OM source of C and nutrients
  - OM additions stimulate microbial growth

Agricultural Practices Affecting Microbial Populations

- Tillage
  - Destroys fungi, meso and macrofauna
  - Reduces OM
  - Reduces aggregation
- Fertilizers
  - N and P fertilizers create acid zones killing microorganisms
- Fumigation
  - Indiscriminant destruction of microbial community
- Monocropping
  - Reduces microbial diversity
  - Promotes pest build-up

What About the Soil Food Web?

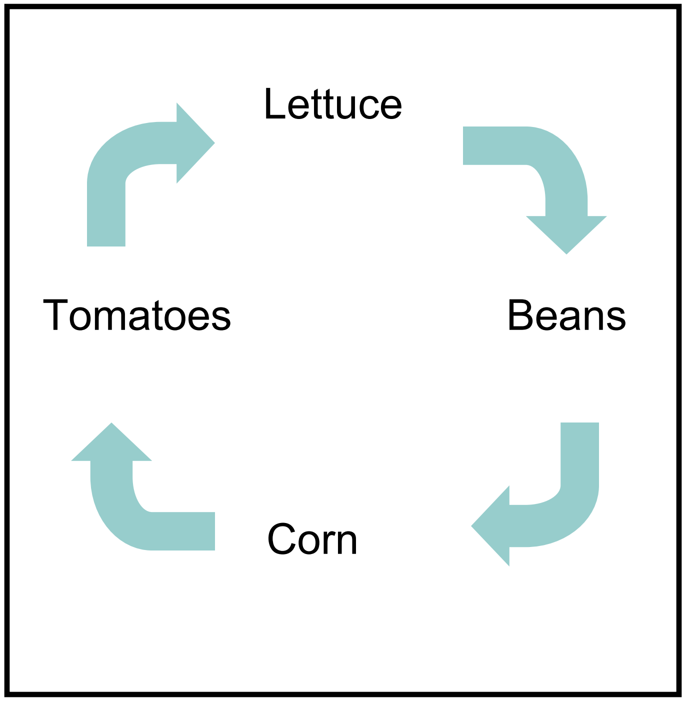


http://www.magicsoil.com/MSREV2/soil_food_web.htm

What About the Soil Food Web?

- Important to recognize the role of each functional group and their interdependence
- Remember that management practices affect microbial interactions
- Soil tests to quantify soil food web are expensive and difficult to interpret
- Hot area for research

Tools and Practices



Crop Rotation

- Soil fertility
  - Legumes for N fixation
  - Diverse rooting habits
- Pest Management
  - Break pest cycles
  - Promote diversity
- Know the family of the crops
- Crops rotated so that crops from different families follow each other

Tools and Practices

Crop Rotation

- Crops rotated so that crops from different families follow each other

Example

Lettuce → Beans → Corn → Tomatoes

Tools and Practices

Green Manures in the Crop Rotation:

- Soil fertility
  - Legumes for N fixation
  - Grasses for OM accumulation
  - Diverse rooting habits
- Pest Management
  - Break pest cycles
  - Promote diversity, attract beneficials
  - Biofumigants (brassicas, sudan grass, sunn hemp)
- Weed Management
  - Perennial rye
  - Oats

Tools and Practices

Composts and Manures:

- Soil Conditioner
  - Feed the soil
  - Improve physical properties
- Nutrient Availability
  - C:N ratio
  - Total N content
  - ≈ 15% of total N in mature composts available in the first year (Bettina et al., 2003)
  - Field trials estimate that composts alone can satisfy crop N demands after 40-80 years

	Feather meal	Dairy Manure	Compost
C:N ratio:	3.2	18	10-17
Total N	12%	2.0%	1.0%

Tools and Practices

<u>Composts and Manures</u>:

- Timing
  - Continuous additions to build up SOM
  - Mineralization potential of soil increases as OM inputs increase with time
  - SOM acts as nutrient reserve continuously releasing nutrients
  - High N materials can be used as a rapid source of N in the short term

Tools and Practices

<u>Intercropping and Companion Planting</u>:

- Interplanting 2 or more mutually beneficial plants to increase biodiversity

http://oregonstate.edu/dept/ncs/photos.html

Tools and Practices

<u>Biological Pest Control</u>:

- Depends on managing beneficial insect predators/parasites
- Seen as default benefit of organic soil management practices that promote above and below ground diversity
- Can include the release of control agents
- *Farmscaping*: long/short term design to create habitats for beneficials

Tools and Practices

Tillage and Cultivation:

- Tools for weed control, residue management, manure incorporation, hardpan destruction, pest control
- Negative impacts:
  - Costly
  - Destroy humus reserves and soil organisms
  - compaction
- Conservation and ridge tillage
  - Organic growers pioneers

Tools and Practices

Mulching:

- Weed control, moisture and temperature control, soil organic matter
- Large quantities of resistant organic materials (wood chips, straw, etc…)
- Not practical on a large scale

Summary

- The farm as an agro ecosystem
  - Balance through diversity
  - Crop and soil management based on understanding of interactions within the ecosystem
  - Maximum yields not always the driving force
- Careful management of soil organic matter the foundation to balance
- Shift approach from treating the symptom to managing the system and all its components

Extension's Role in Assisting Organic Growers

- Understand and appreciate the fundamental approach
- Understand that organic farming operates on the same scientific principles governing any agricultural system
- Apply scientific principles within the agro ecological model embraced by many organic farmers

Soil and Tissue Testing for Organic Systems

- Soil and tissue nutrient concentrations relevant for both conventional and organic systems
- Plant nutrient availability governed by the same chemical and biological reactions regardless of farming systems

Remember the Important Role of Organic Matter in Soils

- Physical
  - Improves aggregation (glue)
  - Improves water holding capacity (surface area)
- Chemical
  - Increases nutrient availability (cycling, P and micronutrient solubility
  - Increases CEC (200 $cmol_c\ kg^{-1}$)
  - Buffers the soil against pH changes
- Biological
  - Increases microbial diversity
  - Assists in pathogen suppression

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Measuring Management Impacts on Soil Organic Matter

- Total C
  - Total C changes slow
  - 0.001 to 0.01% increase in SOM for every ton/a
- Soluble C
  - Hot water soluble C sensitive to organic inputs
- CEC
  - Small increases in soil C have significant impacts on CEC
- Microbial biomass
  - Difficult procedure sensitive to climate and other environmental factors
- Functional Groups
  - Expensive
  - Changes due to organic inputs or other factors?

Making Fertilizer Recommendations in Organic Systems

- Determine crop rotation
- Get soil analysis
  - Same rules apply for pH, exchangeable cations and soil P
  - Interpreting total C and total N is difficult
  - 1-5% of N in SOM mineralized (12 - 60 lbs N/a)
  - Soils receiving lots of OM may have higher N mineralization
- Obtain organic amendment chemical properties
  - C:N ratio
  - Total N

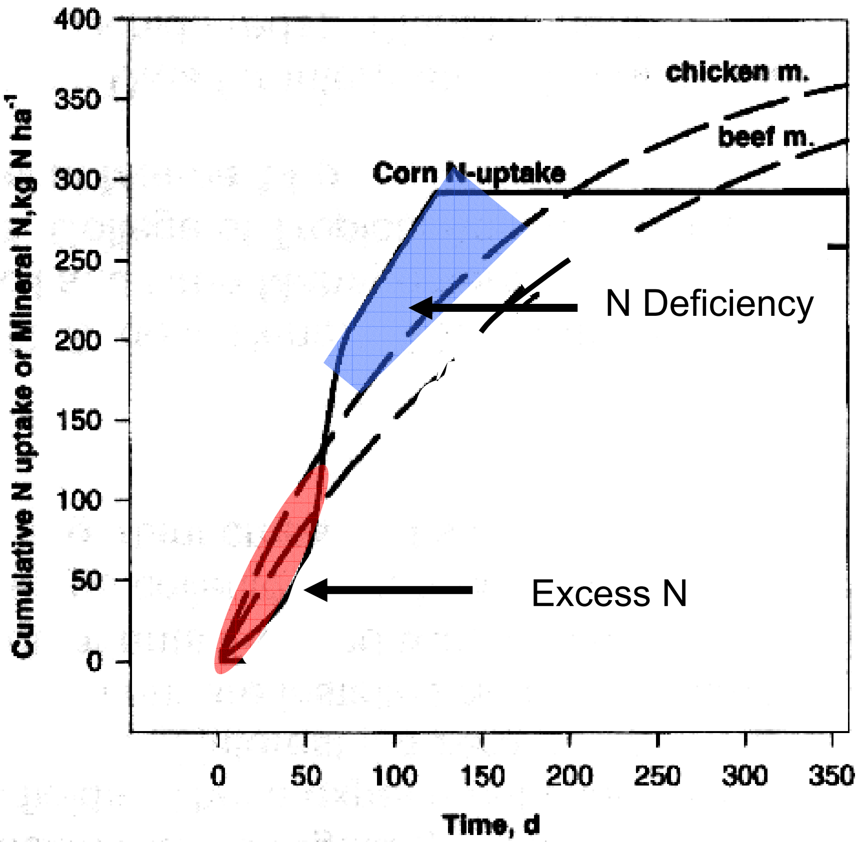
Table 1. Common organic fertilizer materials and their approximate analysis (dry weight basis).

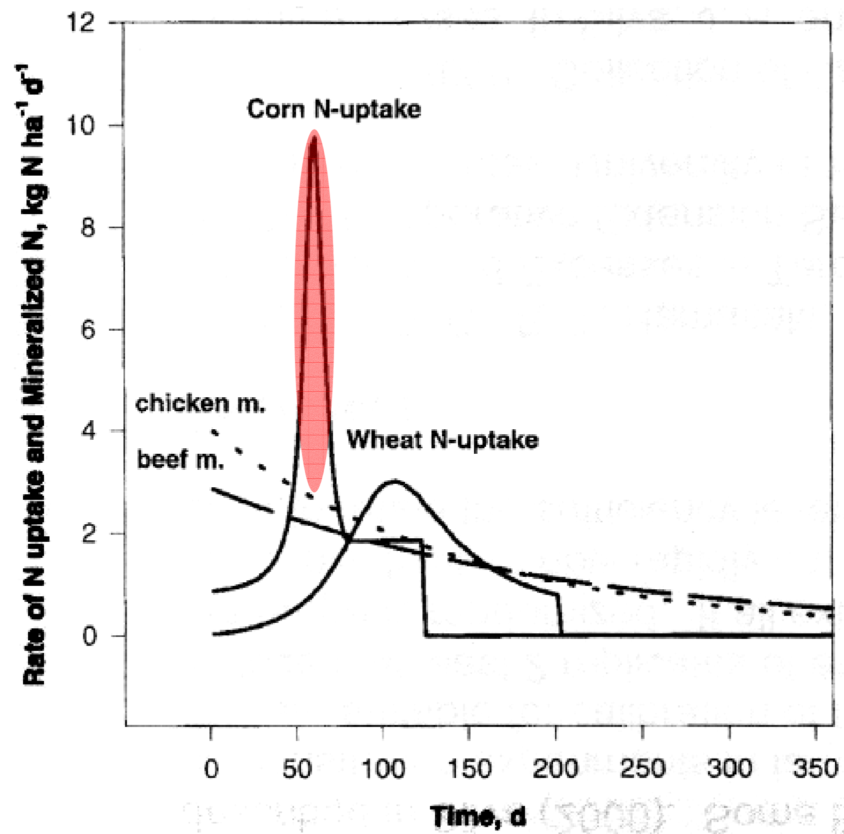
	Nitrogen (N)	Phosphorus (P)	Potassium (K)
		%	
Fish meal or powder	10–11	6	2
Chicken manure	2–3	1.5	1.5
Processed liquid fish residues	4	2	2
Feather meal	12	0	0
Seabird and bat guano	9–12	3–8	1–2
Alfalfa meal	4	1	1
Cottonseed meal	6	0.4	1.5
Soybean meal	7	2	1
Bone meal	2	5	0
Kelp	<1	0	4

Material	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
			% dry weight					ppm (mg/kg) of dry weight		
Poultry (broiler) manure[a]	4.4	2.1	2.6	2.3	1.0	0.6	1000	413	480	172
Composted chicken (layer) manure[b]	2.3	3.5	2.9	15.5	1.3					
Dairy cow manure[a]	2.4	0.7	2.1	1.4	0.8	0.3	1800	165	165	30
Swine manure[c]	2.1	0.8	1.2	1.6	0.3	0.3	1100	182	390	150
Sheep manure[c]	3.5	0.6	1.0	0.5	0.2	0.2	-	150	175	30
Horse manure[c]	1.4	0.4	1.0	1.6	0.6	0.3	-	200	125	25
Feedlot cattle manure[d]	1.9	0.7	2.0	1.3	0.7	0.5	5000	40	8	2

Hue & Silva, 2000

N Mineralization and Crop Nutrition





Source: Pang & Letey, 2000

Calculating Amendment Rate

Material: Blood meal (13% N)

Crop N requirement: 150 lbs/a

N release: High N content - rapid release (80% available during the cropping system)

Calculation: 150 lbs/(0.13*0.8) = 1,442 lbs/acre

Material: Chicken manure (3.0% N)

Crop N requirement: 150 lbs/a

N release: moderate N content - moderate release (50% available during the cropping system)

Calculation: 150 lbs/(0.03*0.5) = 10,000 lbs/acre

Nutrient Additions

P Inputs:

- 3.5% P
- (0.035*10,000lb) = 350 lb P per acre
- Assume 40-50% of total P mineralizes
- Can lead to P accumulation

K Inputs

- Assume 90% of the K available
- (0.9*0.021*10,000lb) = 189 lb K per acre

Manure Application

- Manure composed of Ammonia (10-30%) and organic N
- Manure should be incorporated
  - 25% NH_3 lost to volatilization after 1 day
  - 75% NH_3 lost after a week

Information Gaps

- Nutrient release form organic amendments
- Impact of green manure crops
  - Nutrients
  - Soil pathogens
  - weeds
- Impact of soil management on pest/diseases

Next Steps

- More Interaction with organic growers
- Incorporate lessons from the Mainland and Europe
- A systems approach to research integrating soils, crops, plant pathology, entomology, and weeds

Resources

Books:

Gershuny, G. and J. Smillie. The Soul of Soil

Lampkin, N. Organic Farming

Coleman, E. The New Organic Grower

Magdoff, F. and H. van Es. 2000. Building Soils for Better Crops. Sustainable

Web:

http://www.attra.org/organic.html