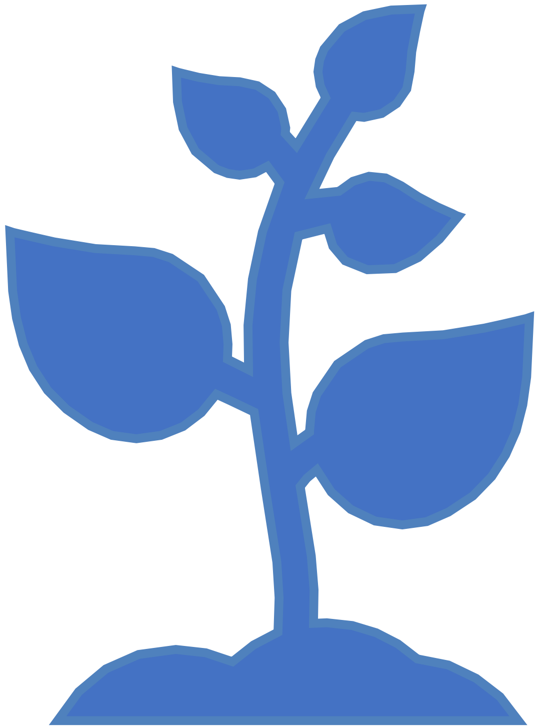


Frontiers in Nitrogen Supply from Soil to Plants

Joji Muramoto Ph.D.

Assistant CE Organic Production Specialist

UCANR, CASFS

Dept. Environmental Studies

UC Santa Cruz

N Forms in Soil and Plant Availability

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

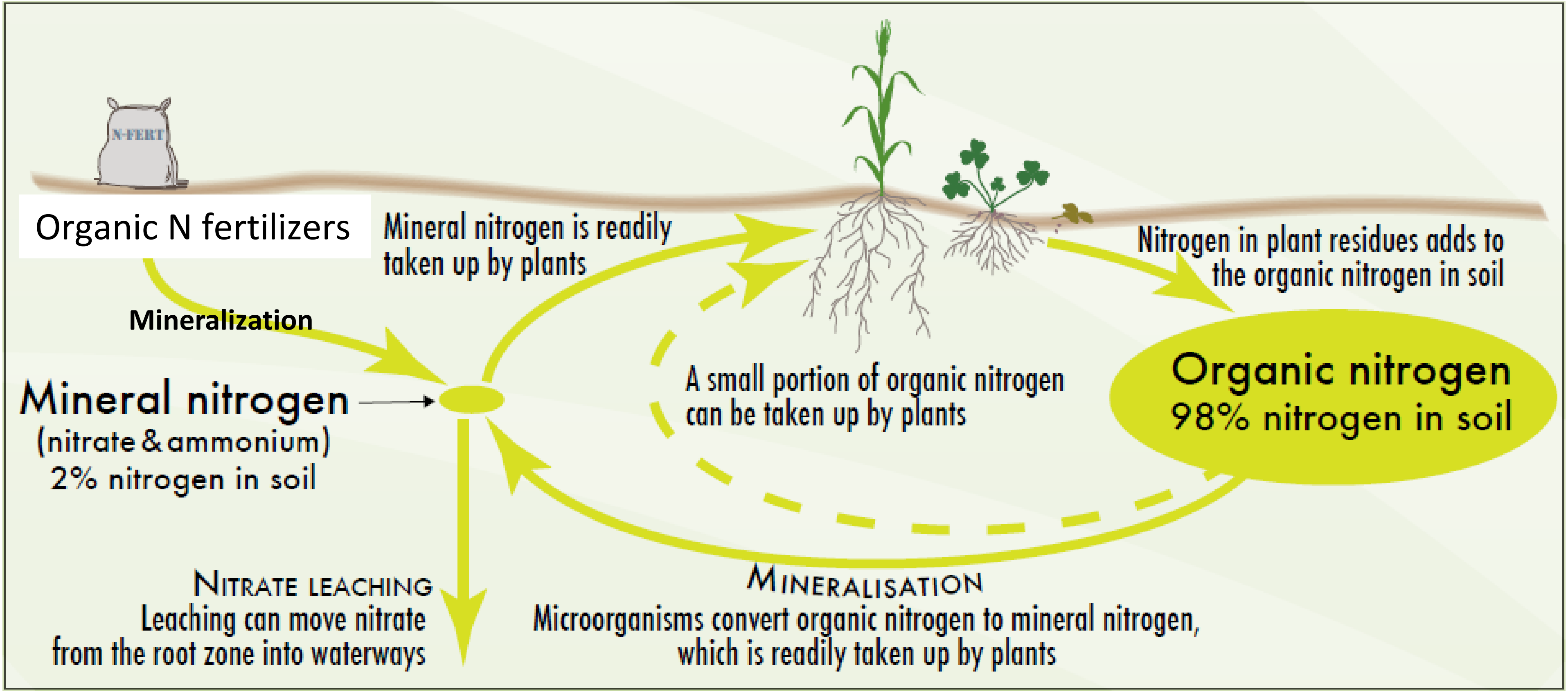
Leaching susceptive

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

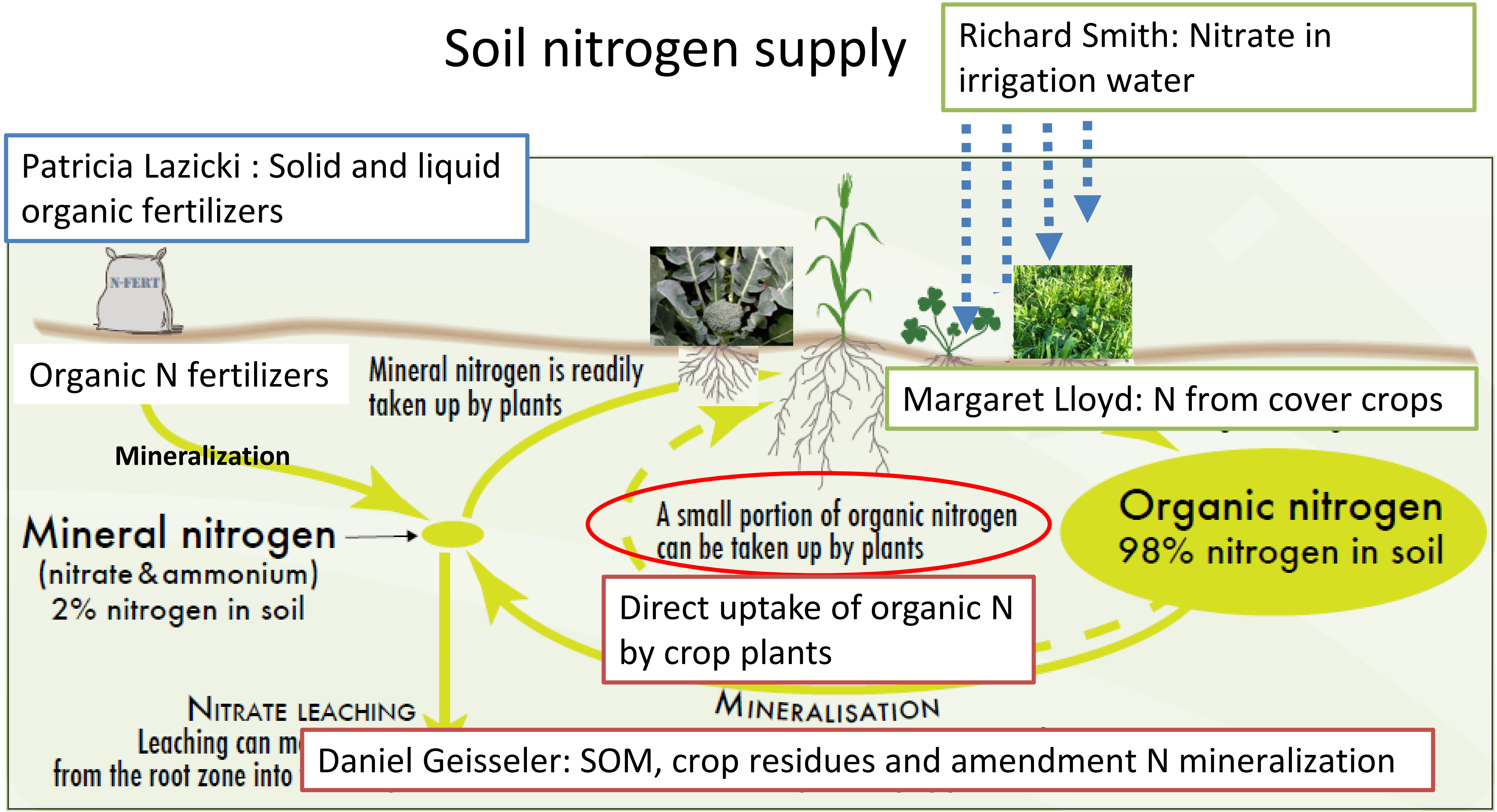
** Biological processes affected by ***environmental factors*** such as ***soil temperature. moisture, pH, oxygen content etc.***

Soil nitrogen supply



(Soil Quality Pty Ltd. 2019. http://soilquality.org.au/factsheets/soil-nitrogen-supply)

Soil nitrogen supply



PERGAMON

Soil Biology & Biochemistry 32 (2000) 1301–1310

Soil Biology & Biochemistry

www.elsevier.com/locate/soilbio

Possible direct uptake of organic nitrogen from soil by chingensai (*Brassica campestris* L.) and carrot (*Daucus carota* L.)

Shingo Matsumoto[a,*], Noriharu Ae[b], Makoto Yamagata[c]

[a]*Shimane Agricultural Experiment Station, Izumo 693-0035, Japan*
[b]*National Institute of Agro-Environmental Sciences, Tsukuba 305-8604, Japan*
[c]*Hokkaido National Agricultural Experiment Station, Memuro 082-0071, Japan*

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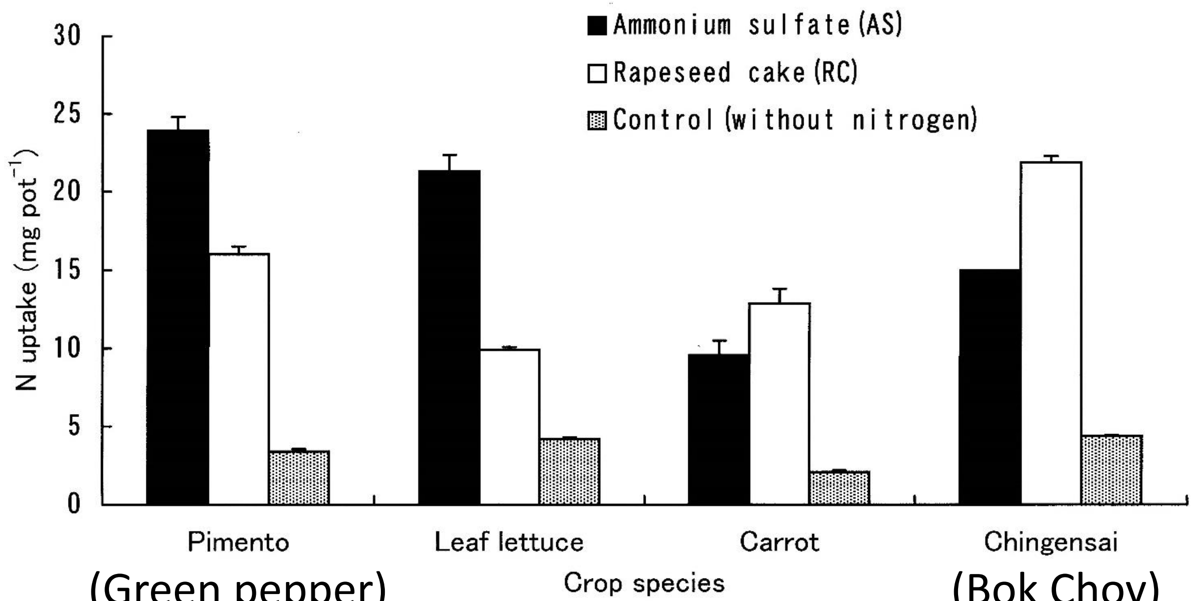


(Green pepper)

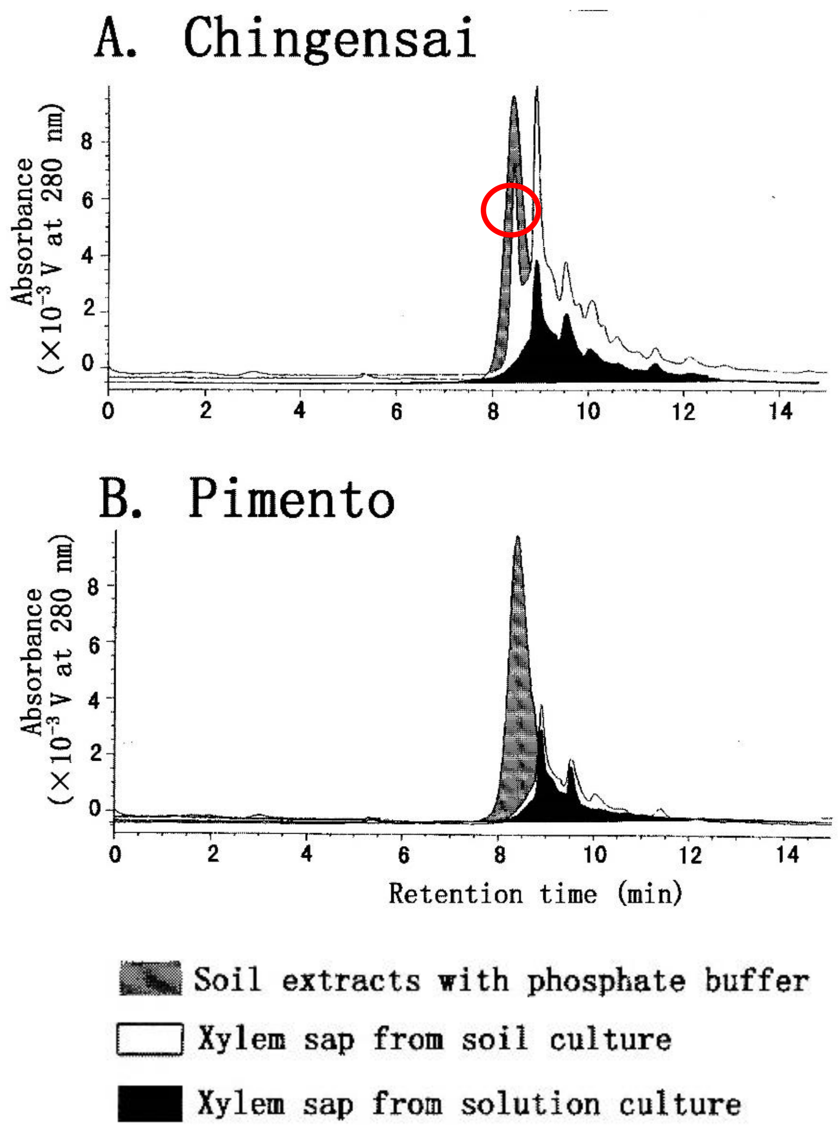
(Bok Choy)

Spinach also showed a similar trend with Chingensai (= Bok Choy)

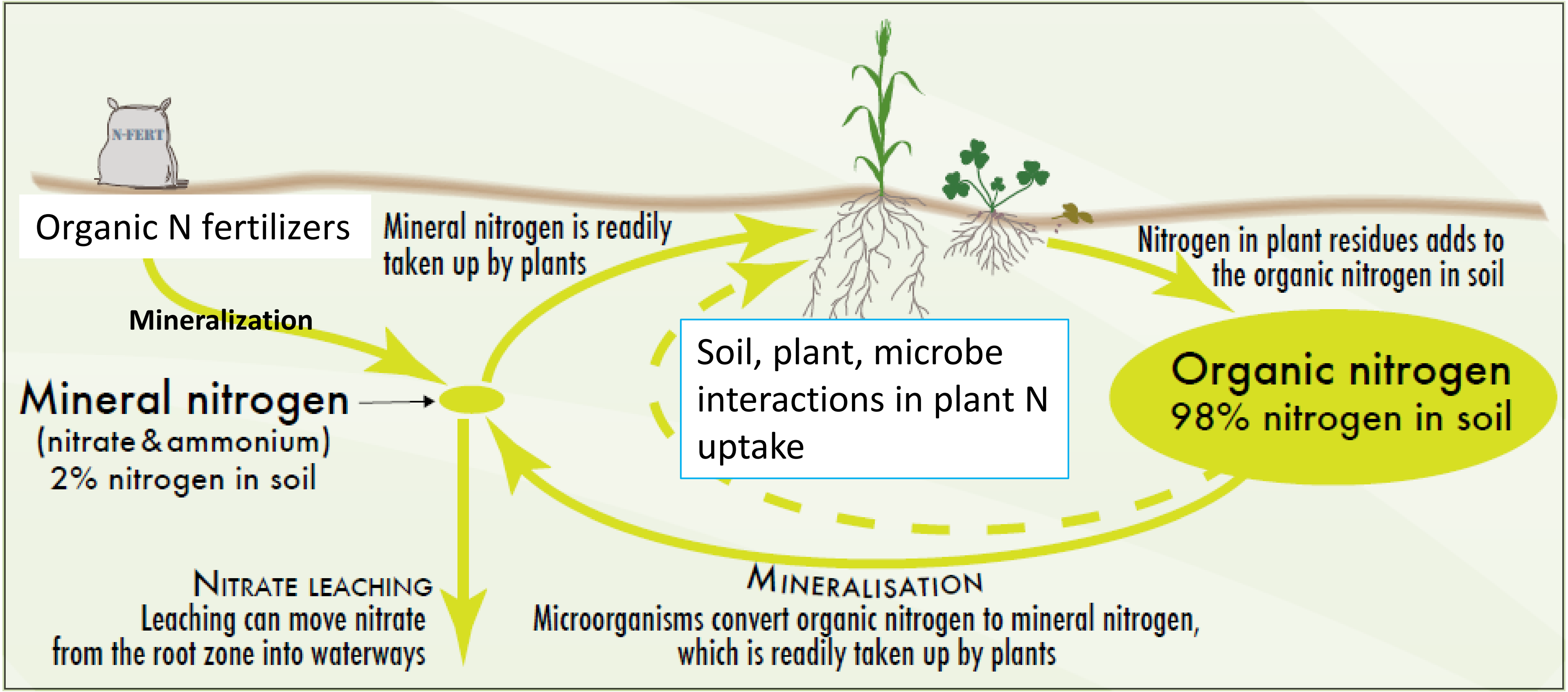
PEON: phosphate buffer-extractable organic N

- Extract with 1/15 M phosphate buffer
- MW: 8,000-9,000 Da
- Bacterial cell wall absorbed to Fe or Al in soil?
- Found in xylem sap in chingensai and spinach
- Non-mycorrhizal plants; *Amaranthaceae, Brasiccaceae*
- Qualitative evidence only
- Contribution to overall N uptake unknown

(Matsumoto et al., 2000a, 2000b)



Soil nitrogen supply



(Soil Quality Pty Ltd. 2019. http://soilquality.org.au/factsheets/soil-nitrogen-supply)

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*

Dark septate endophytic (DSE) fungus symbiosis increases N uptake in nonmycorrhizal plants

(Usuki and Narisawa, 2007 Mycologia)

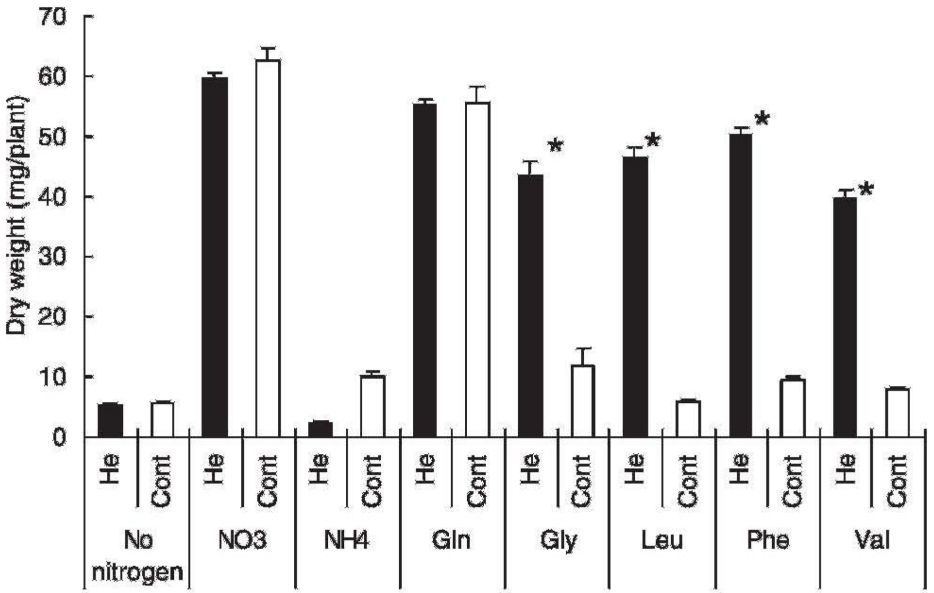
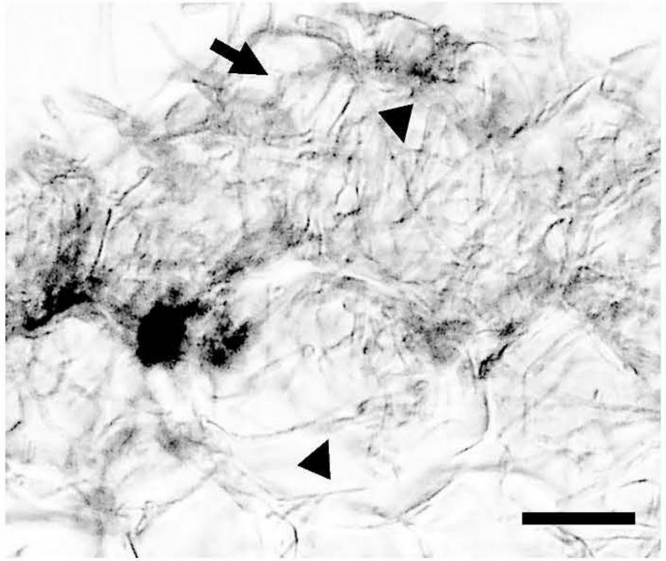


FIG. 1. Dry weights of Chinese cabbage seedlings grown on basal media amended with seven different nitrogen sources. He: *Heteroconium chaetospira* treatment, Cont: control. Data are means ± SE, $n = 5$. Asterisks represent significant differences between treatment and control ($P < 0.05$) following a Tukey's honestly significant difference test.

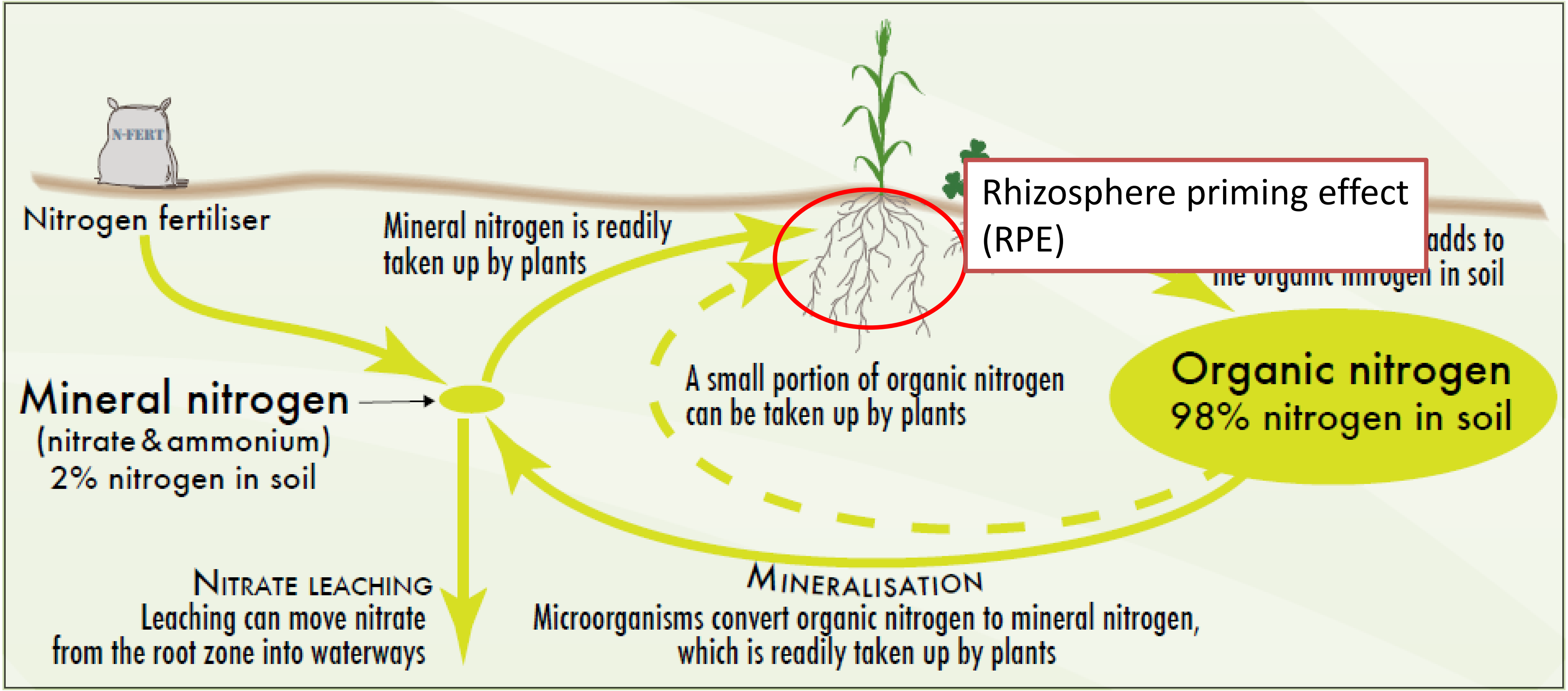
Dark septate endophytic fungus *Heteroconium chaetospira*

- Can be hosted by nonmycorrhizal and mycorrhizal plants
- Absorb organic N in soil and provide it to the host plant
- Receive C from the host-plant



Fungal hyphae in Chinese cabbage seedling roots

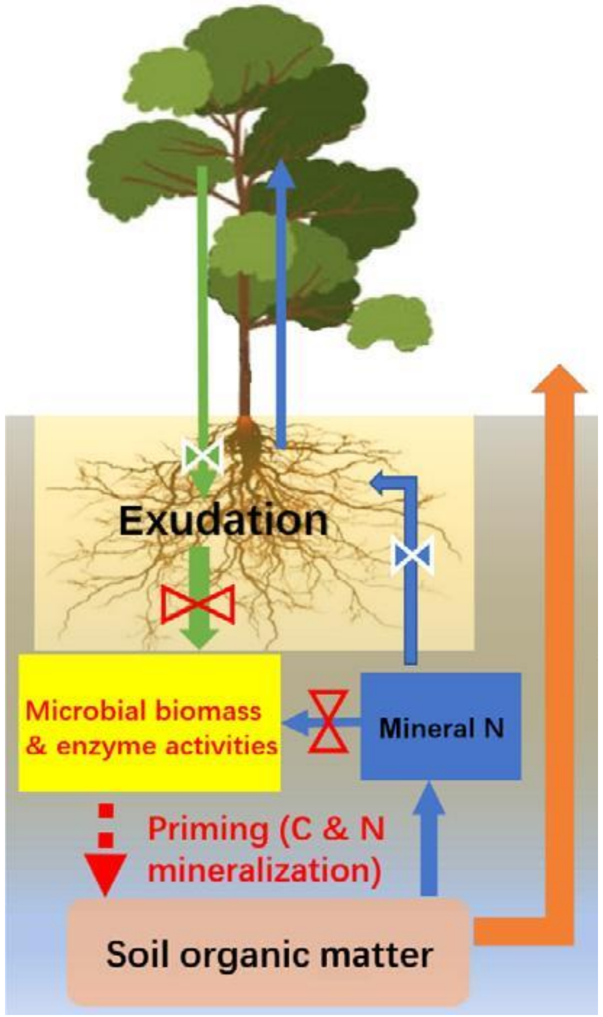
Soil nitrogen supply



(Soil Quality Pty Ltd. 2019. http://soilquality.org.au/factsheets/soil-nitrogen-supply)

Rhizosphere Priming Effect (RPE)

- Plants release significant portion 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)

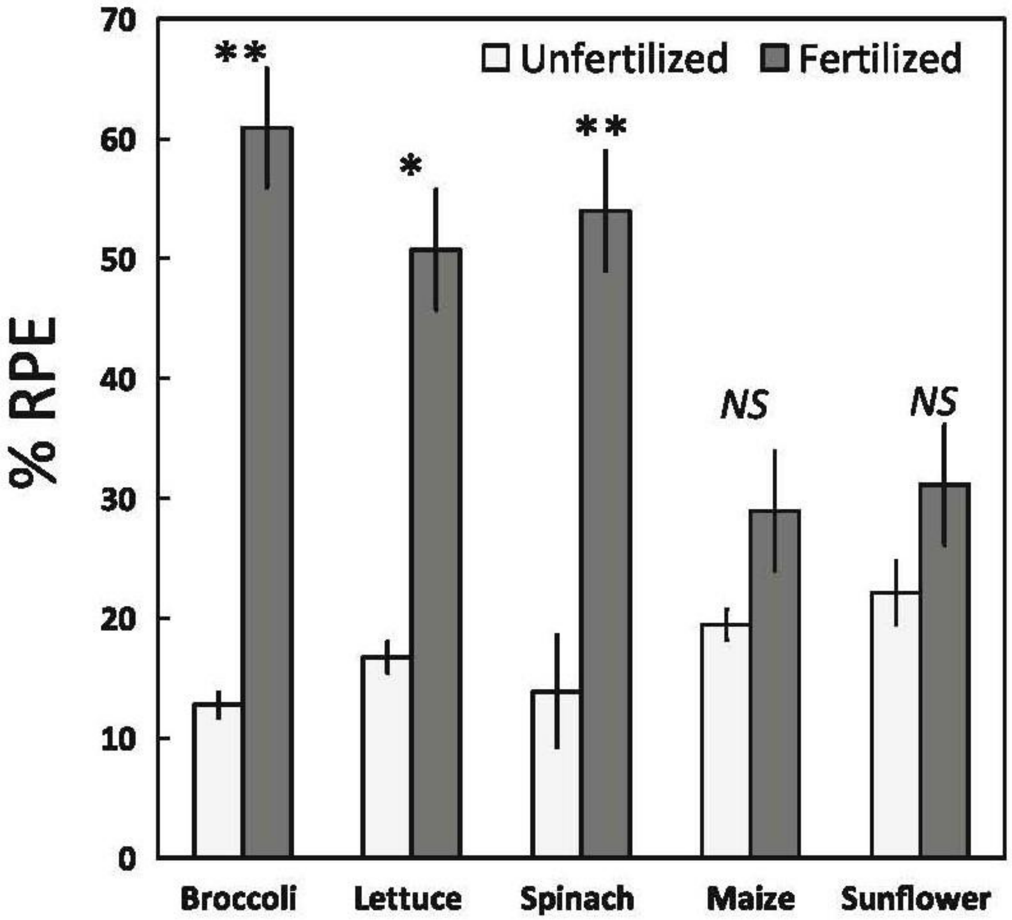
- Highly variable;
  - For C, -50% to +350%
  - For N, 36-52% (soybean and sunflower) (Zhu et al., 2014)

  depending on climate,

  plant, and soil variables
- Pot experiment only….exaggerating RPE due to the higher root density than field conditions?

- Used UCSC organic farm soil

  (20+ yrs of organic management)

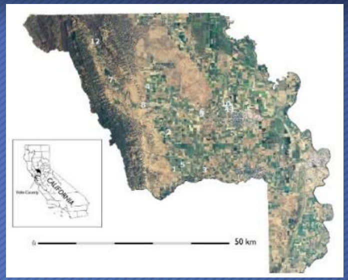


Rhizosphere priming effect (% RPE) on N of each crop by fertilization treatment. Bars are 1 SEM.

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

Organic Tomatoes in California
Tightly-coupled 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



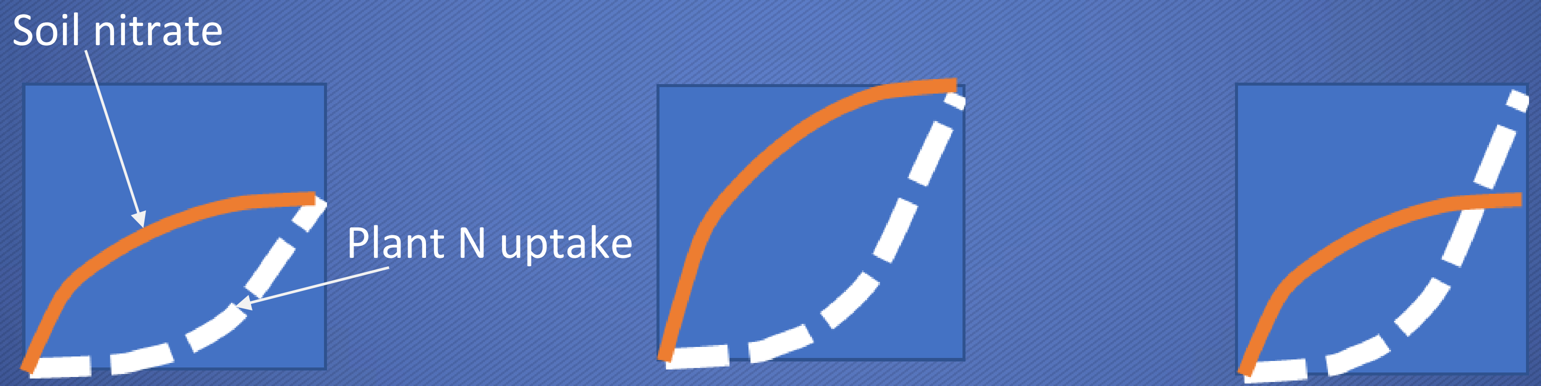
	Mean soil nitrate (0-6 in, mg NO_3^--N/kg soil)		
Field group #	**Transplant**	**Flowering**	**Harvest**
1	5.8	0.2	4.0
2	6.7	16.4	6.2
3	1.8	2.9	4.7

Plant nitrogen (%) @ flowering	Yield (US tons/acre)
1.7	20.2
3.3	41.5
3.2	43.0

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

Organic Tomatoes in California
Tightly-coupled N cycling *(Bowles et al., 2015 Plos One)*

- 3 patters of N cycling



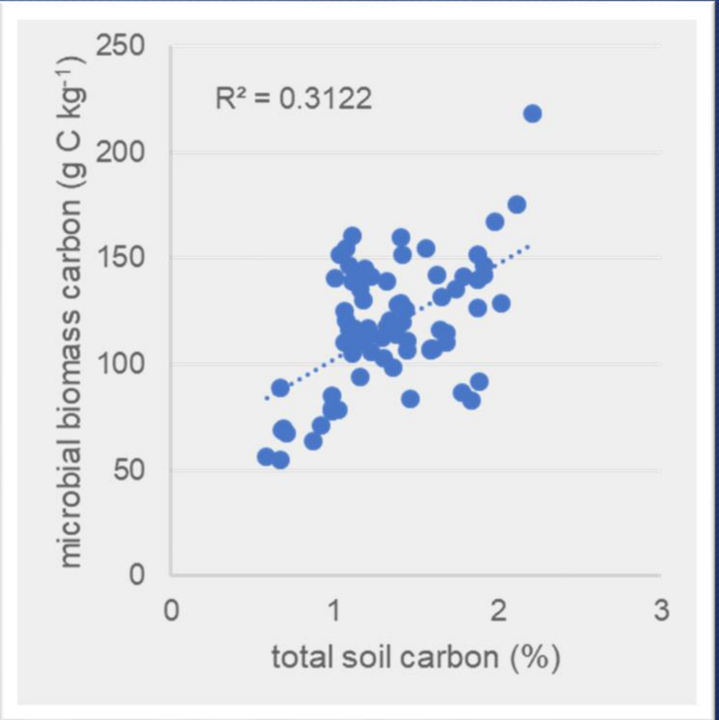
1. N deficient; *low yield, low soil nitrate pool*

2. N surplus; *high yield, high soil nitrate pool*

3. Tightly-coupled N cycling; *high yield, low soil nitrate pool*

Organic Tomatoes in California, USA
Tightly-coupled N cycling (Bowles et al., 2015 Plos One)

- Tightly-coupled N cycling farms:
  - Efficient N management, high soil microbial activity, high available soil C and rapid plant N uptake
    - The higher the SOM, the greater the biomass of microbes
    - Soil organic matter and organic amendments are ~half carbon: Energy for microbes
  - Low nitrate pool, but high nitrate flow (turn over)
    - **Soil nitrate test….a snapshot of the pool size**
    - **For flow, potentially mineralizable N (PMN)**



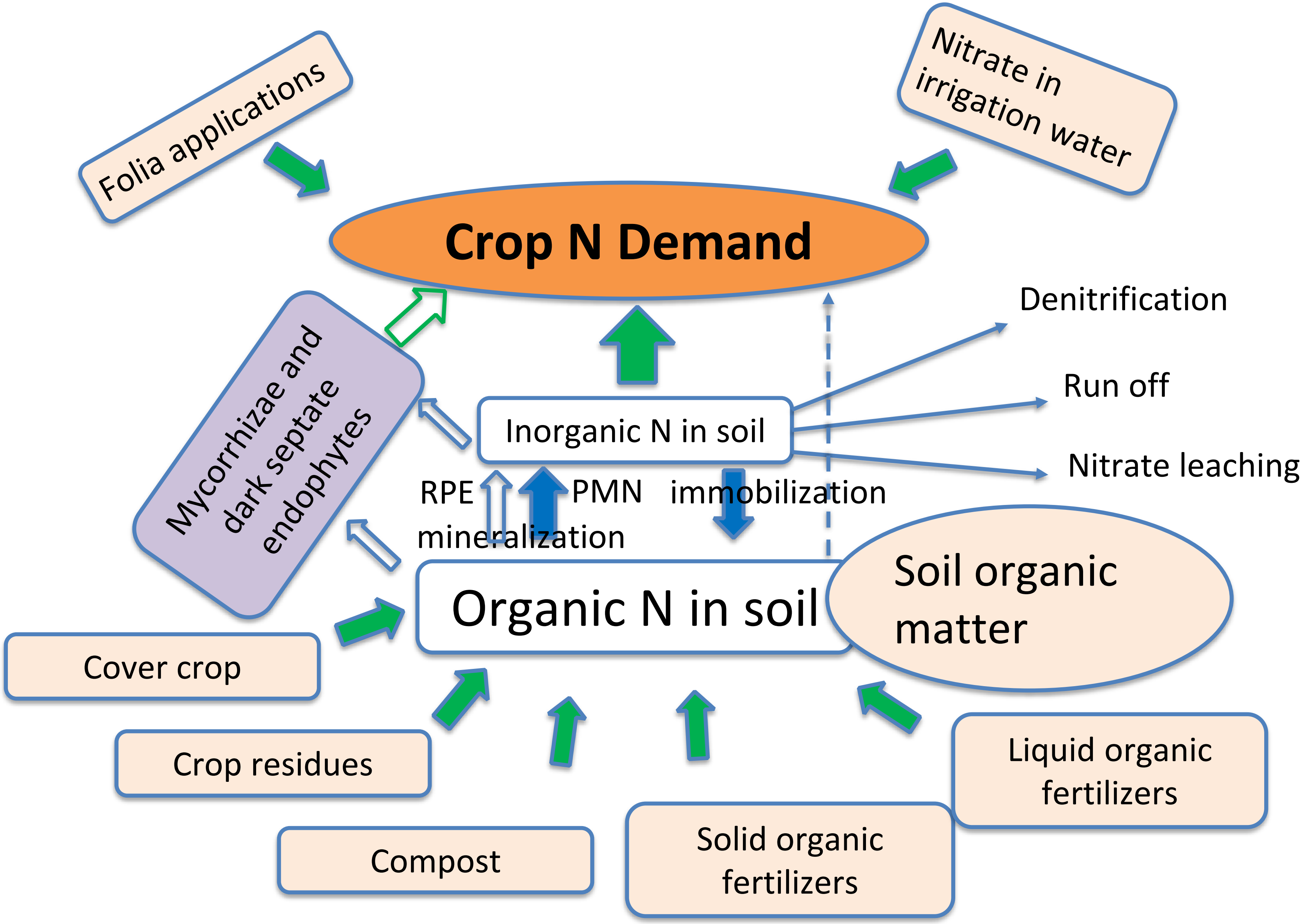
Data are from the same 13 fields. Microbial biomass measured at tomato flowering

Potentially Mineralizable N (PMN)

- A part of soil organic N that is mineralizable
  - Aerobic incubation (moist soil, 86°F, 4 weeks)
  - Anaerobic incubation (flooded soil, 99°F, 1 week)
  - Thresholds need to be developed

Alternatives (positive correlation with PMN):

- Protein N (30 min. autoclaving. Hurrisso et al., 2018)
- Soil respiration (24hr CO_2 Solvita), Water-extractable organic C, Water-extractable organic N (Bustamante & Hartz, 2016)



Potential N dynamics in organic systems