Arbuscular mycorrhizal fungi – Implications for management and conservation planning

Webinar

May 07, 2019

Heike Bücking

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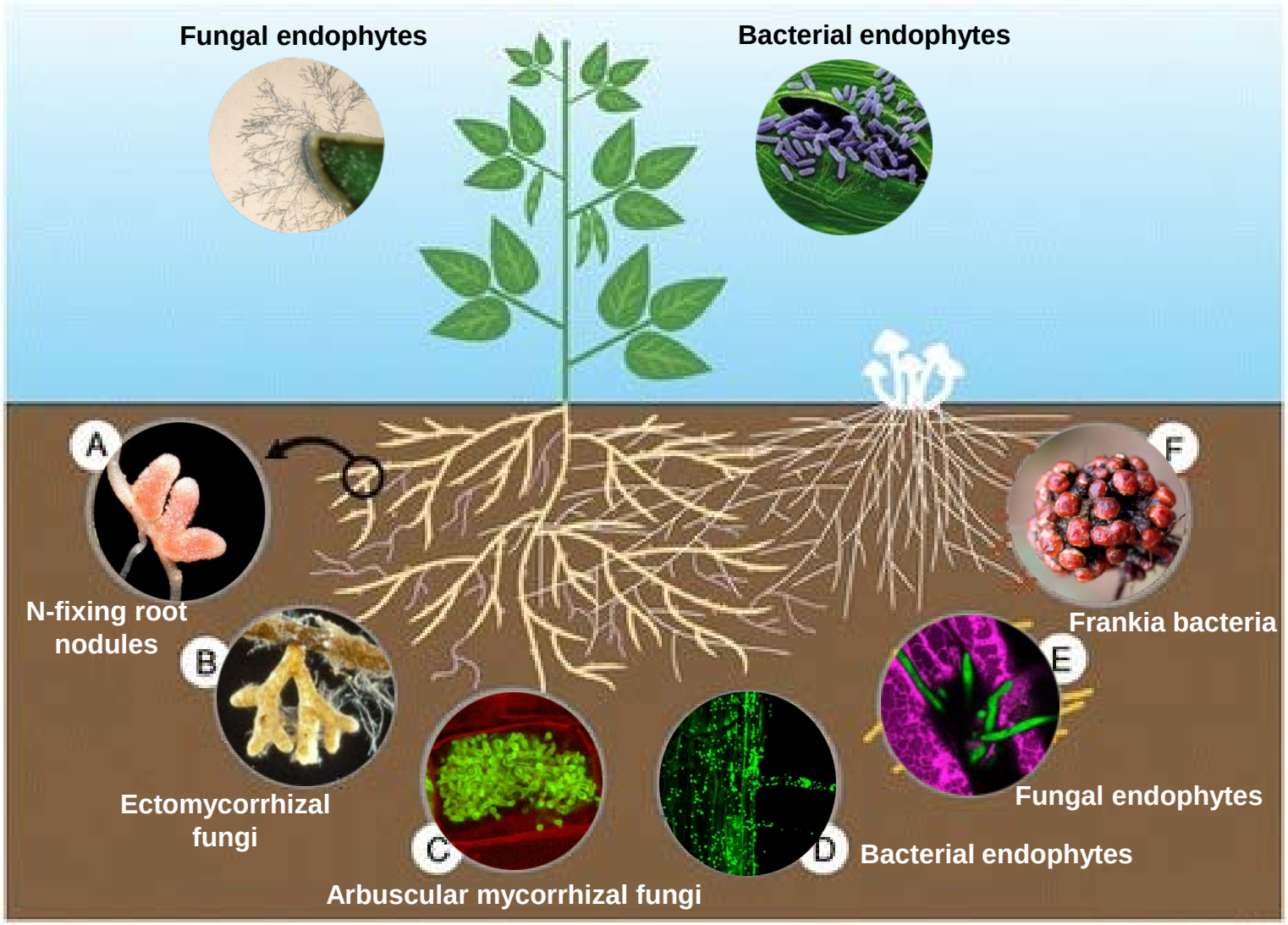
SOUTH DAKOTA STATE UNIVERSITY

Biology and Microbiology Department

Plants are associated with diverse microbiomes



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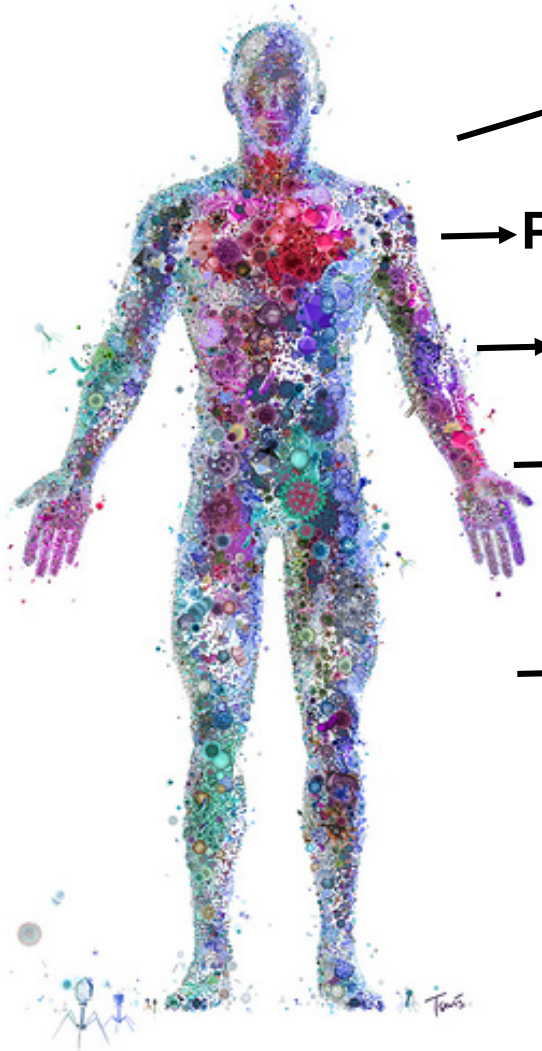
Modified A. W. Chong

The plant microbiome is equally important as the human microbiome



Nutrient uptake

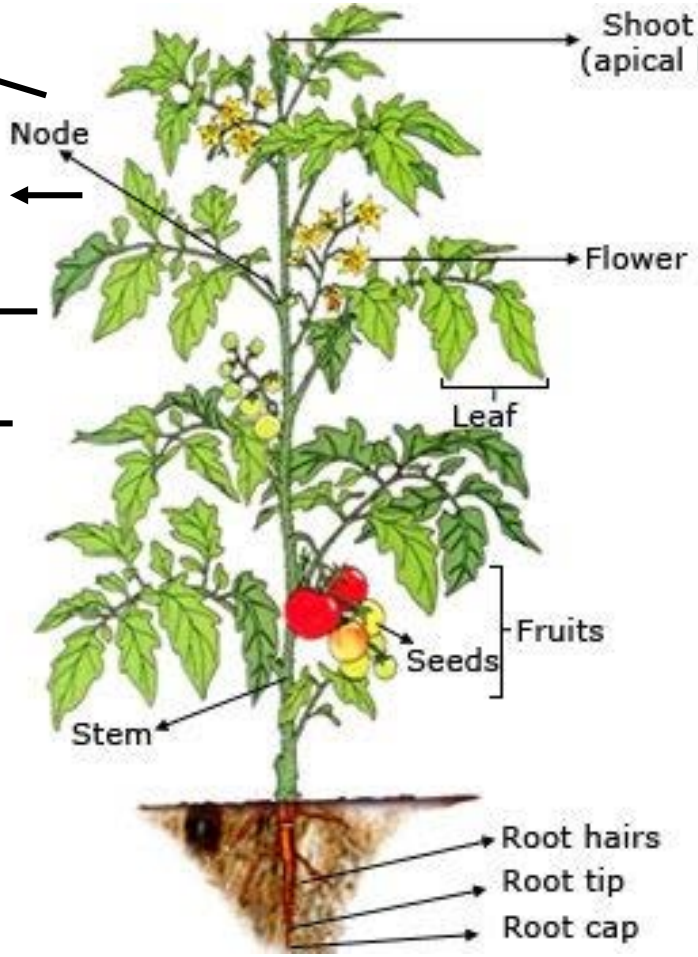
Prevention of disease

Stress resistance

Suppression of pathogens

Shape of host immunity

Host health



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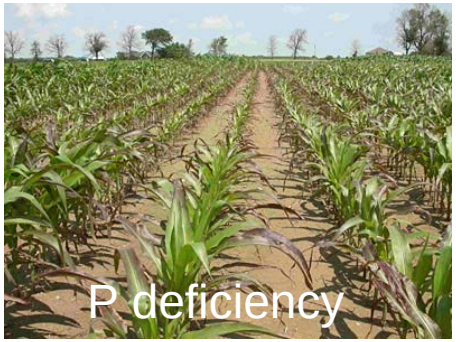
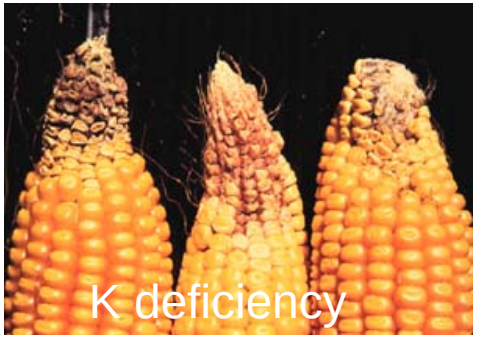
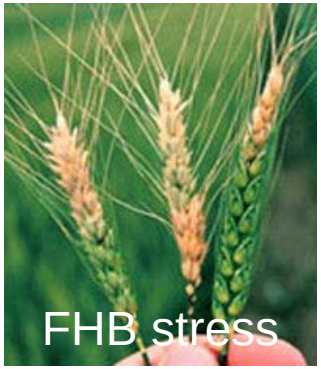
Abiotic or biotic threats of agricultural productivity







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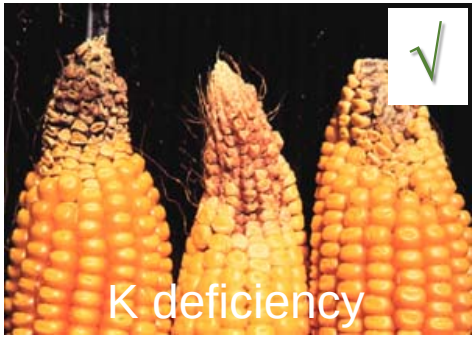
Microbial fertilizers or pesticides can protect plants against all stresses



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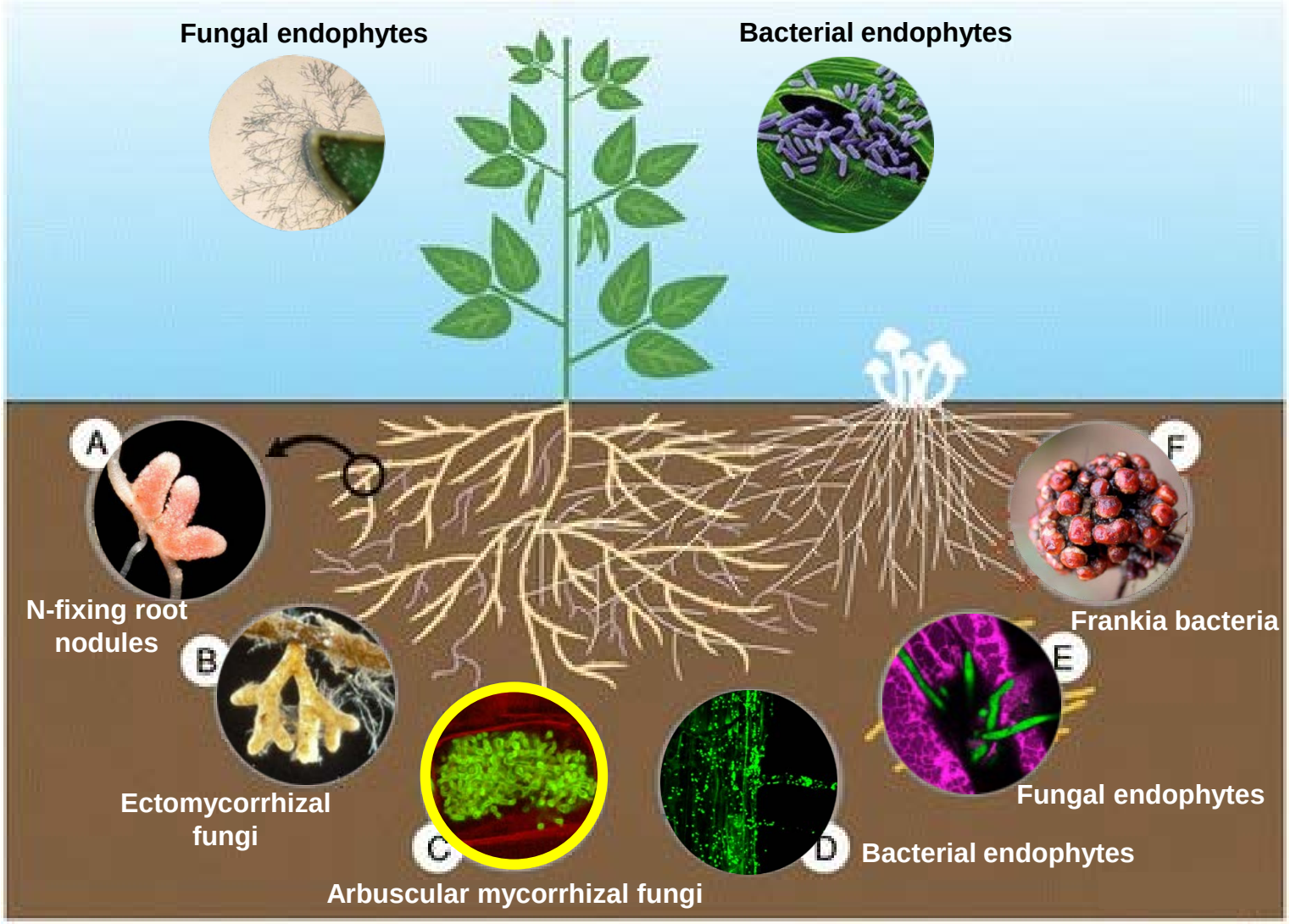
Plants are associated with diverse microbiomes



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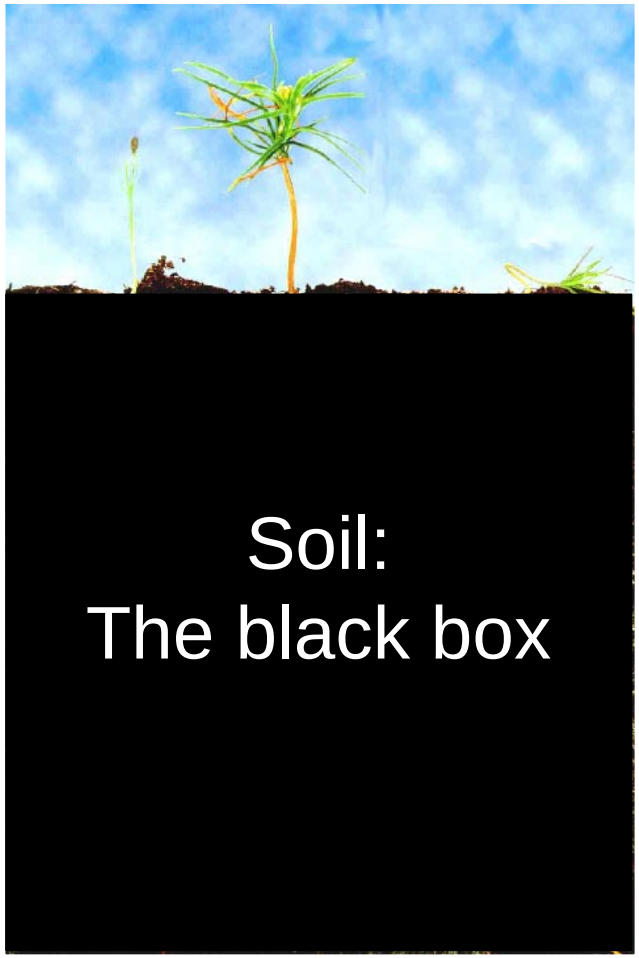
Mycorrhizal interactions of plants



Smith and Read, 2001

80-90% of all known plant species

bryophytes, pteridophytes, gymnosperms and most of the angiosperms

simultaneous colonization by various mycorrhizal types and fungal species, dependent on environmental conditions

Increasing attention for their role as biofertilizers, bioprotectors and bioregulators

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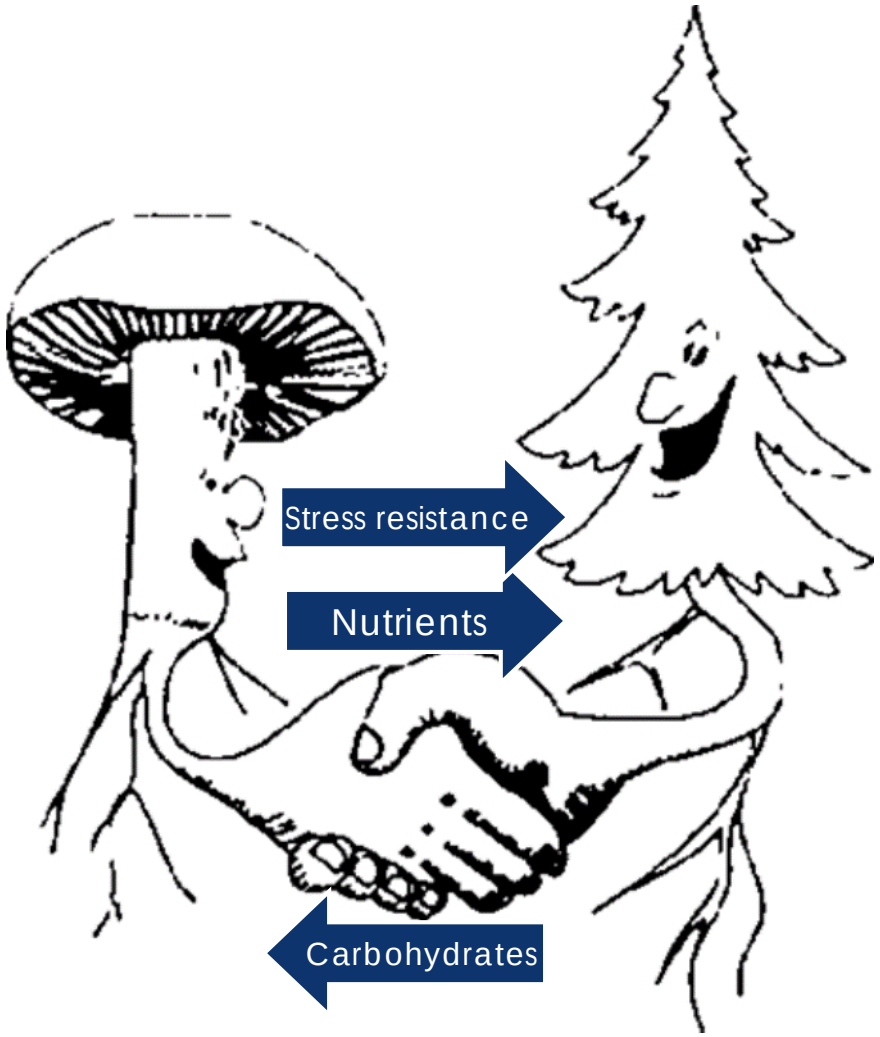
Mycorrhiza – A comprehensive all-around package



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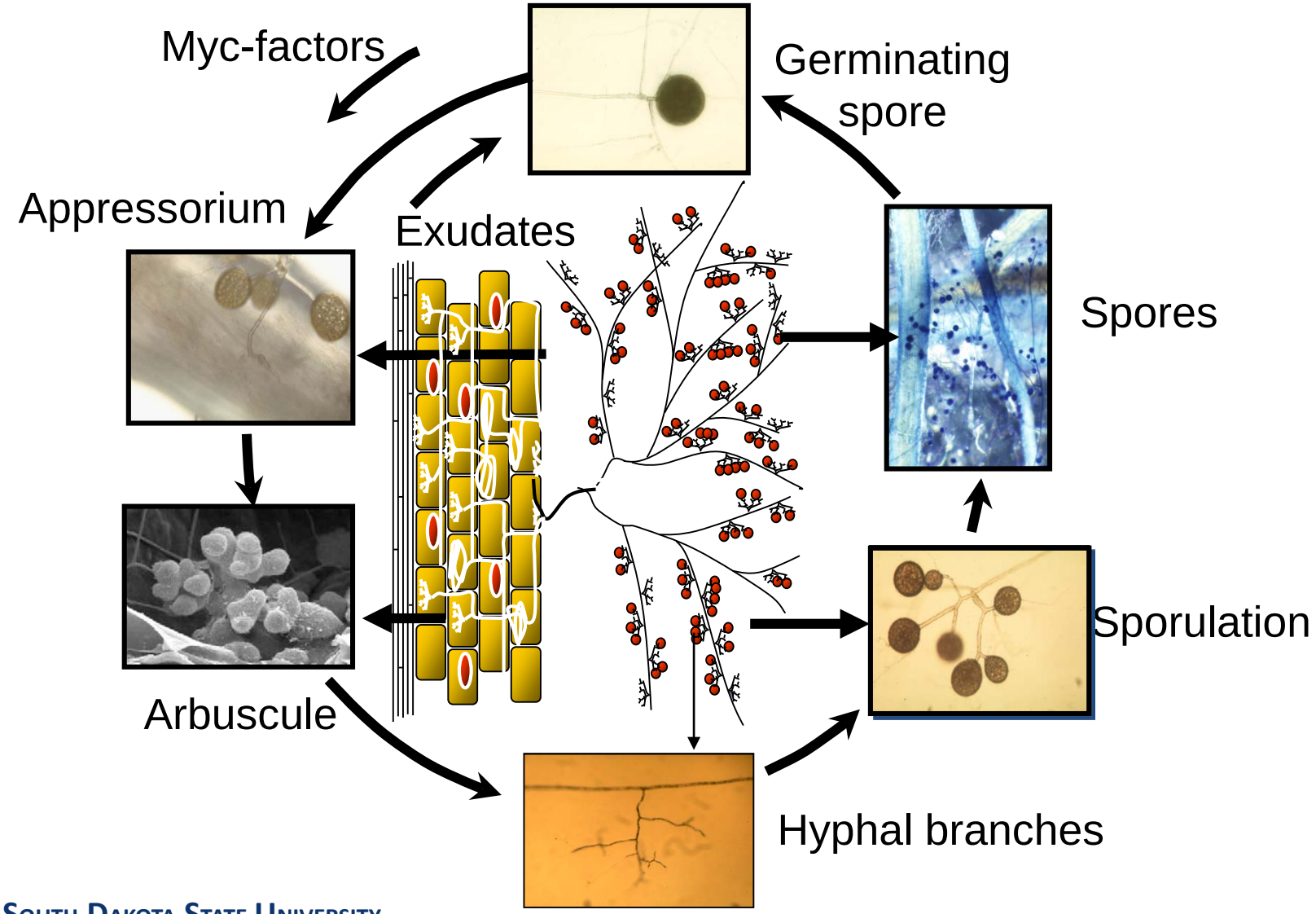
modified Egli, Brunner 2002

The life cycle and morphology of an asexual coenocytic obligate symbiont



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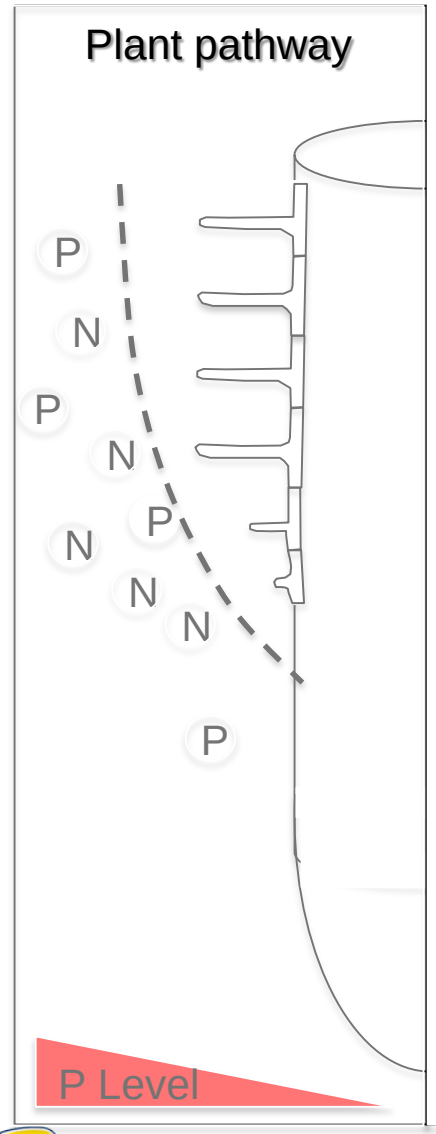
The mycorrhizal uptake pathway



Mycorrhizal pathway

ease in the nutrient
orbing surface area

ient nutrient uptake
ems

er P storage capabilities

zation of organic
ent resources

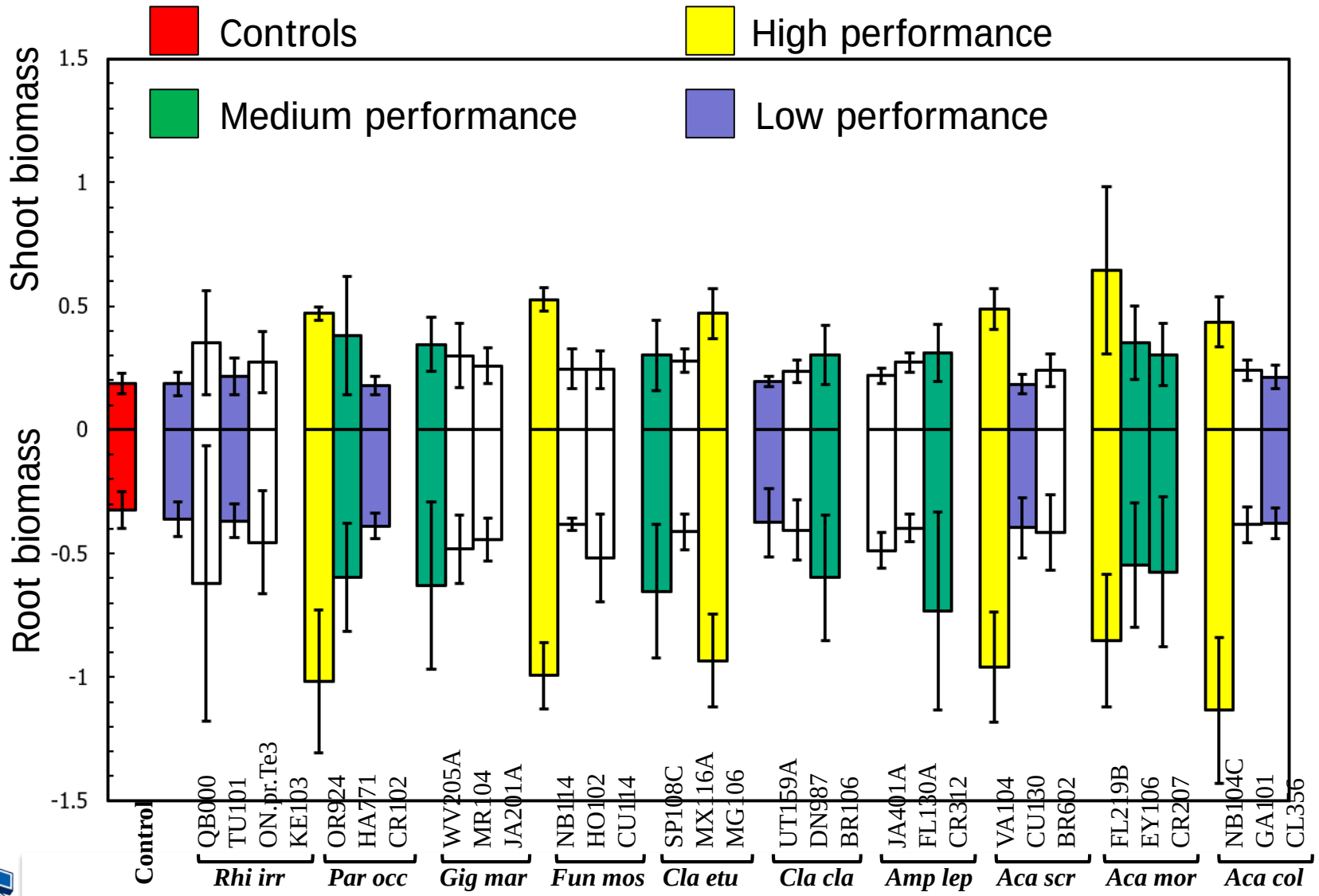
- Ecological niche for soil microbial communities

„The study of plants without their mycorrhizas is the study of artefacts.
The majority of plants strictly speaking, do not have roots, they have mycorrhizas.“

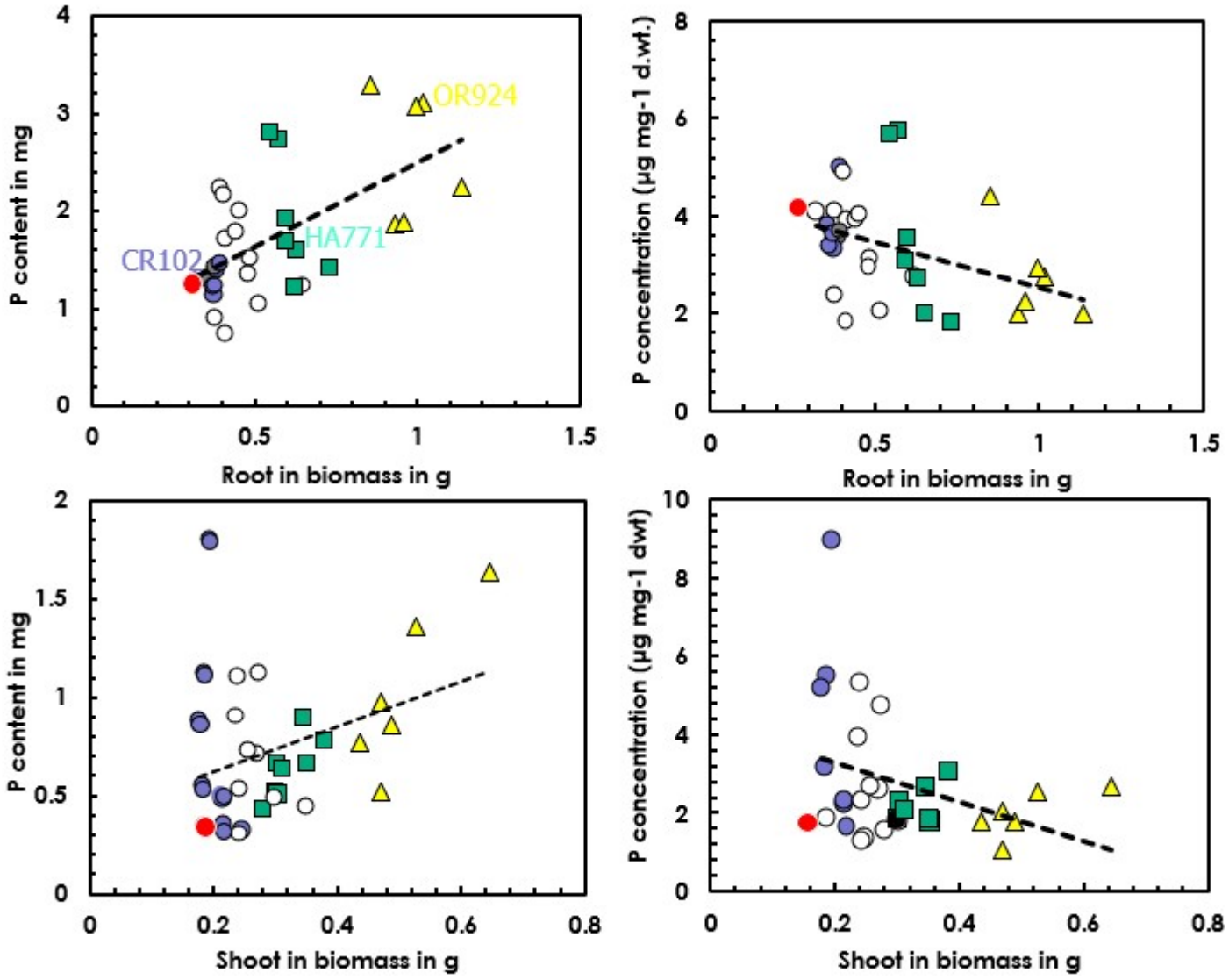
BEG (International Bank of the Glomeromycota) committee, 25th May 1993.

Are all AM fungi equally beneficial?

There are high interspecific, but also intraspecific differences in benefit



Growth benefit is correlated to P benefit



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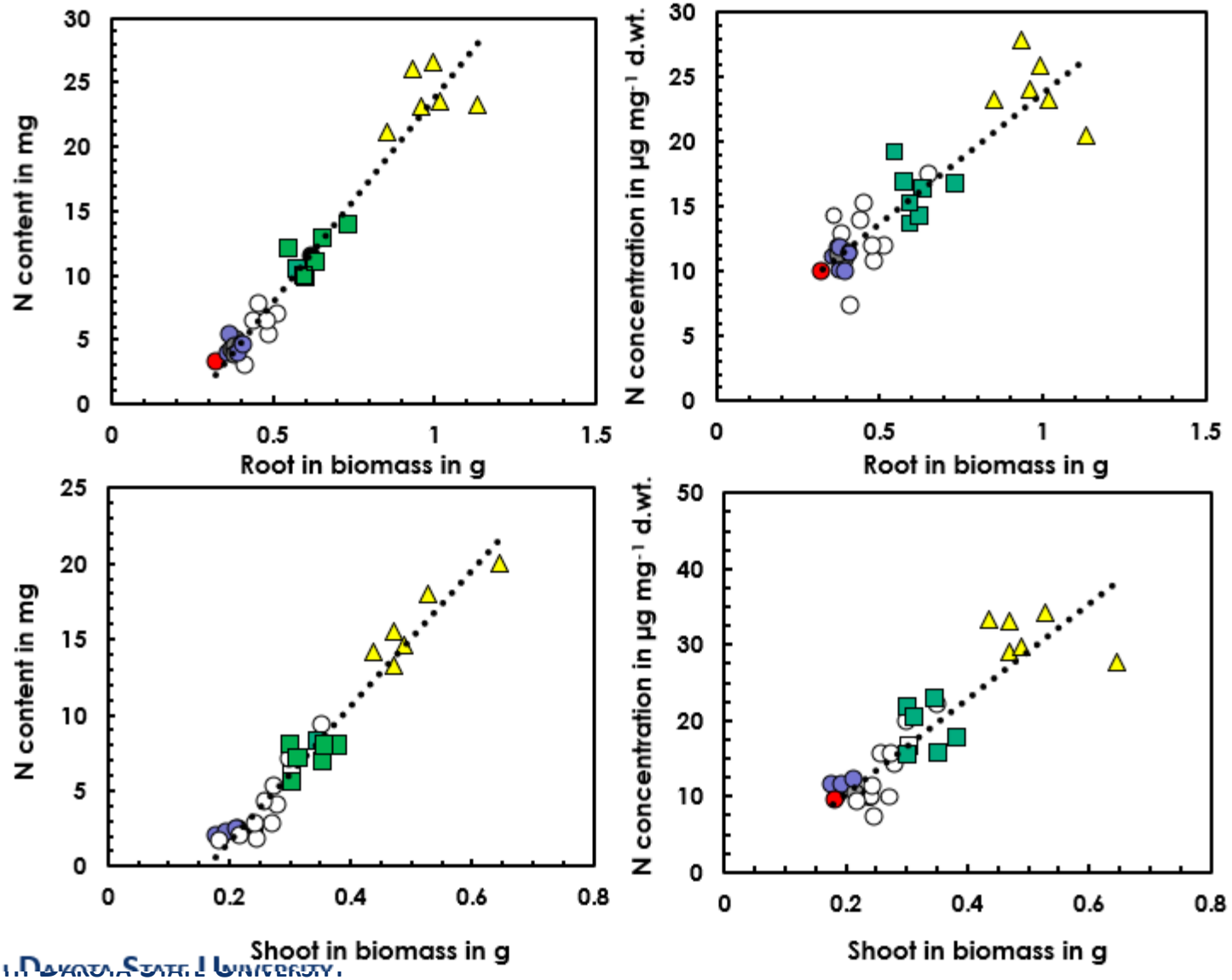
But what really makes the difference is the effect on N nutrition



Are all AM fungi equally beneficial?

- No. There are high inter- but also intraspecific differences in benefit
- The capability of an arbuscular mycorrhizal fungus to provide benefit is not phylogenetically determined
- Growth benefits are closely correlated to the capability of AM fungi to provide phosphate, but plant benefit was particularly correlated to the impact on nitrogen nutrition

How does the combination of arbuscular mycorrhizal fungi and nitrogen fixing bacteria affect legume productivity?

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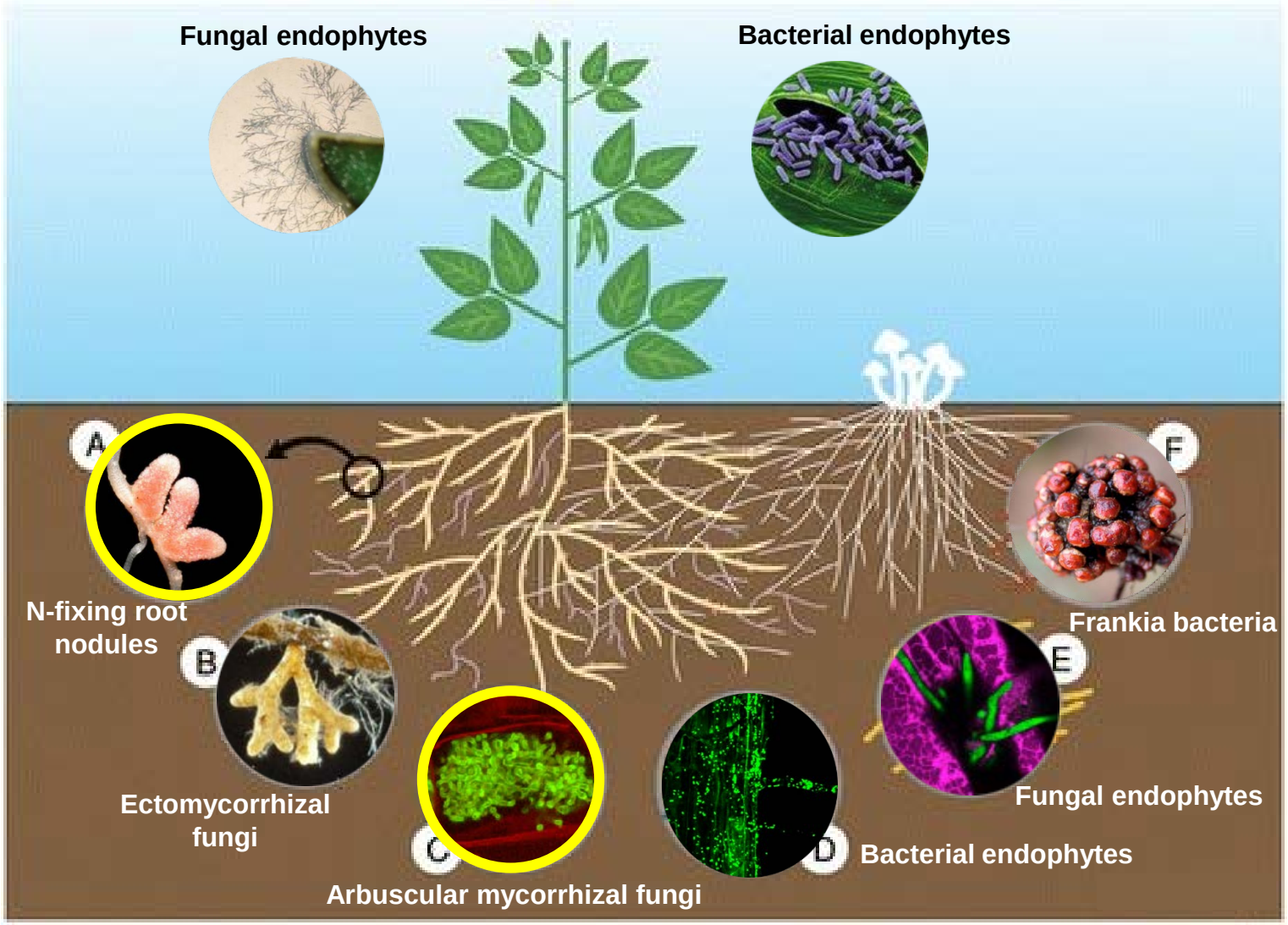
Plants are associated with diverse microbiomes



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Arbuscular mycorrhizal fungi and rhizobia lead to synergistic growth responses

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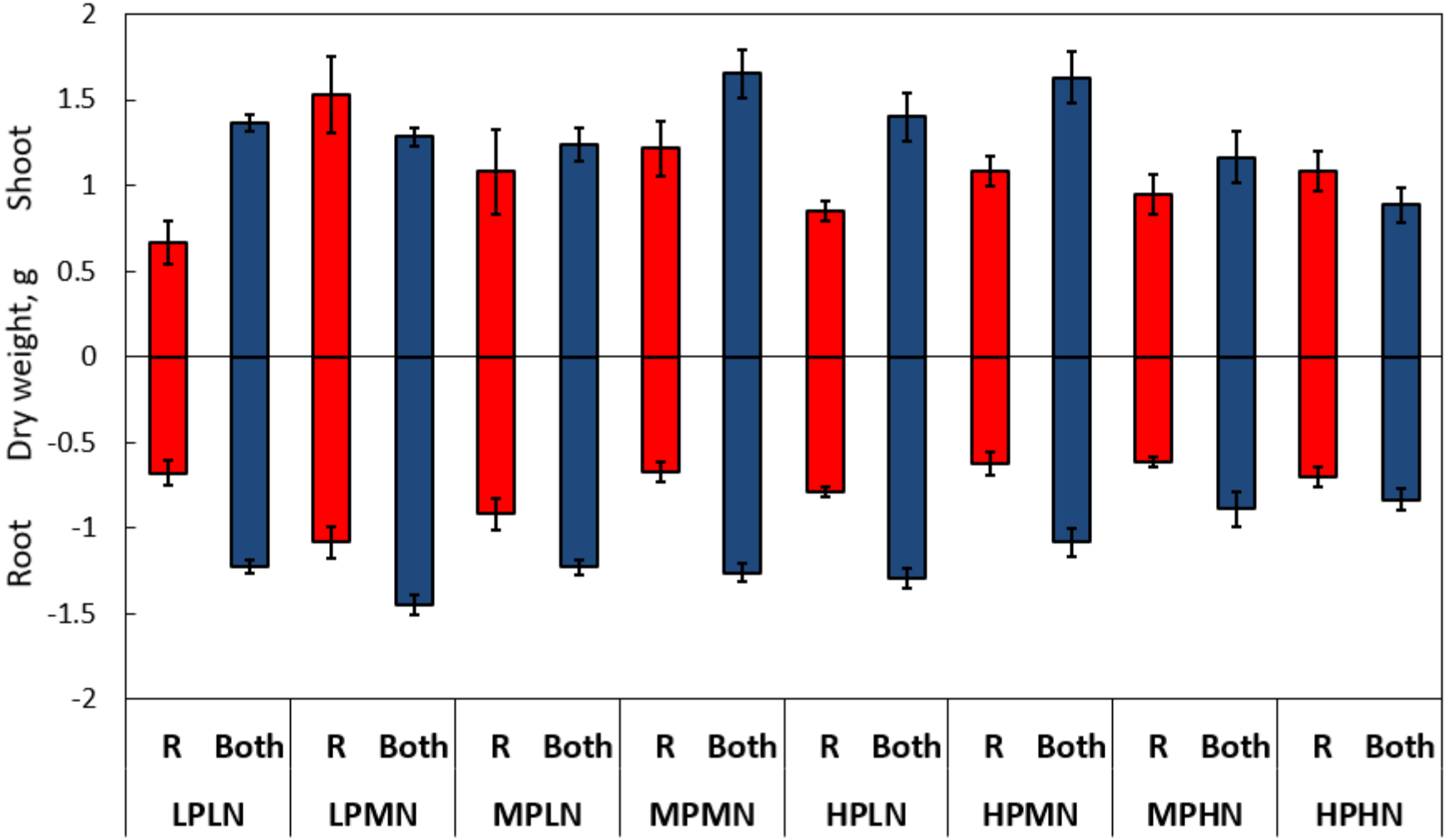
Arbuscular mycorrhizal fungi increase growth of nodulated soybeans particularly under low nutrient supply



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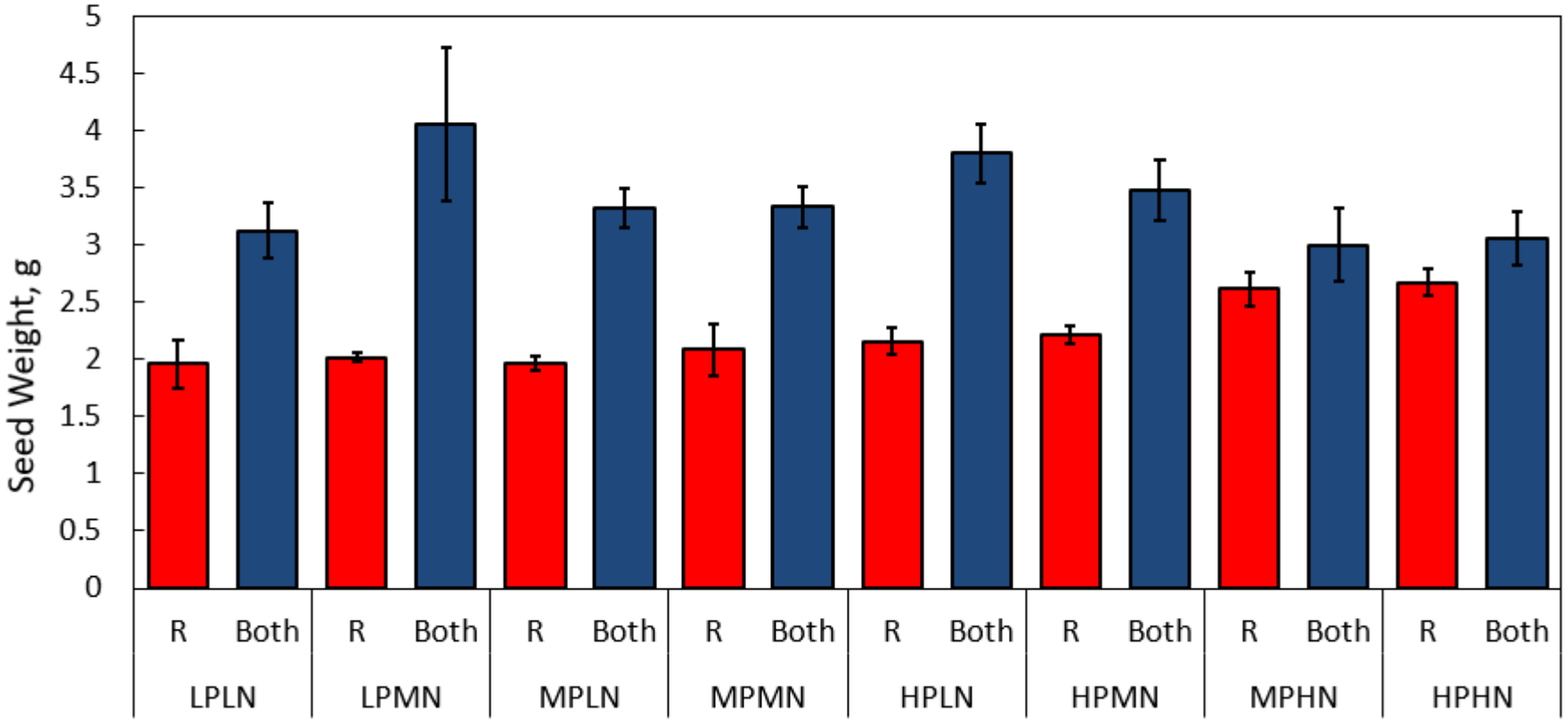
Soybeans associated with both root symbionts reach their maximum yield already under



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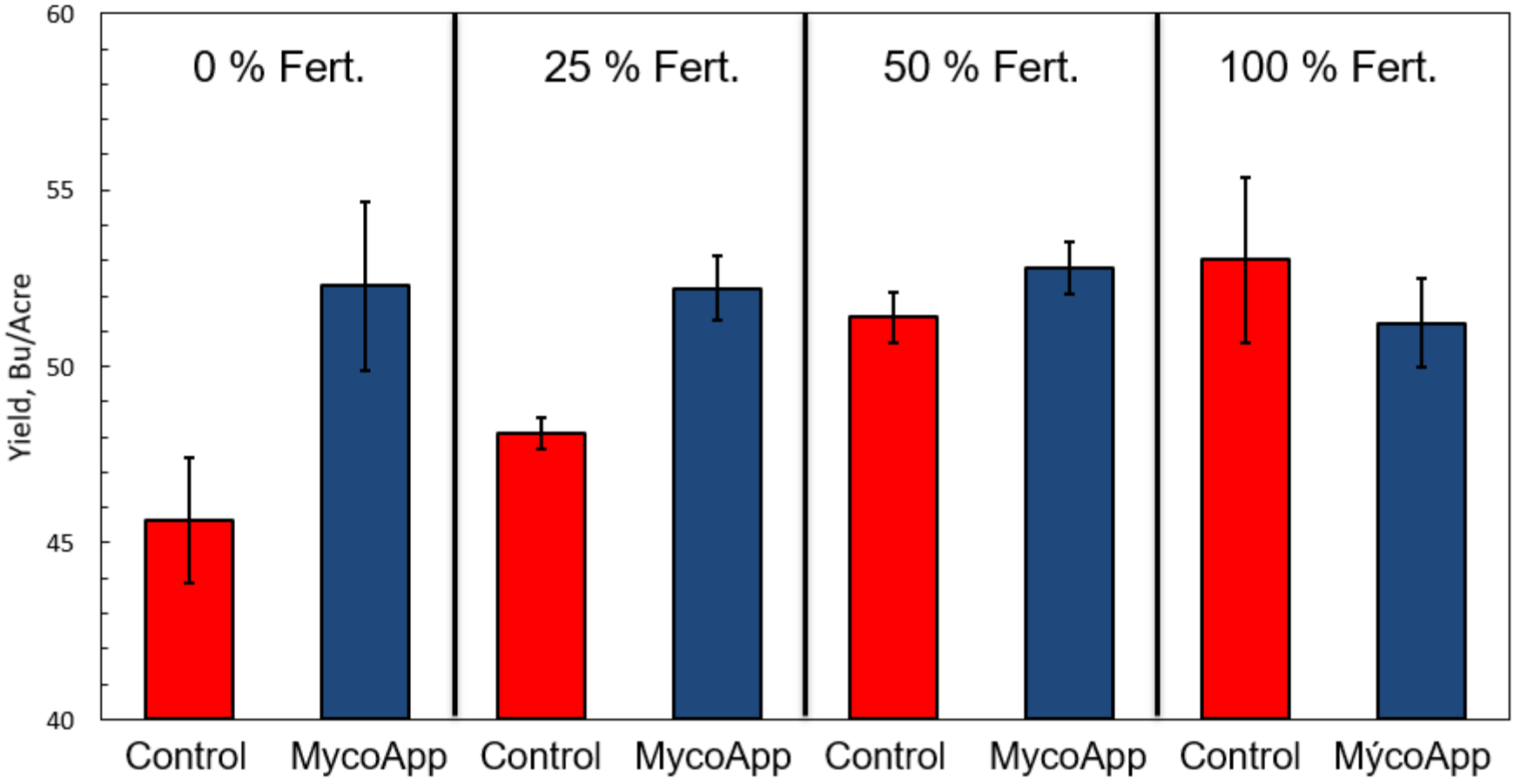
Similar yield responses can also be observed in the field



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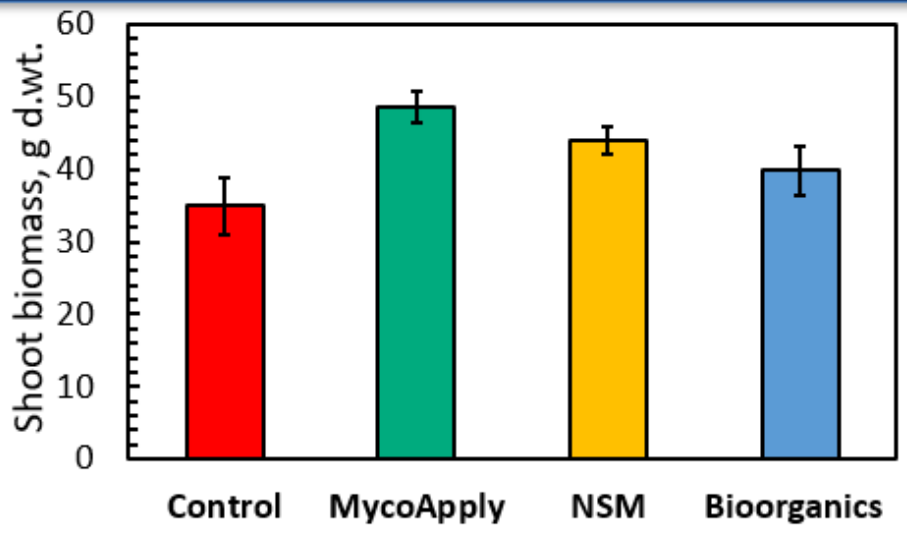
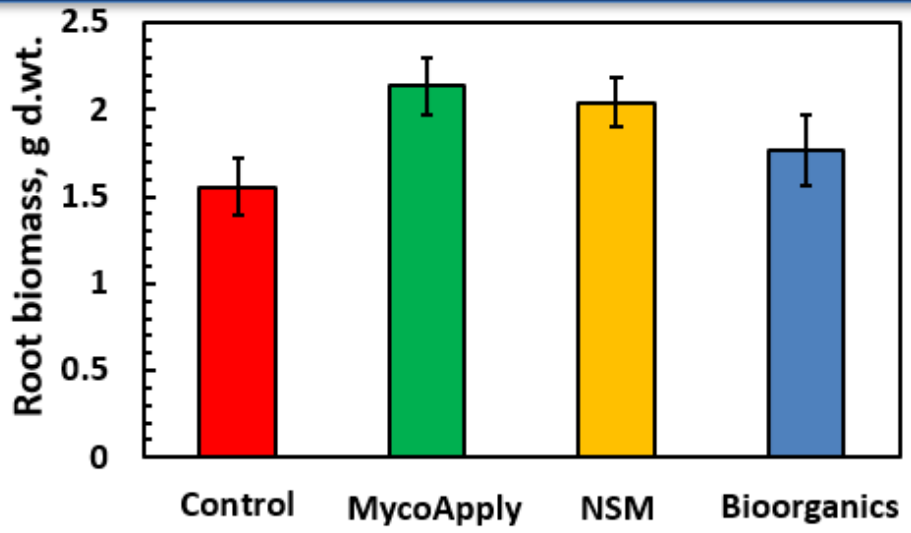
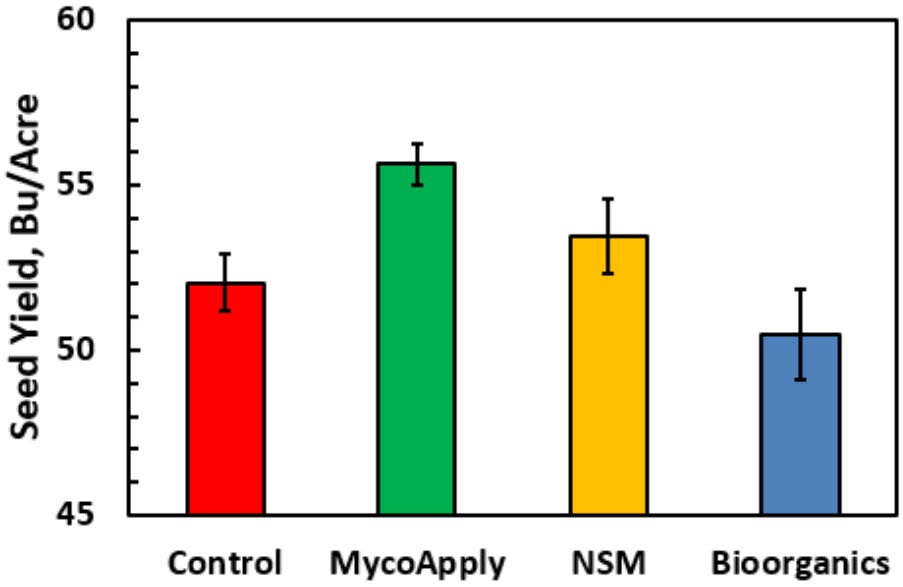
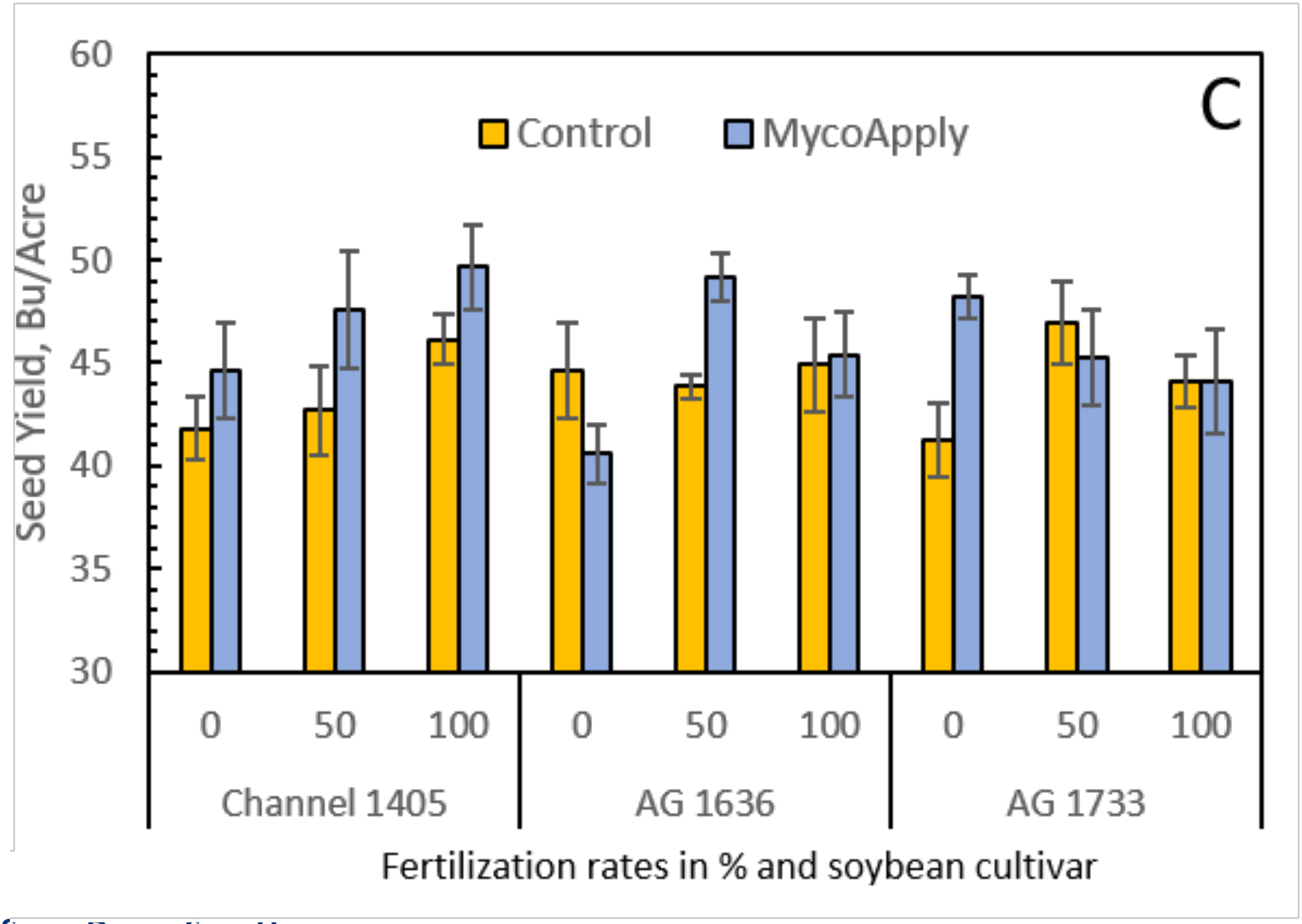
Commercially available fungal additives differ in their effect on soybean growth and yield



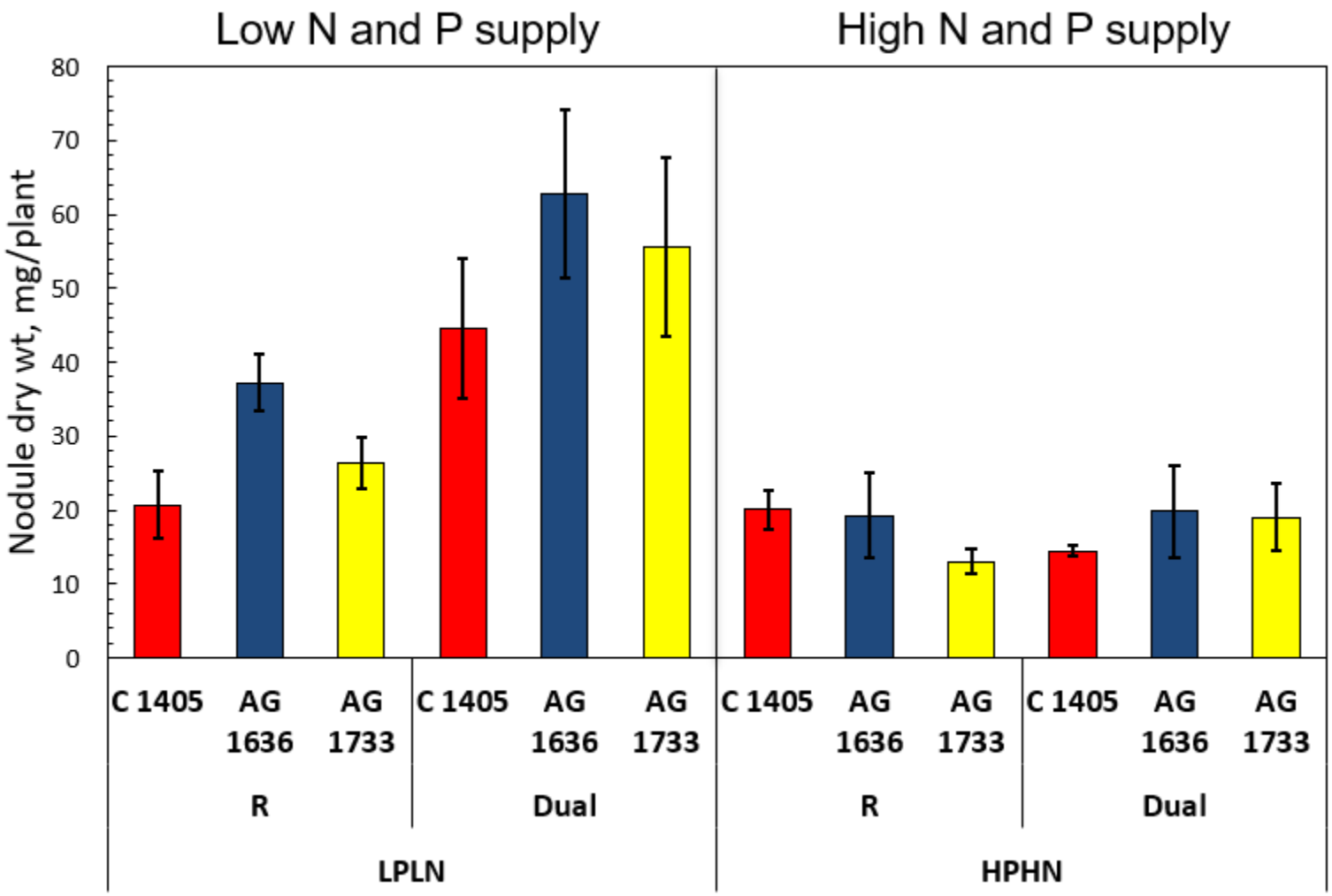




Soybean genotypes differ in their response to AM fungi



Arbuscular mycorrhizal fungi increase root nodulation



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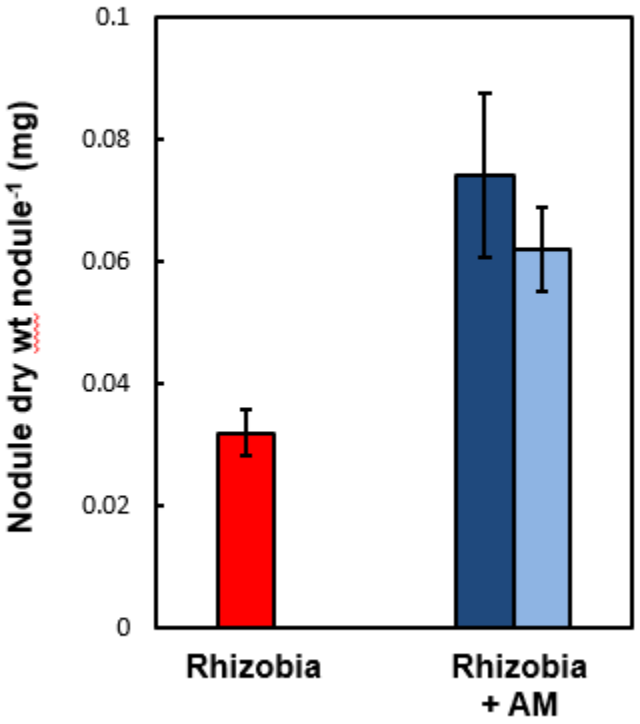
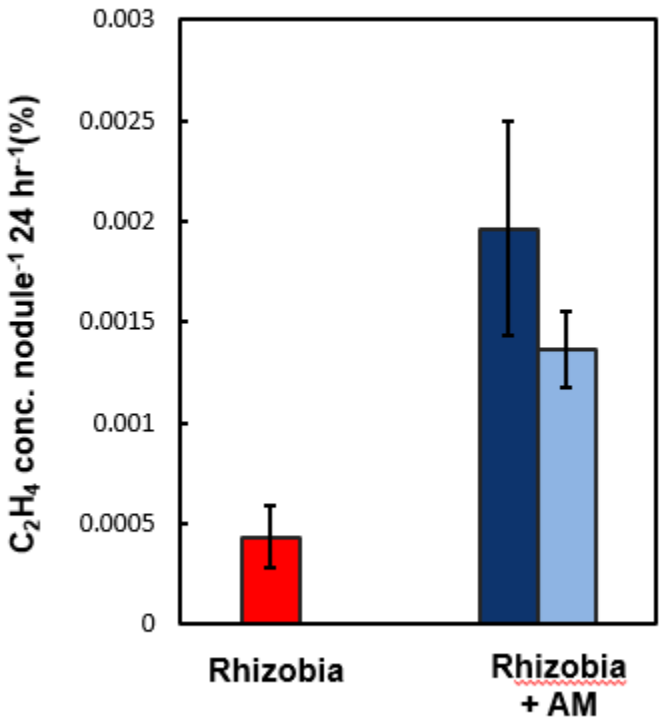
Arbuscular mycorrhizal fungi increase the N fixing ability of root nodules





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How does the combination of arbuscular mycorrhizal fungi and N fixing root symbionts affect soybean productivity

- Legume plants that are colonized with rhizobia and AM fungi show higher biomass, seed yields, and a higher nutrient efficiency than plants that are colonized with N fixing rhizobia alone
- The AM symbiosis improves the P uptake of plants and can thereby support a higher number of root nodules and higher N fixation rates
- With an efficient AM symbiosis soybean plants can reach their full yield potential under low nitrogen and phosphate supply conditions
- AM benefits depend on plant cultivar, and on the microbial community composition.

Acknowledgements

SDSU

Jerry Mensah
Arjun Kafle
Vincent Peta
Alex Soupir
Jaya Yakha

NSF

USDA

UBC OKANAGAN

Miranda Hart
John Kliromonos
Alexander Koch
Pedro Antunes

SOUTH DAKOTA SOYBEAN RESEARCH & PROMOTION COUNCIL

SunGrant INITIATIVE

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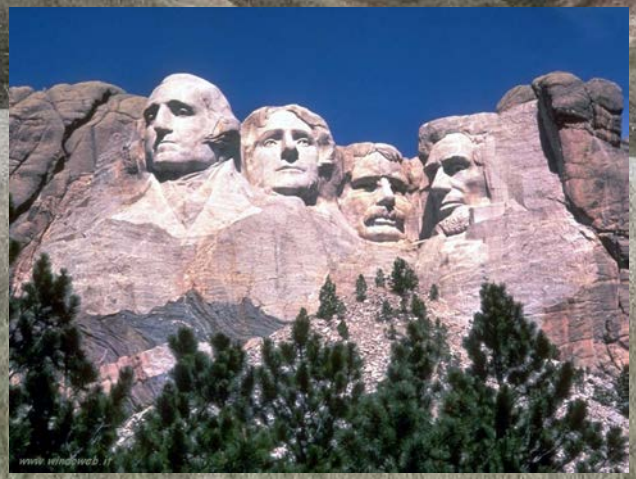
Questions?

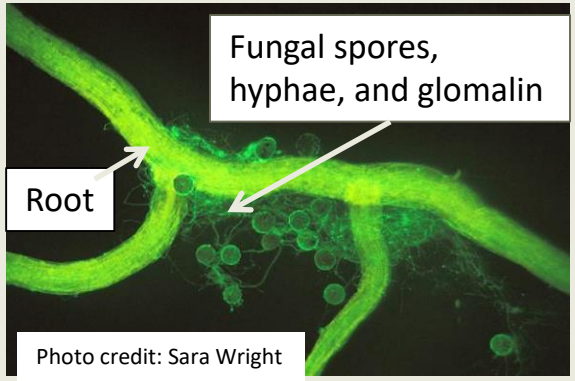


Arbuscular Mycorrhizal Fungi: Management and Measurement

Dr. Mike Lehman
U.S. Dept. of Agriculture - Agricultural Research Service
Brookings, South Dakota, USA

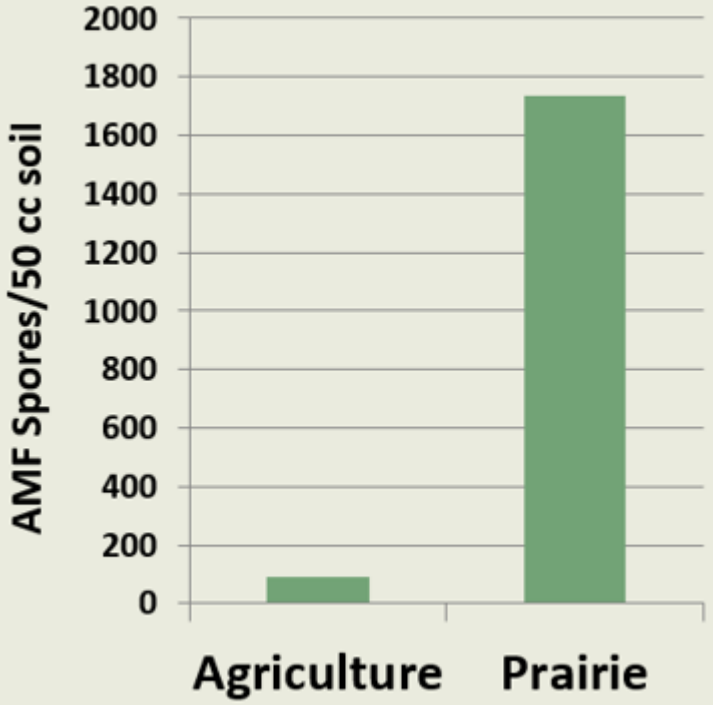
AMF Benefits for Agriculture

- Low #s can stress plant
  - Improve production
- Acquire P, Cu, Zn, other nutrients
  - Reduce fertilizer
- Increase Tolerance
  - Disease
    - Reduce pesticides
  - Drought, salinity
- Improve soil structure
  - Reduce erosion

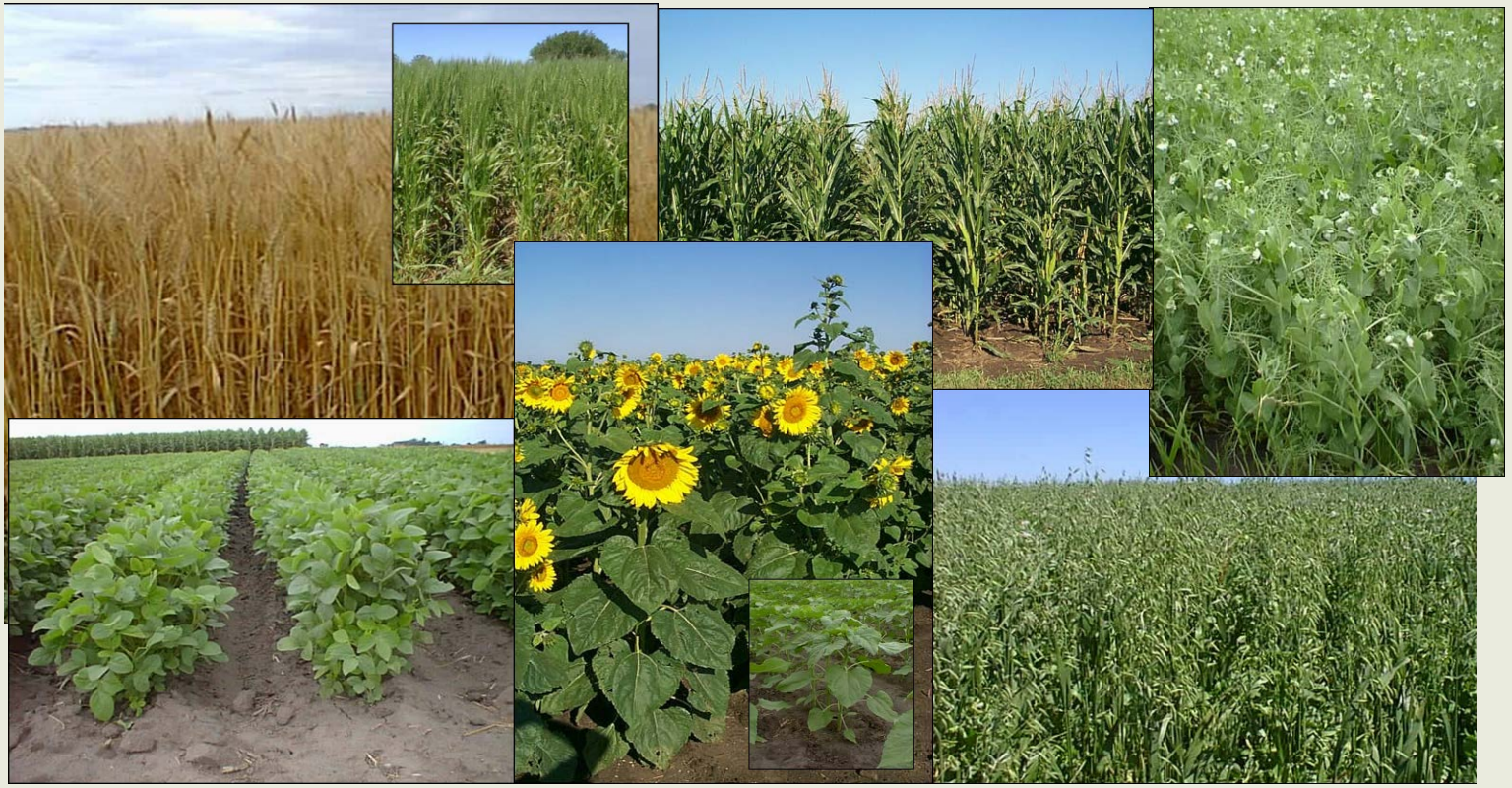


Farming can be Rough on AMF

- Tillage
- Seasonal Fallow
- Annual Fallow
- Monocropping, simple rotations
- Inorganic fertilizer application
- Soil Compaction
- Fungicide, hi rate to soil



Diversified Crop Rotations



Cover Crops

Diversity of Landscape

Inorganic P Inputs can Repress AMF

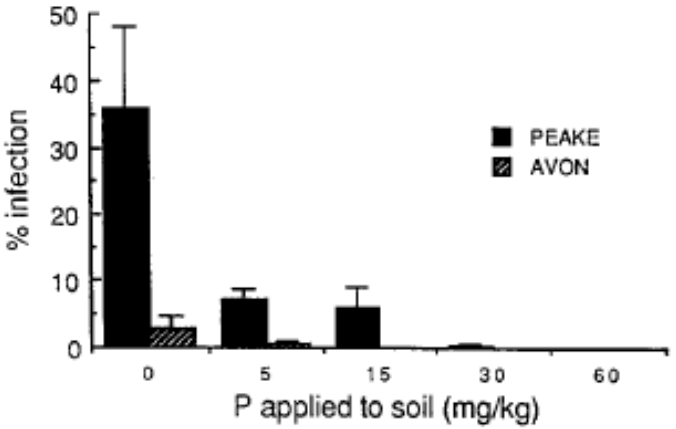
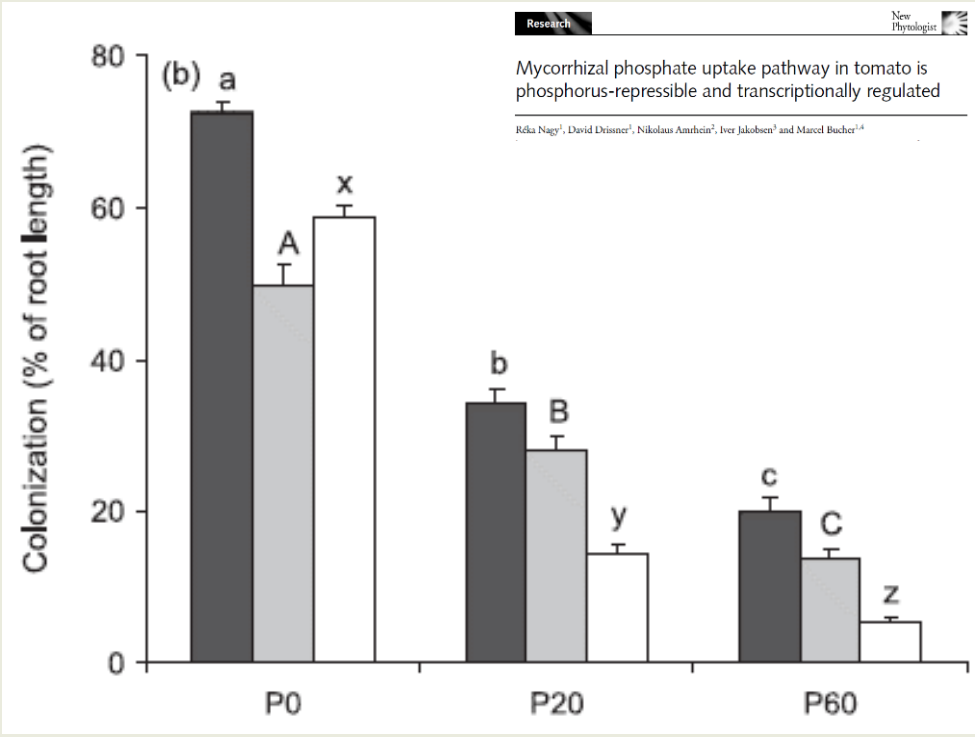
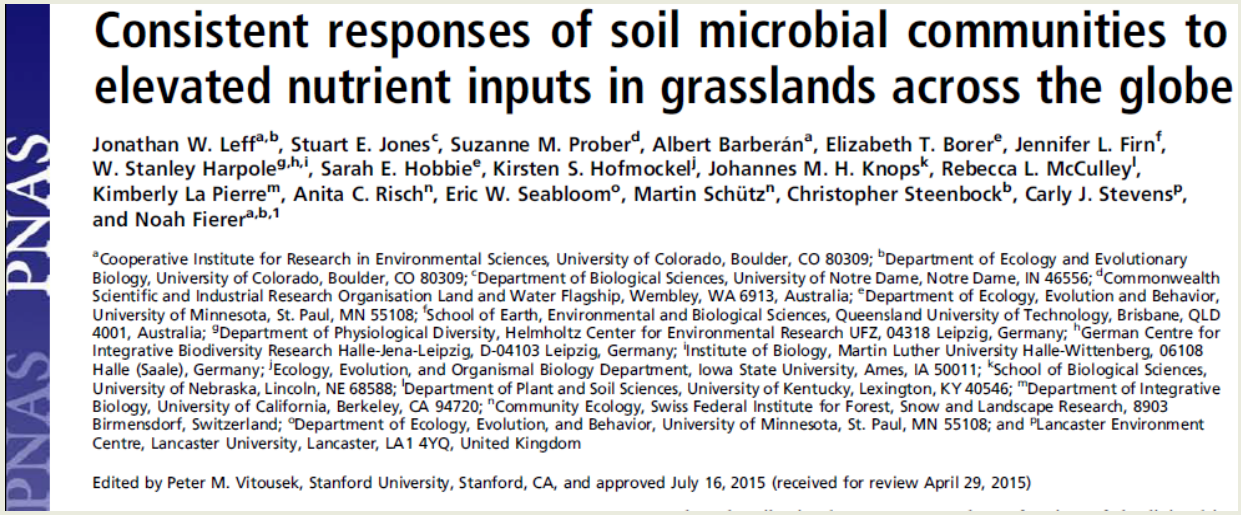


Fig. 1. The effect of applied phosphate on mycorrhizal infection in *Triticum aestivum* cv. Spear grown in two soils with different propagule densities (Most Probable Numbers estimates). Solid bars Peake soil; hatched bars Avon soil. The two soils contained 26 and 0.9 propagules g^{-1}, respectively. Means and standard errors of means of three replicate plants. Results of Baon et al., 1992.



Nitrogen Inputs also Matter



PNAS

Consistent responses of soil microbial communities to elevated nutrient inputs in grasslands across the globe

Jonathan W. Leff[a,b], Stuart E. Jones[c], Suzanne M. Prober[d], Albert Barberán[a], Elizabeth T. Borer[e], Jennifer L. Firn[f], W. Stanley Harpole[g,h,i], Sarah E. Hobbie[e], Kirsten S. Hofmockel[j], Johannes M. H. Knops[k], Rebecca L. McCulley[l], Kimberly La Pierre[m], Anita C. Risch[n], Eric W. Seabloom[o], Martin Schütz[n], Christopher Steenbock[b], Carly J. Stevens[p], and Noah Fierer[a,b,1]

[a]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; [b]Department of Ecology and Evolutionary Biology, University of Colorado, Boulder, CO 80309; [c]Department of Biological Sciences, University of Notre Dame, Notre Dame, IN 46556; [d]Commonwealth Scientific and Industrial Research Organisation Land and Water Flagship, Wembley, WA 6913, Australia; [e]Department of Ecology, Evolution and Behavior, University of Minnesota, St. Paul, MN 55108; [f]School of Earth, Environmental and Biological Sciences, Queensland University of Technology, Brisbane, QLD 4001, Australia; [g]Department of Physiological Diversity, Helmholtz Center for Environmental Research UFZ, 04318 Leipzig, Germany; [h]German Centre for Integrative Biodiversity Research Halle-Jena-Leipzig, D-04103 Leipzig, Germany; [i]Institute of Biology, Martin Luther University Halle-Wittenberg, 06108 Halle (Saale), Germany; [j]Ecology, Evolution, and Organismal Biology Department, Iowa State University, Ames, IA 50011; [k]School of Biological Sciences, University of Nebraska, Lincoln, NE 68588; [l]Department of Plant and Soil Sciences, University of Kentucky, Lexington, KY 40546; [m]Department of Integrative Biology, University of California, Berkeley, CA 94720; [n]Community Ecology, Swiss Federal Institute for Forest, Snow and Landscape Research, 8903 Birmensdorf, Switzerland; [o]Department of Ecology, Evolution, and Behavior, University of Minnesota, St. Paul, MN 55108; and [p]Lancaster Environment Centre, Lancaster University, Lancaster, LA1 4YQ, United Kingdom

Edited by Peter M. Vitousek, Stanford University, Stanford, CA, and approved July 16, 2015 (received for review April 29, 2015)

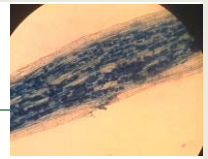
- Loss of sensitive taxa, e.g, mycorrhizal fungi
- Lowered respiration
- Simplified communities

What about Fungicidal Seed Coatings, AMF, and Plant Nutrition?

Agron. J. 109:1005–1012 (2017)

Published May 5, 2017

CROP ECONOMICS, PRODUCTION & MANAGEMENT



Fungicidal Seed Coatings Exert Minor Effects on Arbuscular Mycorrhizal Fungi and Plant Nutrient Content

Jesse C. Cameron, R. Michael Lehman,* Peter Sexton, Shannon L. Osborne, and Wendy I. Taheri

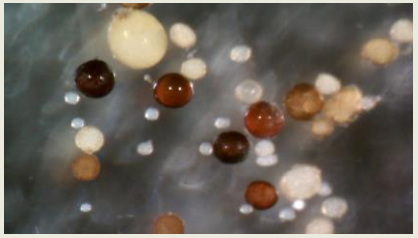
Manage by NRCS Soil Health Principles

- Keep the soil covered
- Minimize soil disturbance
- Increase plant diversity
- Keep living roots in the soil
- Integrate livestock

Measuring AM Fungi Responses to Agricultural Management

Counting Spores Extracted from Soil

Cropped Field



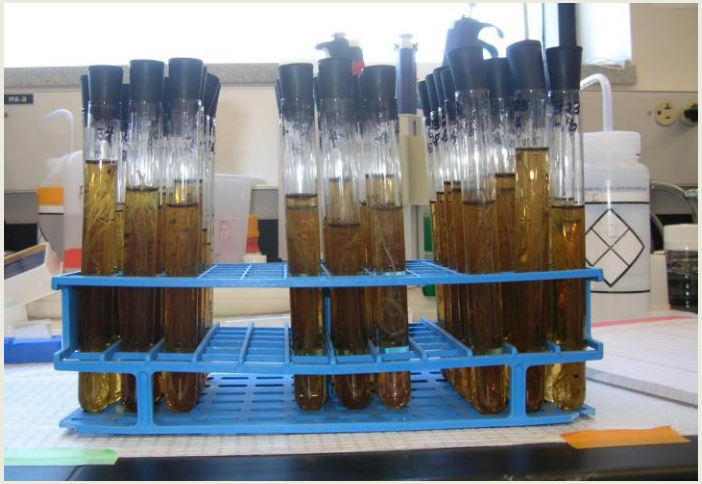
Prairie

Soil Propagules Enumeration

Most-Probable-Number assay

15 pots per each field plot = estimated #

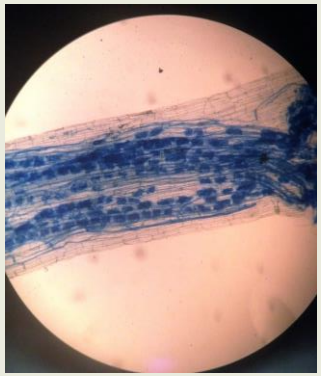
Harvest, Wash, Clear, Stain Roots



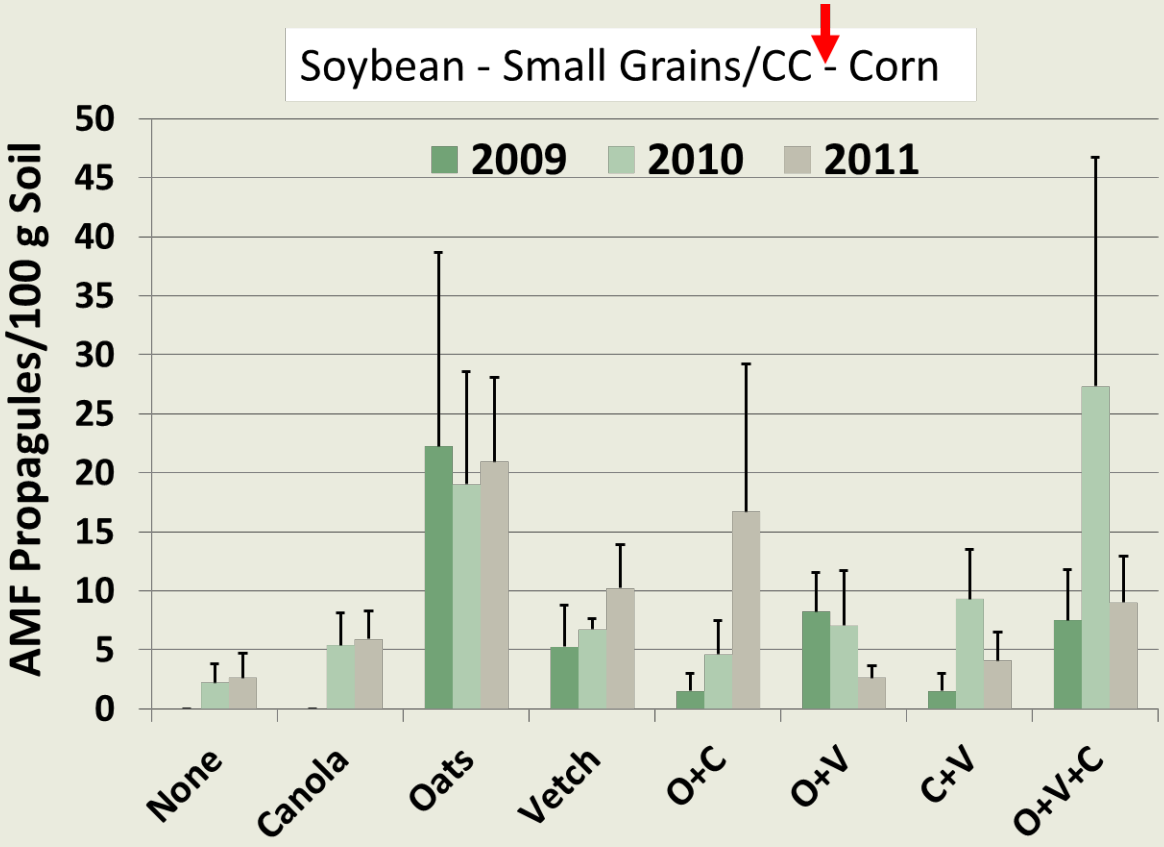
Clear with boiling KOH

Stain with trypan blue

Scoring (±)



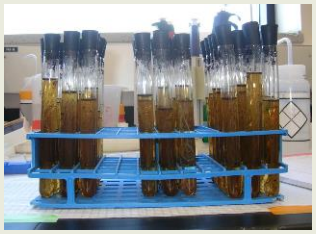
AMF Soil Propagules: Brookings, SD, fall soils



Lehman et al. 2012. Appl. Soil Ecol 64:127-134
Lehman et al. 2019. Mycorrhiza 29:227-235

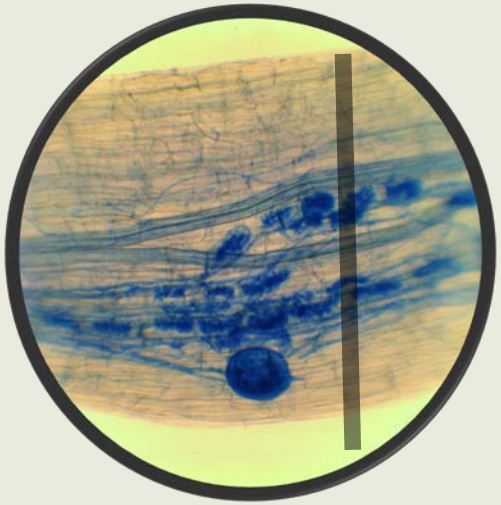
Plant Root Colonization (%)

6 plants per plot



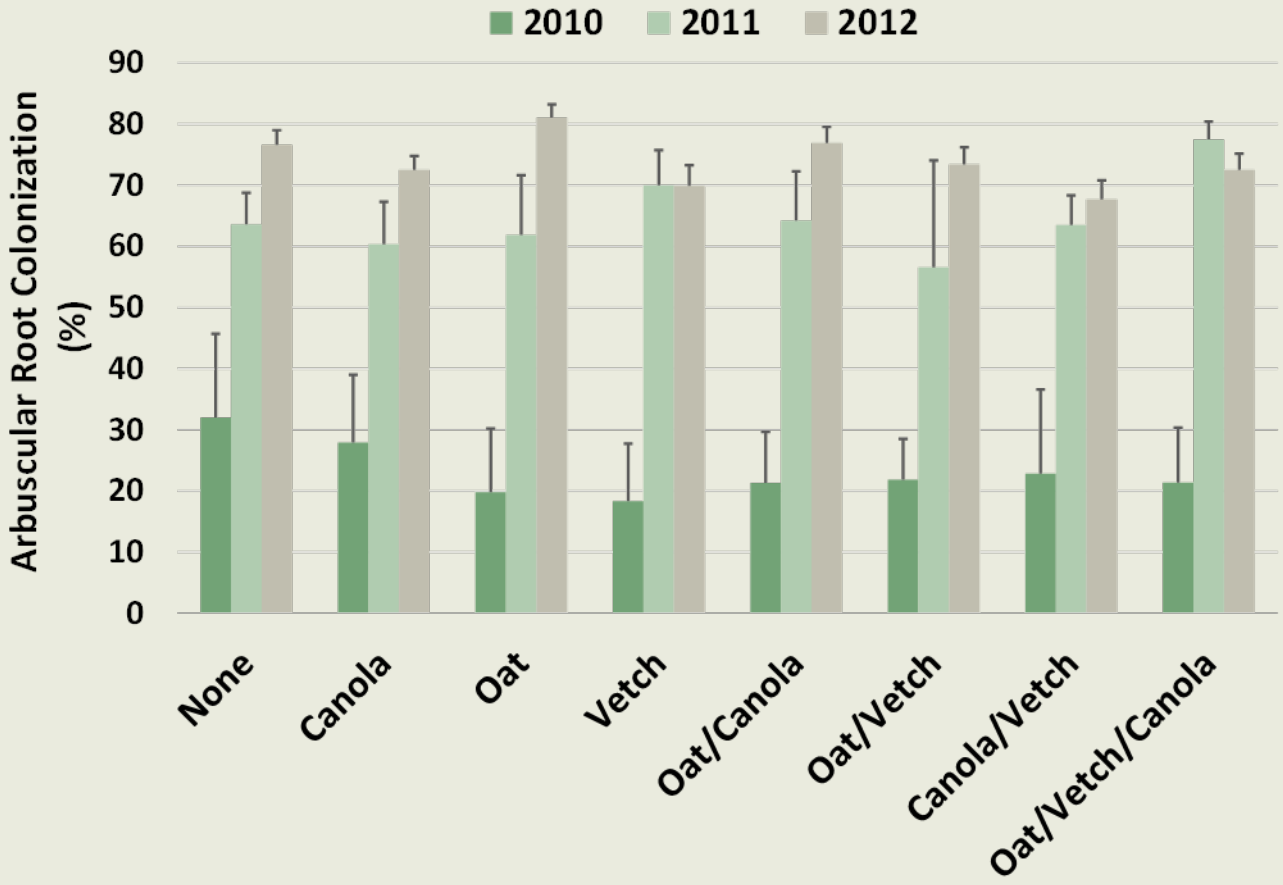
*Or using Cassettes

Random, fine roots



Score 200 scope fields per plant

Corn Root Colonization Response to Covers



Lehman et al. 2019. Mycorrhiza 29:227-235

Fatty Acid Methods
PLFA, NLFA, EL-FAME

Applied Soil Ecology 95 (2015) 86–89

Short communication

Comparison of biochemical and microscopic methods for quantification of arbuscular mycorrhizal fungi in soil and roots

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ARTICLE INFO

Article history:
Received 16 March 2015
Received in revised form 29 May 2015
Accepted 1 June 2015
Available online 1 July 2015

Keywords:
Arbuscular mycorrhizal fungi
PLFA
NLFA
Ester-linked FAME

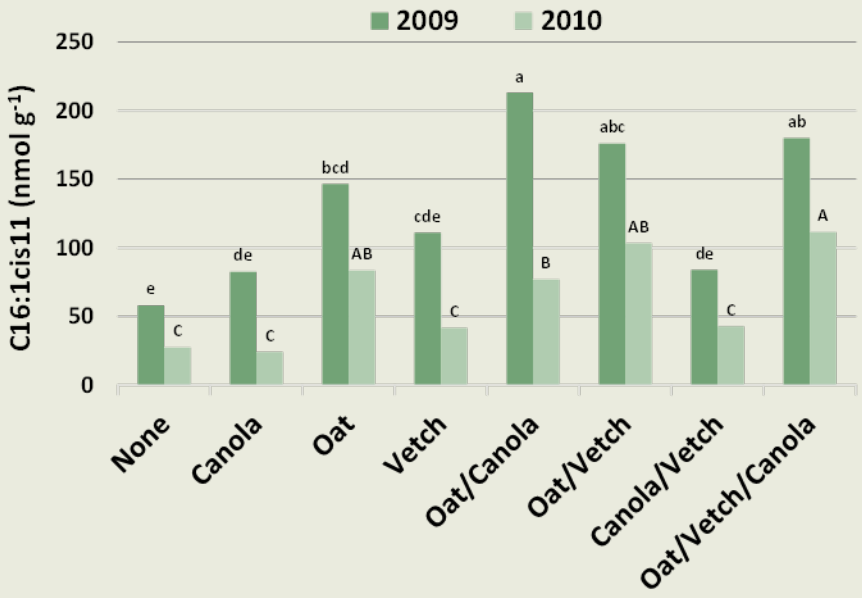
ABSTRACT

Arbuscular mycorrhizal fungi (AMF) are well-known plant symbionts which provide enhanced phosphorus uptake as well as other benefits to their host plants. Quantification of mycorrhizal density and root colonization has traditionally been performed by root staining and microscopic examination methods, which are time-consuming, laborious, and difficult to reproduce between laboratories. A number of biochemical markers for estimating mycorrhizal hyphae and spores have been published. In this study we grew maize plants in three different soils in a replicated greenhouse experiment and compared the results from two microscopic methods, spore density and root colonization, to the results from three lipid biomarker methods: neutral lipid fatty acid, phospholipid fatty acid, and ester-linked fatty acid analysis. Ester-linked fatty acid analysis gave consistent results for both spore density and root colonization, but neutral lipid fatty acid analysis had the highest correlation to AMF spore counts. Phospholipid fatty acid analysis was not correlated to spore density and did not reproducibly correlate to root colonization.

Published by Elsevier B.V.

Fatty Acid Biomarker Response to Covers, Fall Soils

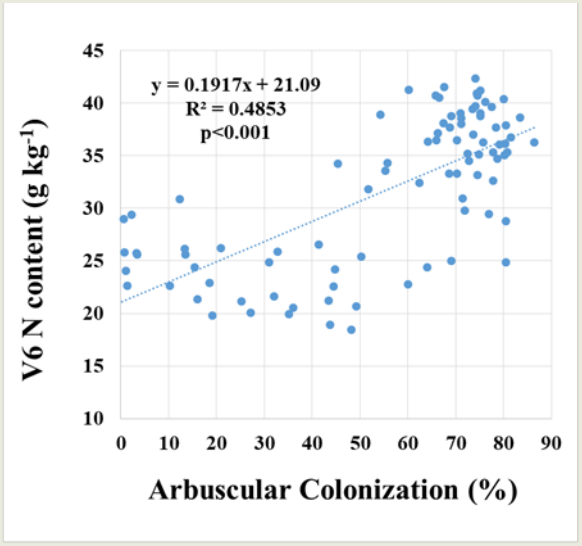
NLFA

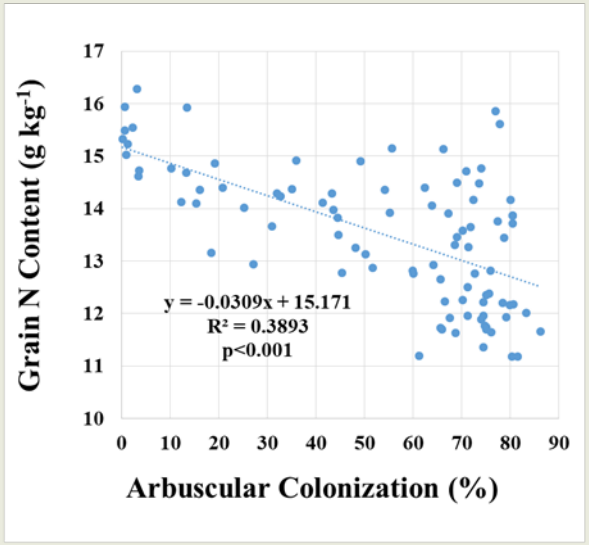


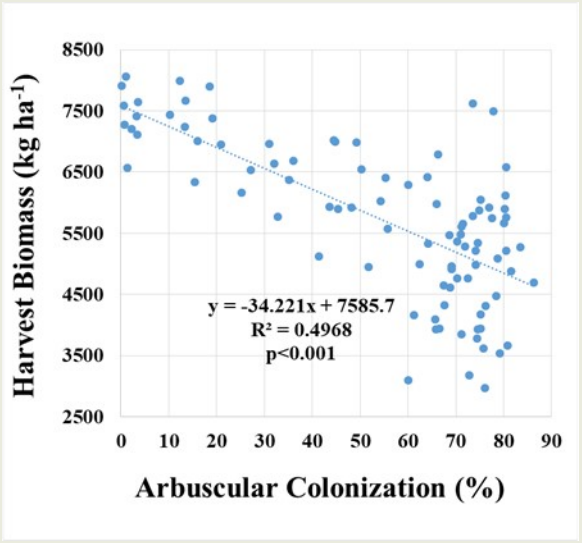
PLFA

Lehman et al. 2019. Mycorrhiza 29:227-235

Relationships with Yield, Nutrient Uptake







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Other Biochemical Measures

- Glomalin
- Enumeration of gene copies (i.e., qPCR)
- Sequence analysis (amplicons or meta-genomes)

Routine, Reliable, Insightful Measurements of AM Fungal Responses in the Field to Agricultural Management Tactics

?

- Field data varies with many environmental factors
- Controlled, small scale or greenhouse expts with +/- AM fungal more likely to show positive relationships

Management Tactics Largely Conclusive

Tend to Reduce Soil Health	Tend to Promote Soil Health
Aggressive tillage	No-till or conservation tillage
Annual/seasonal fallow	Cover crops; Relay crops
Mono-cropping	Diverse crop rotations
Annual crops	Perennial crops
Excessive inorganic fertilizer use	Organic fertilizer use (manures)
Excessive crop residue removal	Crop residue retention
Broad spectrum fumigants/pesticides	Integrated pest management
Broad spectrum herbicides	Mulching, cultural weed control tactics

Lehman et al. (2015) J. Soil Water Conservation 70:12A-18A

Questions?