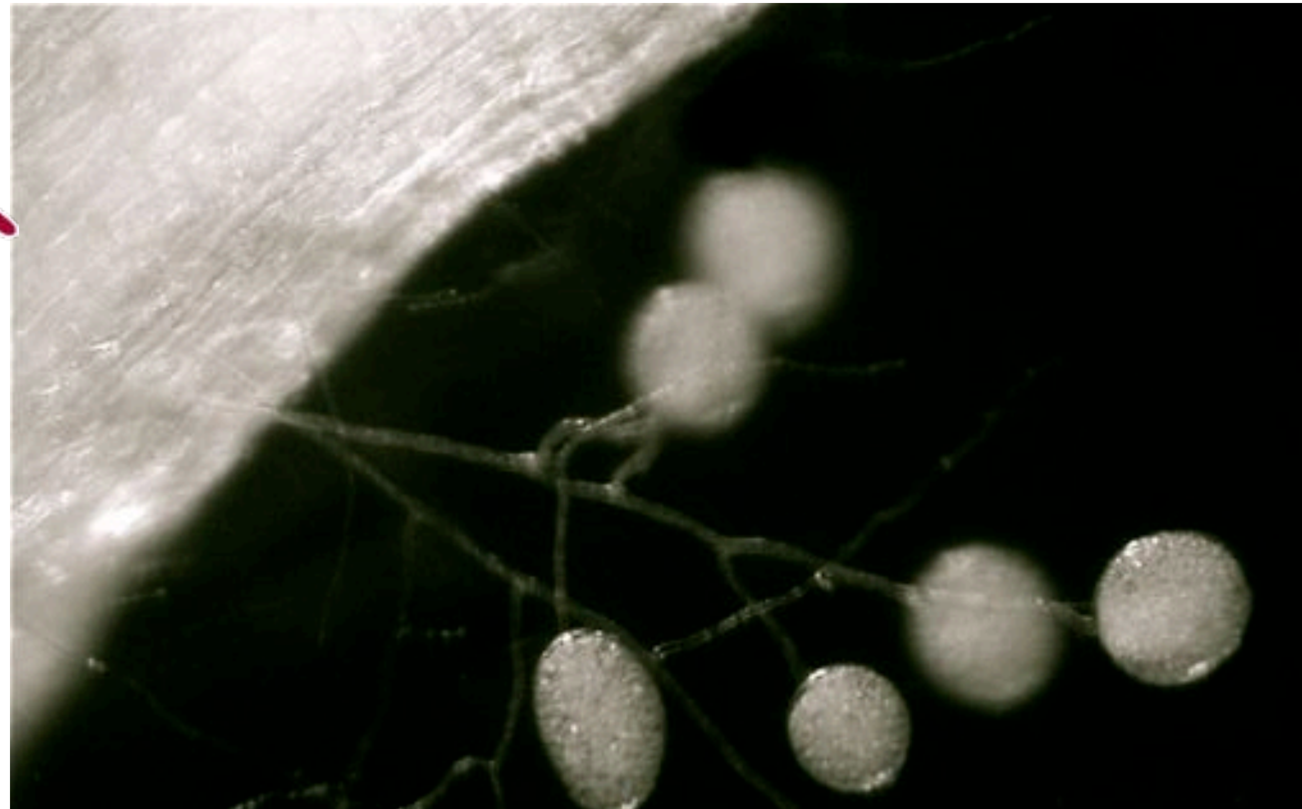
ALGOMA UNIVERSITY

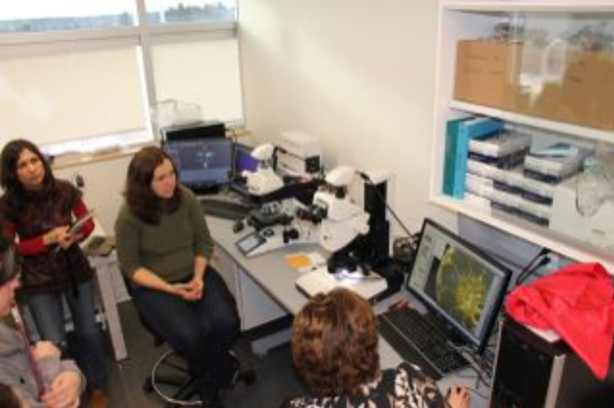


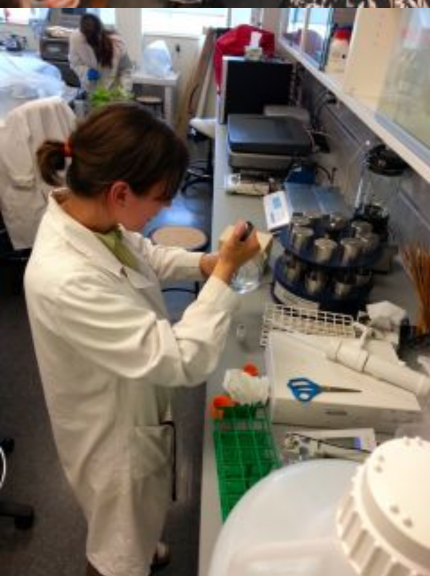
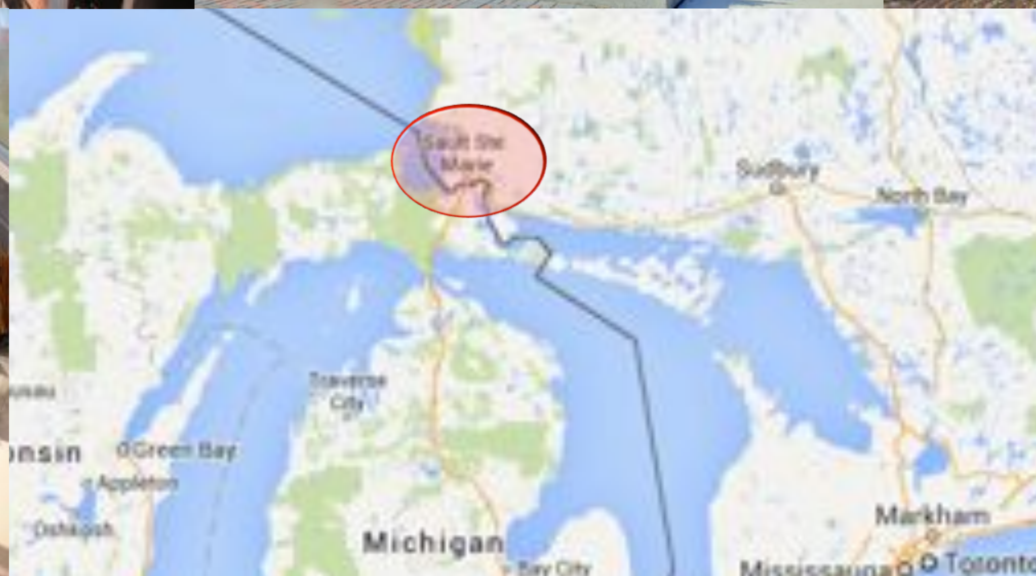
Soil biota in natural and managed plant communities: progress, challenges and opportunities

XXXIV CONGRESSO BRASILEIRO DE CIÊNCIA DO SOLO

CIÊNCIA DO SOLO PARA QUÊ E PARA QUEM?

Pedro M. Antunes

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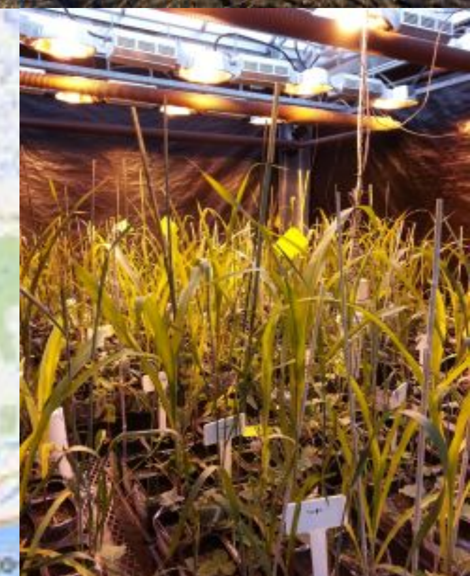
North Bay
Traverse City
Green Bay
Appleton
Oshkosh
Michigan
Bay City
Markham
Mississauga
Toronto



We don't understand...

- …why some plant species are highly abundant while others occur at low densities

Systems

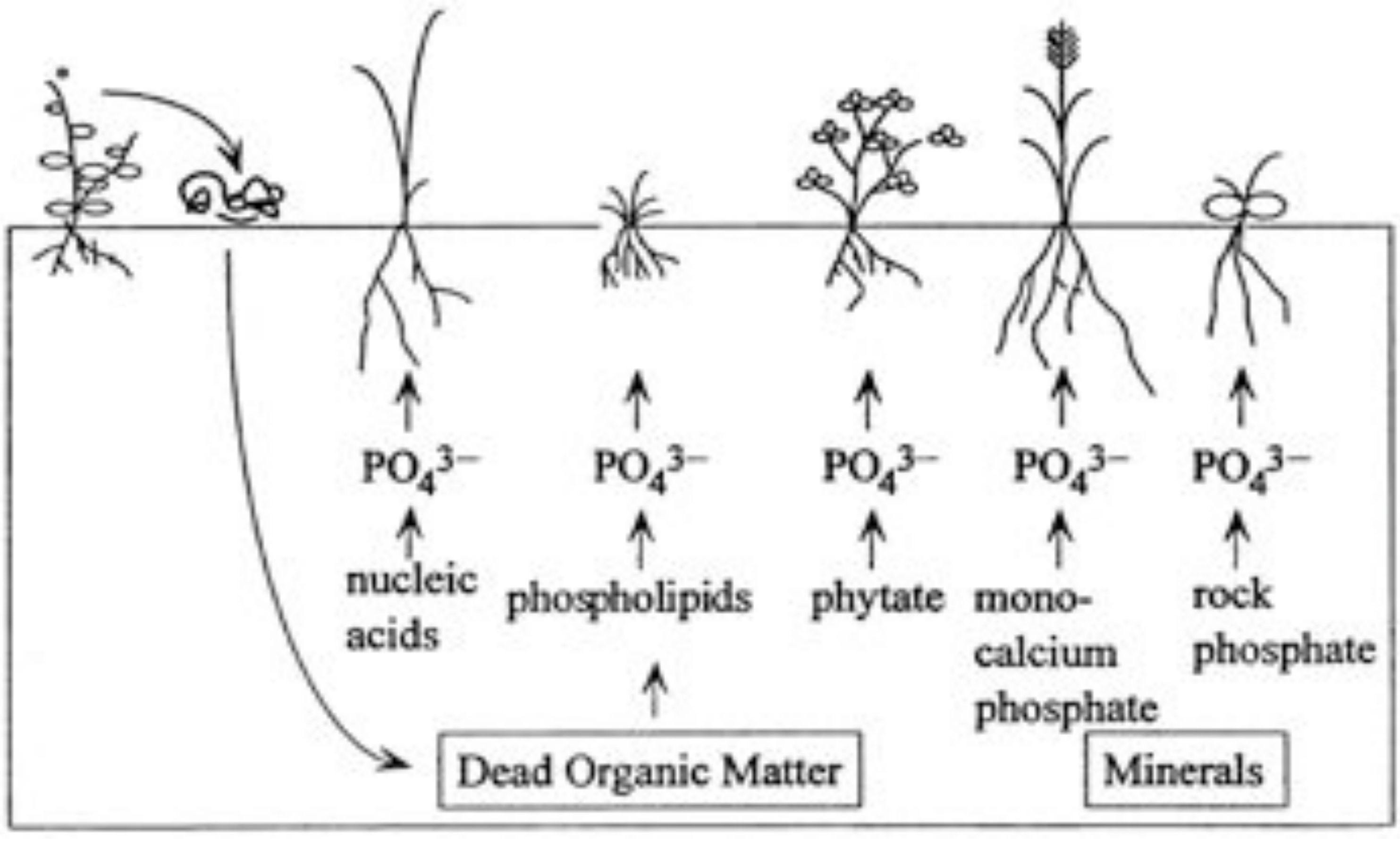
Natural

Agriculture

Invaded

Proposed frameworks to explain why some plants are abundant and others are rare

- Resource partitioning

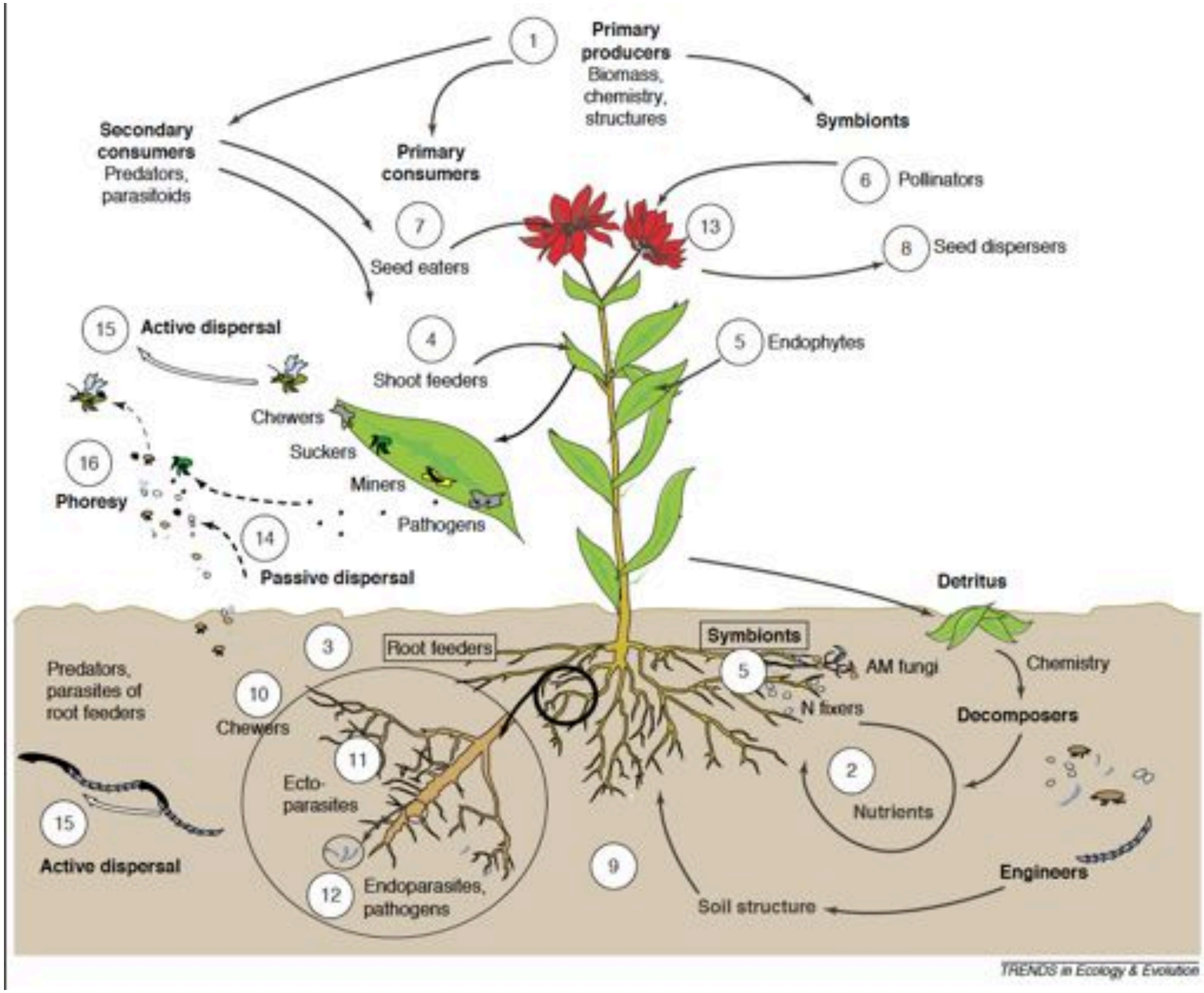


H. L. Reynolds et al., 2003 *Ecology*

- Resource partitioning while neglecting plant microbe interactions fails to explain plant community dynamics (Miller et al., 2005; Bever et al., 2012)

- The role of below-ground soil organisms interacting with plant roots has been gaining increasing attention in recent years

- However, the mechanisms regulating these processes are very poorly understood



de Deyn and van der Putten 2005, TREE

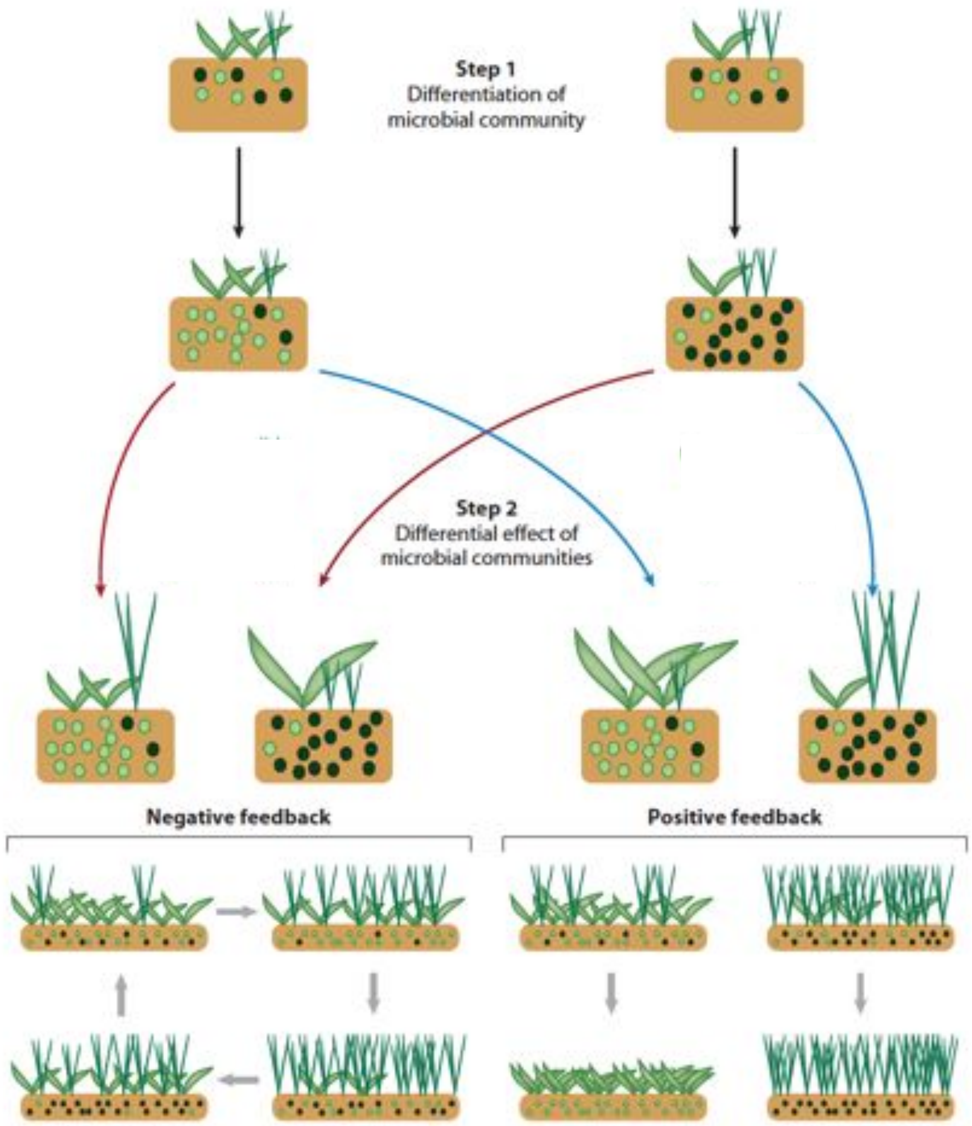
Unknown (rhizosphere)biodiversity

The Fungi: 1, 2, 3 ,… 5.1 million species? (Blackwell, 2011)

Taxo-nomic level	Organism group	Global no. of described species	% known of expected
Kingdom	Plantae	270 000	84
Kingdom	Animalia	358 800	27
	- Vertebrates	52 500	95
	- Insects and myriapods	963 000	1
	- Collembola	7617	15
	- Mites	45 231	4
	- Earthworms	3500	50
	- Nematodes	25 000	6
Kingdom	Fungi	72 000	5
Domain	Bacteria	10 000	1

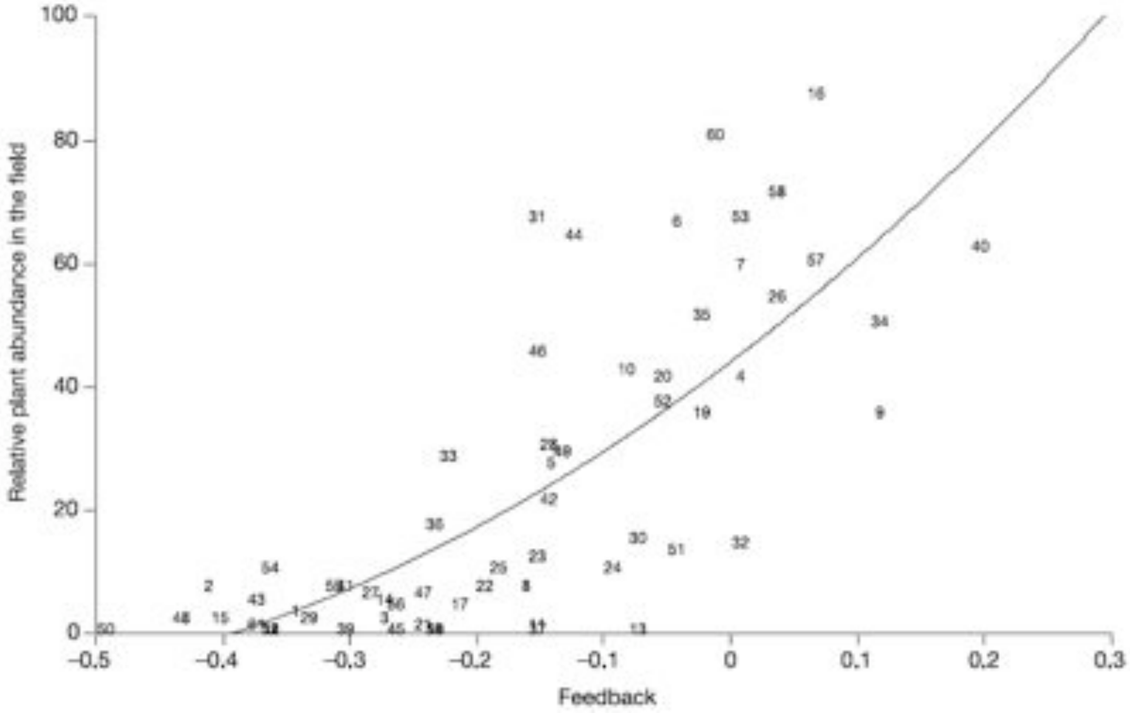
de Deyn and van der Putten 2005, TREE

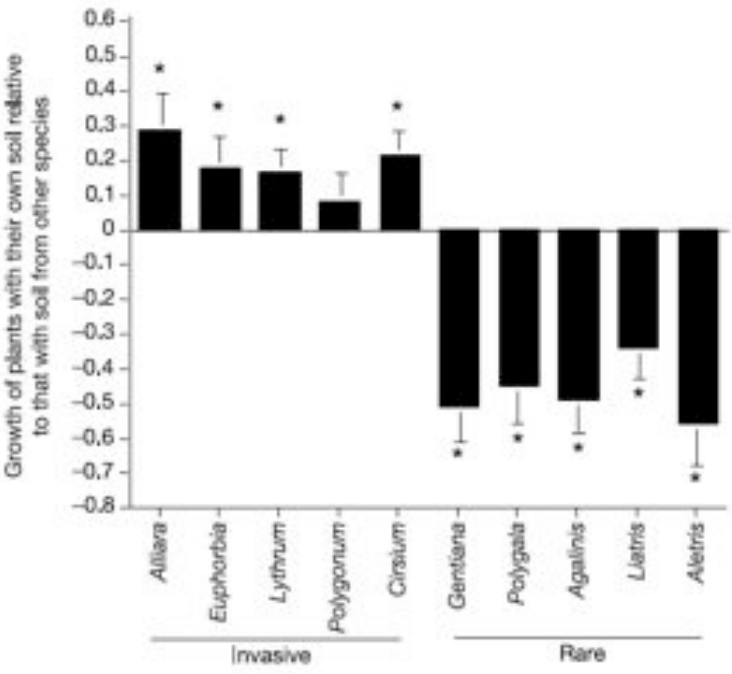
The concept of feedback



Bever et al. 2013, Ann. Rev. Microbiol.

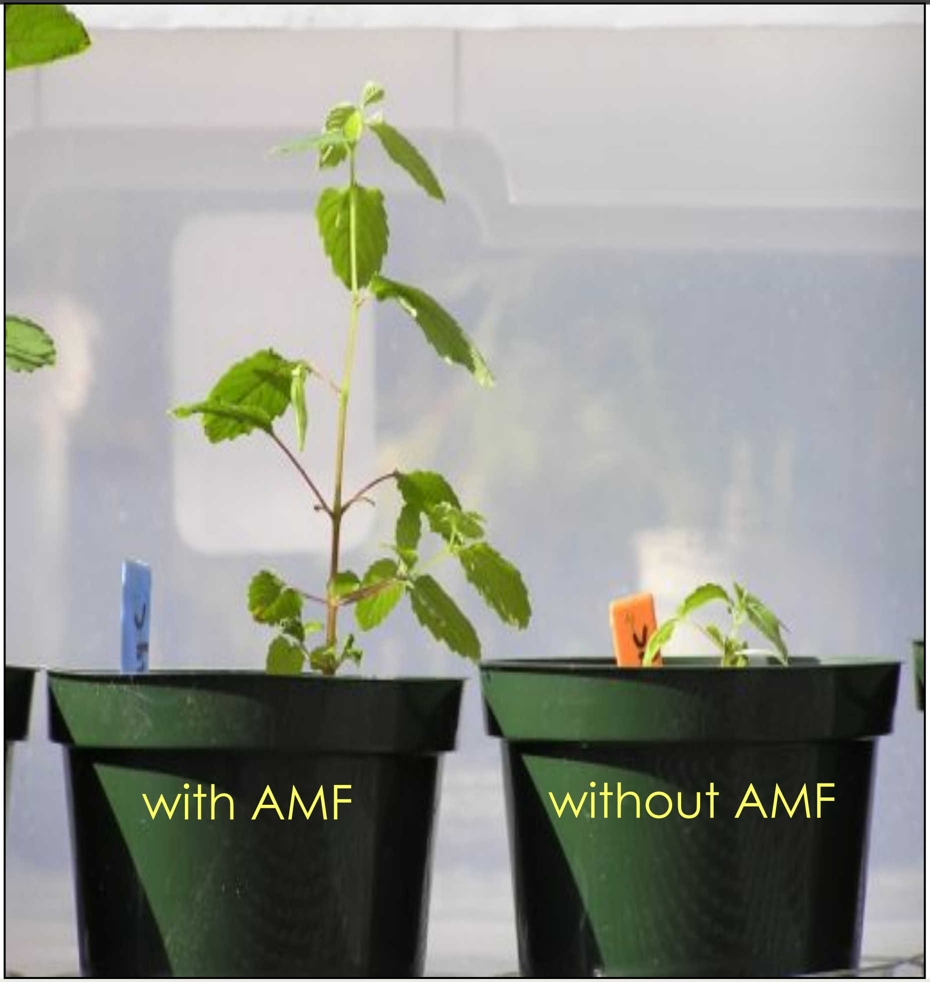
Feedbacks and plant communities - evidence

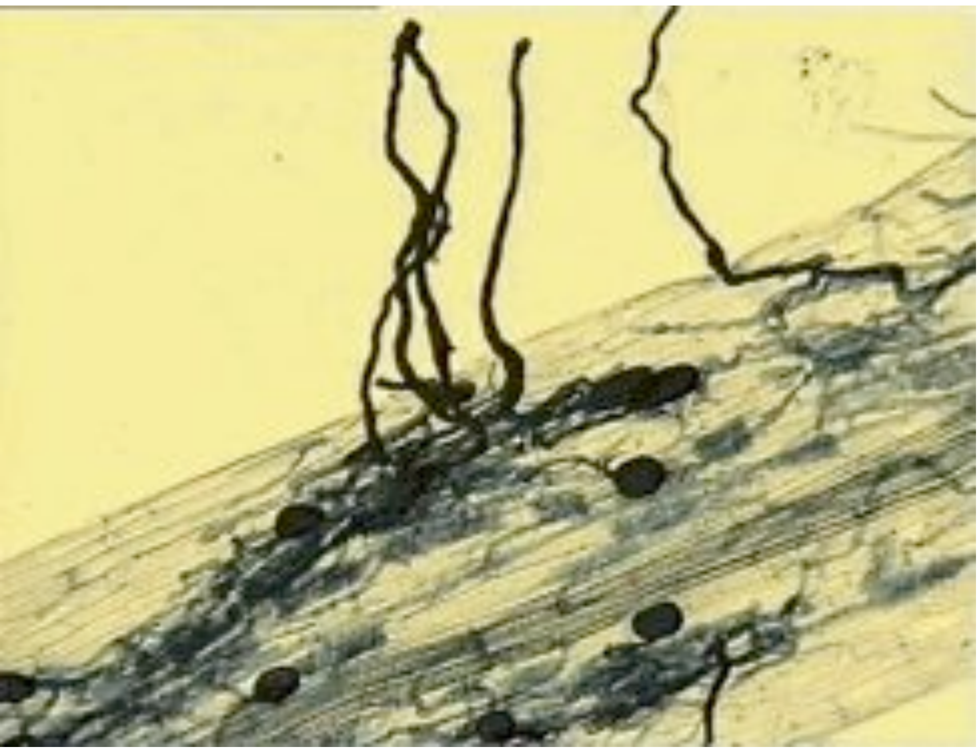




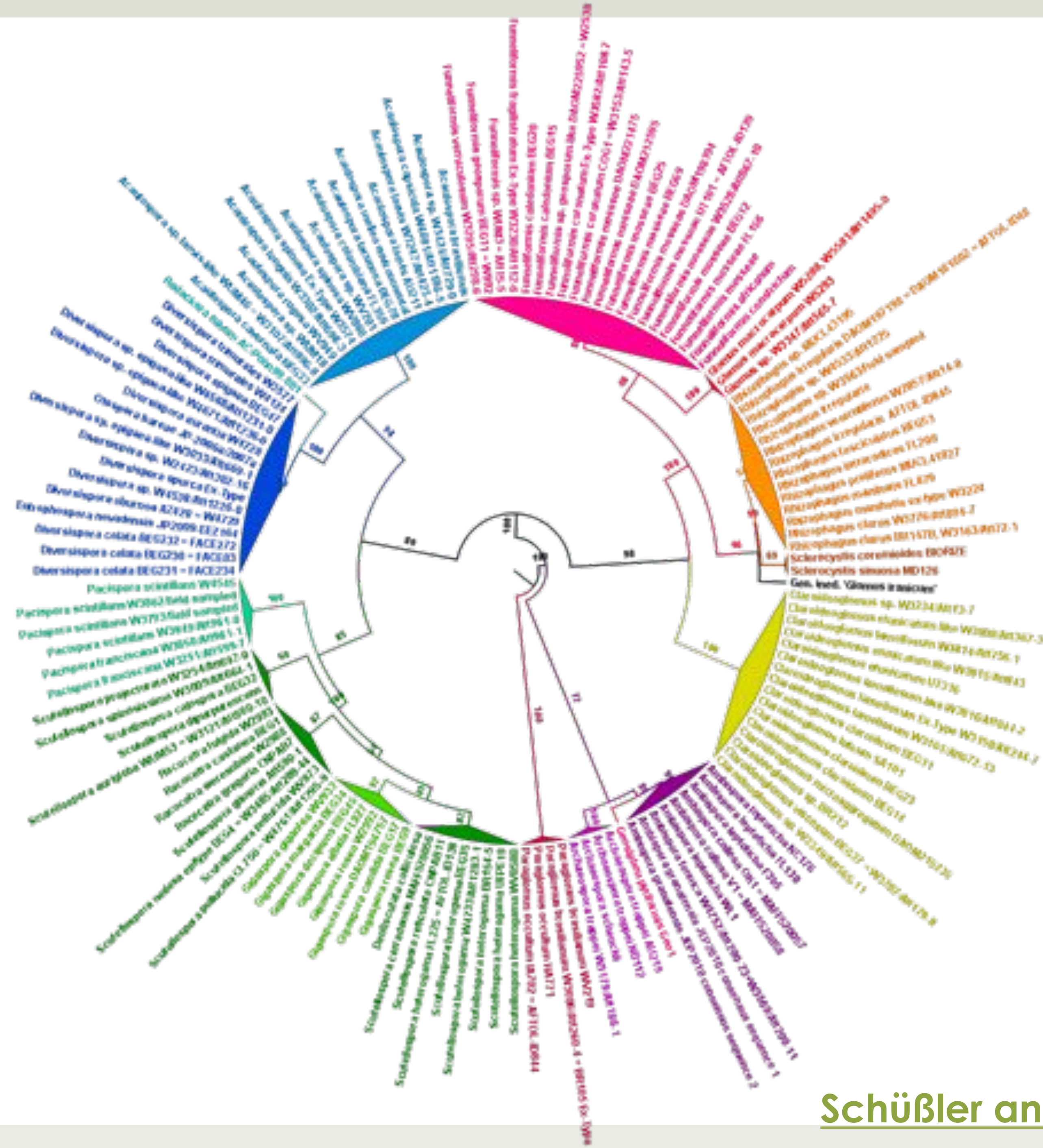
Klironomos *2002, Nature 417:67*

Mycorrhizal fungi



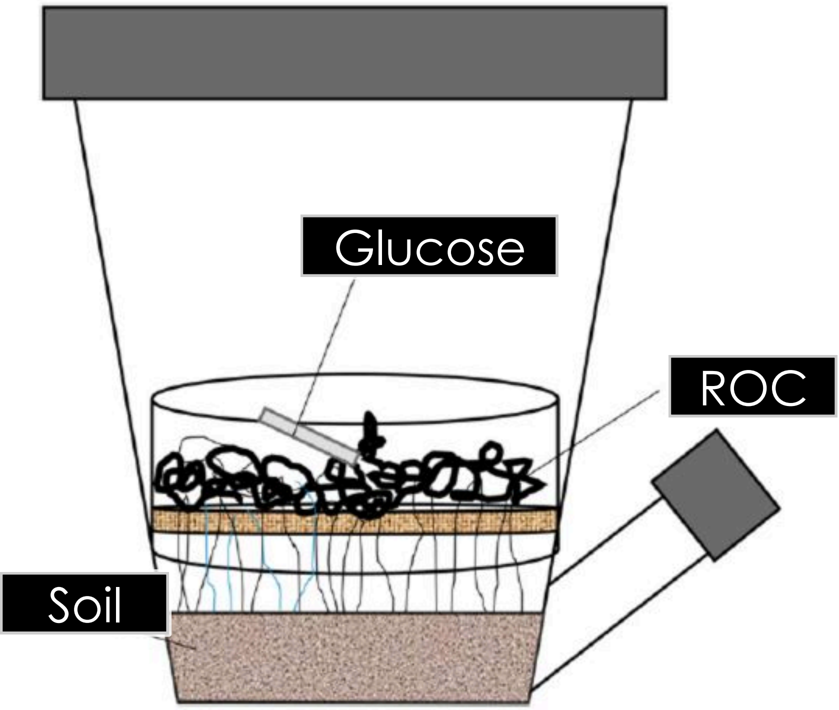


Source: Jim Deacon and Thomas Fester



Schüßler and Walker 2010

Soil responses



Response variable	Non-inoculated (control)	Inoculated	F value (*p* value)
	Whole soil		
AM fungal extraradical hyphal length (m g^{-1} soil)	4.12 (0.33)	12.20 (1.12)	43.8 (**<0.0001**)
Proportion of aggregates with surficial hyphae (%)	10.0 (4.7)	47.9 (5.0)	29.4 (**0.0006**)
Mean weight diameter from dry-sieving (mm)	0.93 (0.06)	0.91 (0.05)	0.09 (0.77) ns
Water-stable macroaggregates >0.250 mm (% of soil weight)	61.8 (2.6)	72.9 (2.7)	8.75 (**0.011**)
Water drop penetration time (seconds)	9.6 (0.7)	11.9 (0.9)	4.0 (0.058) ns
Total C (%)	2.22 (0.06)	2.25 (0.06)	0.11 (0.74) ns
Total N (%)	0.19 (0.005)	0.19 (0.006)	0.11 (0.75) ns
	Stable macroaggregates		
Water drop penetration time (seconds)	12.2 (1.0)	26.3 (2.2)	37.5 (**<0.0001**)
Total C (%)	2.51 (0.03)	2.49 (0.04)	0.17 (0.8) ns
Total N (%)	0.21 (0.002)	0.21 (0.002)	1.46 (0.24) ns

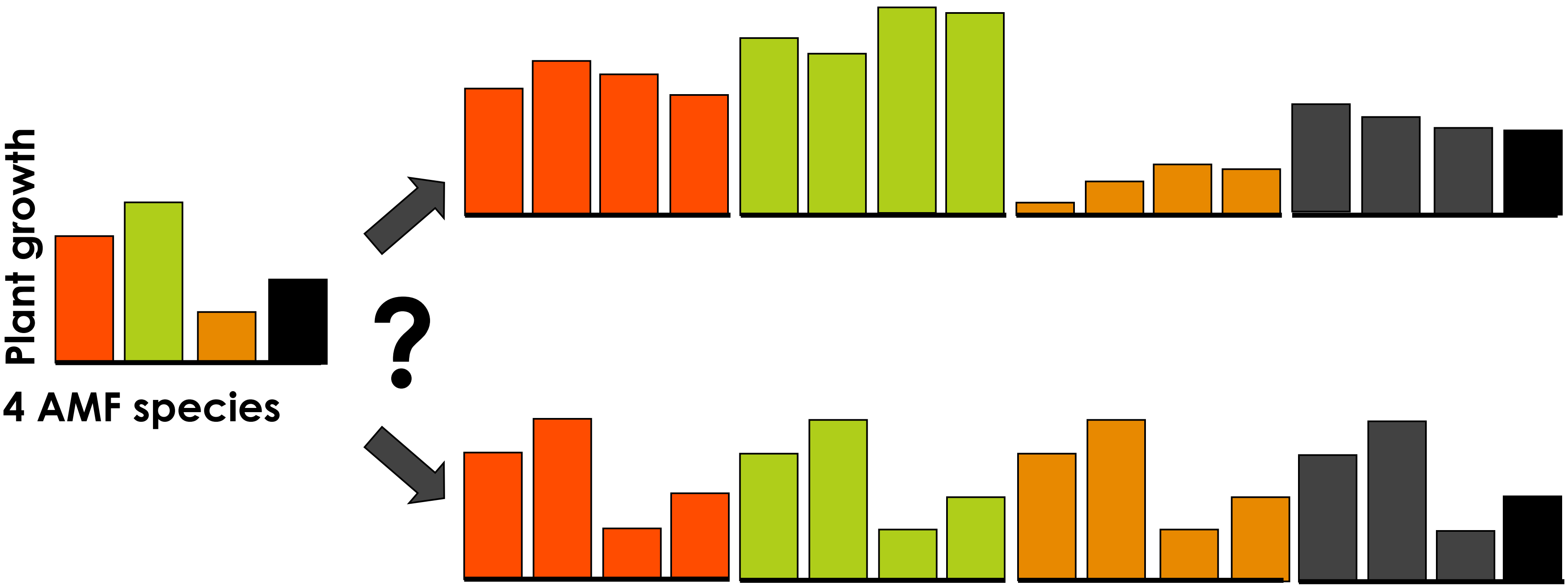
- AM fungi alone can be sufficient to form and/or maintain water-stable soil macroaggregates

Rillig et al 2010. Soil Biol Biochem

Questions – biotic interactions

- Can plant and soil responses be predicted based on biota identity?
- How important is pathogen protection by AMF?
- Are local adaptations to environmental conditions important for symbiotic functioning and, thus, to plant growth responses?

Biomass responses



Can plant growth responses to AMF be predicted based on AMF identity?

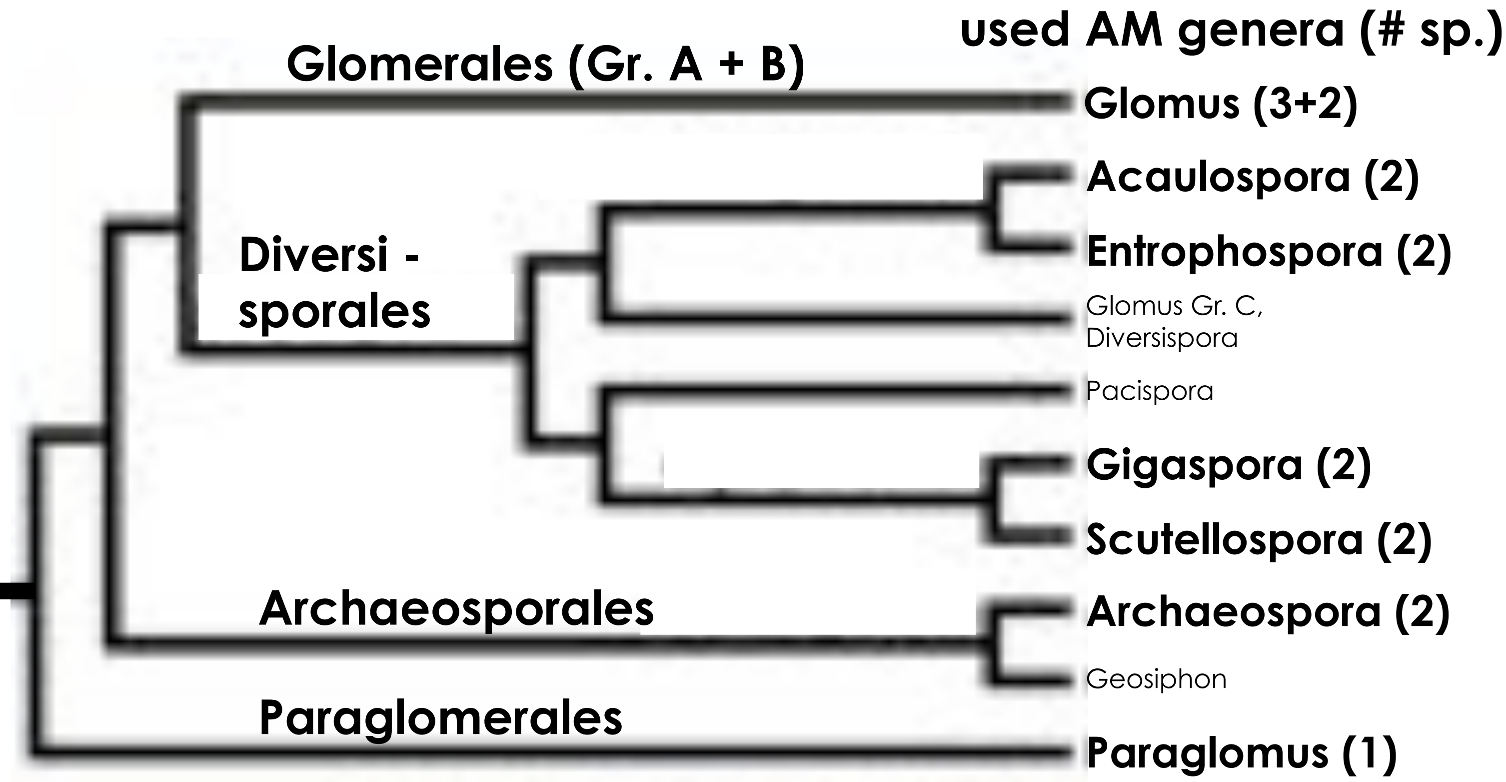
Three plant species…

Achillea millefolium
(Asteraceae)

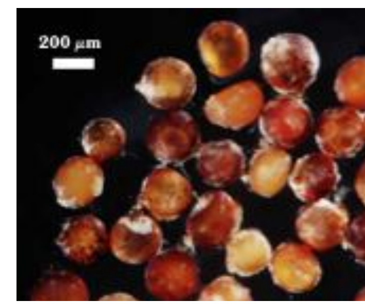
Bromus inermis
(Poaceae)

Medicago sativa
(Fabaceae)

... each inoculated with 56 AM isolates of 16 species (or left uninoculated) most of which were obtained from **INVAM** (**In**ternational Culture Collection of **V**esicular **A**rbuscular **M**ycorrhizal Fungi)



Gl. mosseae



Sc. heterogama

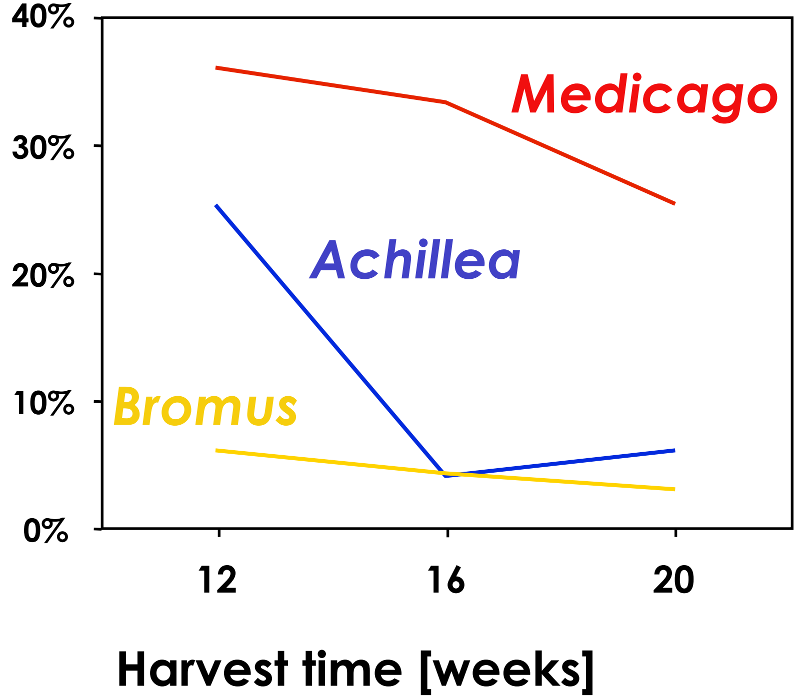
Ar. leptoticha

sources: phylogenetic tree: http://www.tolweb.org/tree
pictures: http://invam.caf.wvu.edu

... individual plants of each AM isolate * host combination (n= 10) were grown in 500 ml containers; (total of 1740 replicate units)

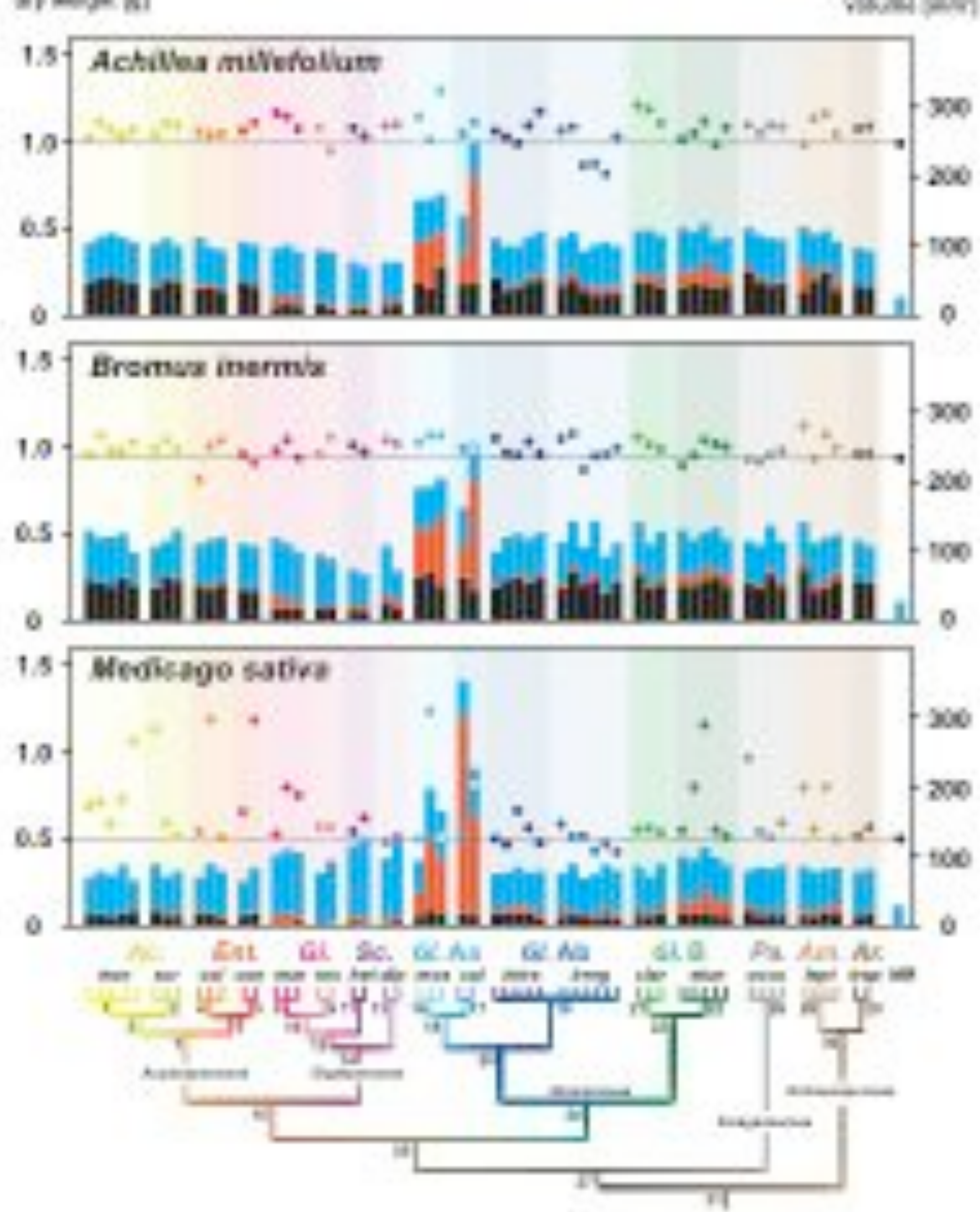
Mycorrhizal plants grew 17% larger than controls...

Growth promotion relative to controls



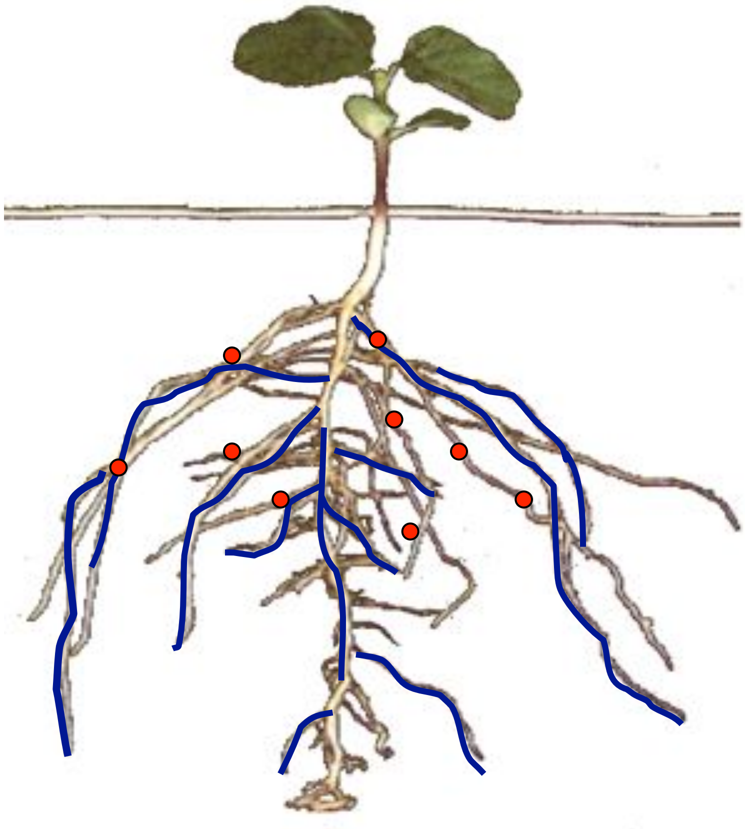
... and the plant species differ in their overall "responsiveness"

Koch, Antunes, Maherali and Klironomos (submitted)



Koch, Antunes, Maherali and Klironomos (submitted)

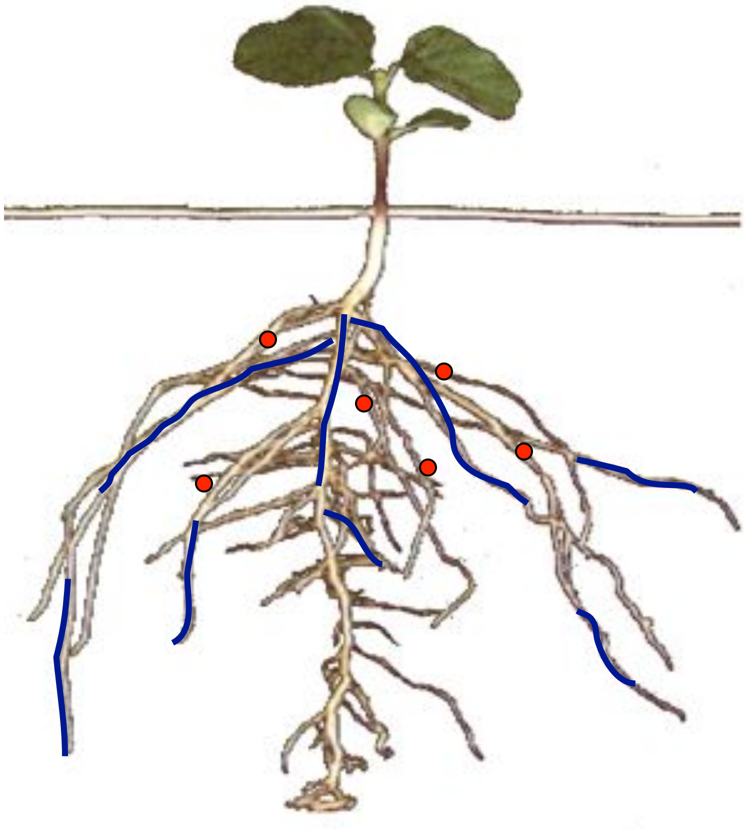
Mutualism-mutualism interactions



Nodules 10.8 a

Arbuscules: 32 a

Hyphae: 58 a



Nodules 6.6 b

Arbuscules: 22 b

Hyphae: 37 b

Antunes et al 2006, Soil Biol Biochem

Cell

Soil Biology & Biochemistry 38 (2006) 533–543

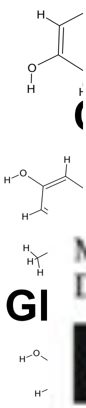
Soil Biology & Biochemistry

www.elsevier.com/locate/soilbio

Specific flavonoids as interconnecting signals in the tripartite symbiosis formed by arbuscular mycorrhizal fungi, *Bradyrhizobium japonicum* (Kirchner) Jordan and soybean (*Glycine max* (L.) Merr.)

Pedro M. Antunes*, Istvan Rajcan, Michael J. Goss

Department of Land Resource Science, University of Guelph, Richards Building, Guelph, Ont., Canada N1G 2W1



Mycorrhiza (2006) 16: 167–173

DOI 10.1007/s00572-005-0028-3

ORIGINAL PAPER

Pedro M. Antunes · Deanna Deaville · Michael J. Goss

Effect of two AMF life strategies on the tripartite symbiosis with *Bradyrhizobium japonicum* and soybean

Gl

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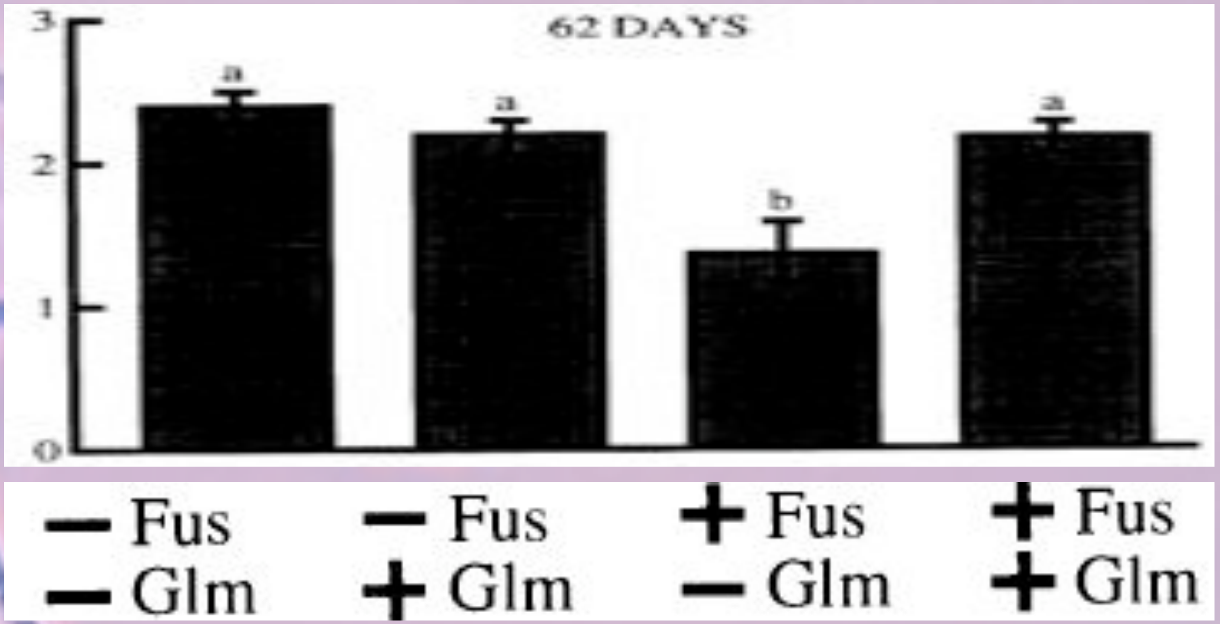
Flavonoids

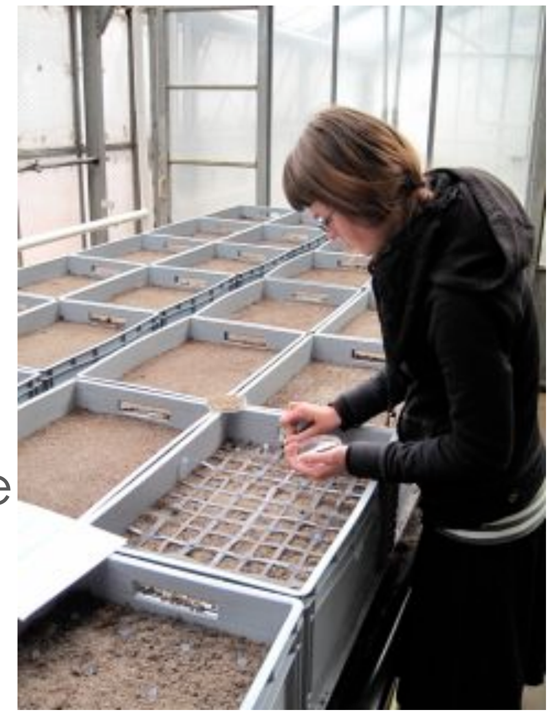
Other responses – AMF- pathogen interactions



Newsham et al., *1995,* J. Ecol. *83:991*

Plant pathogen protection by arbuscular mycorrhizas: A role for fungal diversity?

- Improved nutrient status of the host plant
- Competitive interactions with pathogenic fungi
- Architectural changes in the root system
- Microbial community changes in the rhizosphere
- Activation of plant defense mechanisms



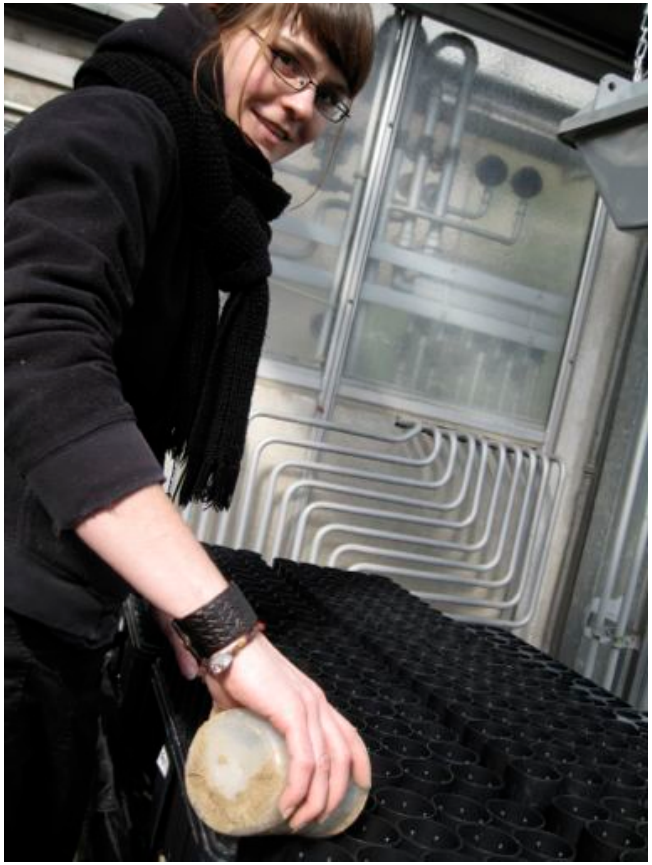
Wehner et al., 2010 Pedobiol.

Indigenous arbuscular mycorrhizal fungal assemblages protect grassland host plants from pathogens

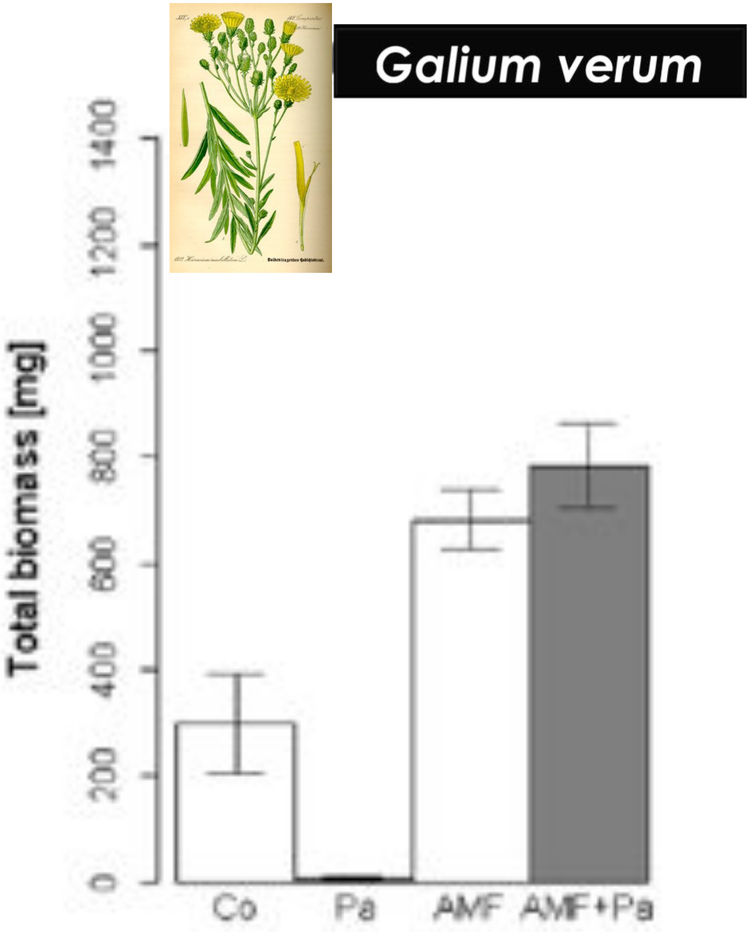
The study site (ODERHÄNGE MALLNOW)

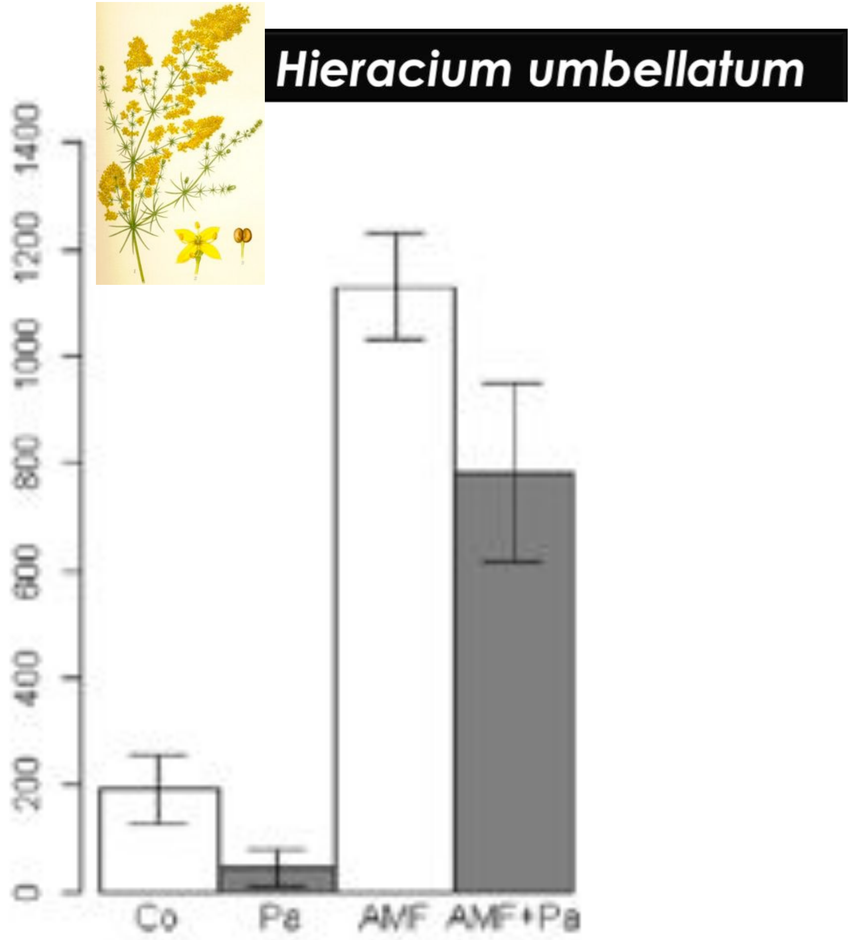
Experimental design

14 plants x 4 Soil microbial treatments x 10 replicates = 980 conetainers



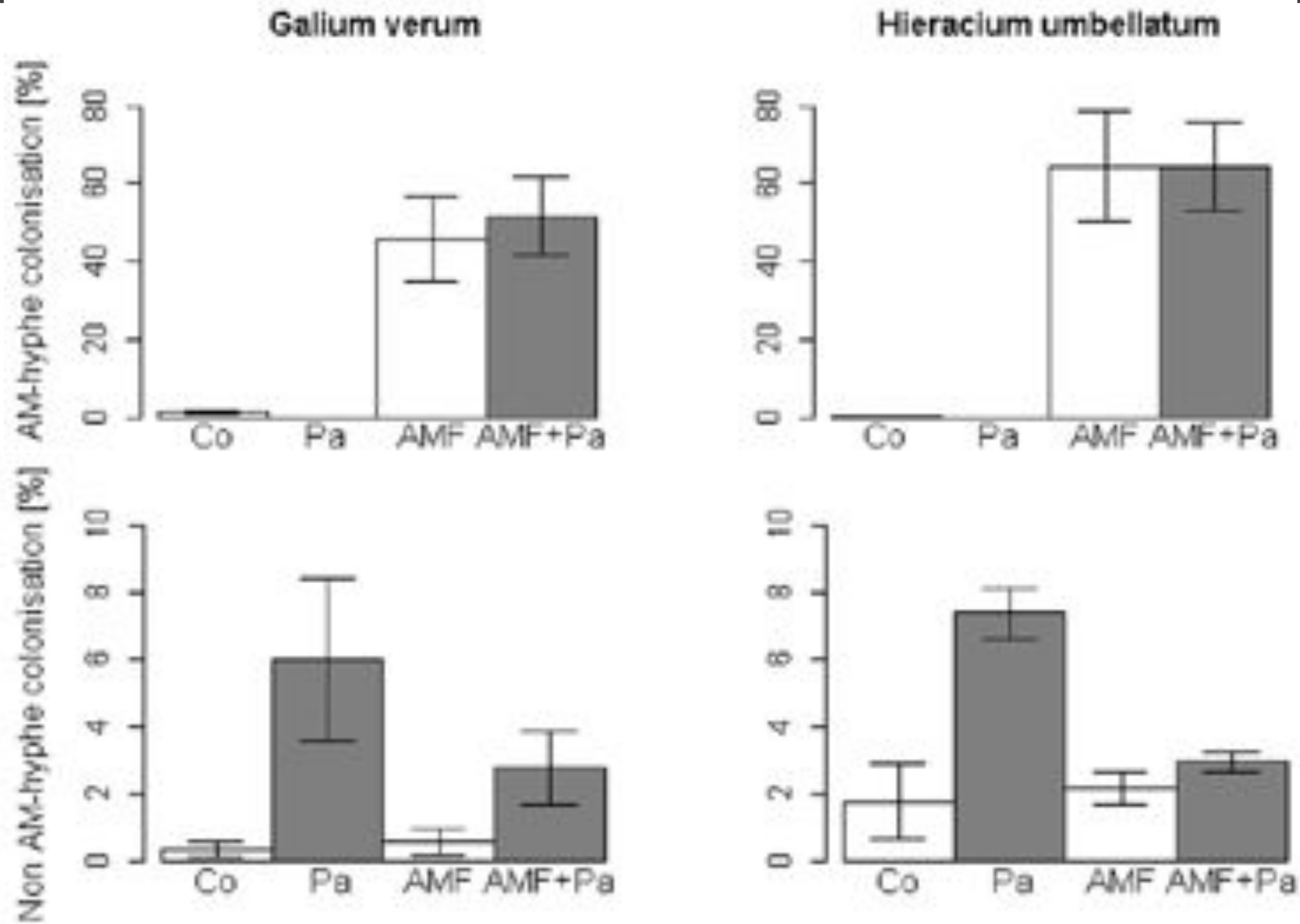
Results





Wehner et al., 2011, PLosOne

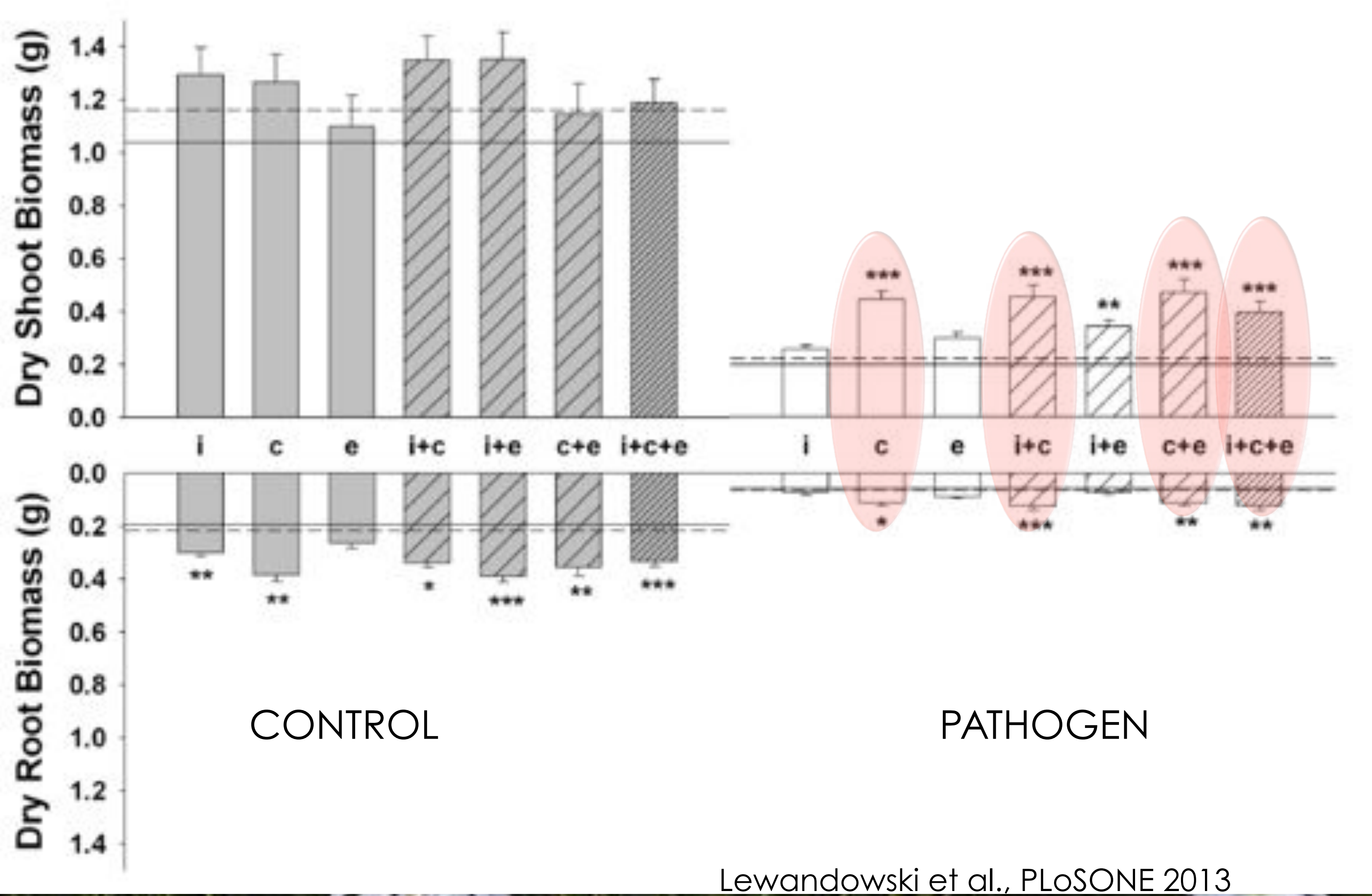
Results



Wehner et al., 2011, PLosOne

Isolate Identity Determines Plant Tolerance to Pathogen Attack in Assembled Mycorrhizal communities

Results



Lewandowski et al., PLoSONE 2013

New Phytologist
Research

Evidence for functional divergence in arbuscular mycorrhizal fungi from contrasting climatic origins

Pedro M. Antunes[1,2,3*], Alexander M. Koch[2,4*], Joseph B. Morton[5], Matthias C. Rillig[3] and John N. Klironomos[2,4]

Functional Ecology
British Ecological Society

Functional Ecology 2011 doi: 10.1111/j.1365-2435.2011.01953.x

Long-term effects of soil nutrient deficiency on arbuscular mycorrhizal communities

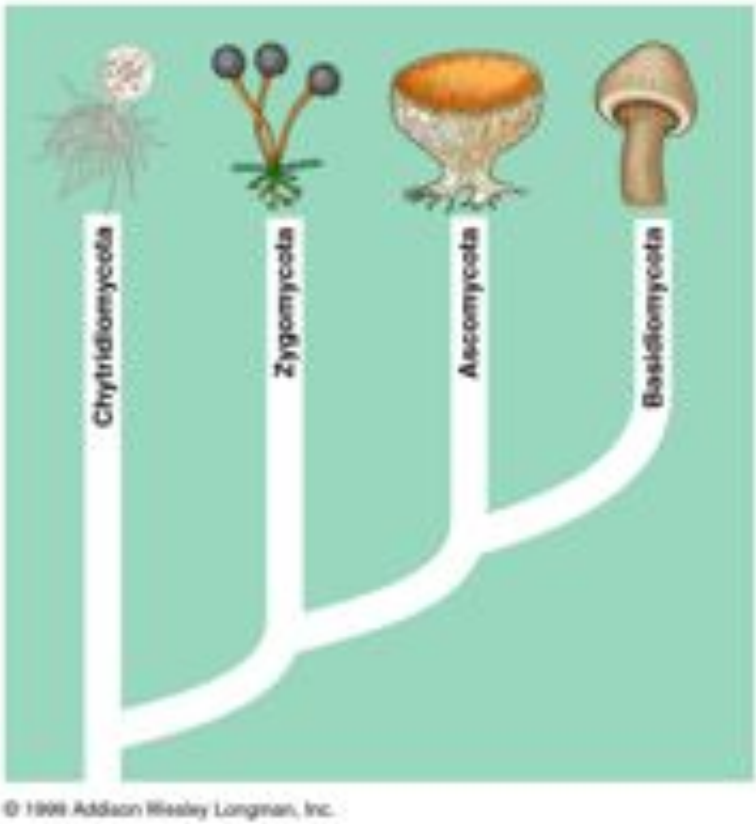
Pedro M. Antunes[1,2*], Anika Lehmann[2], Miranda M. Hart[3], Michael Baumecker[4] and Matthias C. Rillig[2]

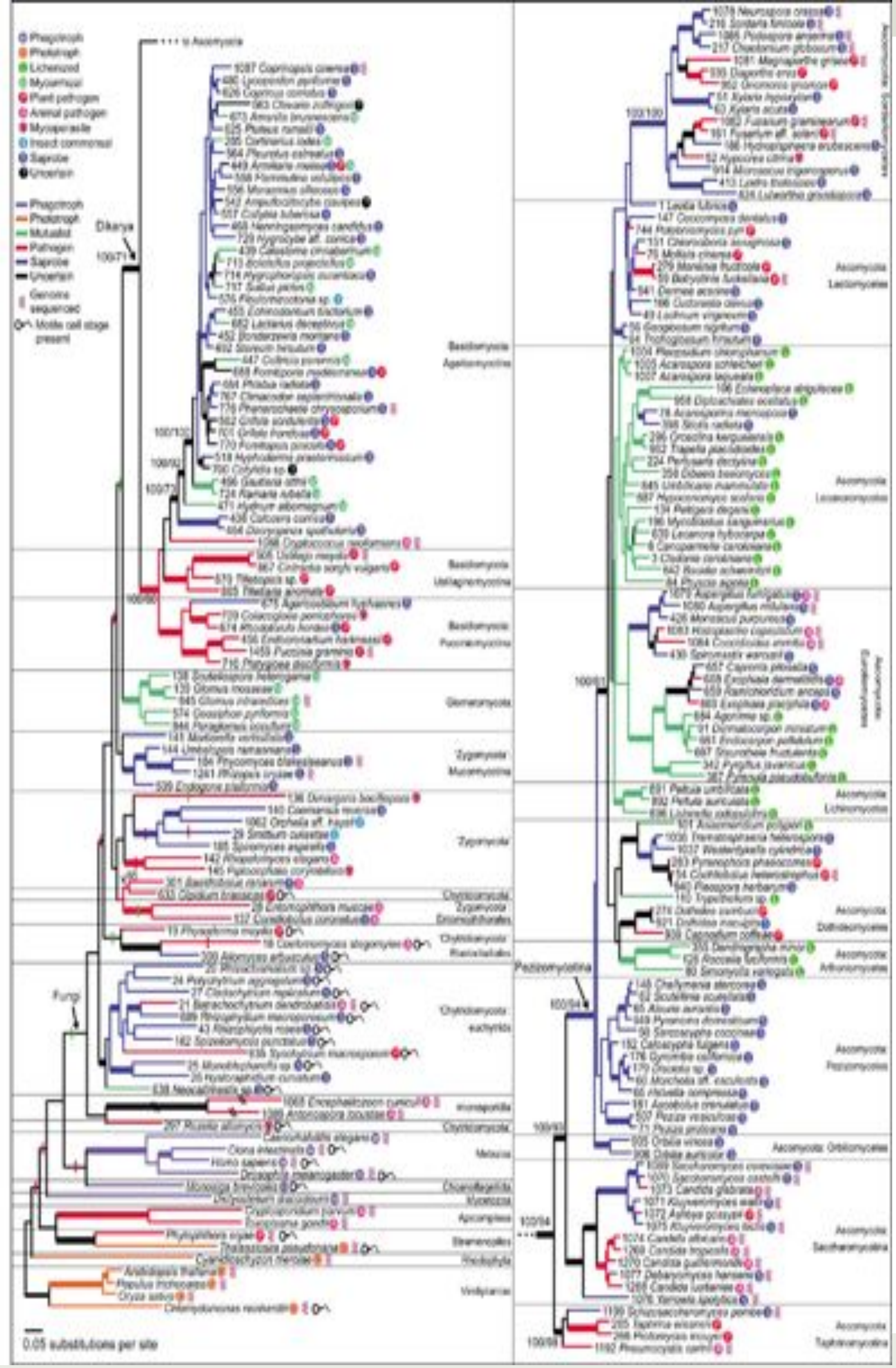
What we don't know

Little is known about the microbial and functional diversity responsible for plant-soil feedbacks

opening the black box

Reconstructing the early evolution of Fungi using a six-gene phylogeny



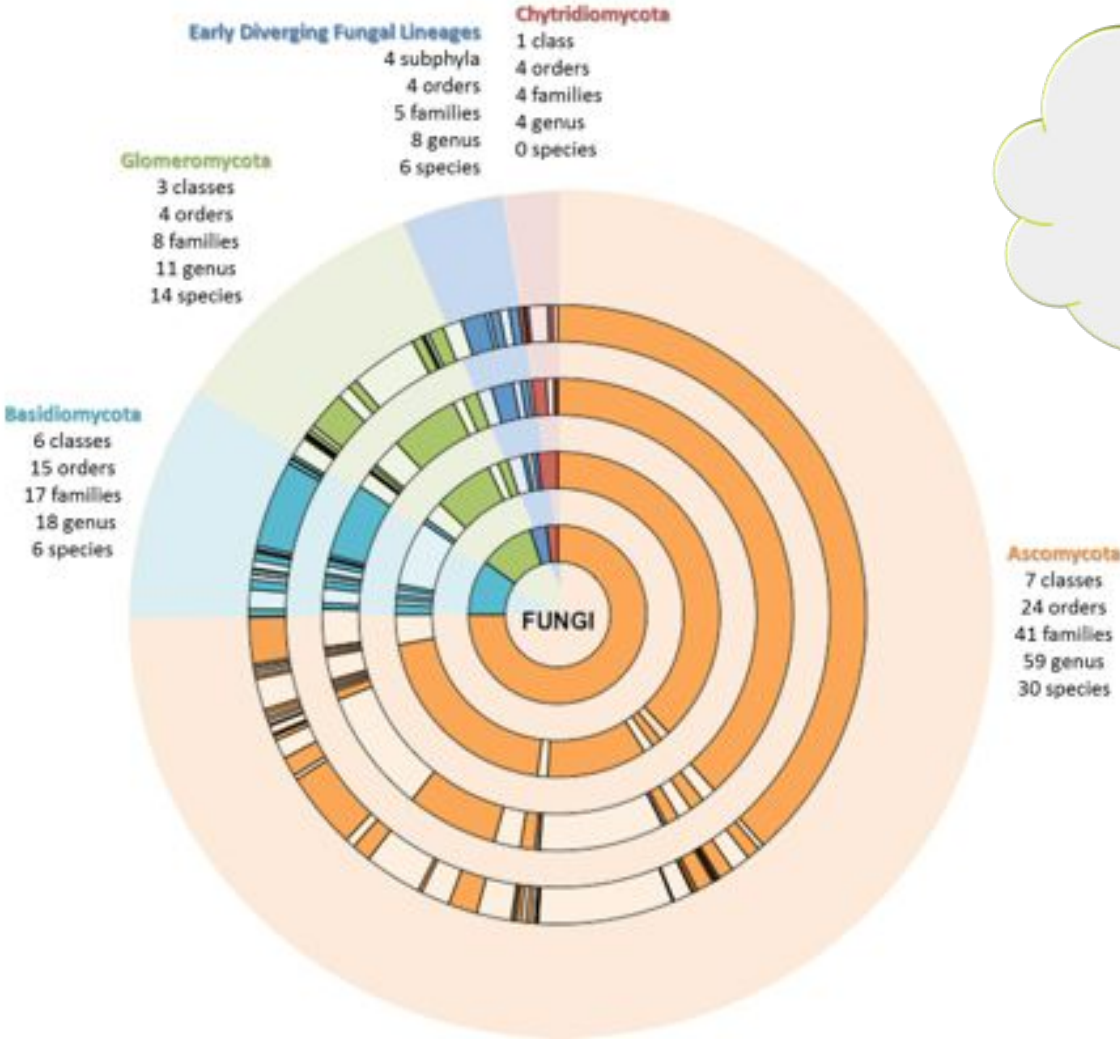


Nature 443, 818-822: 2006

Balance between pathogens and mutualisms and how do they interact?

- Integrating pyrosequencing, with functional response experiments to create database of abundant and keystone species
- Take into consideration co-adaptation in the study of best consortia

New methods to determine functional outcomes - pyrosequencing



FUTURE…

Answers

- Does mutualism prevail across the Glomeromycota?
  - Yes
- Can plant responses to AMF be predicted based on AMF species identity?
  - No
- How important is pathogen protection?
  - Some preliminary evidence that it might be important
- Are AMF adaptations to environmental conditions important for symbiotic functioning and, thus, to plant growth responses?
  - Evidence for biogeographical structure

Acknowledgements

ALGOMA university

- Prof. John Klironomos — UBC Okanagan
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- Prof. Filomena Caeiro — FCUL
- Prof. Matthias Rillig — Free University Berlin
- Prof. Joe Morton — University of West Virginia (INVAM)
- Dr. Alexander Koch — UBC Okanagan
- Jeannine Wehner, Anika Lehman (Berlin), Teresa Dias, Laura Sanderson, Thaddeus Lewandowski (Algoma University), Marta Delgado (FCUL)

MARIE CURIE ACTIONS

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Ministry of Natural Resources