UC SANTA CRUZ
Center for Agroecology

Nitrogen Management in Organic Systems

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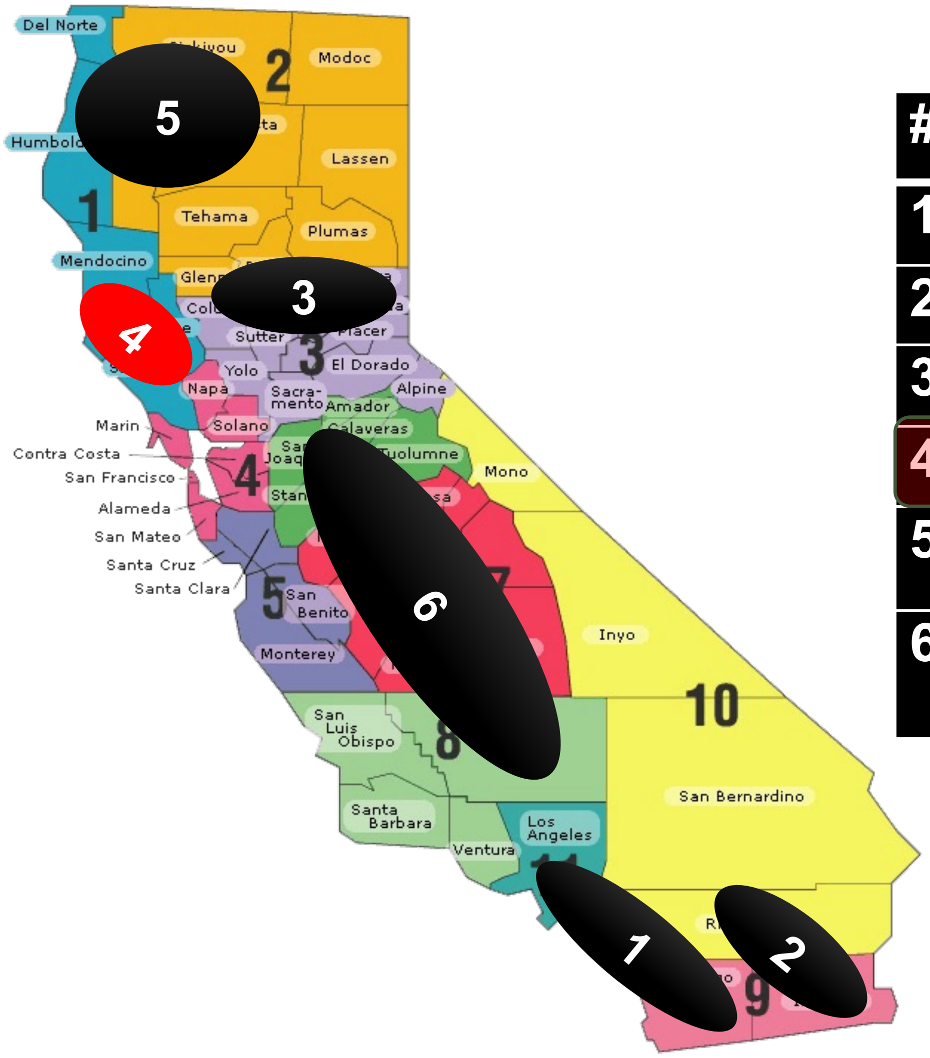
UCCE Organic Crops Day
Hopland, CA
April 24, 2024

UNIVERSITY OF CALIFORNIA
Agriculture and Natural Resources

Visiting the Top 20 Organic Counties* in California

* Number of organic farms per County



#	Month/Year	County
1	Dec. 2022	Los Angeles, San Diego
2	April 2023	Riverside, Imperial
3	Nov. 2023	Sutter, Nevada, Yolo
4	April 2024	Mendocino, Lake, Sonoma
5	Aug. 2024	Humboldt, Siskiyou, Shasta
6	Sep. 2024	Kern, Tulare, Madera, Kings, Fresno, Stanislaus, San Joaquin

Funded by CDFA State Organic Program

Organic Systems Researchers

(Oct. 2023)

- Rob Wilson – Intermountain Research and Extension Center Director, Modoc, Siskiyou (potatoes, onions, small grains, alfalfa, specialty crops)
- Charlie Brummer – UCD Plant Breeding Center Director, Siskiyou, Yolo, Statewide (breeding of forages, alfalfa, spinach, SCOPE)
- Sarah Light – UCCE Agronomy Advisor, Sutter, Yuba, Colusa (agronomy, annual crops)
- Margaret Lloyd – UCCE Small Farm Advisor, Yolo, Solano, Sacramento (fresh market vegetables, berries)
- Allison Krill-Brown – UCD Assoc. Specialist, Sacramento Valley (breeding of wheat, barley, spinach)
- Saarah Kuzay – UCD Student Wheat Breeder, Northern CA (breeding of small grains)
- Cameron Pittelkow– UCD Assoc. Professor, Yolo (establishing an organic research field at UCD)
- Amelie Gaudin – UCD Assoc. Professor, Yolo, Statewide (almonds, vineyards, tomatoes)
- Rachel Vannette – UCD Assoc. Professor, Yolo, Solano (soil health, biocontrol, pollination, tree fruits, orchard, tomatoes)
- Cristina Lazcano – UCD Assoc. Professor, Yolo, Statewide (soil biodiversity & health, wine grapes, corn, strawberries, tomatoes)
- Allen Van Deynze – UCD Assoc. Director, Plant Breeding Center, Yolo, Monterey (breeding of peppers, spinach, tomatoes)
- Neal M Williams – UCD Professor, Northern CA (pollination, bee diversity, bee habitats in working landscape)
- Alda Pires – UCD Assoc. Specialist, Statewide (urban ag, food safety, animal health)
- Tom Tomich – UCD Professor, Statewide (sustainability science and policy)
- Catherine Brinkley – UCD Assoc. Professor, Statewide (organic marketing, land preservation)
- Daniel Geisseler – UCD Assoc. Specialist, Statewide (nutrient management, vegetables, field crops)
- Sonja Brodt – UC SAREP Assoc. Director & Academic Coordinator, Yolo, Statewide (farmer training, biologically integrated farming systems, elderberry)
- Jennifer Sowerwine – UCB Assoc. Specialist, East bay, Statewide (urban agroecology, food safety, food justice)
- Francisco Benitez– Berkeley Food Institute, Project Specialist, Statewide (food value chains, food systems, cooperatives)
- Timothy Bowles – UCB Assist. Professor, Sacramento Valley, Central Coast (applied agroecology, vegetables)
- Houston Wilson –California Organic Institute Director, UCR Assist. Specialist, Central Valley, Statewide (entomology, orchards, vineyards)
- Jeff Mitchell – UCD Specialist, Sacramento, San Joaquin, and Salinas Valleys (cropping systems, vegetables, cover crops)
- Daniel Karp – UCD Assoc. Professor, Central Coast (landscape agroecology, pest control, birds, and food safety)
- Kathryn De Master – UCB Assoc. Professor, Central Coast (sociology in strawberry production)
- Reza Ehsani – UC Merced, Professor (mechanization, automation, and engineering systems for fruits and vegetables)
- Stacy Philpott – UCSC Professor, Santa Clara, Santa Cruz, Monterey (insects, birds, urban garden & farms)
- Joji Muramoto – UCSC Assist. Specialist, Central Coast, Statewide (organic production, agroecology, strawberry, vegetables)
- Damian Parr – UCSC Lecturer, Statewide (sust. ag. education & research)
- Jan Perez – UCSC Food System Specialist, Statewide (sust. ag. evaluation & research)
- Mark Bolda – UCCE Berry Farm Advisor, Central Coast (strawberry, cane berries)
- Eric Brennan – USDA-ARS Research Horticulturalist, Central Coast (vegetables, strawberries)
- Richard Smith – UCCE Vegetable, Weed Farm Advisor, Central Coast (cool season vegetables)
- Kirsten Pearsons– UCCE Entomology Farm Advisor, Central Coast (cool season vegetables)
- Peter Henry – USDA-ARS Research Plant Pathologist, Central-South Coast (strawberries)
- Matthew Grieshop– Cal Poly SLO, Director, Grimm Family Center for Organic Production and Research, Central Coast (vegetables)
- Ashraf Tubeileh – Cal Poly SLO, Assoc. Professor, Central Coast (cropping systems)
- Charlotte Decock – Cal Poly SLO, Assist. Professor, Central Coast (C and N management, soil health, vegetables, vineyards)
- Diego Nieto – Driscoll's. Entomologist, Statewide (biological control in berries)
- Jenny Broome – Driscoll's, Senior Research Manager (integrated organic berry disease management)
- Oleg Daugovish – UCCE Berry Vegetable Farm Advisor, Ventura (berries, vegetables)
- Annemiek Schilder – UCCE Director, Ventura (Plant pathology, berries, vegetables)
- Arianna Bozzolo – Rodale Institute Research Director, Ventura (horticulture)
- Priti Saxena– Cal Poly Pomona, Assist. Professor, Los Angeles (tomato breeding)
- Amrita Mukherjee – UCCE Urban Ag/ Small Farm Advisor, San Bernardino, Orange (vegetables, fruit trees, herbs)
- Milton McGiffen – UCR Vegetable Specialist, CA from Fresno south (vegetables)
- Ramiro Lobo – UCCE Small Farm & Ag Economics Advisor, San Diego (specialty crops, dragon fruit, coffee, blueberries)
- Eric Middleton – UCCE Area IPM Advisor, San Diego, Orange, Los Angeles (dragon fruit, citrus, avocado, vegetables)
- Jimmy Nguyen – UCCE Food Safety and Organic Production Advisor, Imperial, Riverside (leafy greens, onions, berries)
- Brooke Latack– UCCE Livestock Advisor, Imperial, Riverside, San Bernadino (cattle, sheep, goats)

California Organic Facts and Statistics (2021)

- **4.3%** of total farms in CA are organic*
- **4.0%** of total agricultural acreage in CA is organic*.....#4 after Vermont (17%), New York (4.7%), and Maine (4.3%)

*2019 USDA Organic Survey

- **Quizzes: Top 3 Counties in CA**
  - *Organic harvested acreage?* Modoc (198K), Lassen (174K), Humboldt (152K)
  - *Organic farm #?* San Diego (706), Sonoma (439), Riverside (375)
  - *Organic farm gross sales?* Kern (931M), Fresno (811M), Monterey (756M)

Outline

1. Why nitrogen (N)?
    - N in plant and N in soil
    - plant available N in soil
2. N mineralization vs. N immobilization
3. Factors affecting N mineralization in the soil
4. N mineralization of organic fertilizers and composts
    - Incubation studies
    - Online tools and references
5. Non-traditional plant N acquisition pathways and mechanisms
    - Some other pathways
    - Other factors affecting N availability in the soil

Why Nitrogen (N)? A key to crop production

- *Primary nutrient affecting plant growth*
  - *photosynthesis*
  - *biomass structure*
  - *metabolism*
  - *energy production*
  - *reproduction*
- *N deficiency*
  - *Yellowish green leaves, smaller plants, lower yield*
- *N excess*
  - *Dark green leaves, large vegetative plants, susceptive to diseases, groundwater/surface water pollution*

N Forms in Soil and Plant Availability

Soil N

- Organic N **~98%** **[Plant Unavailable*]**
  - **<u>Mineralization (~2%/year)**</u>**
- Inorganic N **~ 2%** **[Plant Available]**
  - Ammonium N (NH_4^+-N) — Adsorb
  - **<u>Nitrification**</u>**
  - Nitrate N (NO_3^--N) — Repel

Leaching susceptive

Clay particle or Soil organic matter (negatively charged)

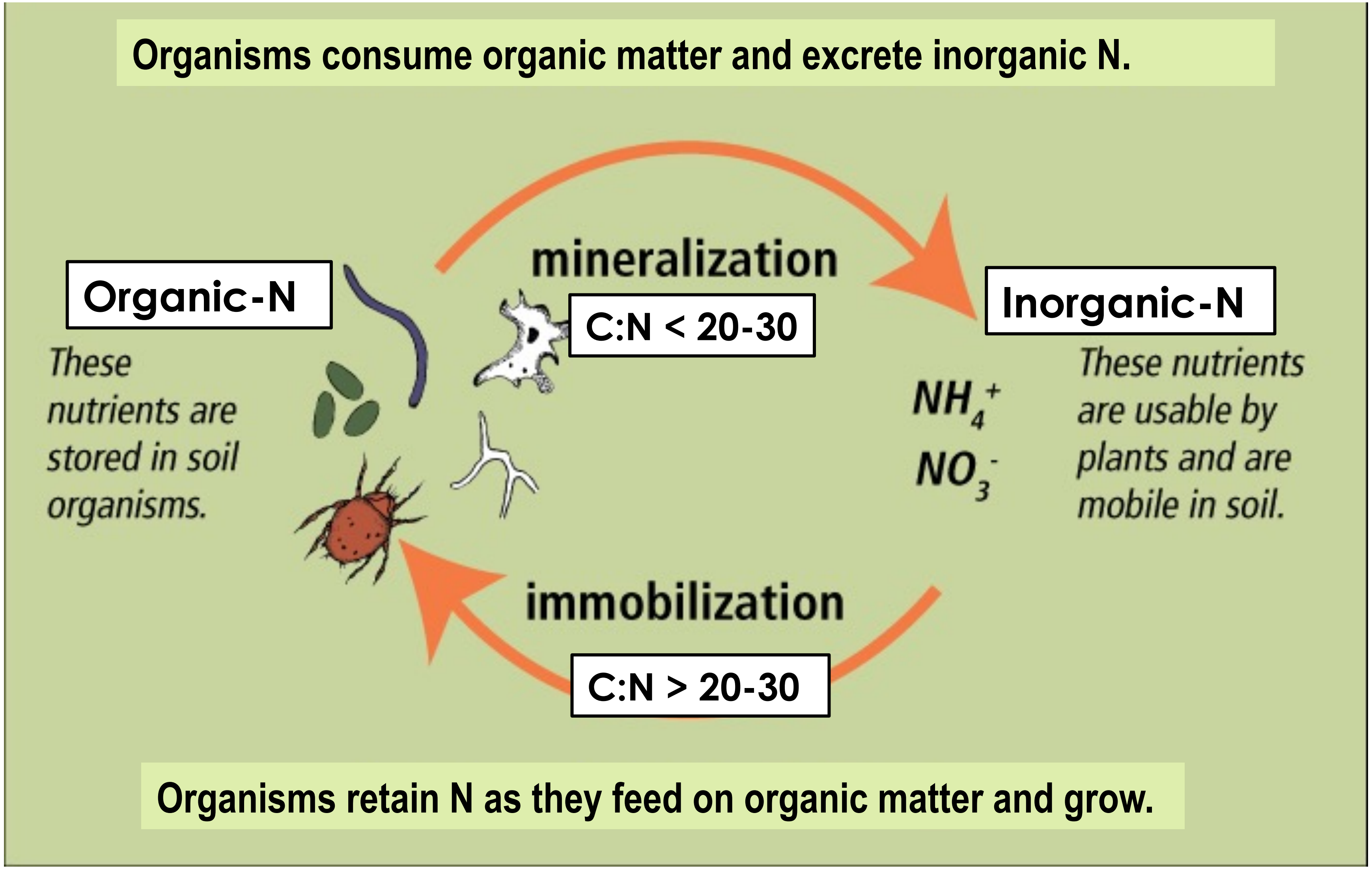
* Plants can absorb small amounts of organic N and some crop plants can do more than others

** **<u>Biological processes</u>** affected by ***environmental factors*** such as ***soil temperature. moisture, etc.***

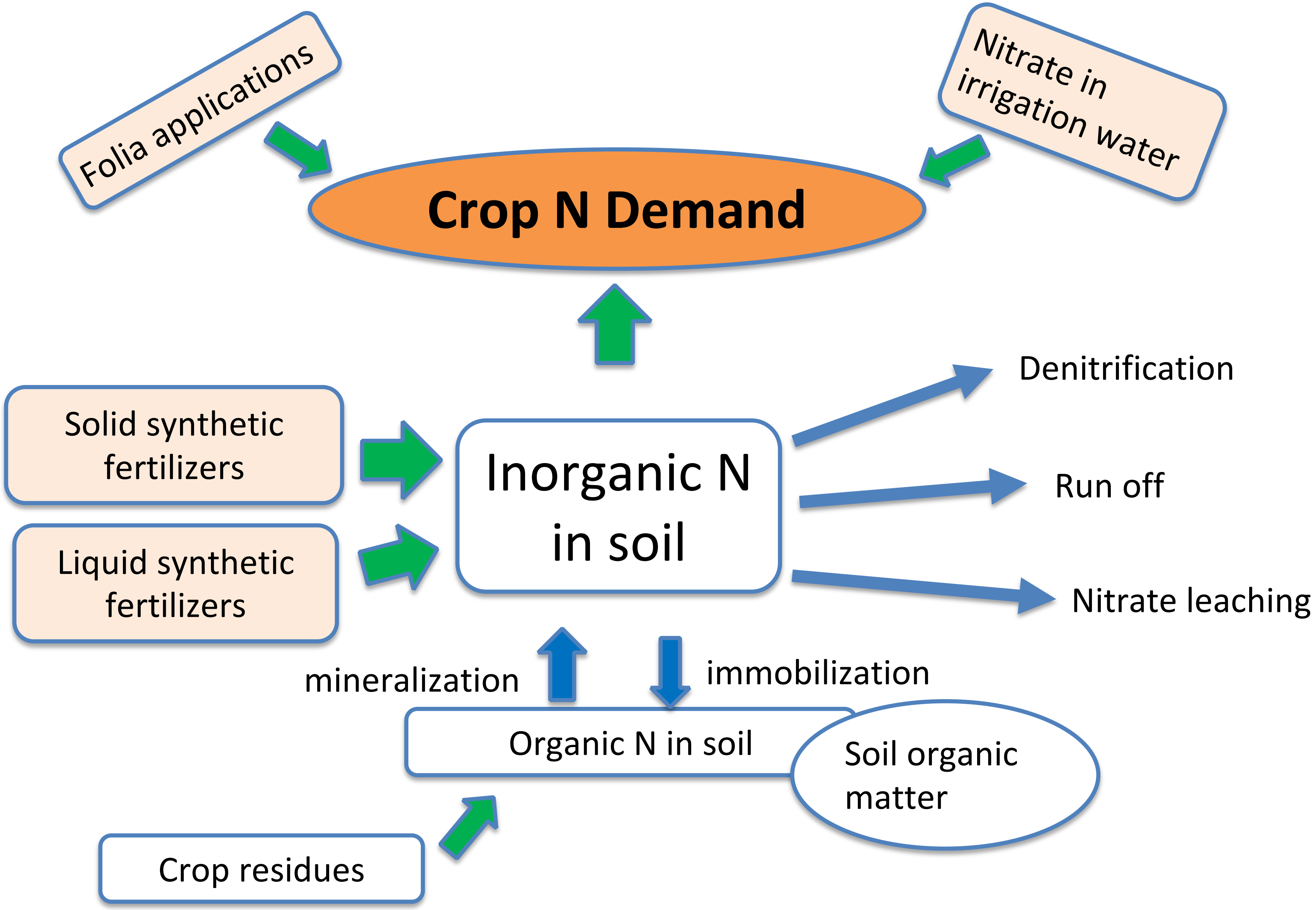
Nitrogen mineralization & immobilization

- Soil microorganisms decompose residue
- Need N and C as building blocks for their own biomass
- C is also used as energy source
- **N mineralization:** Release excess N in the form of NH_4^+ into soil solution
- **N immobilization:** Uptake of NO_3^- or NH_4^+ from soil solution and incorporation into microbial tissue

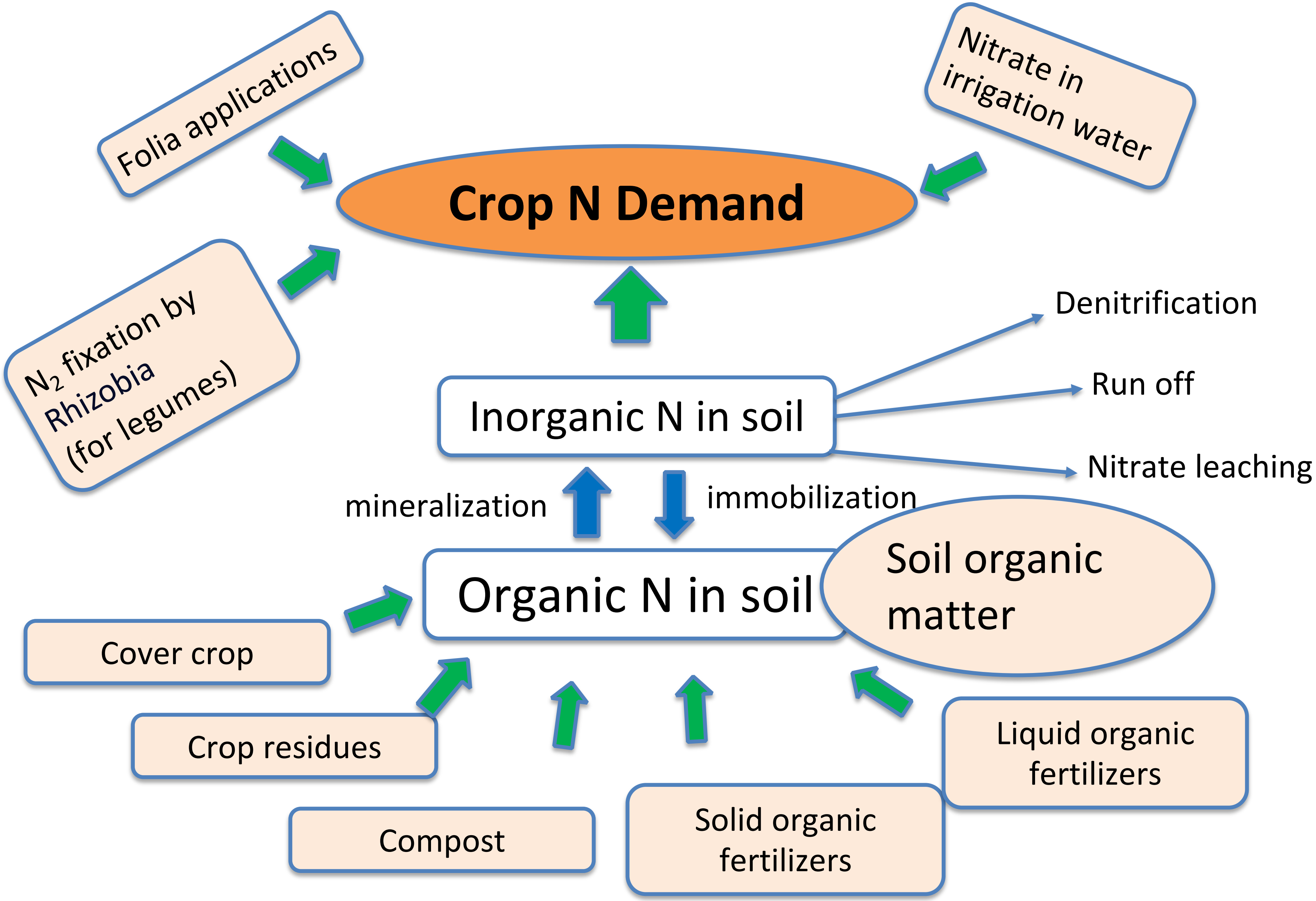
N mineralization vs. N immobilization



(Adopted from USDA-NRCS, 2017)



N dynamics in conventional systems

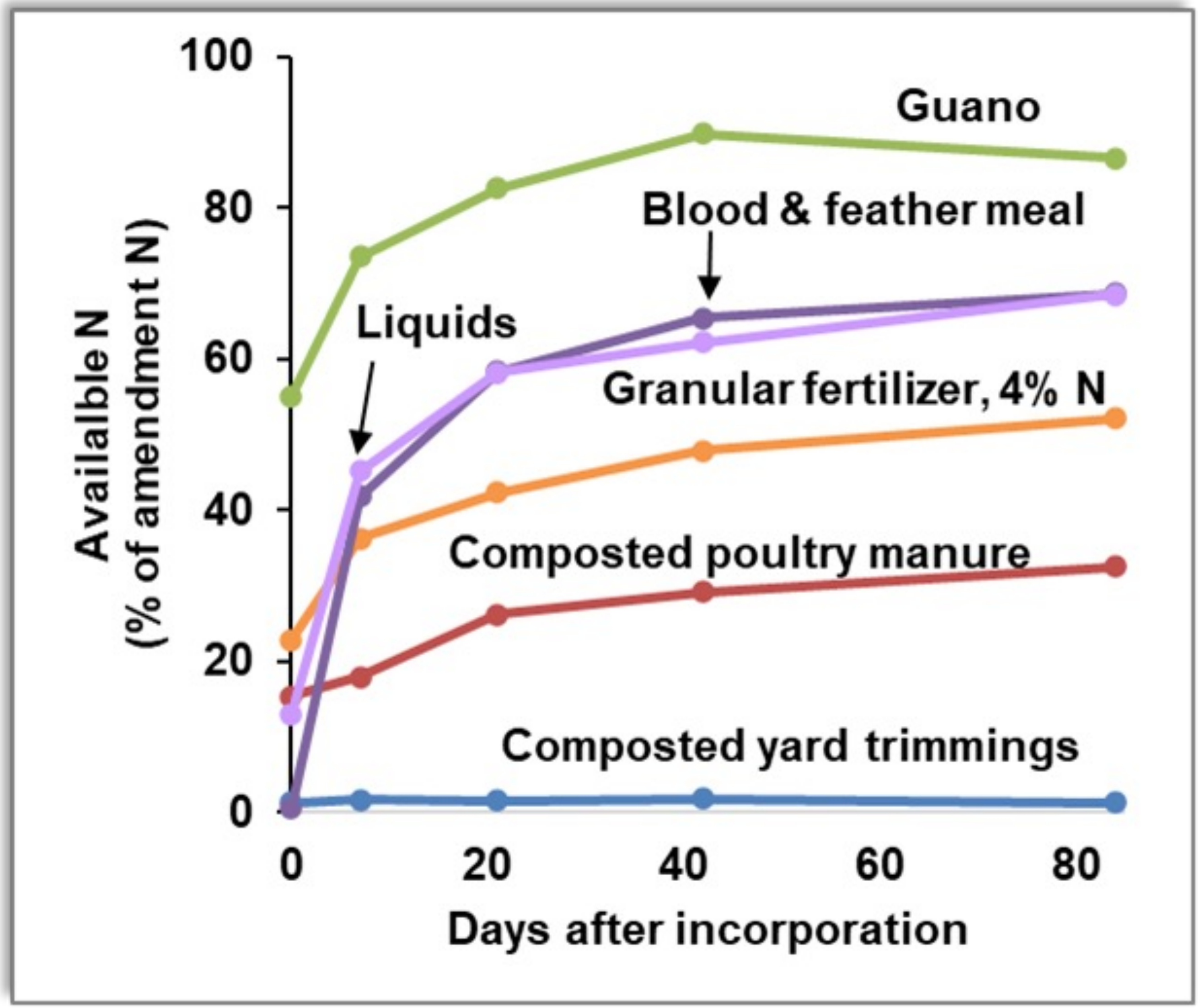


N dynamics in organic systems

Factors affecting decomposition and N mineralization

- Soil temperature
- Soil moisture
- Quality of organic source
  - Nitrogen content
  - C to N ratio
  - Availability of C and N
- Management

N Release Patterns of Organic Fertilizers



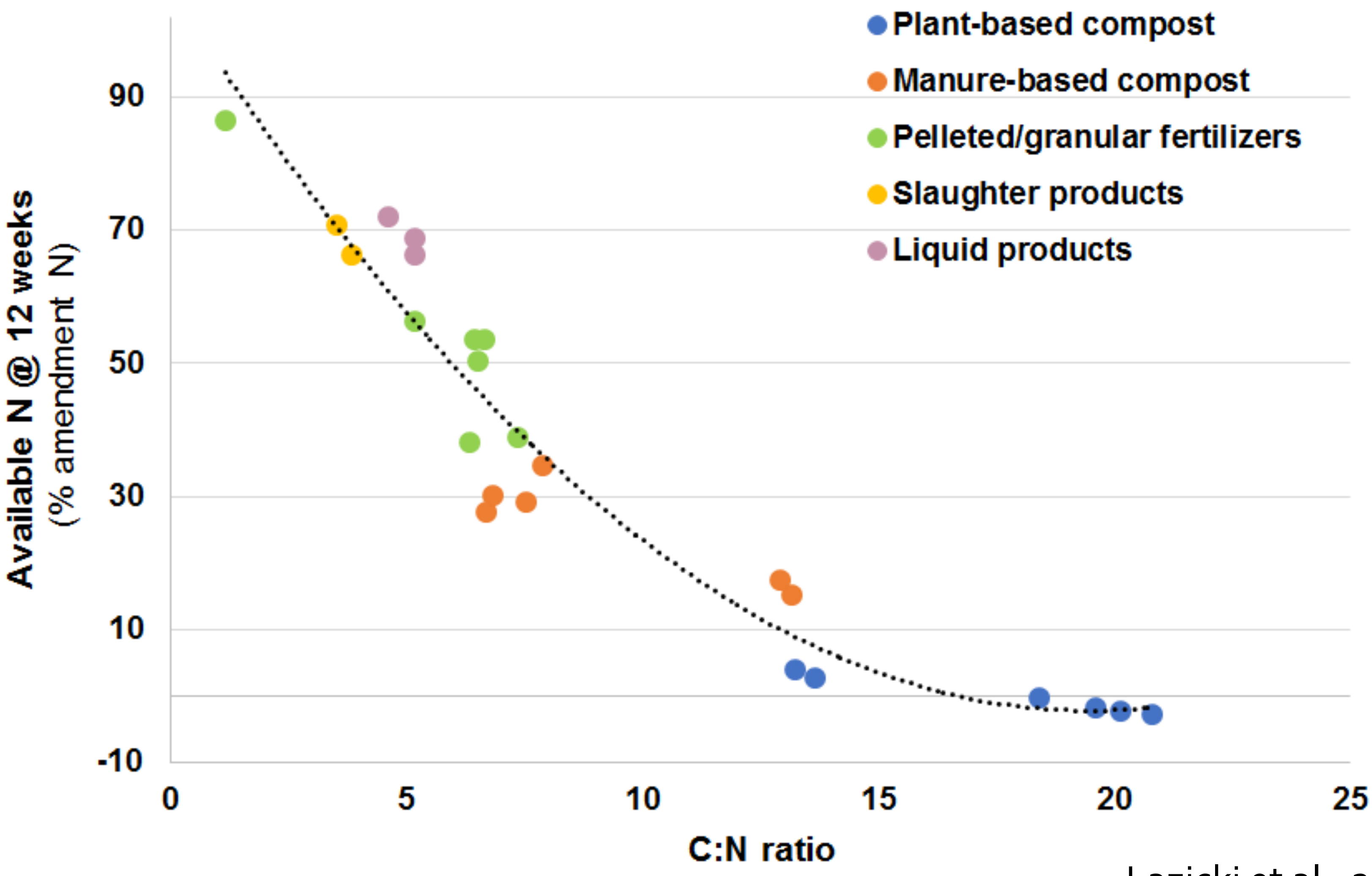
Lazicki et al., 2020

Total N vs. Plant available N after 12 Weeks

Material	Average total N content (%)	N available after 12 weeks	Plant available N content (%)
Municipal yard trimmings composts	1.25	-3 – 4%	0 – 0.1
Poultry manure composts	3.5	30 – 35%	1.1 – 1.2
Granular fertilizers	4.5	38 – 60%	1.7 – 2.7
Blood & feather meals	14	65 – 70%	9.1 – 9.8
Liquid fertilizers	3.0	50 – 100%	1.5 – 3.0
Guano	12.5	80 – 90%	10 - 11

Based on Lazicki et al., 2020

Effect of C to N ratio on N release



Lazicki et al., 2020

AgOrder 4.0

Table MRP-3. Organic Fertilizer Discount Factor

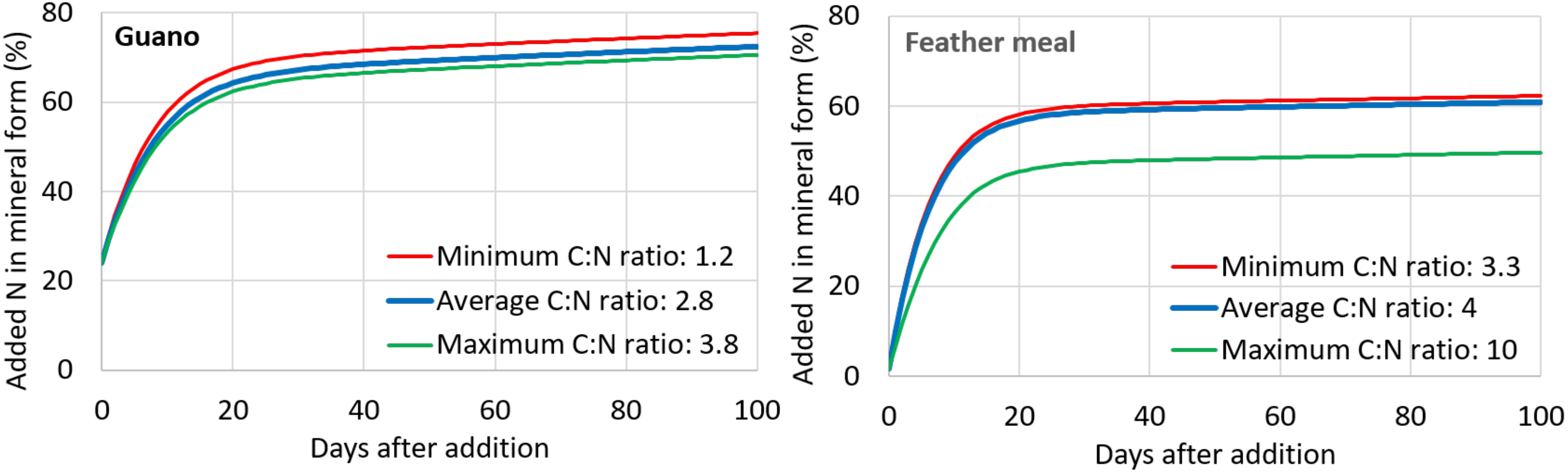
C to N Ratio of Organic Product	Discount Factor Based on Predicted Mineralization Rate (O)
< 1.5	1.00
1.5	0.904
2.0	0.852
2.5	0.802
3.0	0.754
3.5	0.707
4.0	0.661
4.5	0.617
5.0	0.574
5.5	0.533
6.0	0.493
6.5	0.455
7.0	0.418
7.5	0.383
8.0	0.349
8.5	0.317
9.0	0.285
9.5	0.256
10.0	0.228
10.5	0.202
11.0	0.177
11.5	0.153
12.0	0.131
12.5	0.111
13.0	0.091
13.5	0.074
14.0	0.058
14.5	0.043
15.0	0.030

The dataset

Material	Studies	Datasets	Observations	C to N ratio in dataset		
				Average	Min	Max
Guano	4	8	44	2.8	1.2	3.8
Feather meal	7	14	70	4.0	3.3	10.0
Poultry manure	9	29	195	10.3	6.3	19.5
Poultry manure compost	4	16	77	7.3	5.7	9.4
Vermicompost	8	21	125	11.1	14.9	35.0
Yard waste compost	6	25	126	16.1	9.1	22.3

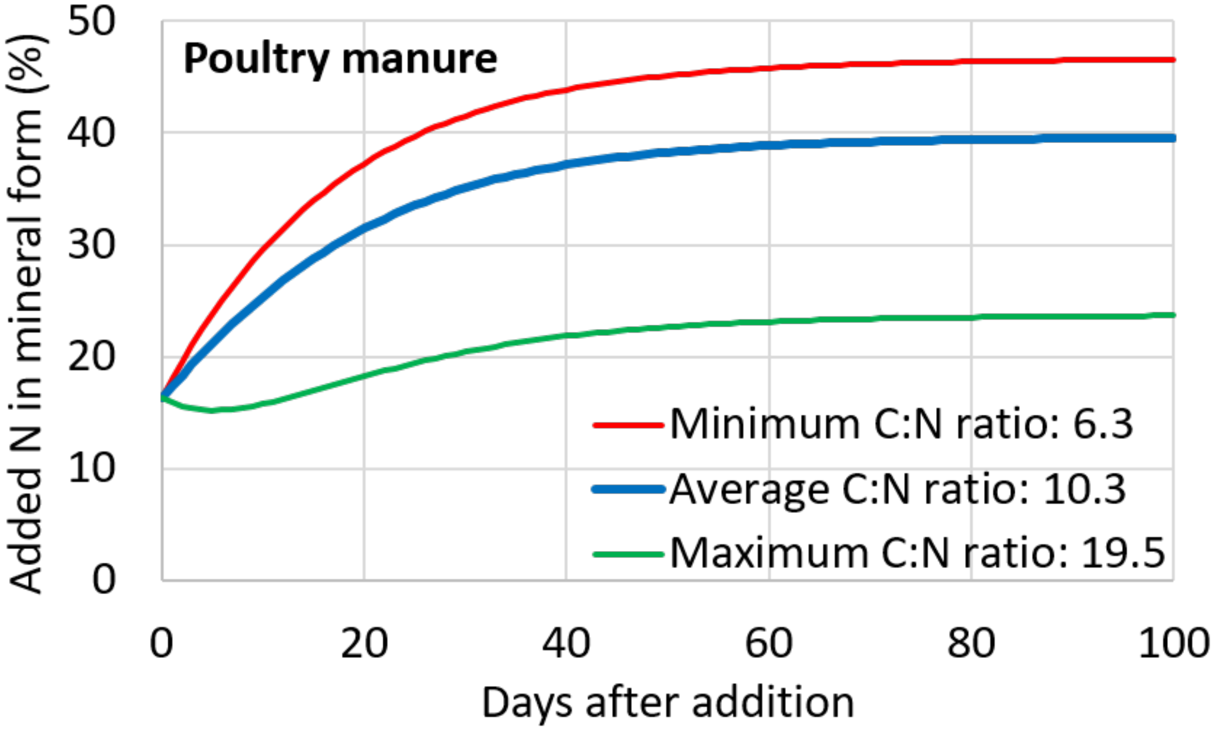
Geisseler et al., 2021

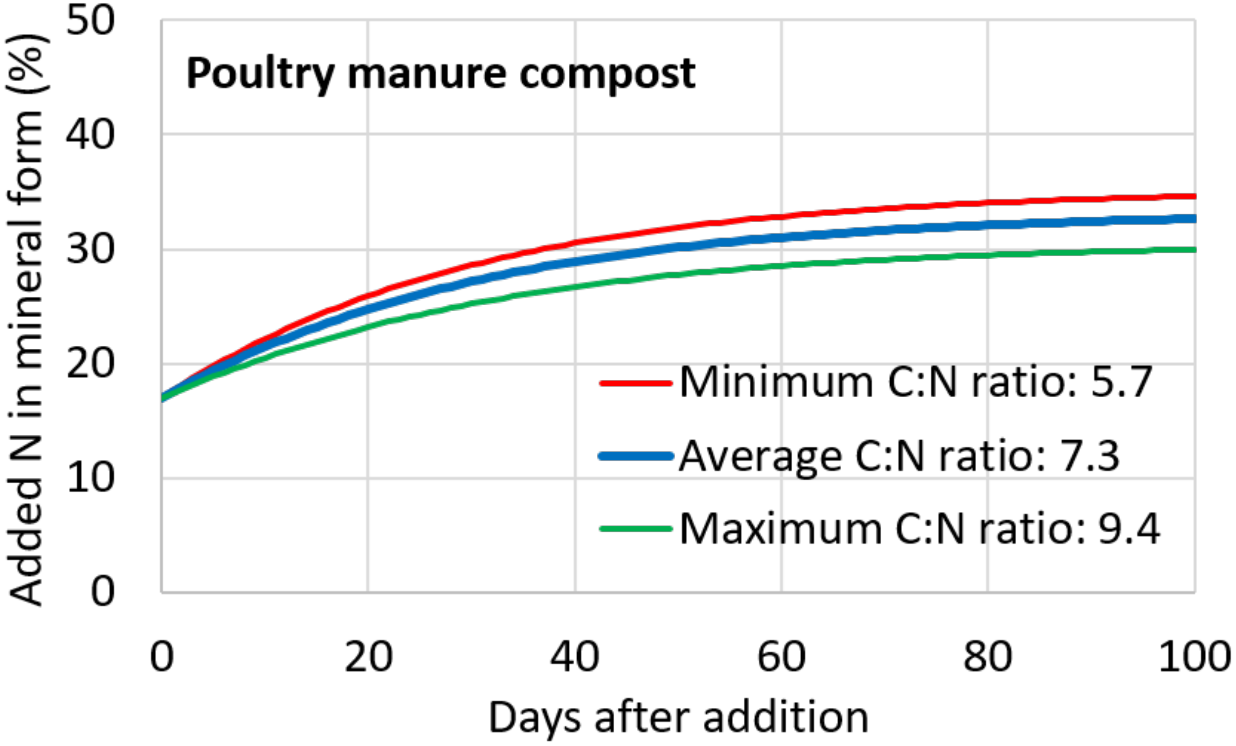
Guano and feather meal



Geisseler et al., 2021

Poultry manure and poultry manure compost





Geisseler et al., 2021

Online Tools

English: http://geisseler.ucdavis.edu/Amendment_Calculator.html
Spanish: http://geisseler.ucdavis.edu/Calculadora_N_Abonos.html

To be integrated with CropManage!

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Geisseler Lab

Nutrient Management

Nitrogen Mineralization from Organic Amendments

The calculations in this tool are based on an analysis of 113 datasets from the scientific literature. Nitrogen mineralization rates are adjusted based on soil temperature data from local CIMIS weather stations. Soil moisture is assumed to be optimal near field capacity. **When amendments are incorporated into dry soil, N mineralization would be slower than calculated. The tool should not be used when amendments are left on the soil surface.**
Information on lines marked with an * needs to be provided. If no information on amendment and soil properties are entered, the tool will use average values. In this case, however, the calculations will be less accurate for a specific situation.

Mineralización del nitrógeno a partir de abonos orgánicos

Los cálculos de esta herramienta se basan en un análisis de 113 conjuntos de datos de la literatura científica. Las tasas de mineralización del nitrógeno (N) se ajustan en función de los datos de temperatura del suelo procedentes de las estaciones meteorológicas locales del CIMIS. Se supone que la humedad del suelo es óptima cerca de la capacidad del campo. Cuando las abonos se incorporan al suelo seco, la mineralización del N será más lenta de lo calculado. La herramienta no debe utilizarse cuando se dejan abonos en la superficie del suelo.
Es necesario proporcionar información sobre las líneas marcadas con un *. Si no se introduce información sobre los abonos y las propiedades del suelo, la herramienta utilizará valores medios. En este caso, sin embargo, los cálculos serán menos precisos para una situación concreta.

The online tool Input

Amendment Application

Region*:	Sacramento Valley - Yolo	
Type of amendment*:	Feather meal	
Application rate*:	1	tons/ac
Application date*:	04 / 01 / 2021	
Period of interest:	6 Months	
Depth of incorporation*:	8	inches

* Required input.

Amendment Properties

Amendment dry matter:	95	%
Total nitrogen:	14.5	% in dry matter
Carbon to nitrogen ratio:	4	
Mineral nitrogen: (ammonium and nitrate)	0.06	% in dry matter

Soil Properties

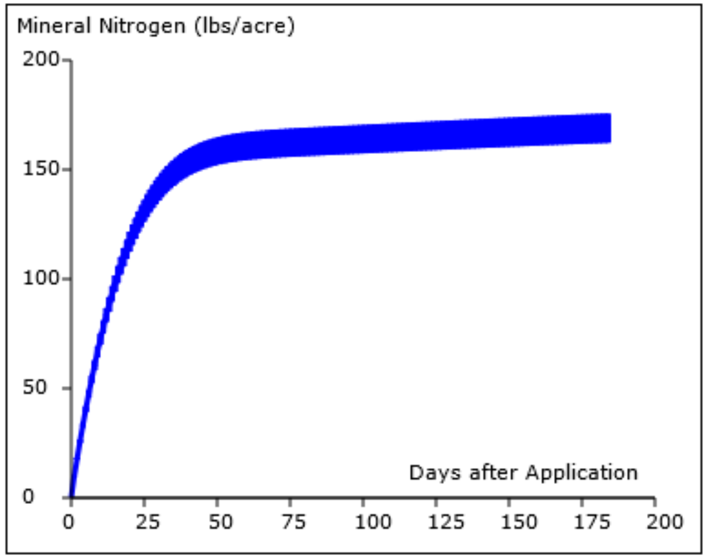
Soil organic matter:	3	%
Residual soil nitrate:	10	ppm Nitrate-N

Display Results/Changes

The online tool

Output: Feather meal, Sacramento Valley

Nitrogen Mineralization

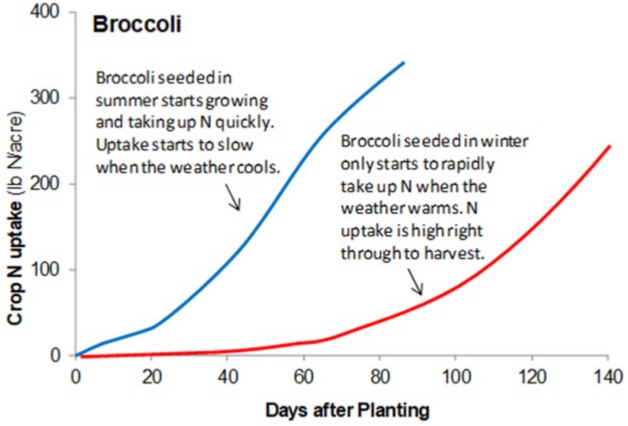


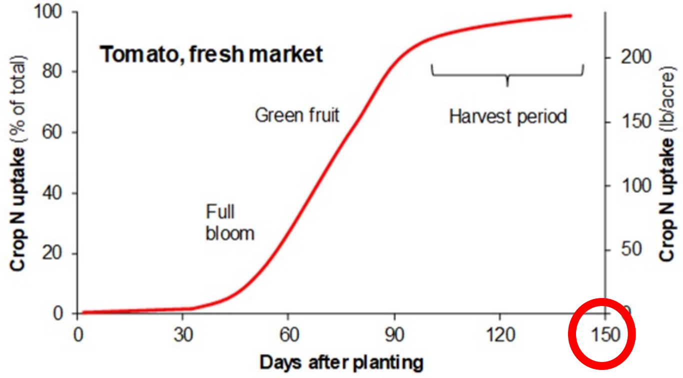
The graph and the calculations are based on average values from scientific studies. Weather conditions, soil properties, amendment characteristics and management all can affect N mineralization rates. It is therefore **important to monitor N availability of the field with soil or leaf analyses**. More information about soil and leaf sampling can be found here.

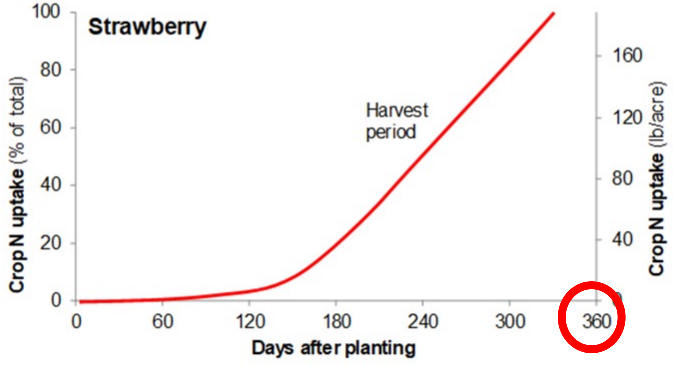
Total N applied:	276 lb/ac
Total mineral N applied:	1.3 lb/ac
Estimated available N:	162 - 176 lb/ac
Percent available:	59 - 64 %

Next Steps

- What is N release pattern of cover crops?
- How can we synchronize (= match) N supply from multiple organic fertilizers with the crop N demand?





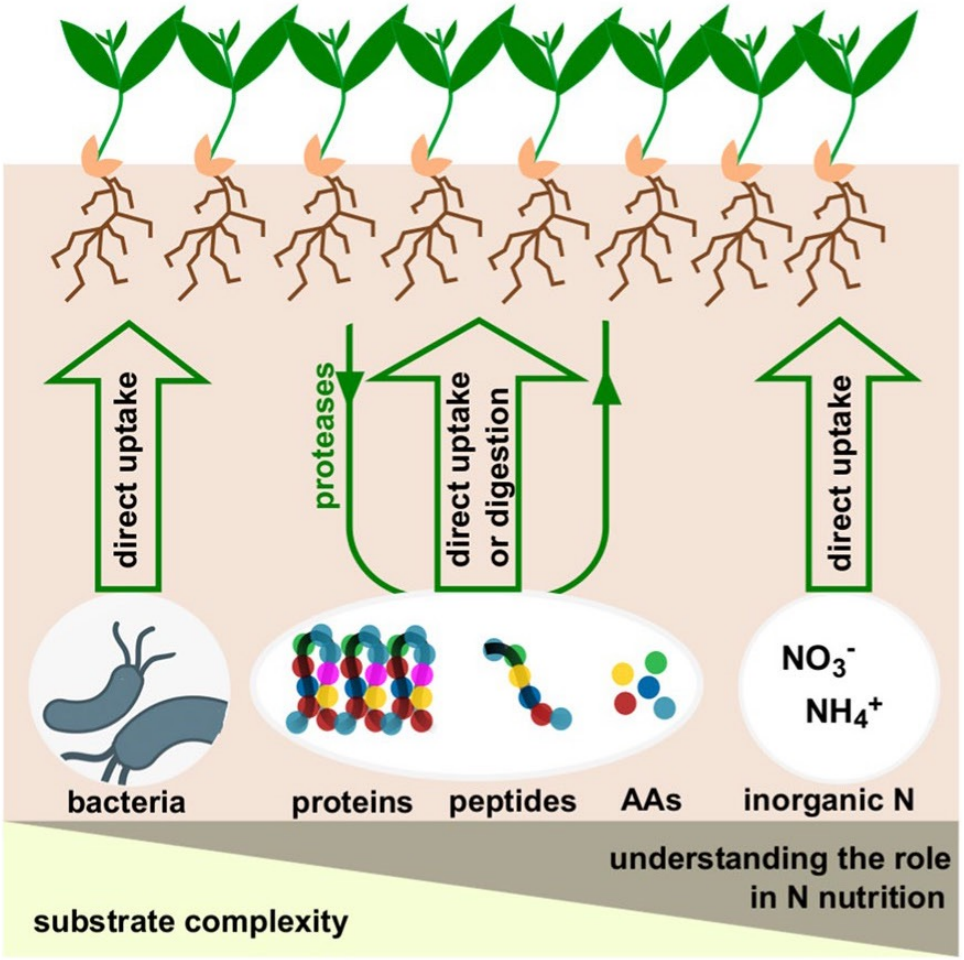


Resources

- Crop Nitrogen Uptake and Partitioning by D. Geisseler and W.R. Horwath
  http://geisseler.ucdavis.edu/Guidelines/N_Uptake.html

- Estimating Nitrogen Availability in Organic Annual Production:
  For Nitrogen Budgeting and Other Purposes. UCANR publication 8712,
  https://anrcatalog.ucanr.edu/Details.aspx?itemNo=8712

Plants' N acquisition from any other pathways
1) Direct uptake of organic N



- Cumulative evidence shows plants can absorb small to large organic nitrogen molecules
- More common in arctic regions and boreal forests where less inorganic N is available
- Qualitative evidence only
- Contribution to overall N uptake is unknown

  (Adamczyk 2021)

Plants' N acquisition from any other pathways

2) Microbe-associated N acquisition

Mycorrhizal symbiosis increases N uptake

Arbuscular Mycorrhiza (AM)

- Present in 92% of plant families
- Extend root zone
- Protect plant from pathogens
- Protect plant from extreme environment
- Assist communication between plants

- On California farms with healthy soils:
  - AM increased crop N uptake, including nitrate
  - AM can reduce nitrate leaching
  - AM can reduce nitrous oxide emissions
  - Relative N contribution rate unknown

Cavagnaro *et al.*, 2012; *Plant Soil*
Bender *et al.*, 2014; *ISME Journal*
Bowles *et al.*, 2016; *Science of the Total Envir.*
Cavagnaro *et al.*, 2015; *Trends in Ecol. and Evol.*
Lazcano *et al.*, 2014; *Soil Biology and Biochemistry*

Proc. Natl. Acad. Sci. USA
Vol. 91, pp. 11841–11843, December 1994
Plant Biology

Four hundred-million-year-old vesicular arbuscular mycorrhizae

(Endomycorrhizae/symbiosis/fossil fungi/mutualism)

WINFRIED REMY*, THOMAS N. TAYLOR†‡, HAGEN HASS*, AND HANS KERP*

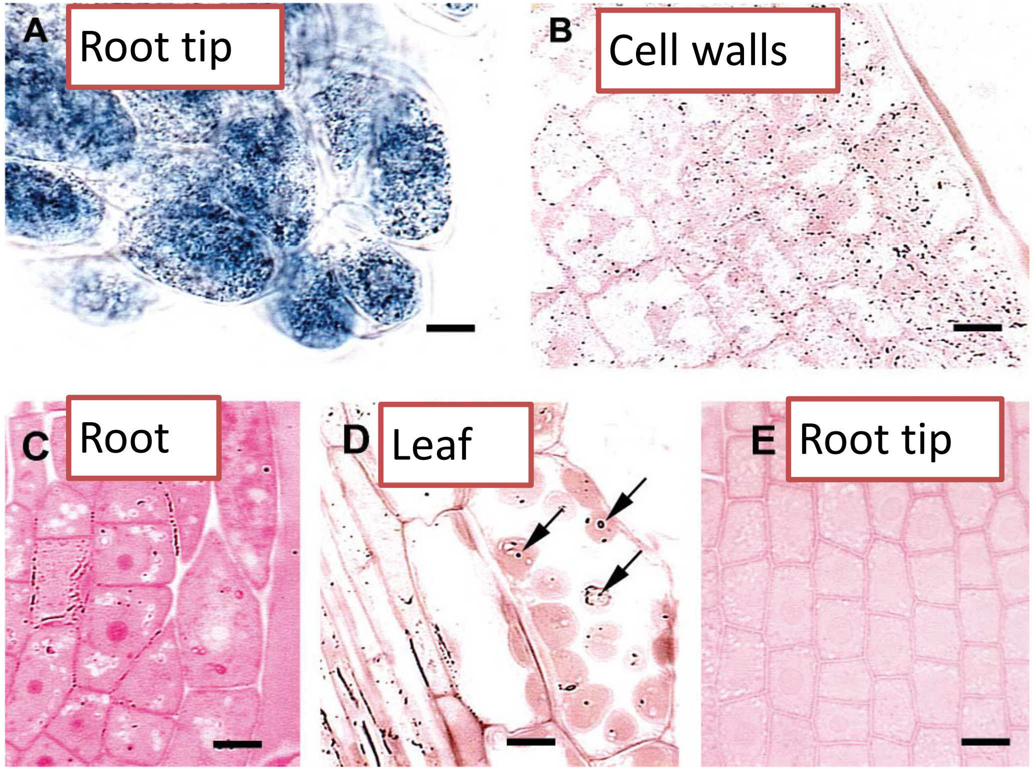
*Forschungsstelle für Paläobotanik, Westfälische Wilhelms-Universität, Münster, Germany; and †Department of Plant Biology, Ohio State University, Columbus, OH 43210

Contributed by Thomas N. Taylor, August 24, 1994

Plants' N acquisition from any other pathways

2) Microbe-associated N acquisition

N-fixation by Non-nodulating endophytic bacteria



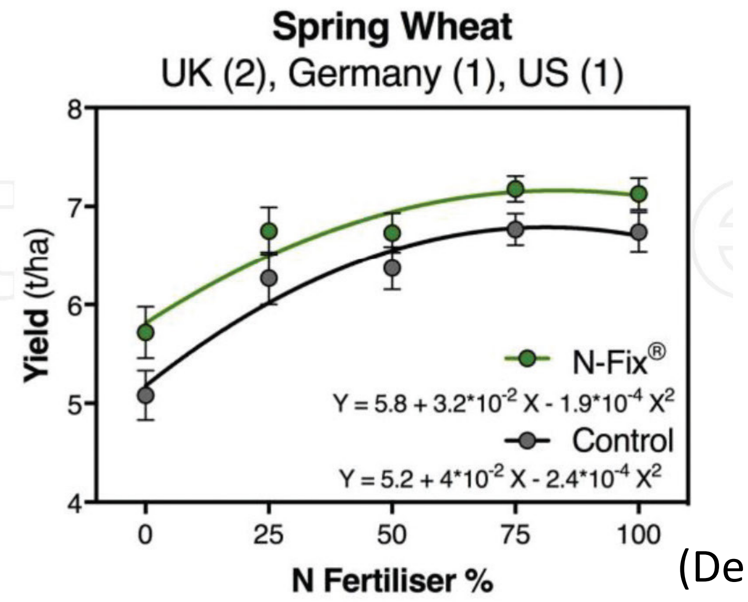
Light micrographs of **maize** inoculated with *G. diazotrophicus* (A-D) and uninoculated control (E) (Cocking et al., 2006)

- ***Gluconacetobacter diazotrophicus***
- Discovered in sugarcane stems and roots in Brazil where sugarcane had been produced with little use of nitrogen fertilizers without yield loss (Cavalvante and Dobereiner, 1988)

- Up to 80% of N in sugarcane through biological nitrogen fixation (BNF)

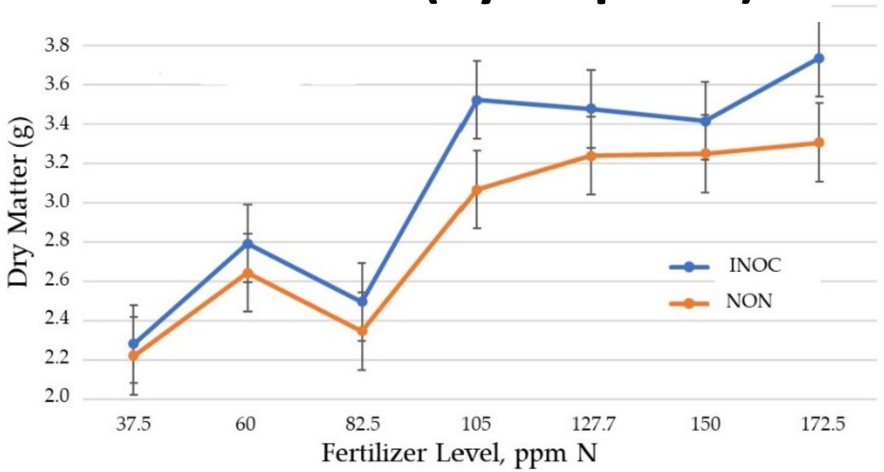
N-fixation by Non-nodulating endophytic bacteria (cont.)

- A wide range of plant species can host this bacteria: mango, beet, carrot, oil palm, radish, pineapple, forage cactus, corn, sweet potato, cassava, banana, guava, cereal and grasses, coffee, tomato, tea, lettuce
- High N in the medium does not restrict the N-fixing effect
- Inoculant commercially available: https://www.azotic.com/the-science/



(Dent, 2018)

Lettuce Shoot (hydroponic)



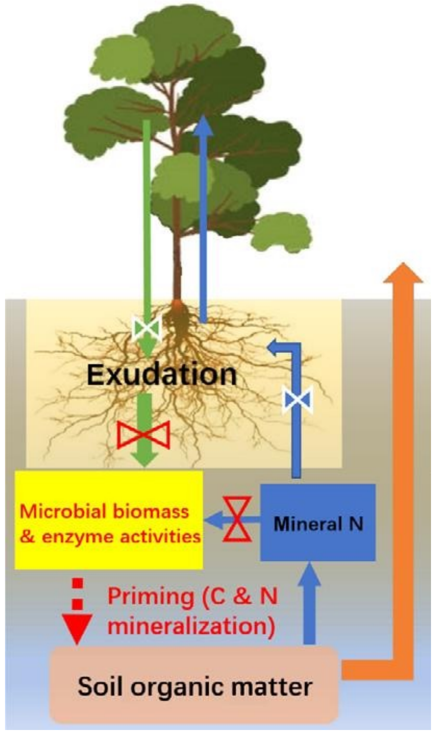
(Sebring et al., 2022)

Other factors affecting N availability in the soil

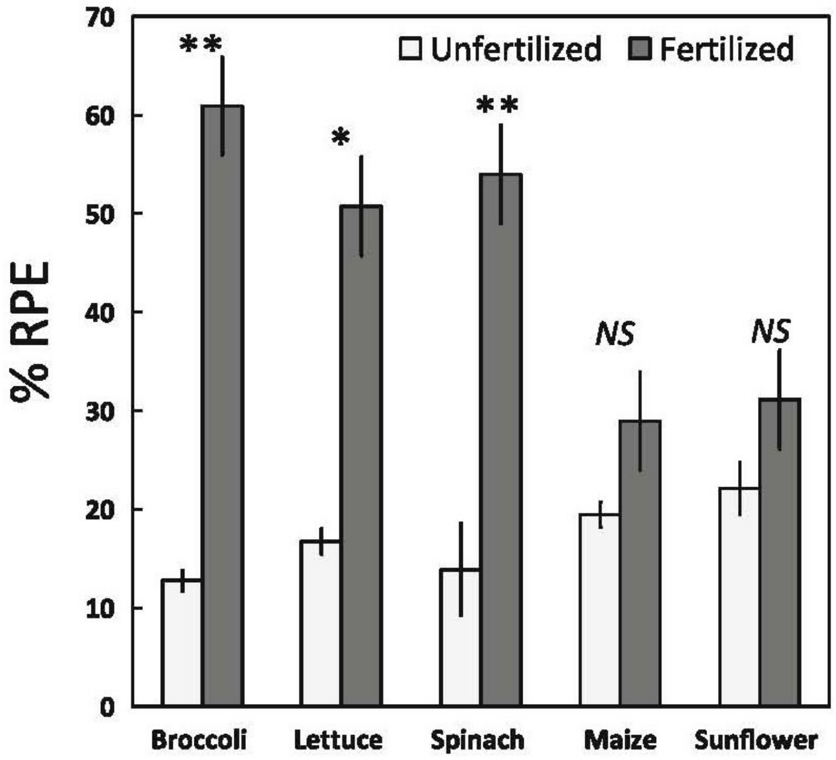
1) Effect of plant root exudates on N acquisition

Rhizosphere Priming Effect (RPE)

- Plants release <40% of photosynthesized carbon from roots as exudates
- The stimulation or suppression of soil organic matter (SOM) decomposition by live roots and associated rhizosphere organisms when compared to SOM decomposition from rootless soils under the same environmental conditions (Cheng et al., 2013)



(Yin et al., 2018)



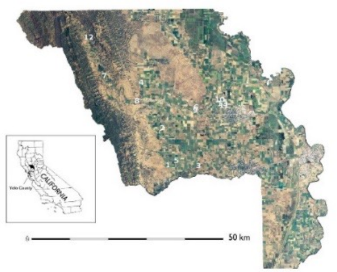
Rhizosphere priming effect (% RPE) on N of each crop by fertilization treatment. Bars are 1 SEM.

(Vargas et al., 2020, Plant and Soil)

Other factors affecting N availability in the soil

2) ***Tightly-coupled Plant-Soil N cycling*** ***(Bowles et al., 2015 Plos One)***

- Surveyed 13 organic Roma-type tomato fields on similar soil types in Yolo Co., California
- Found 3 patters of N cycling



	Mean soil nitrate (0-6 in, mg NO_3^--N/kg soil)			Plant nitrogen (%) @ flowering	Yield (US tons/acre)
Field group #	Transplant	Flowering	Harvest		
1	5.8	0.2	4.0	1.7	20.2
2	6.7	16.4	6.2	3.3	41.5
3	1.8	2.9	4.7	3.2	43.0

A study suggest 10-15 mg N kg^{-1} soil post-transplant as “action threshold” for organic processing tomatoes

- This “tightly-coupled plant-soil N cycling” was supported by rapid soil microbial N flow without accumulating a large soil inorganic N pool
- These fields had the highest total and labile soil C and N and received organic inputs with a range of N availability

2) Tightly-coupled Plant-Soil N cycling (cont.)

“Amazing thing is that these growers developed these (tightly-coupled plant-soil N cycling) systems from experiences”

Louise Jackson

A role of agricultural scientists: Learn from pioneer organic growers, document it, discover the principles, and share with others

This is especially important in developing sustainable organic management practices since many organic practices are grassroot practices developed by organic growers on their farms with particular biotic and abiotic conditions

2) Tightly-coupled Plant-Soil N cycling (cont.)

Plant and Soil 110, 9–17 (1988)

PLSO 7573

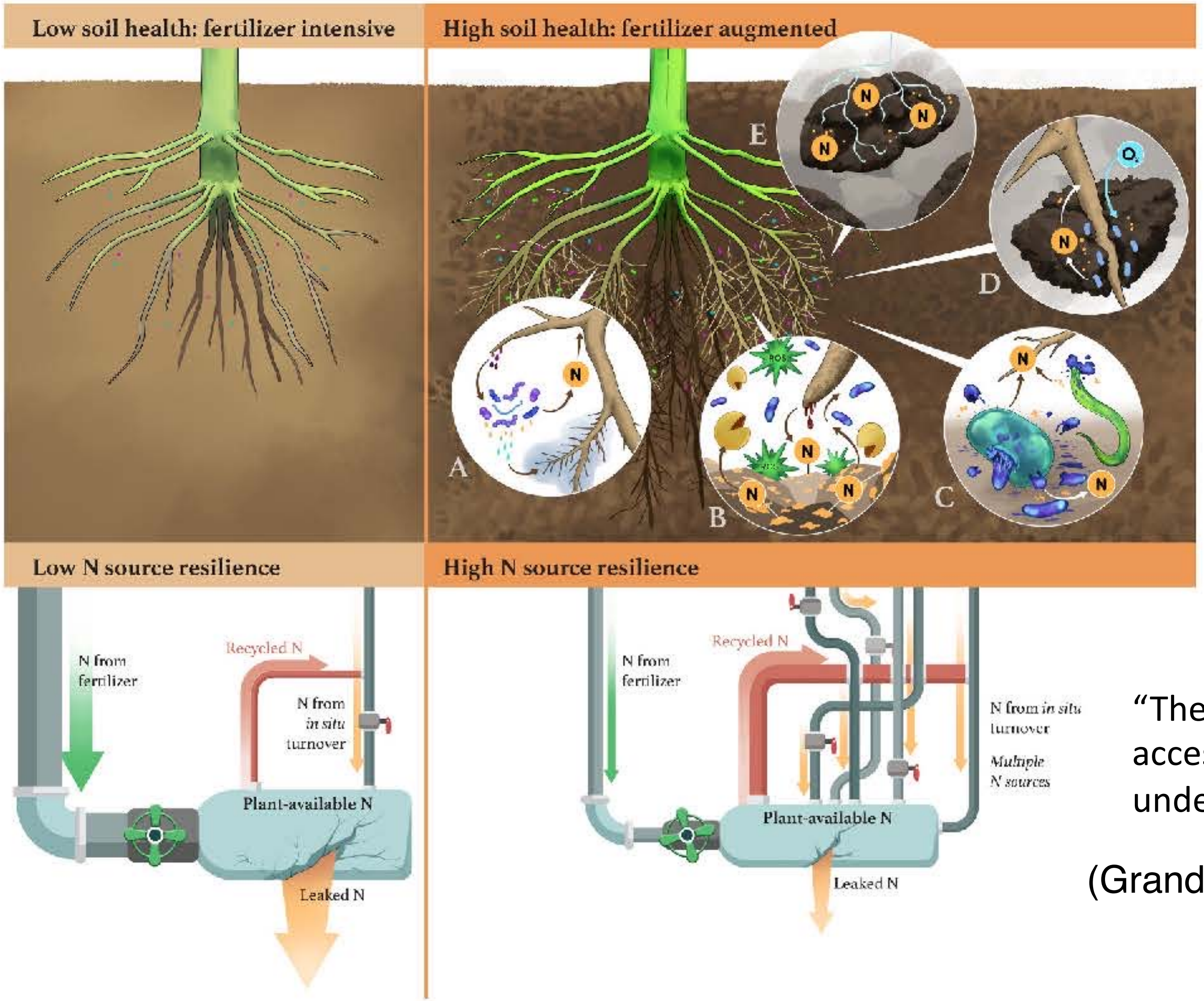
Plant and soil nitrogen dynamics in California annual grassland

L. E. JACKSON,* R. B. STRAUSS, M. K. FIRESTONE and J. W. BARTOLOME[1]
Department of Plant and Soil Biology, University of California, Berkeley, CA 94720, USA. [1]Department of Forestry and Resource Management, University of California, Berkeley, CA 94720, USA

Abstract

Seasonal changes in soil water and nitrogen availability were related to the phenology and growth of plants in California annual grassland. Plant accumulation of nitrogen was mainly confined to two short periods of the year: fall and early spring. At these times, plants were in the vegetative growth phase, roots were growing rapidly and soil moisture was high. During these periods, soil nitrate was low or depleted. High flux of nitrogen in this ecosystem, however, is indicated by the rapid disappearance of the previous year's detrital material, high microbial biomass, and high mineralizable nitrogen and nitrification potential.

3) Effect of soil health on soil N availability



A: Root exudates->auxin production by microbes -> fine roots development

B: Root exudates-> higher microbial activities -> mineral –associate organic N release

C: Protists, nematodes -> feed on microbes -> release N

D: Fine roots grow into aggregates and open microsites ->access available N

E: Mycorrhizae penetrate aggregates -> access occluded pockets of N

“The multiple pathways for plants to access N provide more resilient N supply under variable conditions”

(Grandy et al., 2022 Soil Biol. Biochem.)

Thank you!
Question?

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