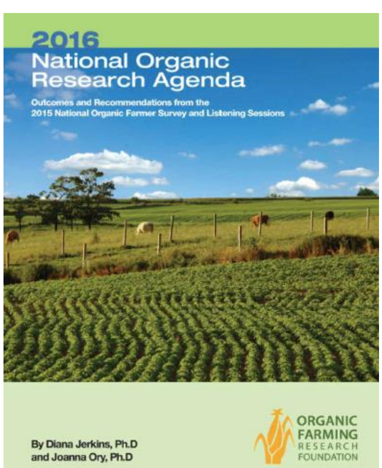
Nutrient Management for Crops, Soil, and the Environment

Research-based Practical Guidance for Organic and Transitioning Farmers

Diana Jerkins and
Mark Schonbeck
Organic Farming
Research Foundation

Organic Farmer Research Priorities



Soil Health – 74%

Nutrient management – 66%

Topics include:

- Matching crop needs
- Minimizing nutrient losses.
- Nutrient efficient cultivars.
- Nutrients, soil life, and pest resistance.

Download full report at http://ofrf.org/.

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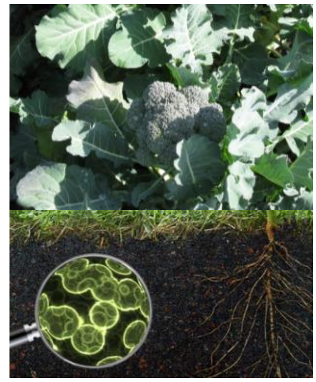
Soil Health and Crop Nutrition

Healthy, living soils:

- Retain and recycle plant nutrients.
- Nourish crops from nutrient reserves in soil organic matter (SOM).
- Minimize nutrient losses, protect water quality.



"Feed the soil, and the soil will feed the plant."

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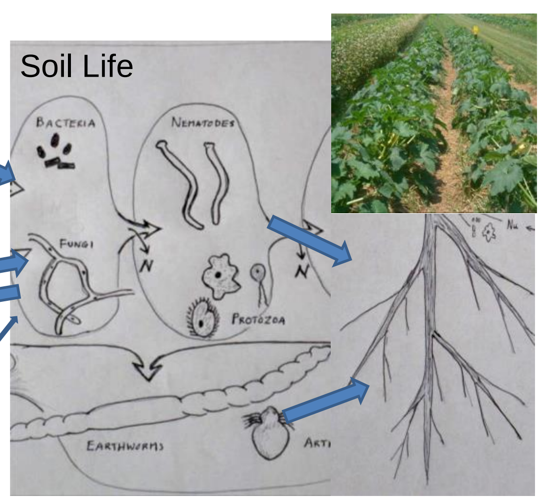
Nutrient Dynamics in Living Soil

Inputs:
- Plant residues
- Manure
- Fertilizers
- Amendments

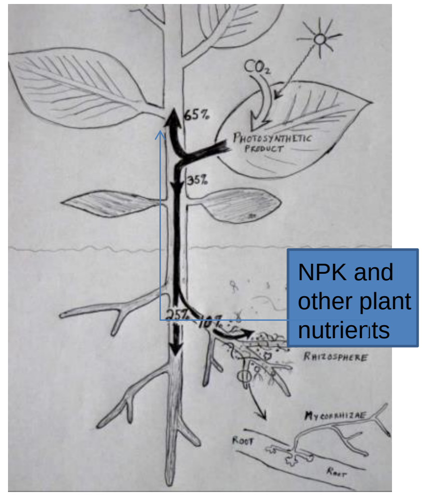
Soil Organic Matter

Soil Minerals



Two-way Exchange

- Plants deliver 10 – 30% of their photosynthetic product to soil life.
- Beneficial microbes in the rhizosphere (root zone) enhance plant nutrition and health.
- Mycorrhizal fungi assist nutrient and moisture uptake and protect host plants from disease



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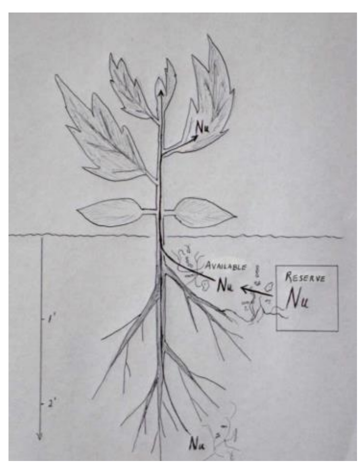
Crop Nutrient Sufficiency

Healthy soil provides:

- Adequate nutrient reserves; favorable pH.
- Abundant and balanced soil life.
- Deep, open soil profile, allowing roots to explore large volume of soil.



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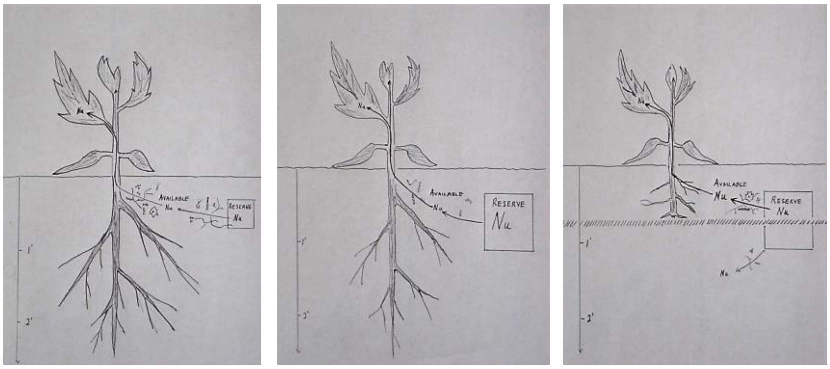
Causes of Crop Nutrient Deficiency



Crop nutrition suffers when soil nutrients are depleted (left), when soil life is scarce or stressed (center), or when soil compaction restricts root growth (right).

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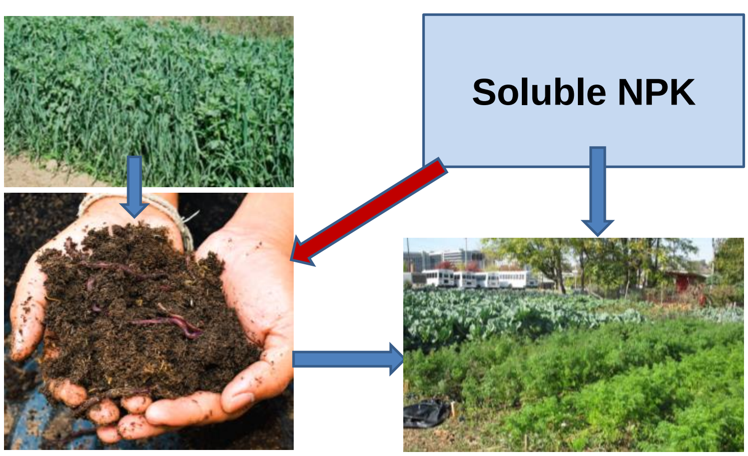
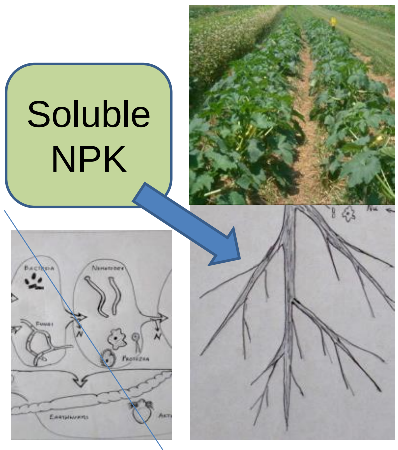
Soil Health and Plant Nutrients



Building soil health enhances nutrient release from organic matter. Fast-release fertilizers stimulate crops but can undermine soil health.

20th Century Nutrient Management



- "Feed the plant":
  - Synthetic NPK
  - Other nutrients if needed
  - Lime for acid pH
- Soil life disregarded
- Rates determined by:
  - Expected crop response based on soil test
  - A little more added for "insurance."

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Organic Nutrient Management, Step 1: *Understand Essential Crop Nutrients*

Major Nutrients

- Nitrogen (N) – *nitrate anion* (NO_3^-) *or ammonium cation* (NH_4^+)
- Phosphorus (P) – *phosphate anions* (HPO_4^{2-} *and* $H_2PO_4^-$)
- Potassium (K) – *cation* (K^+)

Secondary Nutrients

- Calcium (Ca) – *cation* (Ca^{2+})
- Magnesium (Mg) – *cation* (Mg^{2+})
- Sulfur (S) – *sulfate anion* (SO_4^{2-})

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Essential Micronutrients

Essential for crops:

- Boron (B) – *borate anion*
- Copper (Cu) – *cation or chelate*
- Zinc (Zn) – *cation or chelate*
- Iron (Fe) – *cation or chelate*
- Manganese (Mn) – *cation or chelate*
- Molybdenum (Mb) – *molybdate anion*
- Nickel (Ni) – *cation or chelate*
- Sodium (Na) – *cation (Na^+)*
- Chlorine (Cl) – *anion (Cl^-)*

Important for animal and human nutrition:

- Cobalt (Co), Selenium (Se), Chromium (Cr).

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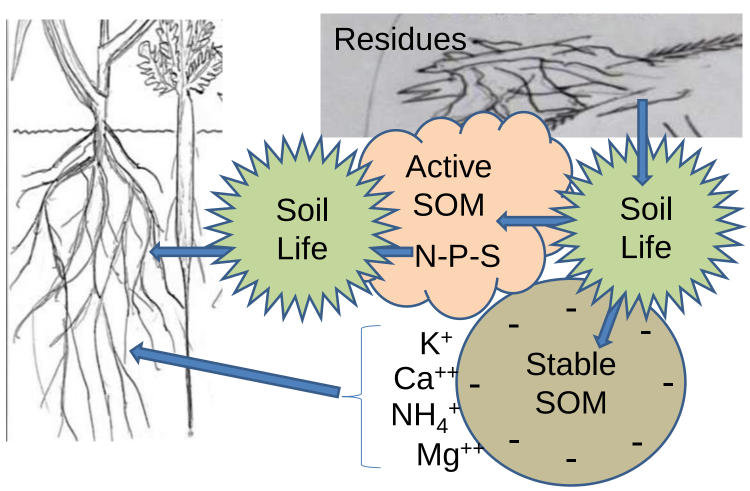
How Soil Life and Soil Organic Matter Hold and Deliver Nutrients to Plants



Organic Nutrient Management, Step 2
Feed the Soil Life a "Balanced Diet."

Organic Nutrient Management, Step 3: *Test the Soil*

A standard soil test reports:
- pH (acidity)
- Plant-available P, K, Ca, Mg, some micronutrients
- % total SOM
- Cation exchange capacity (CEC)

Additional tests available through some labs:
- Nitrate-N, potentially mineralizable organic N
- Active SOM
- Soil microbial respiration

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Organic Nutrient Management, Step 4: *Provide Supplements as Needed*

Use organic and natural mineral nutrient sources (right) to:

- Restore depleted soils
- Remedy deficiencies
- Adjust soil pH
- Sustain crop yields
- Replenish nutrients removed in harvest

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Nutrient Management Challenge #1: *Translating Soil Tests to "Organic"*

Standard soil test recommendations include:

- Lime based on soil pH and buffer index.
- N based on crop only.
- P and K based on soil test P and K and crop grown.

Challenges for organic producers:

- Complex nature of biological nutrient cycling.
- Variable NPK contents of manure, compost, etc.
- Lack of research in organically managed soils.

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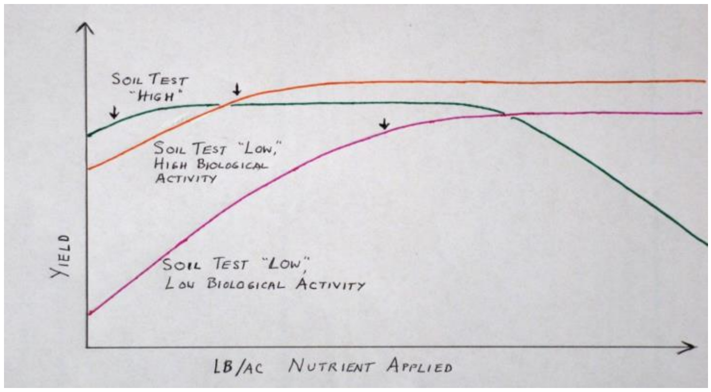
Research-based Nutrient Recommendations

↓= most profitable application rates.



Soil life can modify crop response to applied nutrients.

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Nutrient Management Challenge #2: *Nitrogen*

Organic crops are often N limited when:

- Soil life is depleted or out of balance.
- The field is newly transitioned to organic.
- N-poor residues like straw are tilled in.
- An early spring heavy N feeder is grown.
- Excessive rains leach soil N.
- Cold or dry soil slow biological N release.
- Crop cultivars have been developed in and for high-input conventional systems.

N deficiency in spring-planted organic broccoli.

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Nitrogen and Soil Health: Potential Tradeoffs

- Cover crops with reduced tillage build soil health, but can slow N mineralization and limit crop yields.
- Providing N in concentrated forms such as poultry litter can:
  - Leach nitrate-N to groundwater.
  - Increase N_2O emissions.
  - Accelerate SOM decomposition.
  - Deter beneficial plant root-microbe interactions.

Organic no-till snap beans show visible N deficiency.

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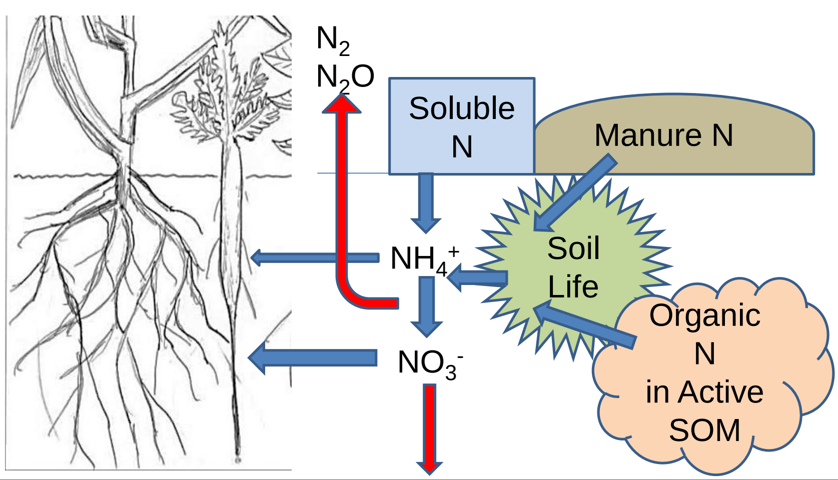
Nitrogen is Challenging for *All* Farmers …



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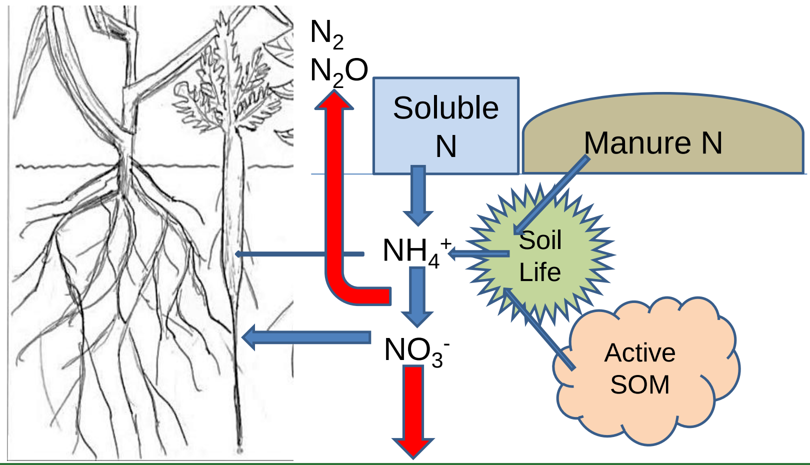
… Especially When Soil Life is Depleted.



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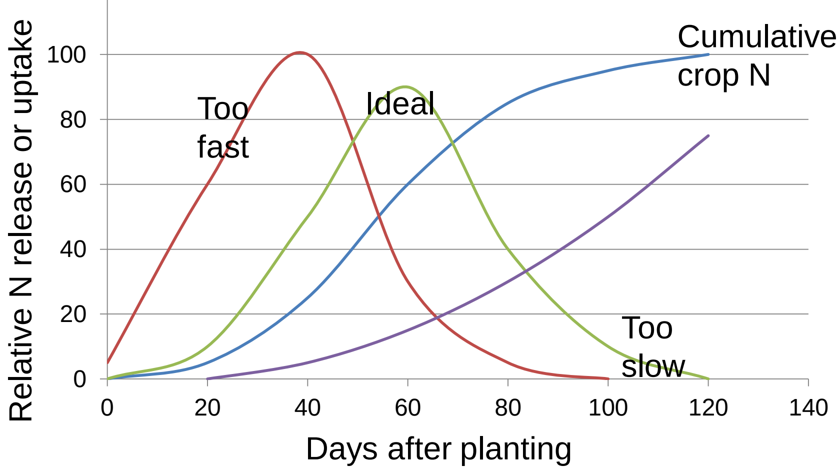
Matching N Release to Crop Demand



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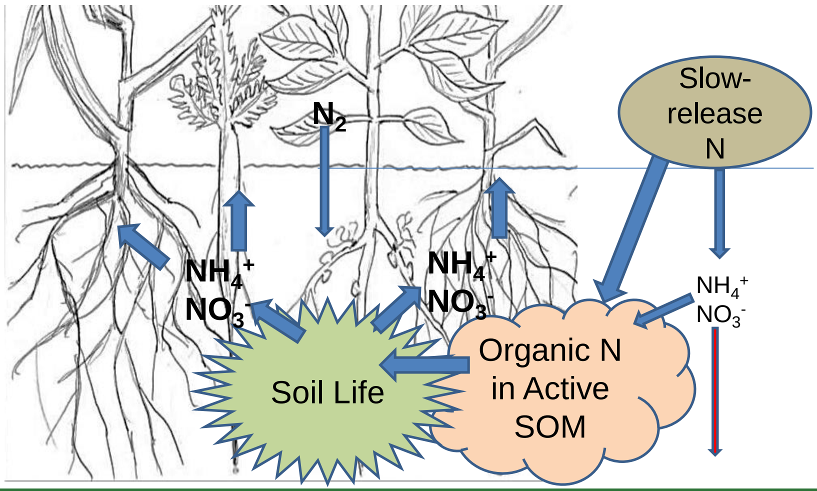
Delivering the N Where it is Needed



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Nutrient management challenge #3: *Phosphorus*

- Crops use 5 – 8 lb N for every 1lb P.
- Manure and compost provide 2 – 3 lb N per lb P.
- Using manure and compost to meet crop N needs can build excess soil P and:
  - Release P into runoff.
  - Inhibit mycorrhizal fungi.
  - Tie up micronutrients.

Heavy compost used to rebuild depleted soil can accrue P surpluses.

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Nutrient management challenge #4: *Intensive Multi-cropping, High Tunnels*

Intensive multiple-cropping can:

- Deplete N and K.
- Consume SOM through tillage.
- Reduce residue return to the soil.

Using large amounts of compost to replenish soil can:

- Build up P, other nutrients.
- Build up salts in high tunnel.

High tunnels permit year-round production and pose special soil health challenges.

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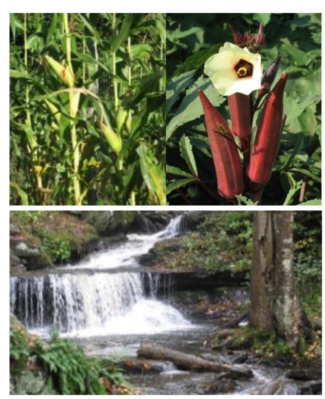
Goals of Organic Nutrient Management

- Maintain yields and quality.
- Protect soil health, water quality, and climate.
- Build soil capacity to meet crop needs with minimal input.
- Remedy soil nutrient deficiencies and imbalances.
- Replenish nutrients removed in harvest.
- Avoid or draw down nutrient excesses.



Abundant crops and clean waters.

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Replenishing Nutrients: Vegetable Crops

Crop	Yield t/ac[1]	Lb/ac removed: N[1,2]	P[1]	K[1]	Rec. rate, lb/ac[3] N	P	K
Broccoli	5.6	20 – 53	7	36	175	22	42
Lettuce	12.0	20 – 62	7	60	100	44	83
Onion	19.4	28 – 73	11	60	85	22	42
Squash	15.0	27 – 52	8	96	85	22	83
Tomato	13.2	14 – 37	6	54	70	44	83
Mixed compost (1-1-1) at 5 t/ac adds:					100	44	83
Poultry litter (5-4-3) at 1 t/ac adds:					100	35	50

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Replenishing Nutrients: Field Crops

Crop	Yield	Nutrient removal, lb/ac N	P	K
Corn, grain	150 bu/ac	150	29	35
Soybean, grain	50 bu/ac	190[a]	18	34
Wheat, grain	80 bu/ac	128	21	30
Grass hay	5 t/ac	185	24	195
Corn, silage	5 t (dry)/ac	170	31	183
Compost (1-1-1), 5 t/ac		100	44	83
Poultry litter (5-4-3), 1 t/ac		100	35	50

[a] Much of this N is fixed by *Bradyrhizobium* symbiosis.

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Grain Crops May Need Little Fertilizer on Healthy Soils

- Corn-soy-wheat + cover crops
- SC coastal plain sandy soils
- With / without recommended P and K

Results
- Cover crops build SOM
- Full grain yields without added P or K, and 50% recommended N
- Little change in soil P or K

Standard soil tests & recommendations:
- Measure top 6 inches only.
- Ignore soil biology.
- Assume soil is "leaky".
- Overlook nutrient recovery by cover crops.

"Living soil changes everything"
Robin Kloot, 2017 Organic Agriculture Research Symposium, Lexington, KY.

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Broccoli: a Nitrogen Hog?

In California, organic broccoli required 220 lb N/ac for optimum yield.

This much organic N:
- Leached ~180 lb N/ac.
- Emitted 17-42 lb/ac N_2O.
- Leached another 100 lb N/ac from tilled broccoli residues.

(U. California, Santa Cruz)

At Virginia Tech, organic broccoli required150 lb N/ac in addition to cover crop, for maximum yield.

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Tight N Cycling in Organic Tomato

3 types of organic tomato fields in CA:

- N deficient – low soluble N, low yield.
- N saturated – high soluble N, high yield and high leaching risk.
- Tight N cycling – low soluble N, high yield, minimal leaching risk.
  - ➢ Diverse organic inputs with low to high C:N ratio promoted tight nutrient cycling.

(U. California at Santa Cruz)

Vigorous tomatoes grown on low-N compost.

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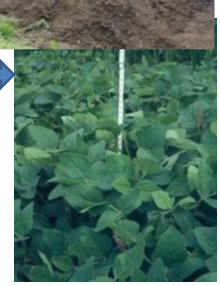
Adjust Amendment Rates to Soil Test P

Obtain soil test and total nutrient analysis for compost or manure.

- On low-P soil, apply compost to meet N and K needs and build P.
- If soil P is optimum, apply compost to maintain P; grow legumes for N.
- For very high or surplus soil P, use compost sparingly if at all.

Remember: a little compost goes a long way for soil health.



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Cover Crops: a Vital Tool for Organic Nutrient Management

Cover crops:

- Feed soil life, build SOM.
- Fix N (legumes).
- Absorb and retain soluble N.
- Retrieve nutrients from subsoil, protect water quality.
- Enhance plant-available soil P (legumes, buckwheat) and K (grasses) when needed.
- Never aggravate P or K excesses.

Clockwise from top left: pearl millet, hairy vetch, buckwheat, four-way mix.

Cover Crop Types and N Dynamics

Mix and match cover crops to manage nitrogen for production and environmental goals.




	LEGUME	CRUCIFER	MIX	GRASS
N fixation potential	High	None	High	Limited
N recovery	Low-mod	Very high	Mod-high	High
Residue C:N ratio	Low	Low	Moderate	High
Available N release	Rapid	Rapid	Slow	N tie-up
N leaching & N_2O risk	High	High	Low-mod	Low

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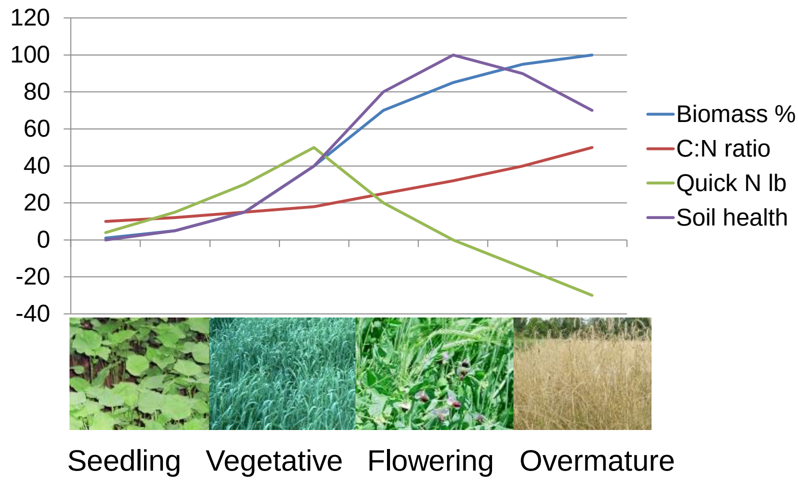
Cover Crop Maturity and N Dynamics



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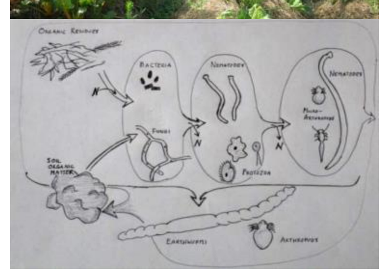
Managing SOM: a Balancing Act

"Management of SOM to enhance soil quality is a key determinant of successful organic farming, which involves balancing two ecological processes: **mineralization** of carbon (C) and nitrogen (N) in SOM for short term crop uptake, and **sequestering** C and N in SOM for long term maintenance of soil quality."

Delate et al., 2015. *Sustainable Agric. Res. 4(3): 5-14.*(Emphasis added)



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Zone Tillage: Releasing Nutrients Where They Are Needed

- Ridge tillage promotes early-season nutrient release in crop rows, leaving between-row soil undisturbed.
- High-residue cultivator moves organic residues into crop row, providing additional fertility.
- Other ways to concentrate nutrient release in the "grow zone" include:
  - Strip tillage.
  - Band application of fertilizer
  - In-row drip fertigation

USDA NRCS

Ridge tillage in a corn-soybean rotation

Zone Planting for Nutrient Management

N-fixing forage soybean in "grow-zone" of a following broccoli crop with N-immobilizing, weed-suppressive sorghum-sudan in alleys.

- Planting legumes or crucifers in future crop rows with grasses in alleys can promote efficient use of N released from cover crop residues.
- Strip or zone tillage (grass alleys mowed or rolled) can further reduce N losses.

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Summary: Best Organic Nutrient Management Practices

- Build and maintain healthy soil, grow cover crops.
- Use perennial sod crops to restore soil fertility.
- Test your soil and organic amendments regularly.
- Use crop foliar analyses to supplement soil analyses.
- Adjust manure/compost rates according to soil P.
- Use organic nutrient budgeting tools.
- Do side-by side trials with/without organic fertilizers.
- Promote nutrient release in crop row (zone management).

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Organic Nutrient Management Research Priorities

- Evaluate responses of a range of crops to N, P, K, and other nutrients in organic systems.
- Develop decision tools for organic N rates, considering crop, preceding crop, climate, soil type and soil condition.
- Explore tight N cycling in a wider range of crops, soils, and climates.
- Fine tune cover crop management to minimize N_2O.
- Breed and develop new crop cultivars for nutrient efficiency, and effective partnership with soil life.

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Download the Soil Health and Organic Farming Guides at www.ofrf.org

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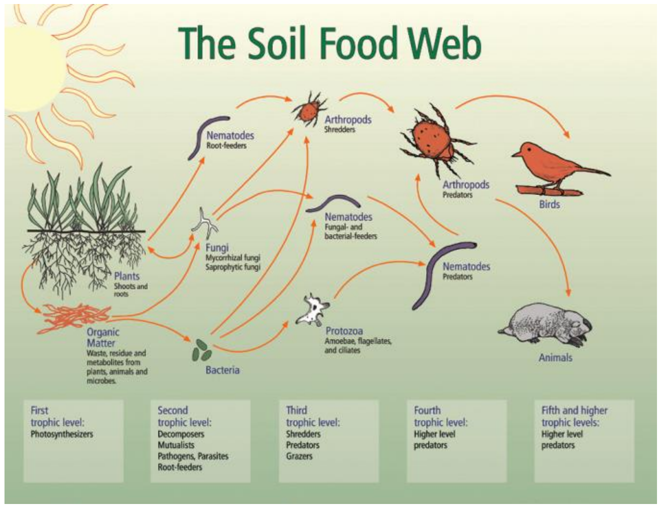
Questions?



Ingham, E. 2000. Soil Biology Primer. Soil and Water Conservation Society, Ankeny, IA, USA. www.mdpi. com/2071-1050/7/1/988/pdf