Arbuscular mycorrhiza and agroecology

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International Bank for the Glomeromycota

UMR 1347 Agroécologie (INRAE, UBFC, AgroSup, CNRS)

plants

Function of mycorrhiza

carbon compounds (sugar)

mineral nutrients (phosphate, nitrogen etc.)

fungi

Symbiotic partners of arbuscular mycorrhiza

plants

-about 70-80% of vascular plants: mainly herbs, tropical trees

-hornworts, liverworts, horsetails, clubworts

(> 150 000 species)

fungi

phylum

Glomeromycota

(>300 described species)

(+Mucoromycota: ?? species)

The ubiquitous symbiosis for house, garden and agriculture

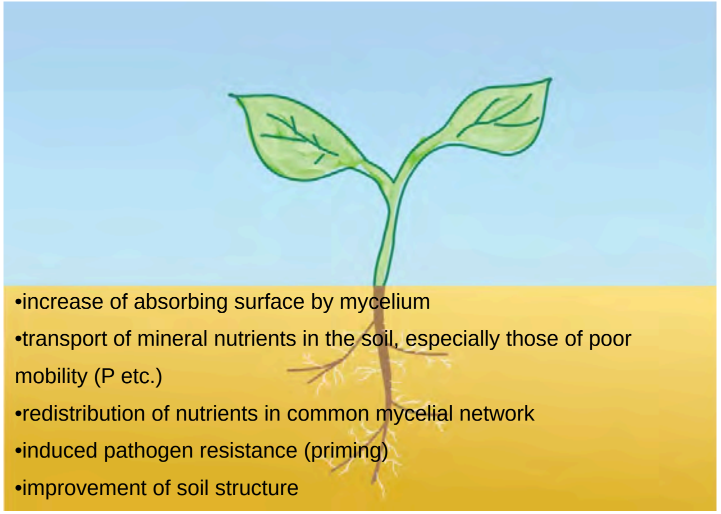
Fungi: Glomeromycota

(Photo: V. Gianinazzi-Pearson)

Plant hosts:
leek, onion, tomatoes, potatoes, beans, peas, carrots, parsley, cereals, lettuce, vines, apple trees, grasses etc.

Non-hosts:
cabbage, spinach, rutabaga

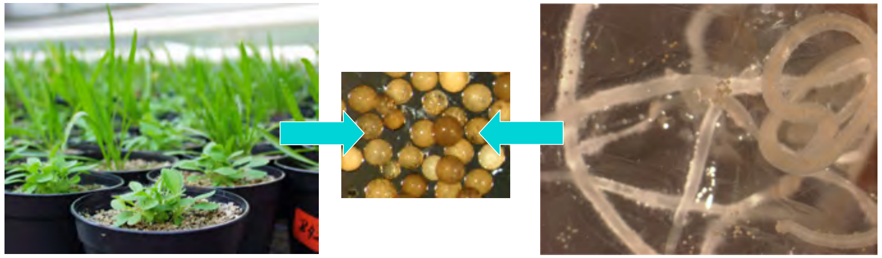
Common Mycorrhiza Functions:

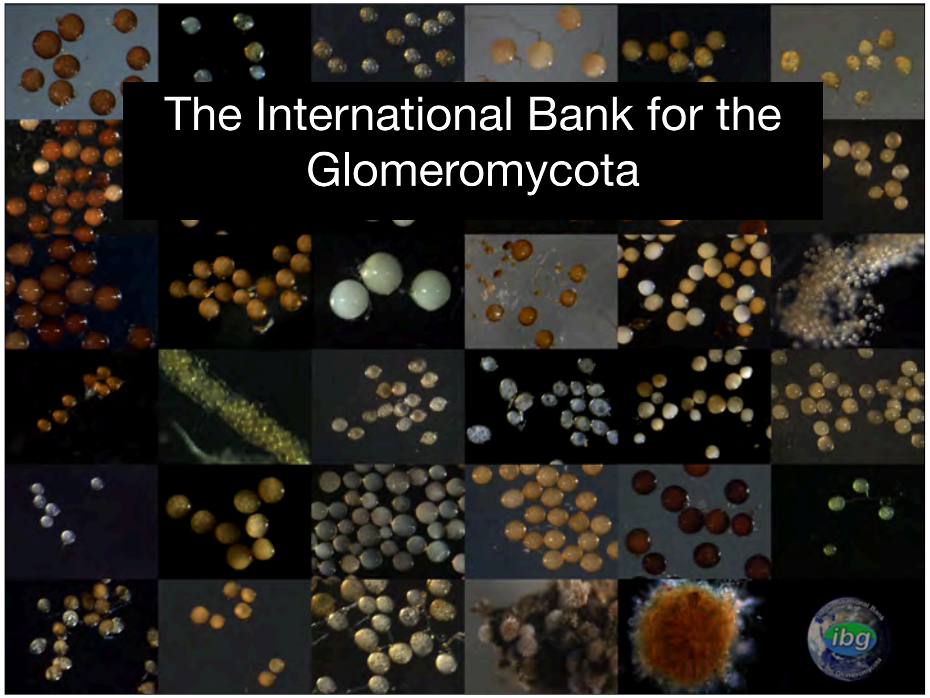


- increase of absorbing surface by mycelium
- transport of mineral nutrients in the soil, especially those of poor mobility (P etc.)
- redistribution of nutrients in common mycelial network
- induced pathogen resistance (priming)
- improvement of soil structure

Culturing Glomeromycota

- obligate biotrophs
- spores contain numerous other microorganisms
- except few species cultivated on transformed roots (“in vitro culture”)
- host specificity in cultivated isolates very low, host preferences in seminatural systems





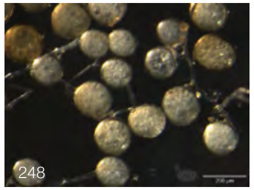
The International Bank for the Glomeromycota

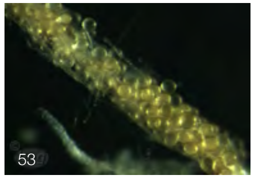
Installations

main collection:
3 climatized rooms with
10 custom-built growth cabinets

The isolates

- 43 isolates in 30 species (312 pot cultures) on their plant hosts
- 6 of these also available *"in vitro"* on transformed carrot roots
- origin:
  - -Europe: 24 (France: 3)
  - -N America: 9
  - -S America: 3
  - -Australia/New Zealand: 3
  - -Asia: 4
- type strains (*ex-type*): 11





Approaches for mycorrhizal biotechnology

- management: maintaining and supporting existing indigenous species
  - establishing conditions conducive to AMF diversity and abundance: e.g. no-till, low pesticides, low fertilisation, avoiding non-host plants in rotations
- inoculation: adding fungal propagules
  - competition problem, can be challenging due to inoculum quantity; most inoculation studies do not verify inoculation success and many use sterile soil as control
  - well-established for plants in sterile potting substrates and then outplanted
- (plant breeding: plant cultivars differ in their mycorrhizal response)

Effects of agriculture on AMF diversity: Land use intensity and AM fungal diversity in soils (spore abundance)

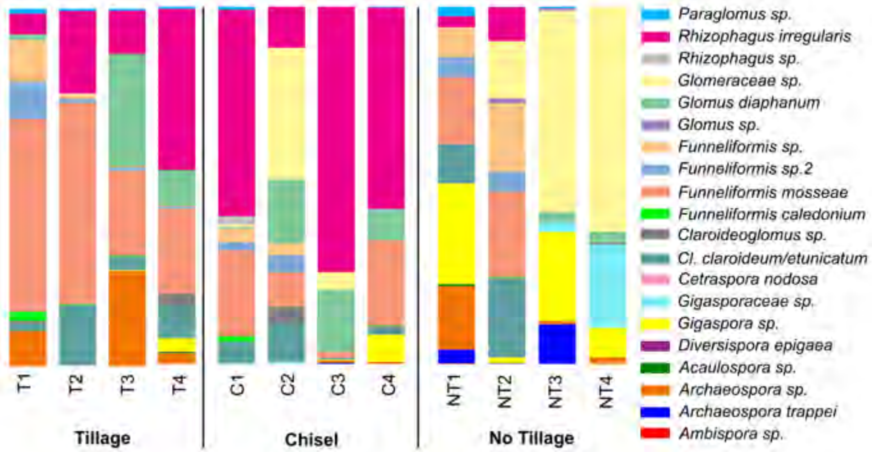
Oehl et al. AEM 2003

Land use	Fertilisation	Total number AM fungal species	Species diversity index (Shannon-Weaver)
Permanent grassland	No fertilisation (20 yrs)	24 25 20	2.29ab 2.32ab 2.34ab
Arable			
7 yr crop rotation (grass-clover)	Bio-organic Conventional	18 13	2.45a 2.14b
Monocropping (maize)	Mineral & organic Mineral Mineral	10 9 8	1.70c 1.72c 1.32c

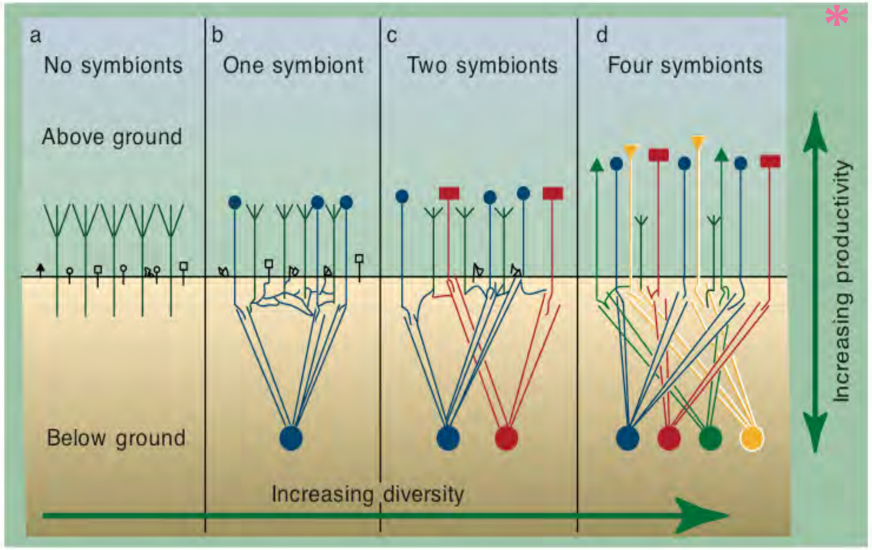
AM fungal diversity: disturbed (arable) < non-disturbed (grassland) ecosystems

Community structure of AMF in a field experiment in Tänikon (CH) based on 454 Titanium FLX+ sequencing of an rpb1 region

(Stockinger et al., 2014)



16 molecular taxa   15 molecular taxa   19 molecular taxa



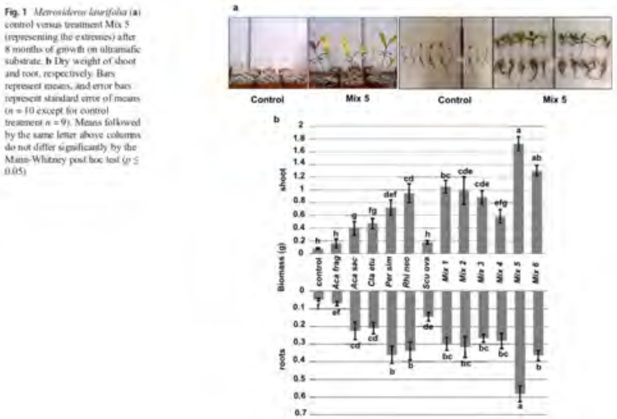
Aboveground and belowground biodiversity are correlated (M. van der Heijden et al. / D. Read, Nature 396, 1998)

AMF effects on plant communities

Encouraging diversity. Grasses prevail in poor soil conditions (right) but are overrun by a broader plant community when mycorrhizal fungi are added to the soil (left).

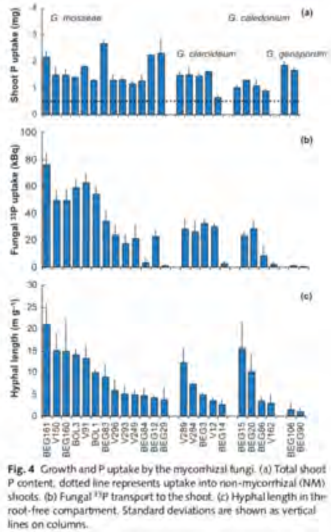
Photo: Marcel van der Heijden

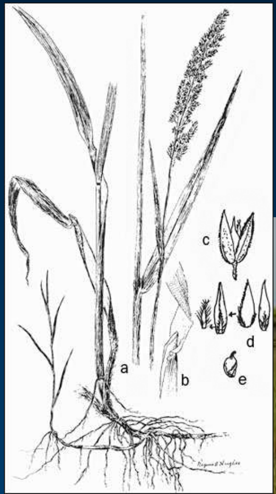
Is a mixture of arbuscular mycorrhizal fungi better for plant growth than single- species inoculants? Crossay et al., 2019



A large part of AMF functional diversity may be found on the intraspecific level

- Need to take into account inter-isolate variation
- Strong inter-isolate variation of AMF-induced yield differences in crop plants with *F. mosseae* (Munkvold et al., 2004)
- Possible intra-species ecotypes grassland vs. elsewhere of *R. irregularis* (Börstler et al., 2010)





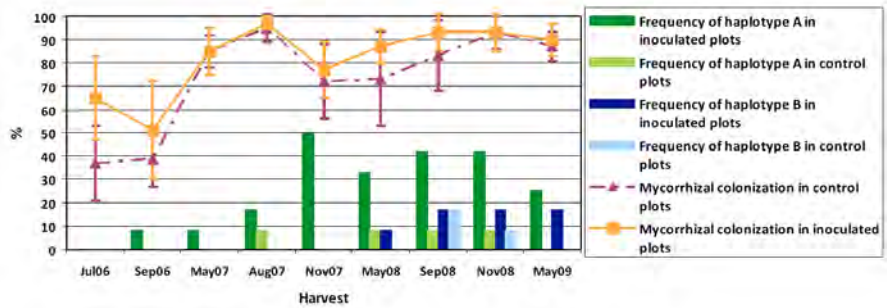
Phalaris arundinacea

AMF are already there!
Using mtLSU markers to trace an inoculated strain in the field:

Sýkorova et al., 2011

Re-vegetated mine spoil at Chomutov, Czech Republic

Frequency of haplotypes A and B and mycorrhizal colonization in the roots of *P. arundinacea*



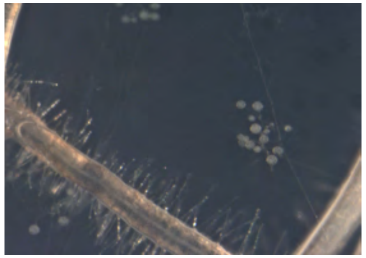
Using *Rh. irregularis* mtLSU haplotypes to demonstrate inoculation success:

Haplotype A was significantly more frequent in the inoculated than in uninoculated plots

(Analysis of variance Df error=11; F=24.43; $p<0.001$)

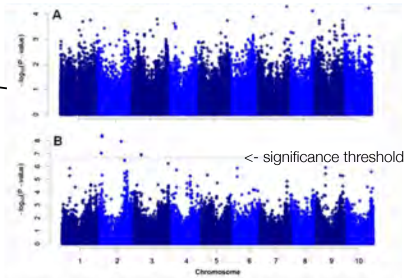
The “*in vitro*” dilemma

- *“in vivo”* inoculum production often has problems with purity or propagule density.
- Root organ culture offers the only way to produce axenic AMF biomass
- Higher technologial effort necessary for large-scale production
- Only very few AMF species are available using this method (basically *Rhizophagus* isolates)
- Most *in vitro* inoculum produced worldwide is from a single isolate: *Rh. irregularis* DAOM 197198



Plant breeding, a possible door opener for mycorrhizal technology?

- Plant cultivars are known to differ in mycorrhizal growth response (MGR) and root colonization (Graham etal., 1991; Hetrick et al., 1993)
- Does domestication negatively affect MGR? Breeding for improved root soil exploration for P could result in selection for a lower MGR and such plants may limit colonisation (Graham et al., 1991)
- Breeding for high colonization may be difficult due to low heritability (Leiser et al., 2016)
- Is it more important to select for P use efficiency?



Genome-wide association study of
A: mycorrhiza root colonization,
B: single-tiller biomass of *Sorghum* cultivars

Importance of mycorrhiza collections for sustainable agriculture

- ressource centers for research and inoculum production:
  - culturing methods, detection/identification, functional diversity, interactions with plant cultivars…
  - well-defined inoculum isolates
- represent intraspecific diversity of of “common colonizers” (*Rh. irregularis, C. claroideum, F. mosseae* etc.)
- represent maximum taxonomic (and functional?) diversity outside of “common colonizers”

Thank you very much for your valuable attention!

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