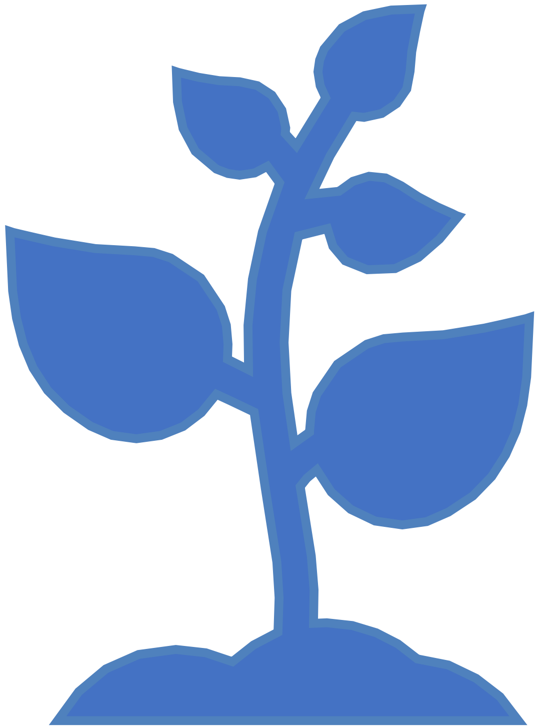

# Frontiers in Plant Nitrogen Acquisition


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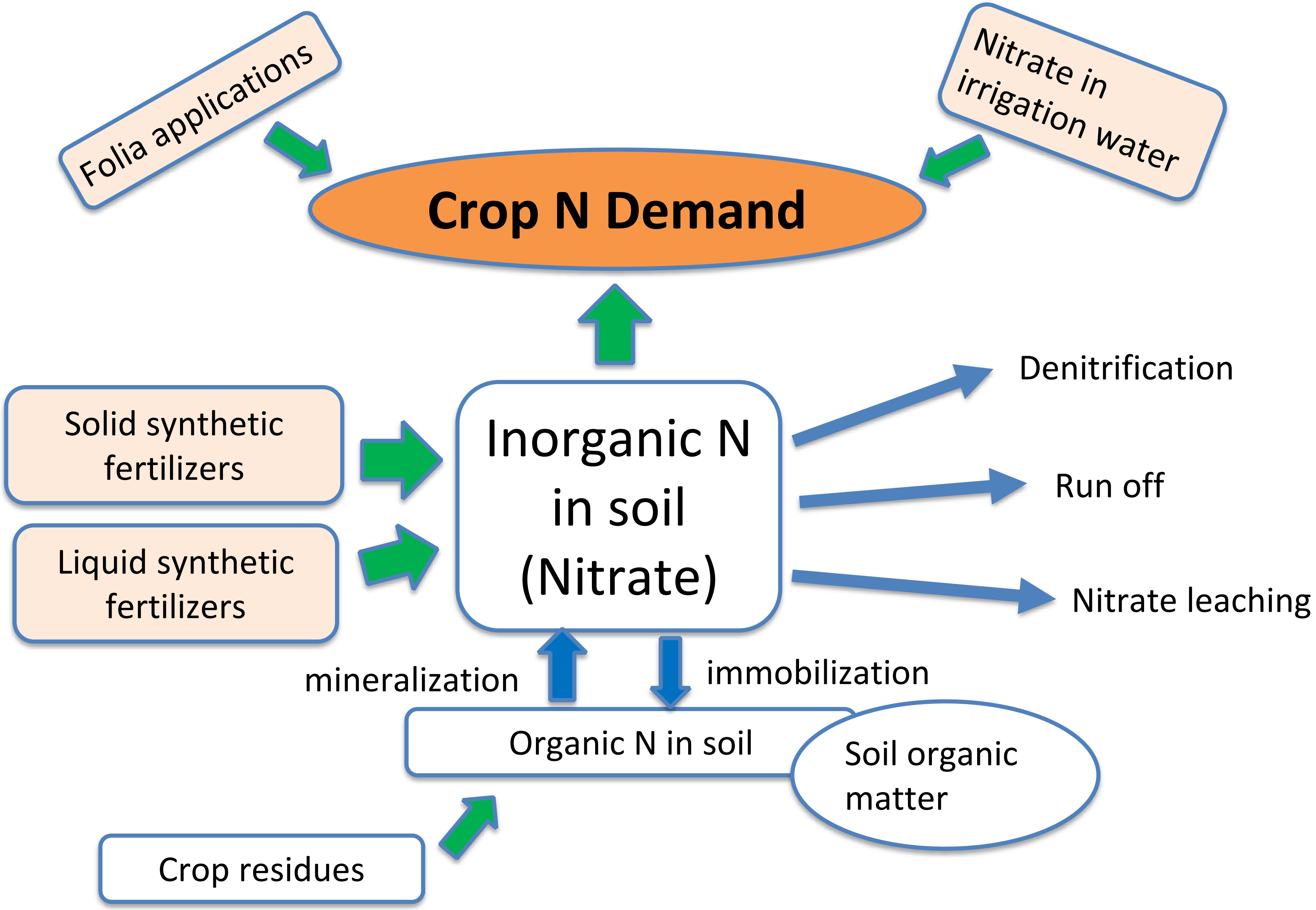
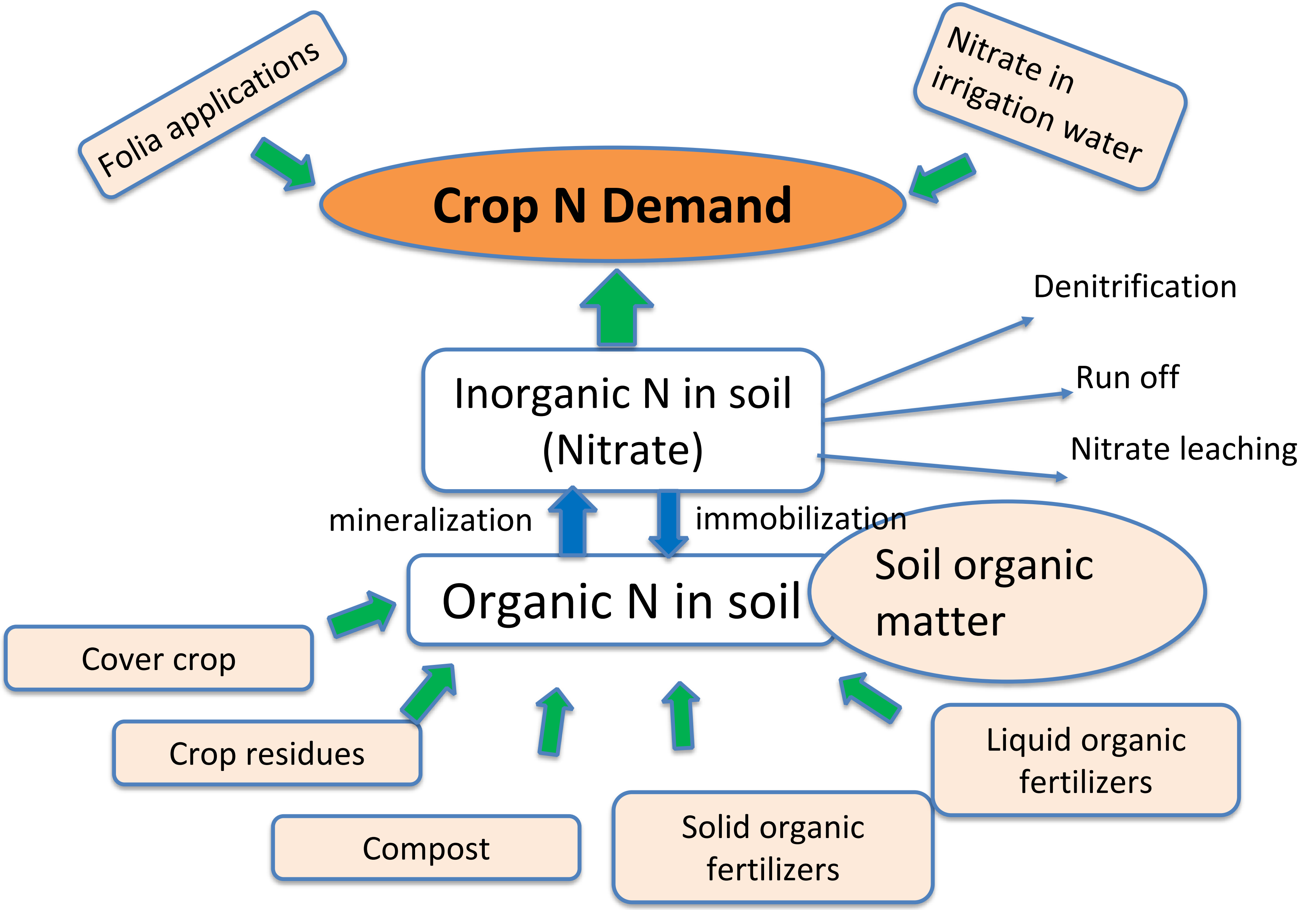
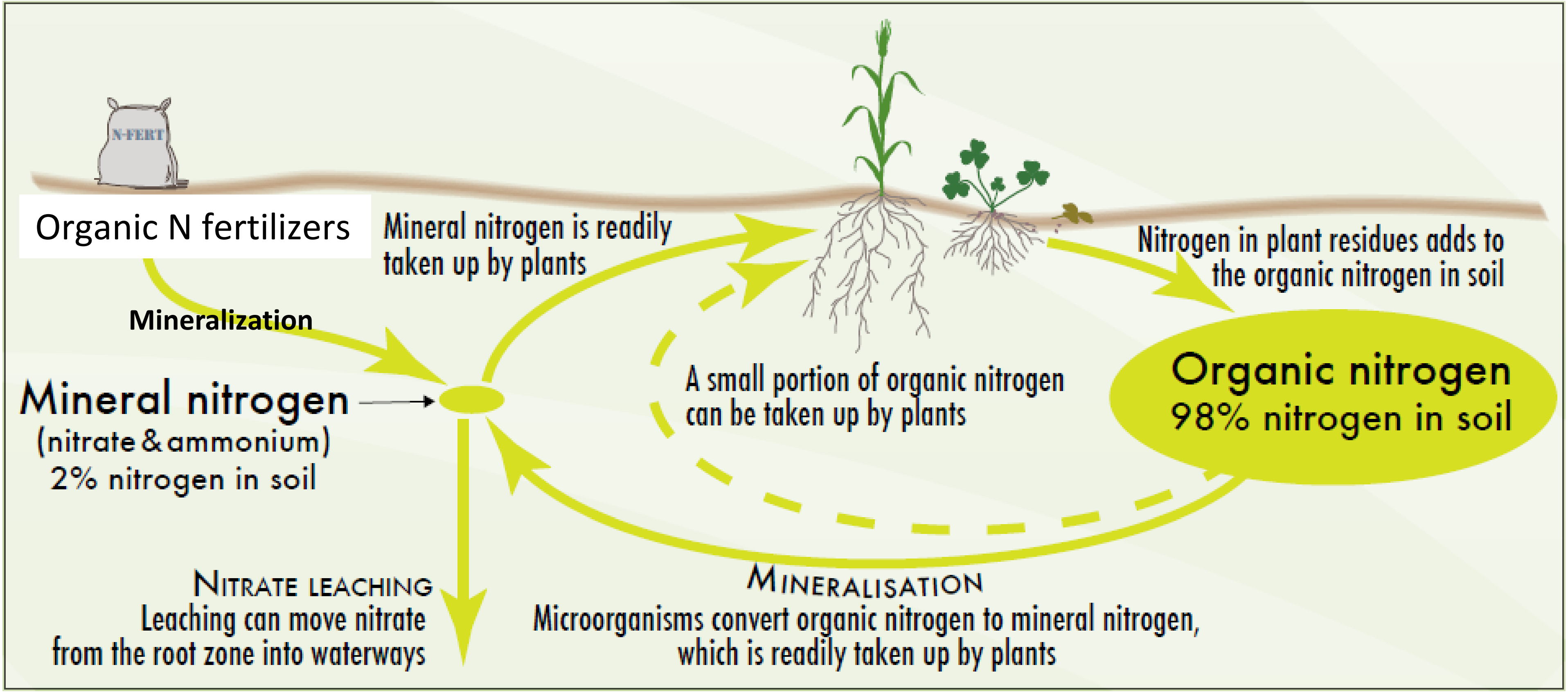



N dynamics in conventional systems



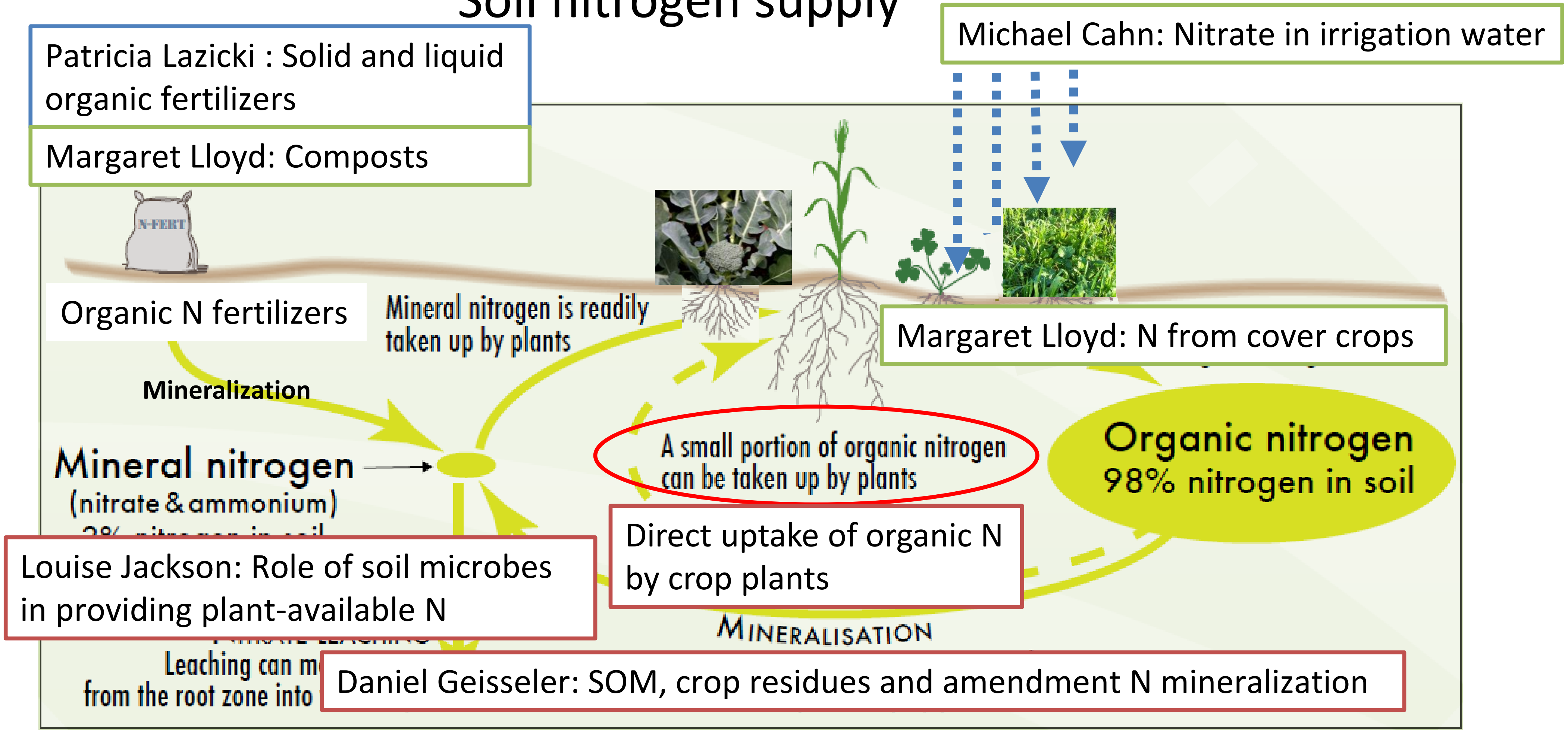

N dynamics in organic systems

# 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]

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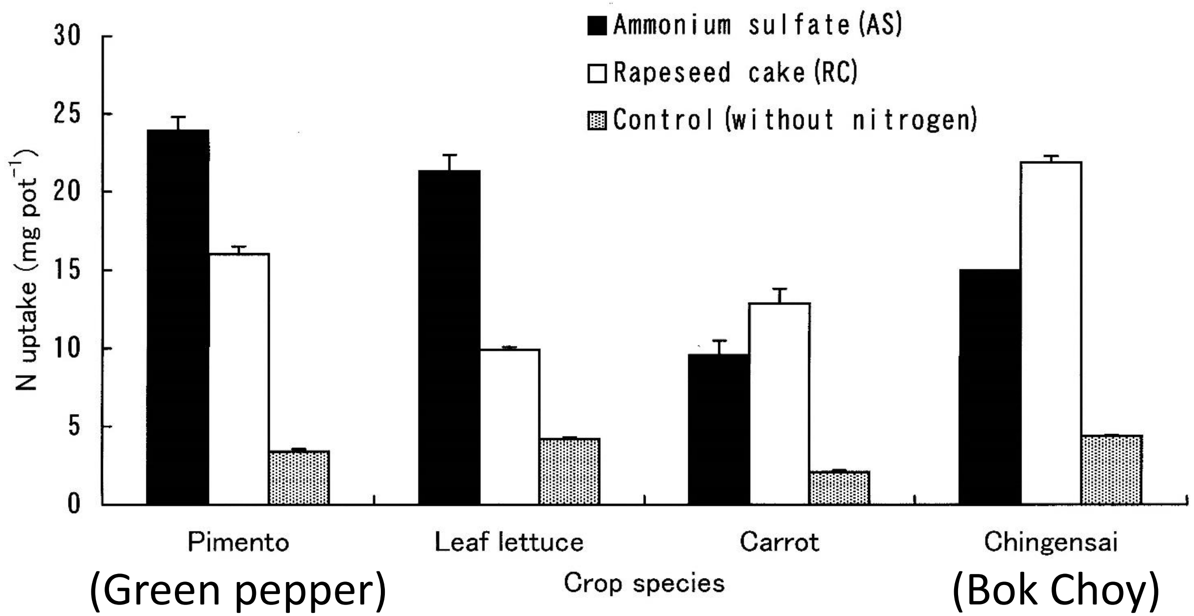
[c]*Hokkaido National Agricultural Experiment Station, Memuro 082-0071, Japan*

Received 8 April 1999; received in revised form 8 September 1999; accepted 16 February 2000




(Green pepper)

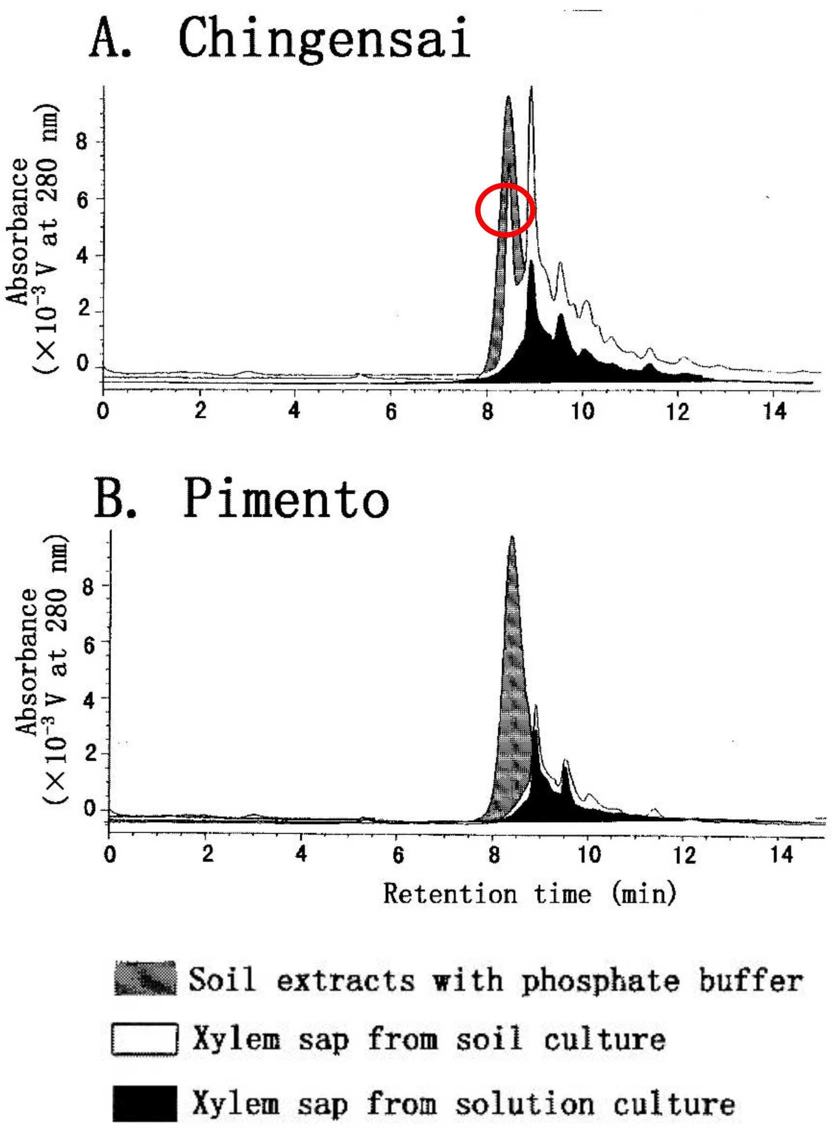
(Bok Choy)

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

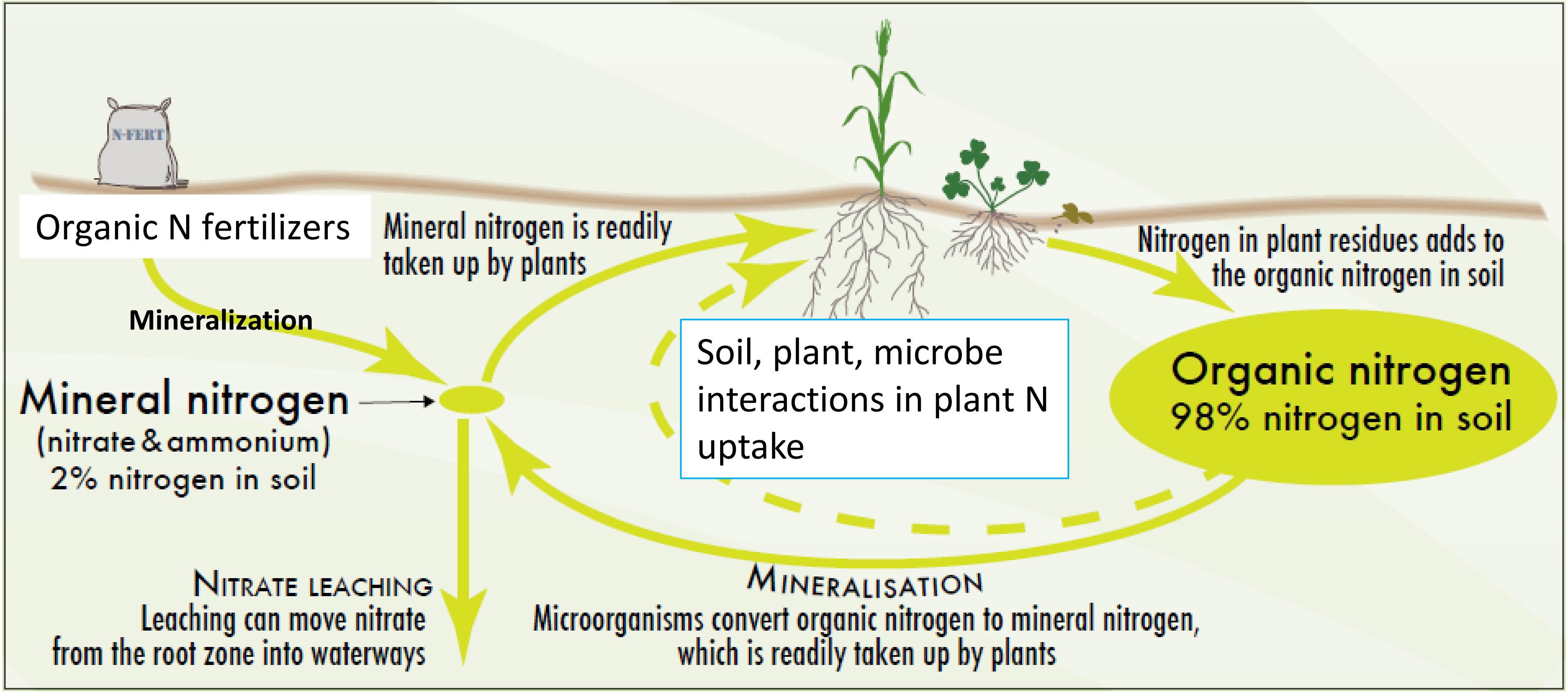
# PEON: phosphate buffer-extractable organic N

- 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

- 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*

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

*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*

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

(Usuki and Narisawa, 2007 Mycologia)

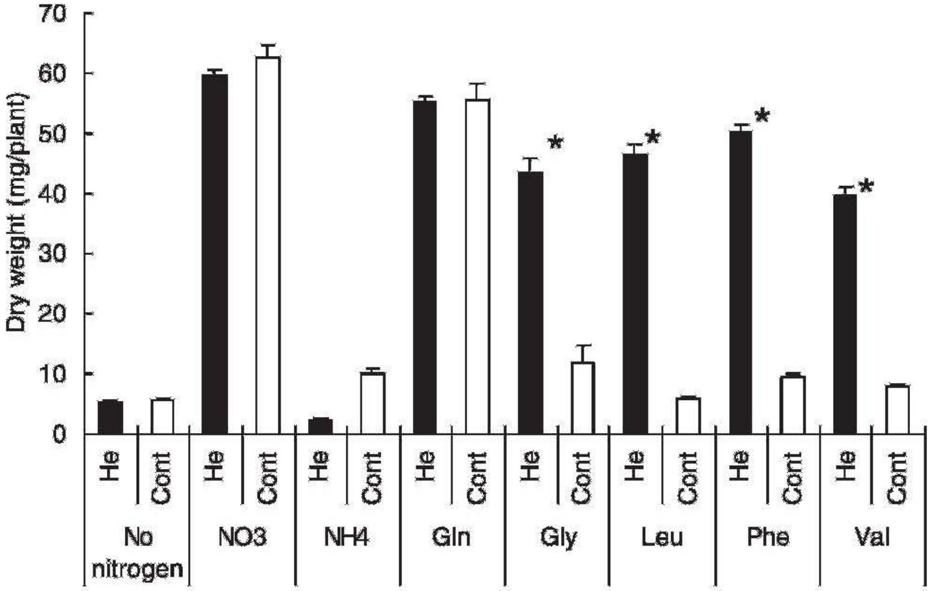
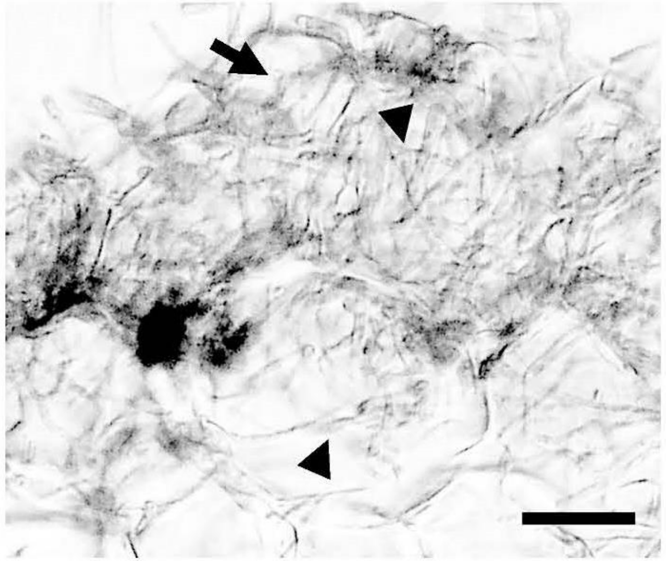



FIG. 1. Dry weights of Chinese cabbage seedlings grown on basal media amended with seven different nitrogen sources. He: *Heteroconium chaetospira* treatment, Cont: control. Data are means ± SE, $n = 5$. Asterisks represent significant differences between treatment and control ($P < 0.05$) following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

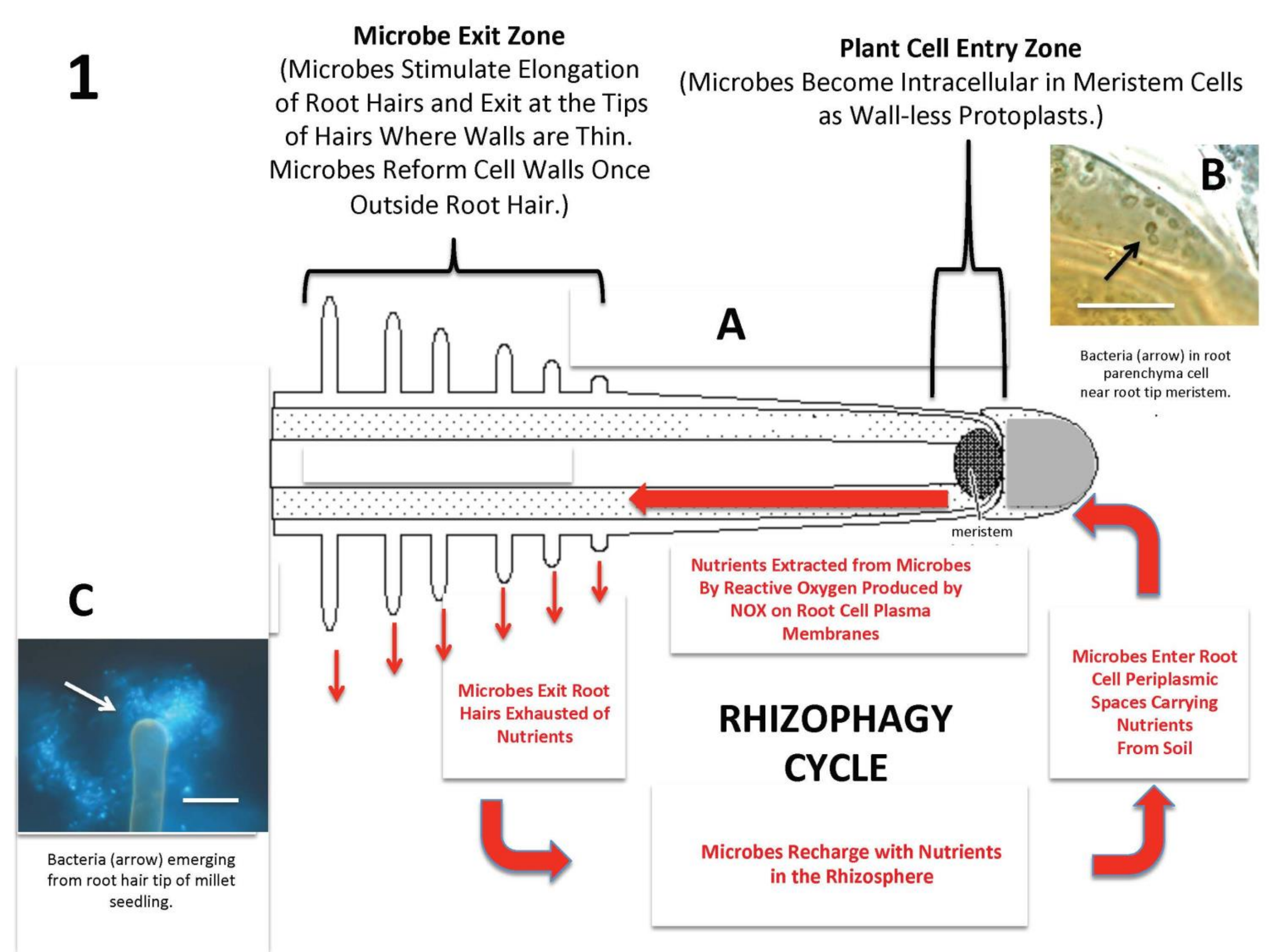
Dark septate endophytic fungus
*Heteroconium chaetospira*

- 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

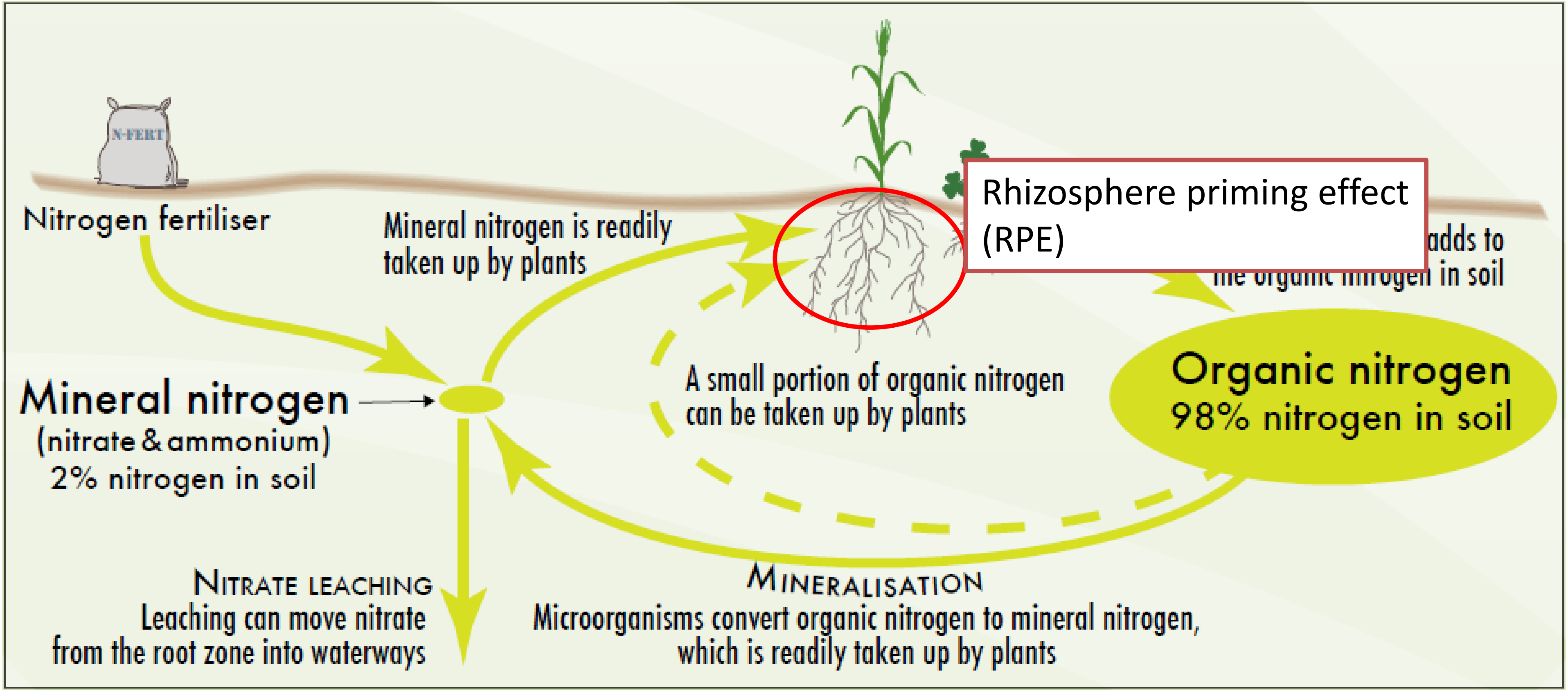
# Rhizophagy cycle (White et al., 2018)




Precisely what nutrients are transferred through rhizophagy or how important this process is for nutrient acquisition is still unknown.

(Thanks to Mr. Tom Willey)

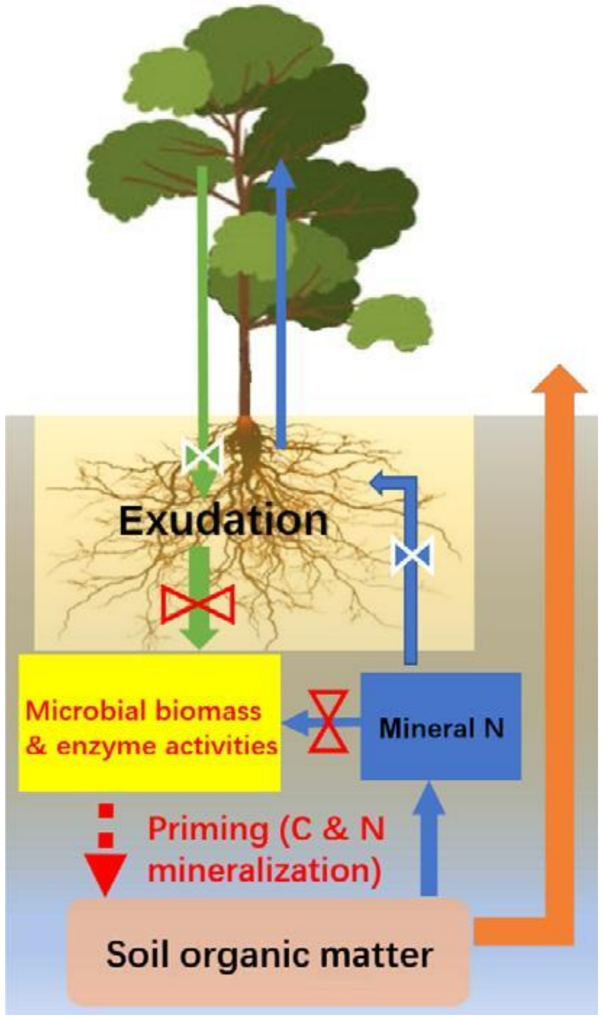
# Soil nitrogen supply




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

# 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)



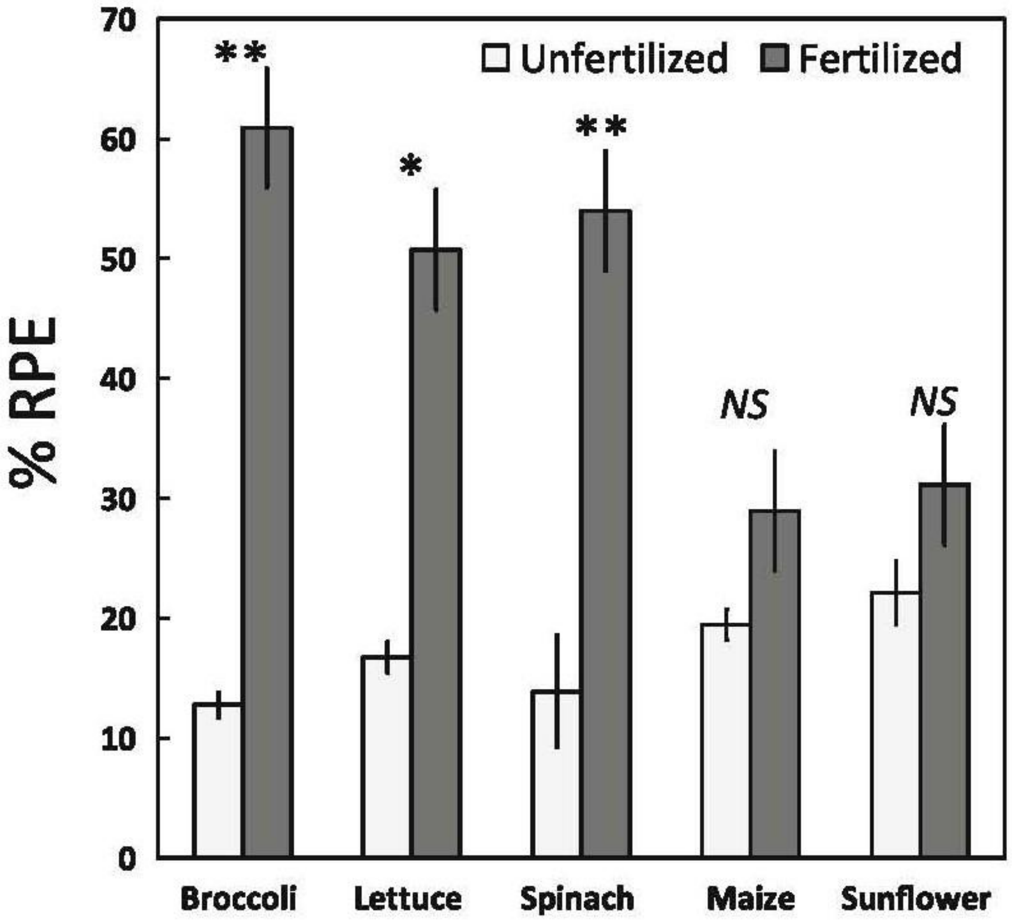

(Yin et al., 2018)

# Rhizosphere Priming Effect (RPE)

- 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….probably over estimating RPE due to the higher root density (especially fertilized plots) than field conditions?

- Used UCSC organic farm soil
  (20+ yrs of organic management)

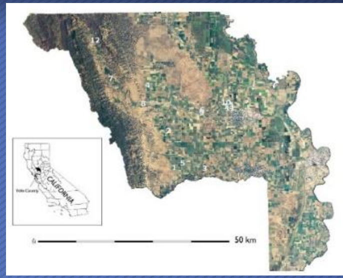



Rhizosphere priming effect (% RPE) on N of each crop by fertilization treatment. Bars are 1 SEM.

(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



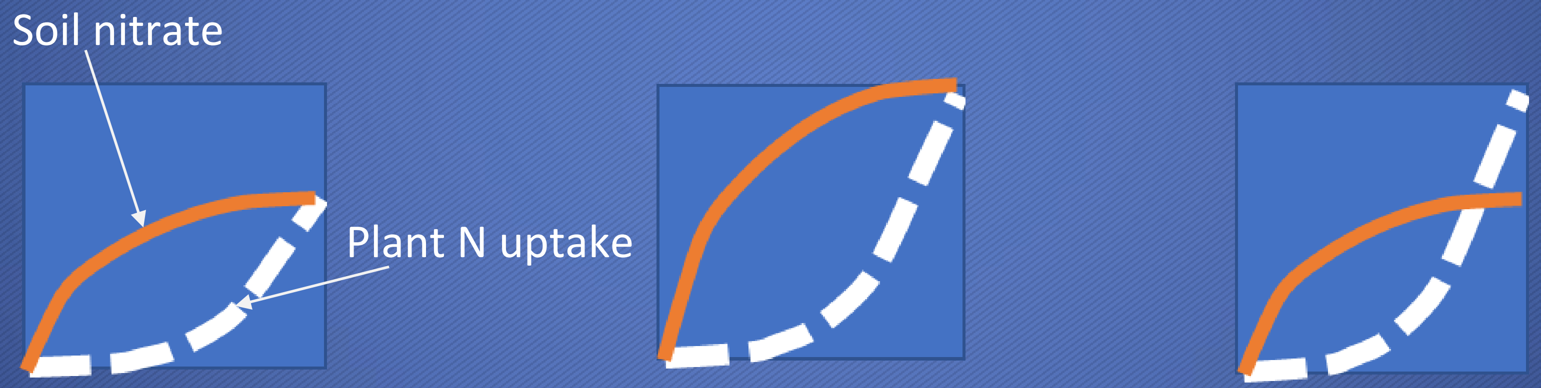
| | Mean soil nitrate (0-6 in, mg $NO_3^-$-N/kg soil) | | |
|---|---|---|---|
| Field group # | Transplant | Flowering | Harvest |
| 1 | 5.8 | 0.2 | 4.0 |
| 2 | 6.7 | 16.4 | 6.2 |
| 3 | 1.8 | 2.9 | 4.7 |

| 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



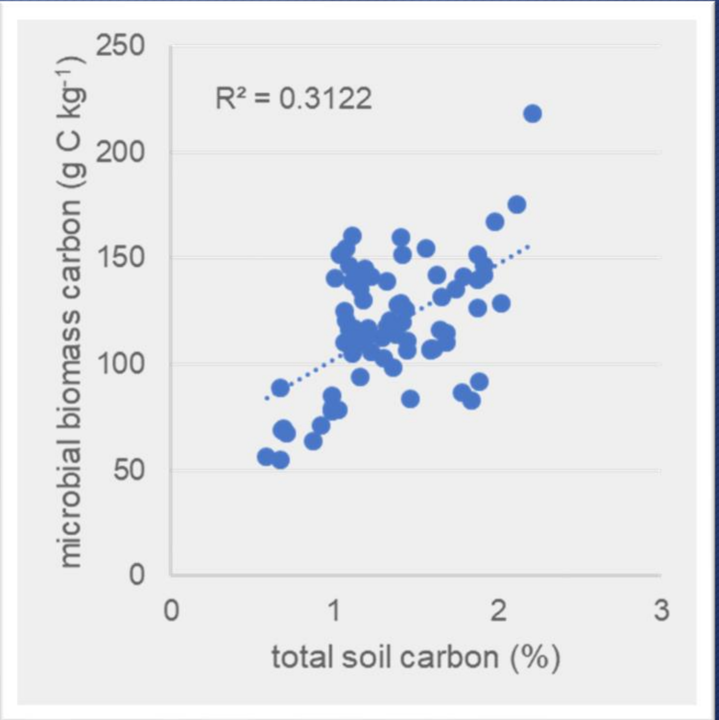

1. N deficient; *low yield, low soil nitrate pool*

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
  - <u>Low nitrate pool, but high nitrate flow (turn over)</u>
    - **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

# Learning from pioneer organic growers

"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

# Learning from natural ecosystems

Plant and Soil 110, 9–17 (1988)
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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.

Plant Soil (2012) 359:1–18
DOI 10.1007/s11104-012-1357-6

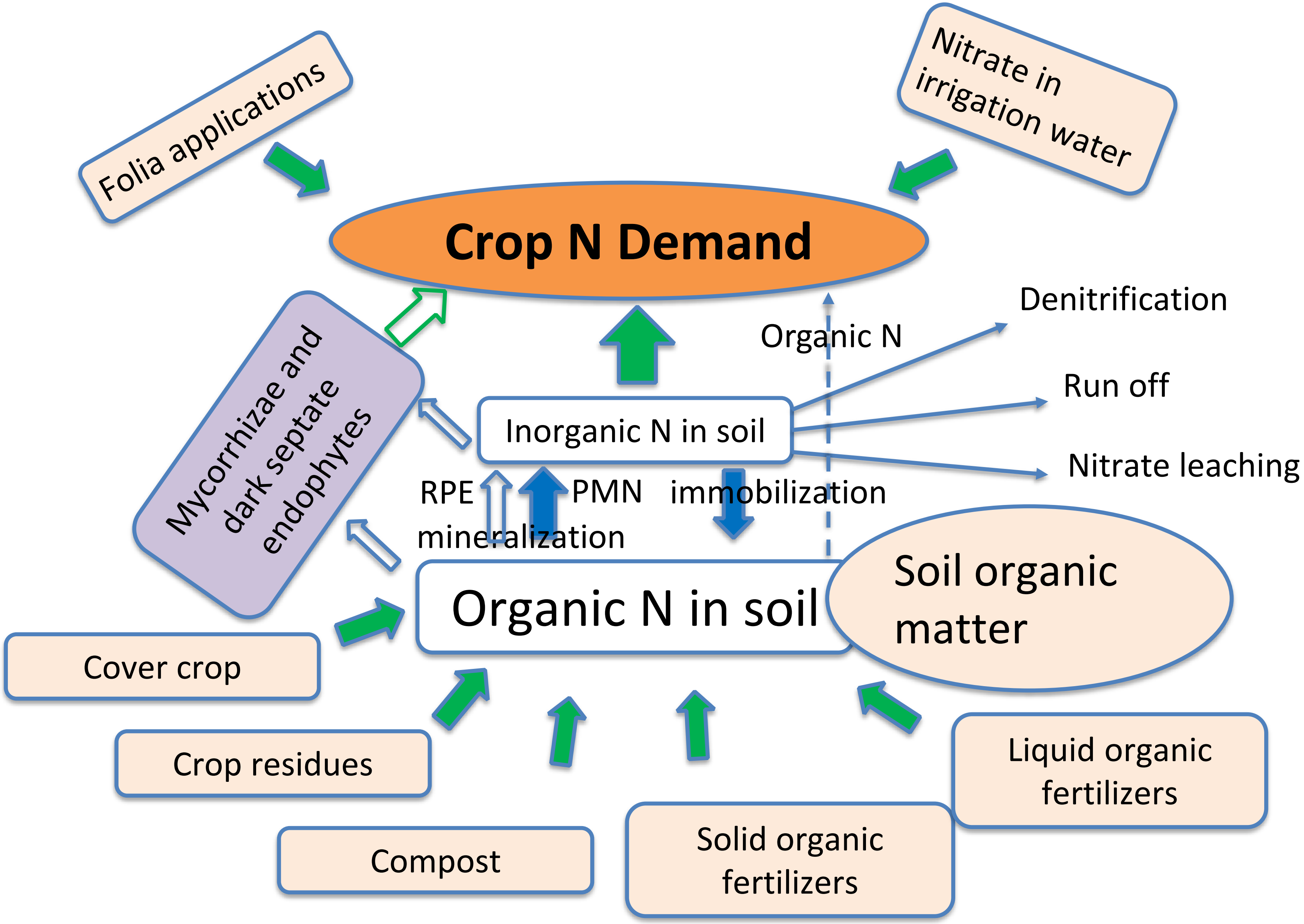
MARSCHNER REVIEW

# Past, present and future of organic nutrients

Chanyarat Paungfoo-Lonhienne · Jozef Visser ·
Thierry G. A. Lonhienne · Susanne Schmidt

Received: 7 November 2011 / Accepted: 28 June 2012 / Pul
© Springer Science+Business Media B.V. 2012

*Conclusion* After decades of focussing on inorganic nutrients, perspectives have greatly widened again. As has occurred before in agricultural history, science has to validate agronomic practises. We argue that a framework that views plants as mixotrophs with an inherent ability to use organic nutrients, via direct uptake or aided by exoenzyme-mediated degradation, will transform nutrient management and crop breeding to complement inorganic and synthetic fertilisers with organic nutrients.




Potential N dynamics in organic systems