Kommer biologisk vittring att fylla på skogsmarkens förråd i framtidens bioekonomi?

Roger Finlay

Uppsala BioCenter

Dept. Forest Mycology & Plant Pathology

Swedish University of Agricultural Sciences

Uppsala, SWEDEN

FORMAS

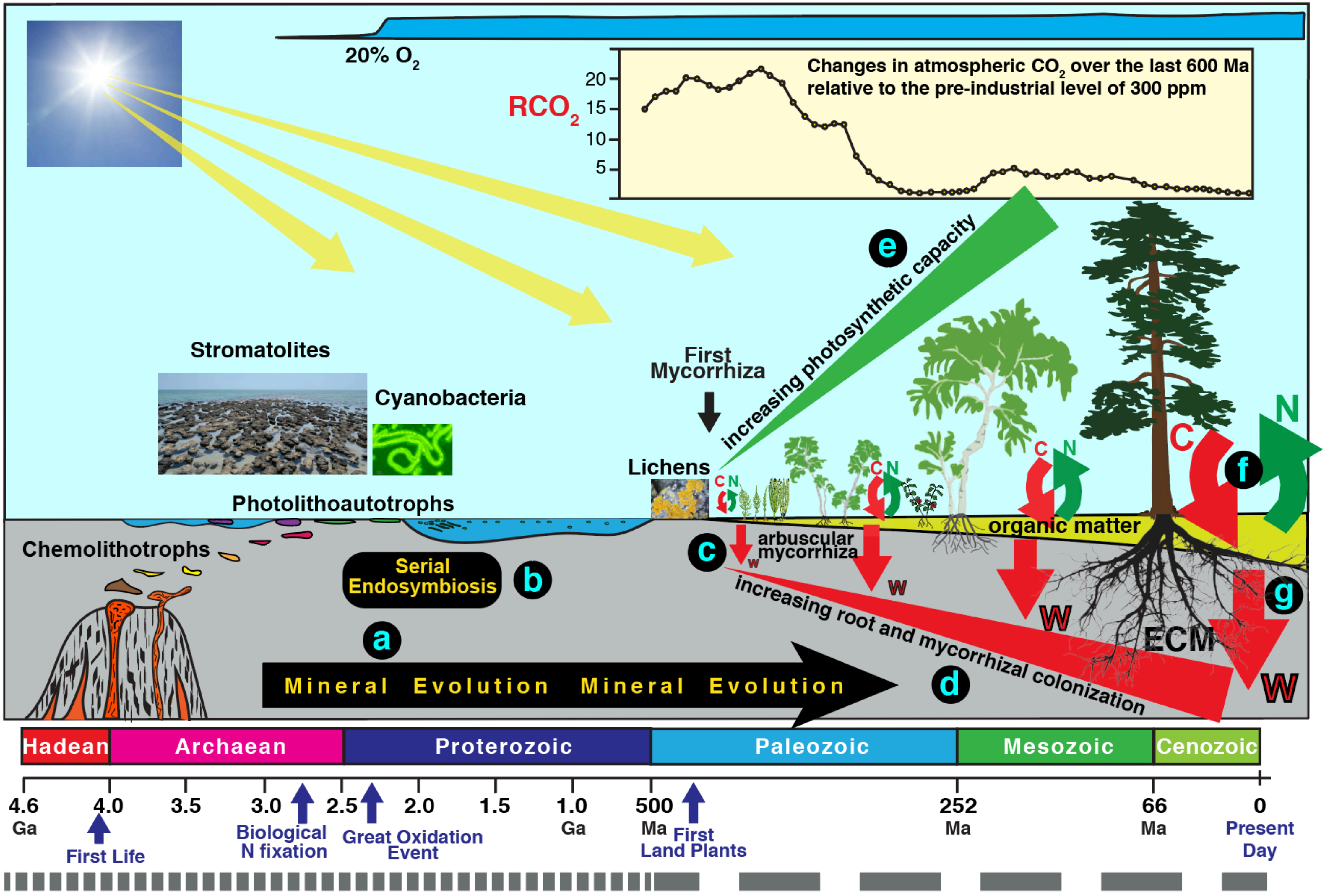
QWARTS

SLU

Kommer biologisk vittring att fylla på skogsmarkens förråd i framtidens bioekonomi?

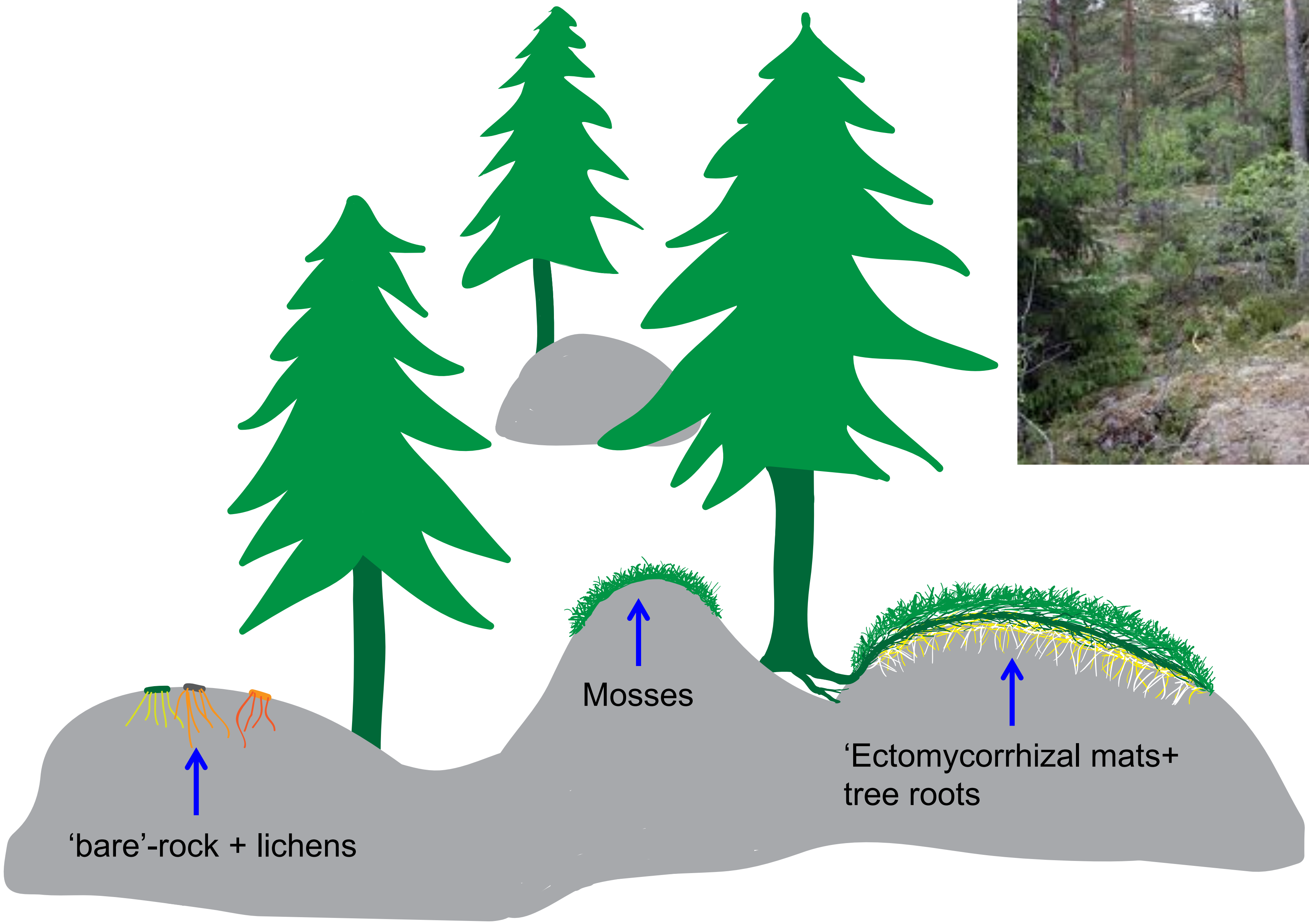
SLUTSATS

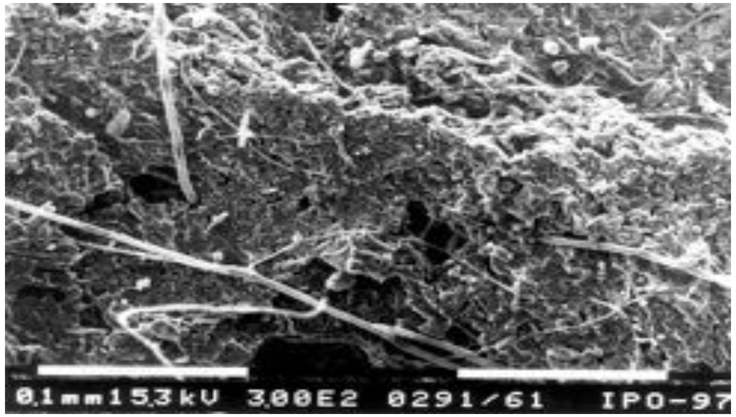
Våra studier visar att mykorrhizasvampar spelar en viktig roll i vittring av mineraler. Studier med stabila isotoper av magnesium tyder på att (mykorrhiza)svamphyfer kan vittra mineraler i B-horisonten och öka Mg upptag när planttillväxt ökas. Vittring kräver allokering av kol (från fotosyntes) till hyyfer i kontakt med mineraler. När tillgång till (organisk) kväve begränsas p.g.a. uttag av organiskt material, begränsas planttillväxten p.g.a. kvävebrist med följd att även kolallokering till mineraler minskas. Resultaten tyder på att, utan återföring av förlorat kväve, kommer biologisk vittring ej att "fylla på" skogsmarkens förråd av baskatjoner.



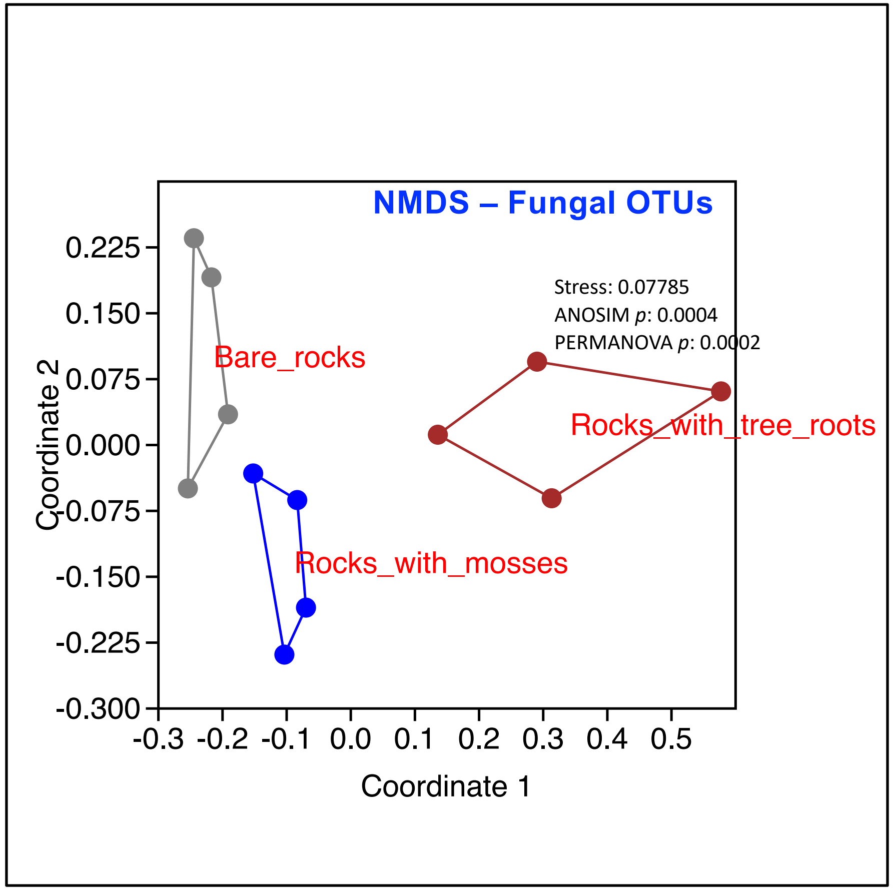
20% O_2
Changes in atmospheric CO_2 over the last 600 Ma relative to the pre-industrial level of 300 ppm
RCO_2
20
15
10
5
e
increasing photosynthetic capacity
Stromatolites
Cyanobacteria
First Mycorrhiza
Lichens
Photolithoautotrophs
Chemolithotrophs
C
N
W
organic matter
arbuscular mycorrhiza
c
Serial Endosymbiosis
b
f
g
a
increasing root and mycorrhizal colonization
ECM
d
Mineral Evolution Mineral Evolution
Hadean
Archaean
Proterozoic
Paleozoic
Mesozoic
Cenozoic
4.6 Ga
4.0
3.5
3.0
2.5
2.0
1.5
1.0 Ga
500 Ma
252 Ma
66 Ma
0
First Life
Biological N fixation
Great Oxidation Event
First Land Plants
Present Day

Undersökning av svamp- och bakteriesamhällen

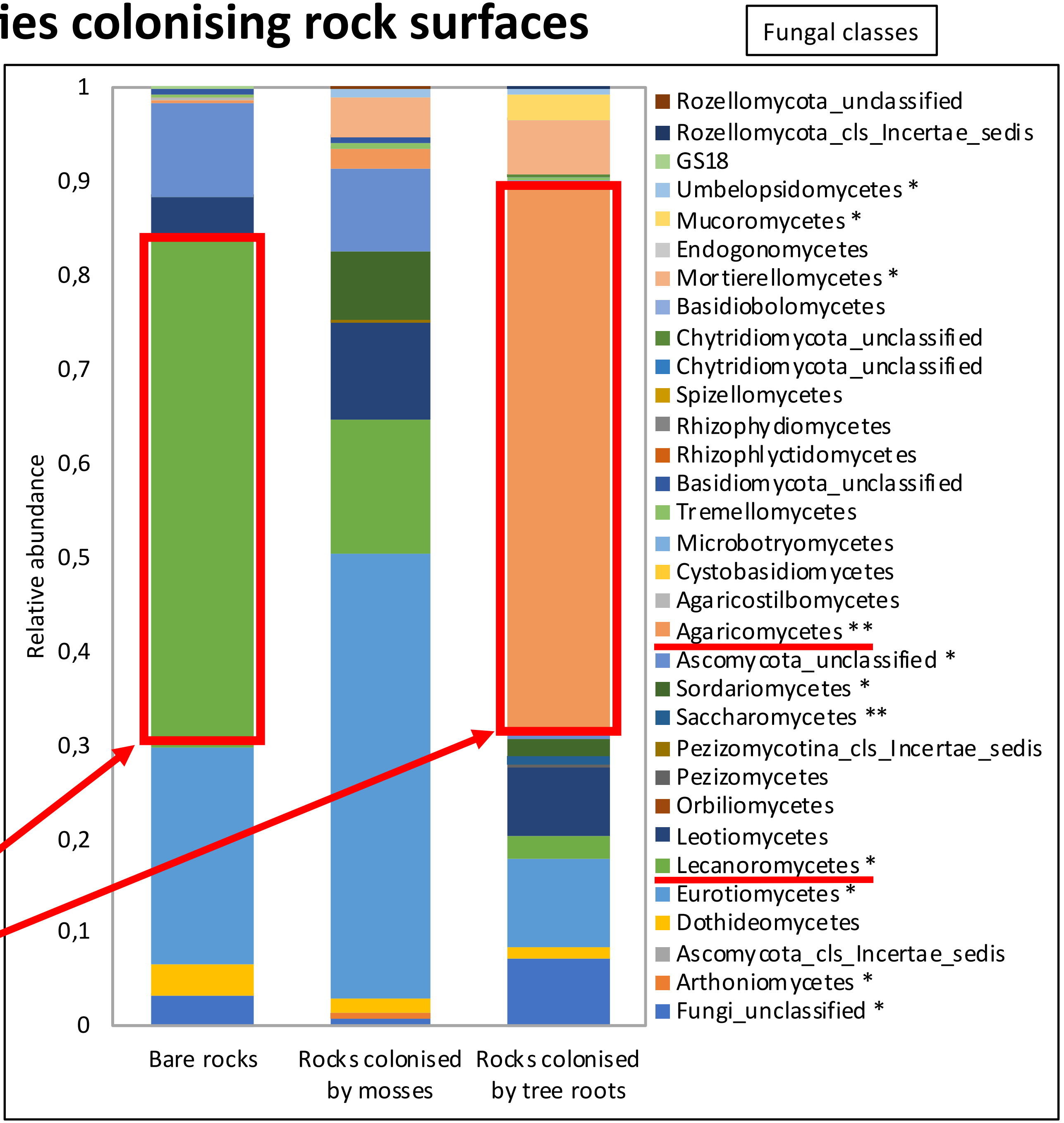




Fungal communities colonising rock surfaces



Skilda svampsamhällen



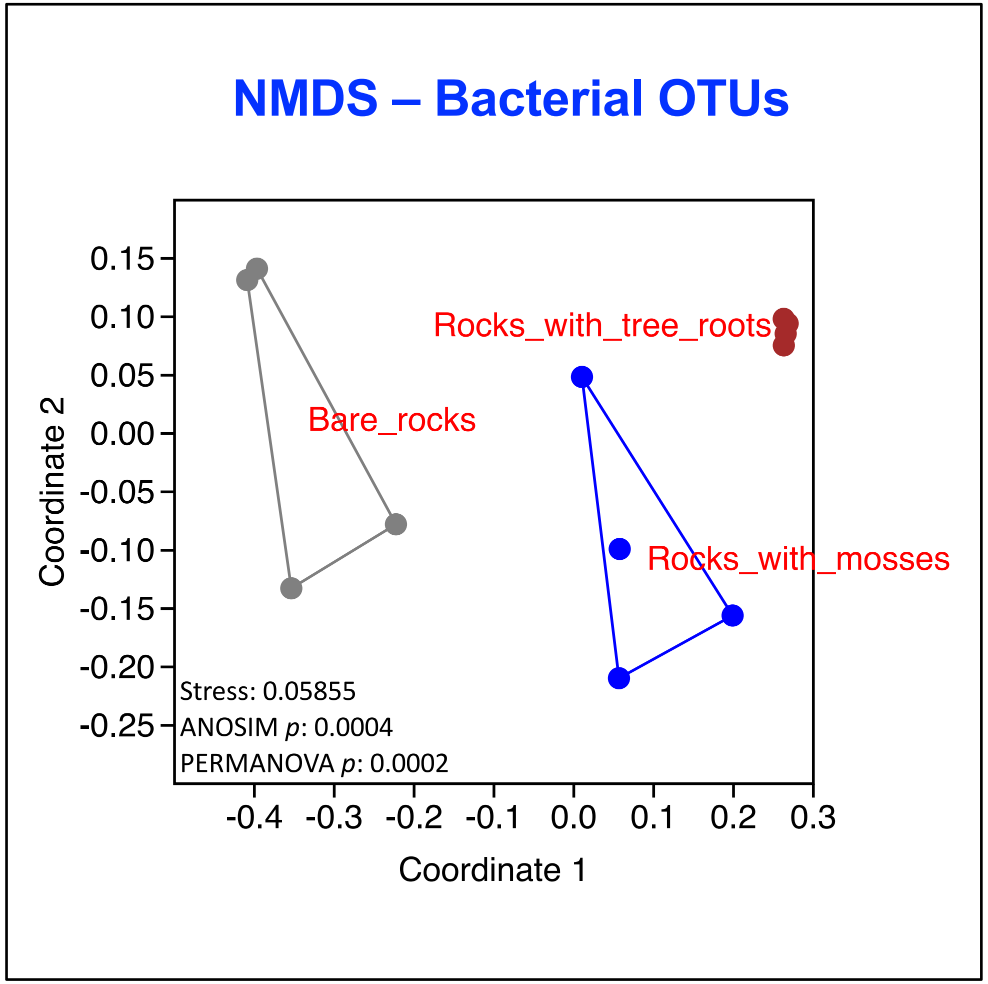
Ektomykorrhizasvampar ersätter lavbildande svampar när trädrötter koloniserar stenytor

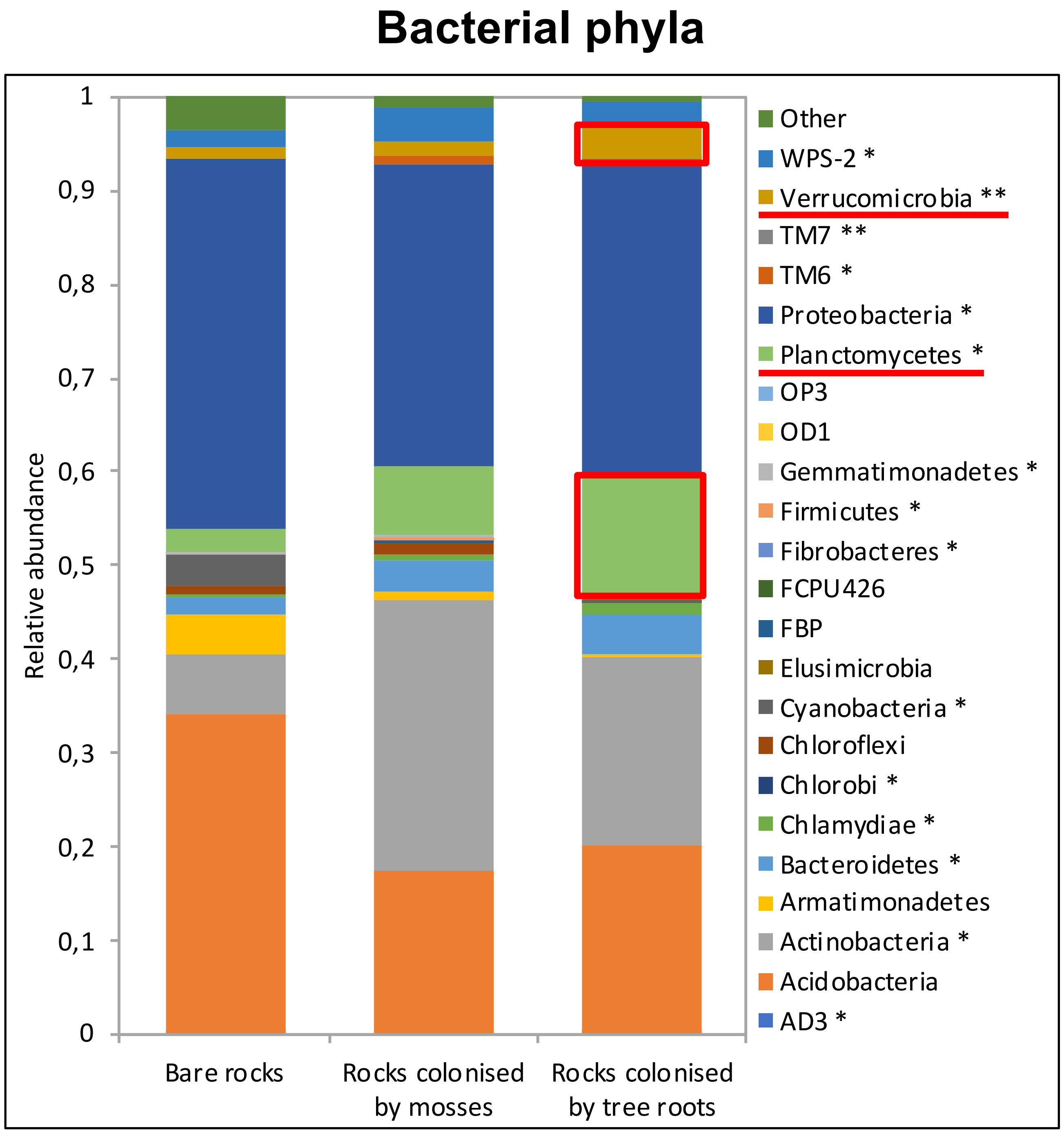
Fungal communities colonising rock surfaces

Träd
- Stora “kolfabriker”
- Stora sänkor för mobiliserade näringsämnen

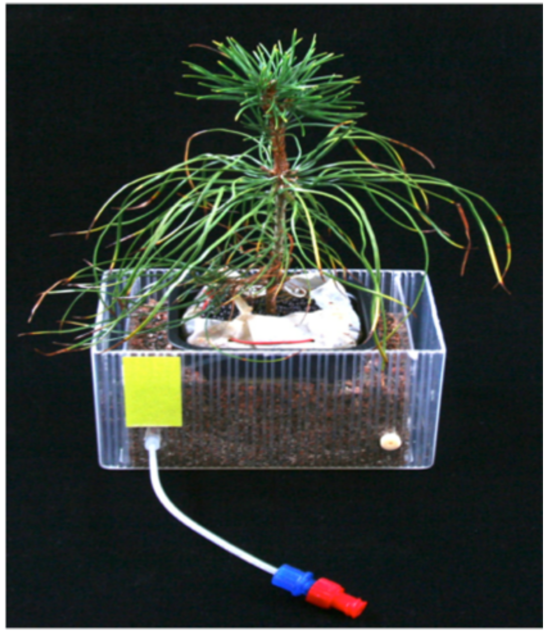
Ektomykorrhizasvampar ersätter lavbildande svampar när trädrötter koloniserar stenytor

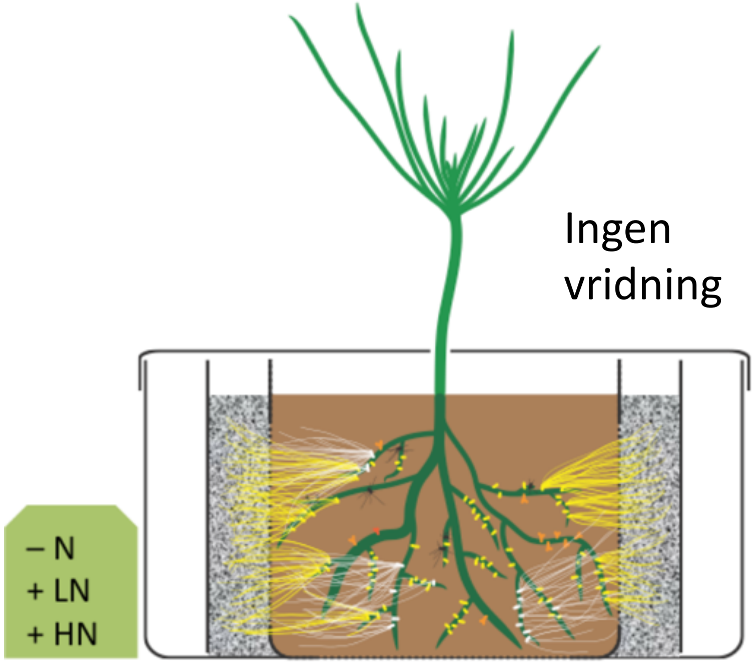
Svampar brukar bildar symbiotiska associationer med fotobionter när de koloniserar mineraler





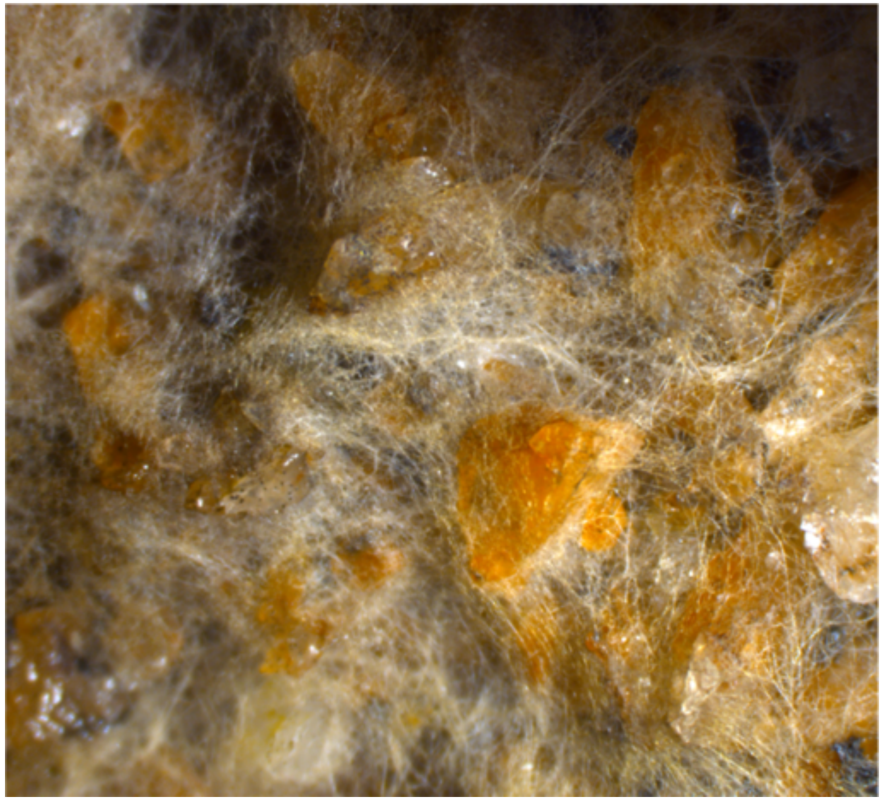
Planctomycetes & Verrucomicrobia ökar i nävaro av ektomykorrhiza

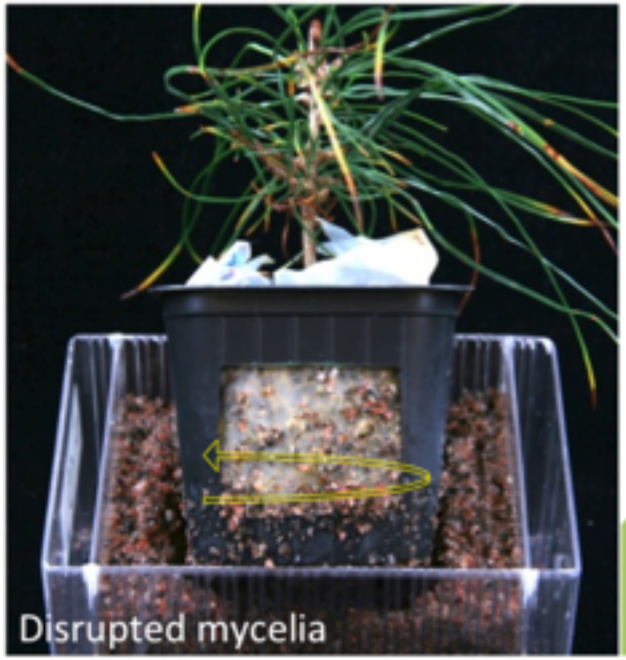


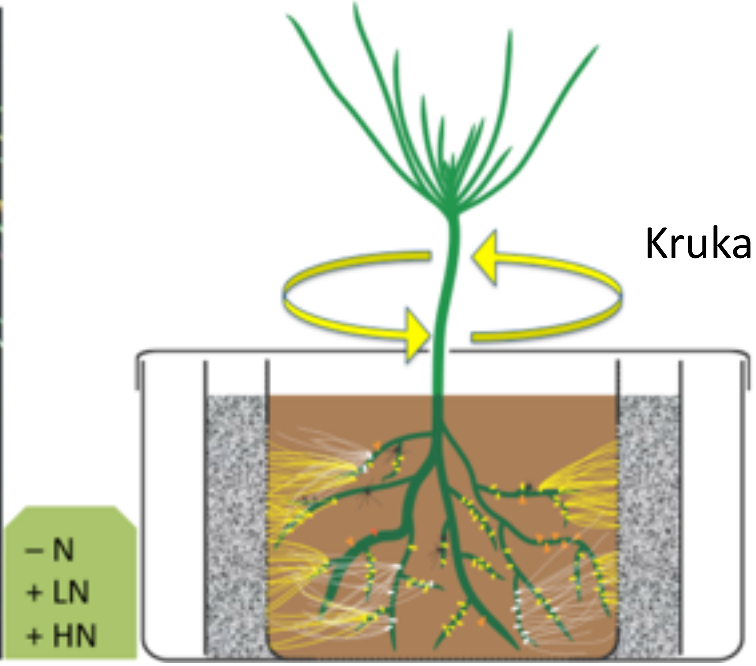


Intact mycelia

Ingen vridning

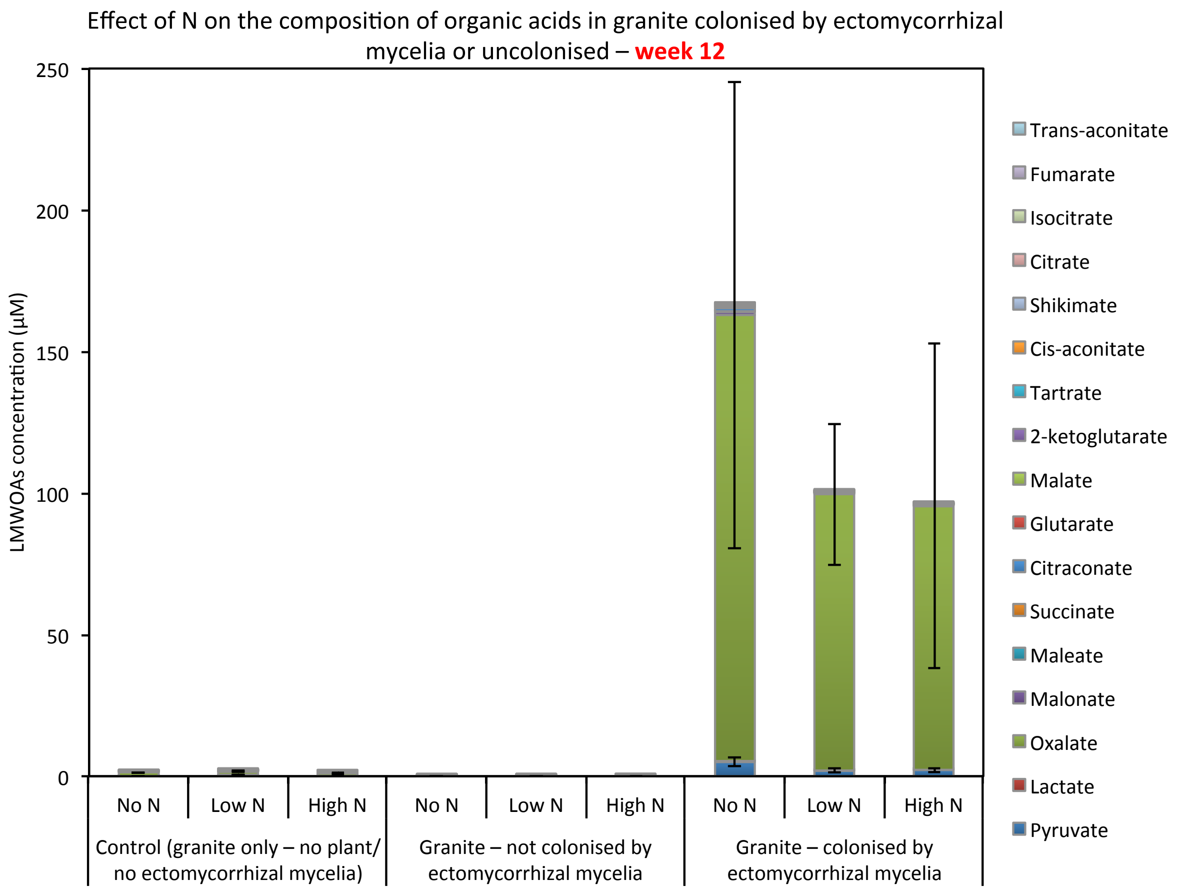


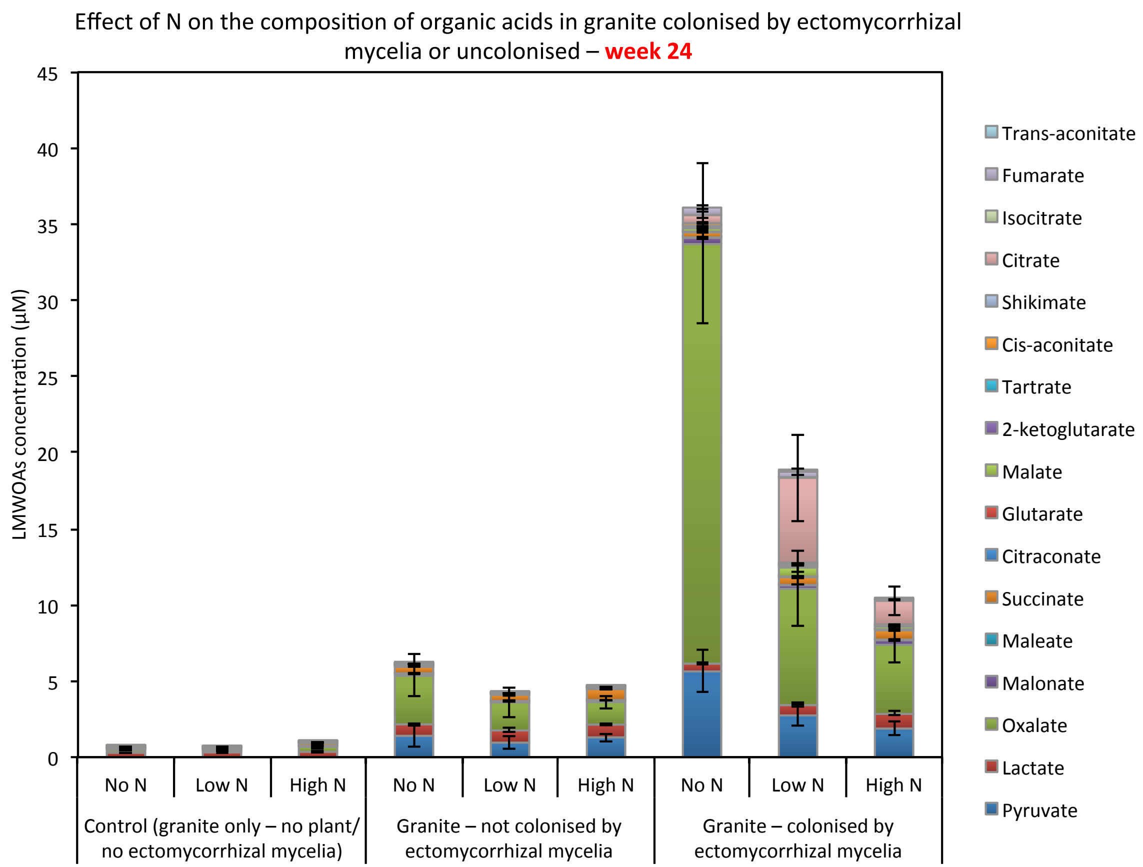




Krukan vrids varje dag

Ingen/begränsad kolonisering

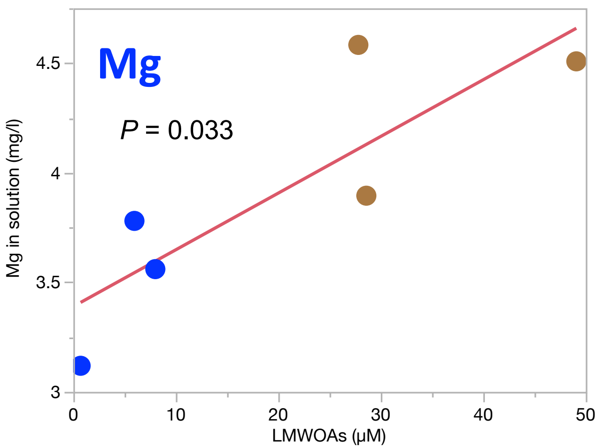


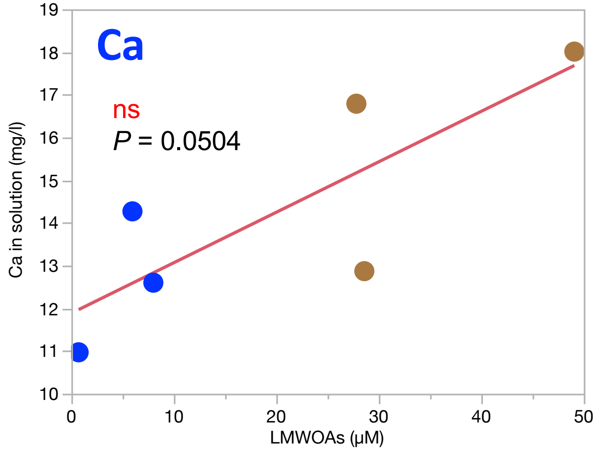


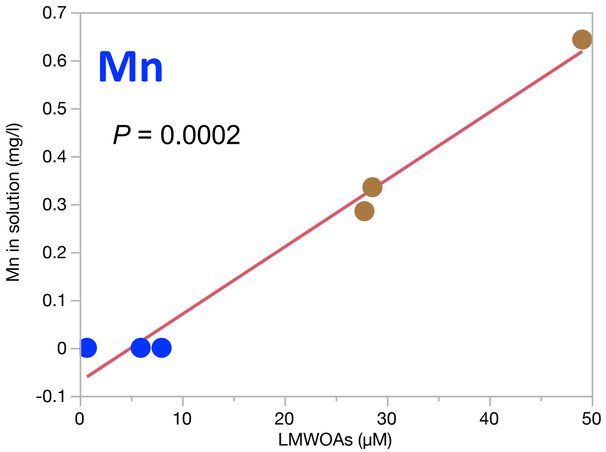
- **Bättre produktion av organiska syror när mykorrhizsvampar kan kolonisera granitpartiklarna**

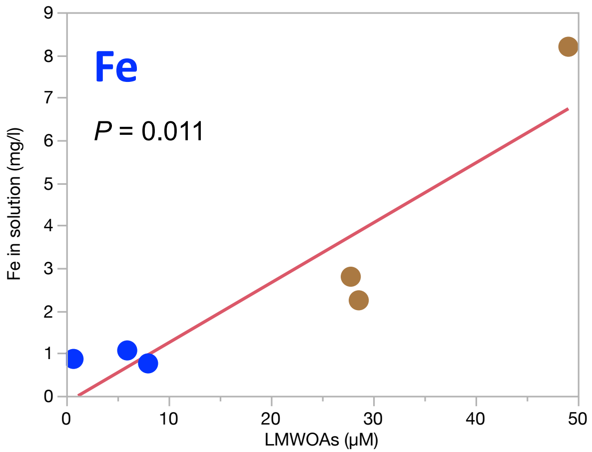
LMWOAs vs. elements in solution…

- – Ectomycorrhizal mycelium
- + Ectomycorrhizal mycelium

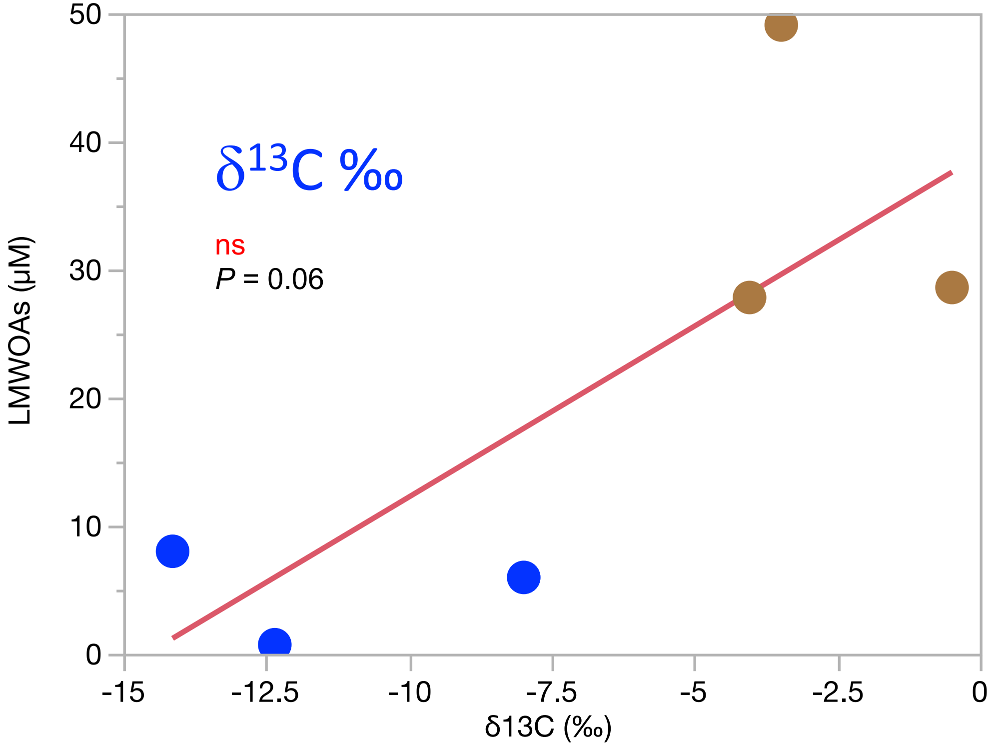




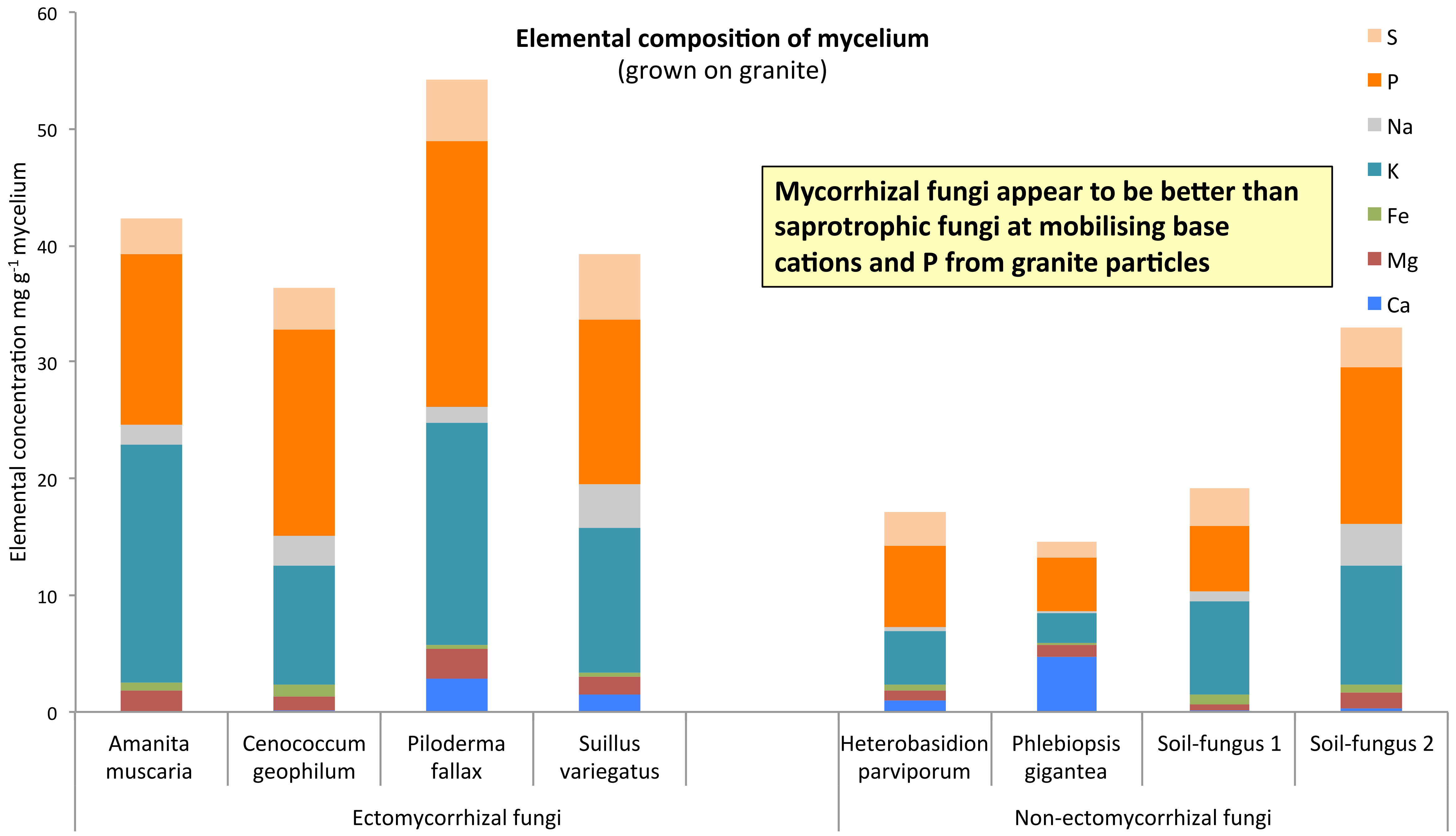


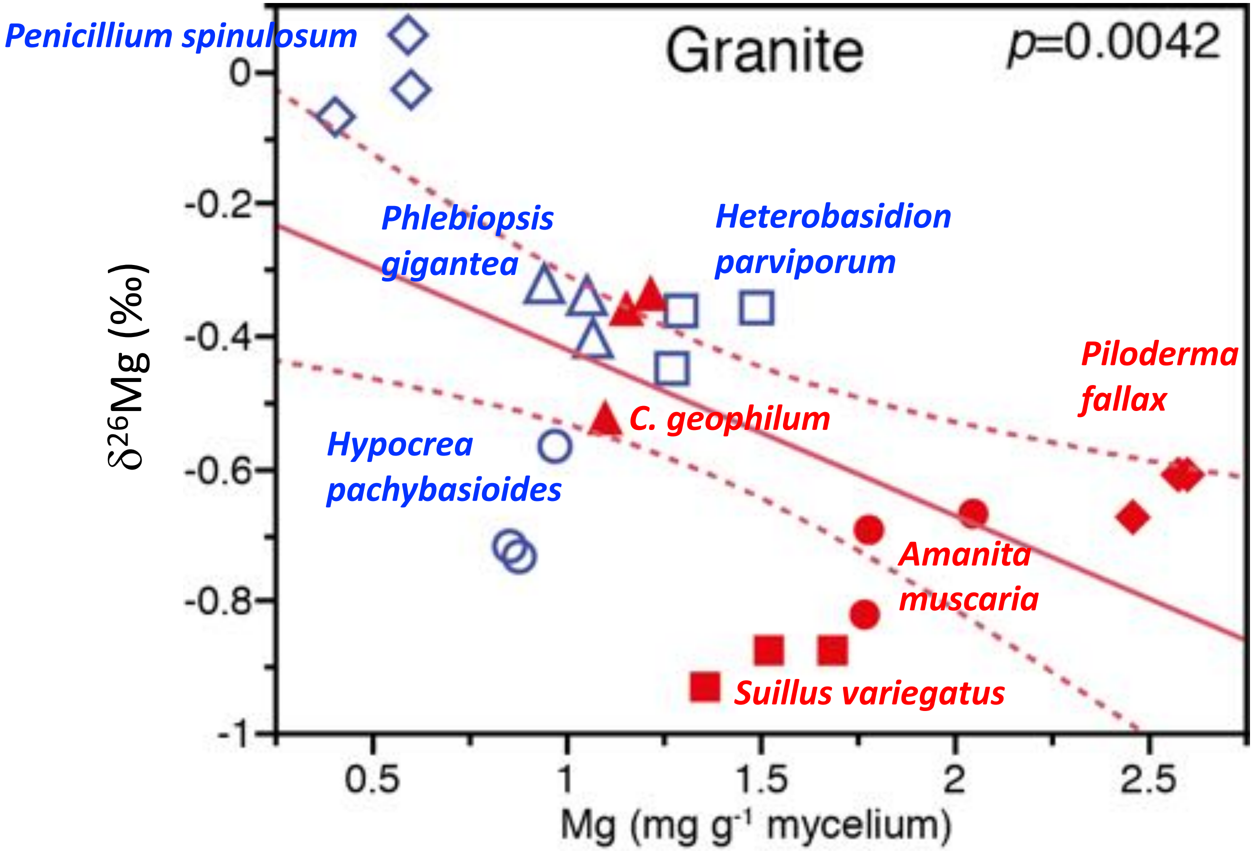


LMWOAs vs. C allocation



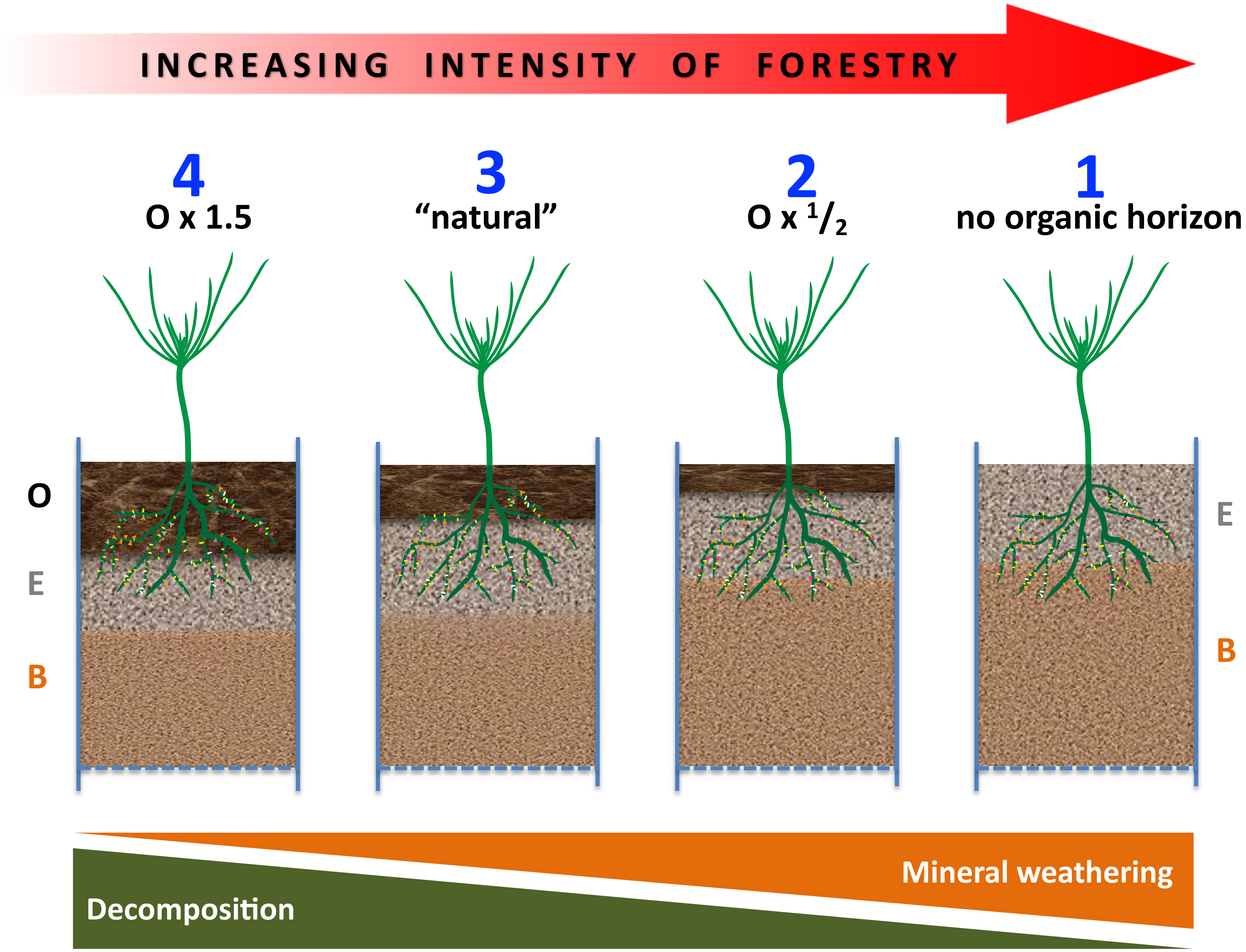
- **Mobilisering av Mg, Mn & Fe bättre vid högre koncentrationer av organiska syror**


Elemental composition of mycelium
(grown on granite)
Mycorrhizal fungi appear to be better than saprotrophic fungi at mobilising base cations and P from granite particles
S
P
Na
K
Fe
Mg
Ca
Elemental concentration mg g-1 mycelium
0
10
20
30
40
50
60
Amanita muscaria
Cenococcum geophilum
Piloderma fallax
Suillus variegatus
Heterobasidion parviporum
Phlebiopsis gigantea
Soil-fungus 1
Soil-fungus 2
Ectomycorrhizal fungi
Non-ectomycorrhizal fungi

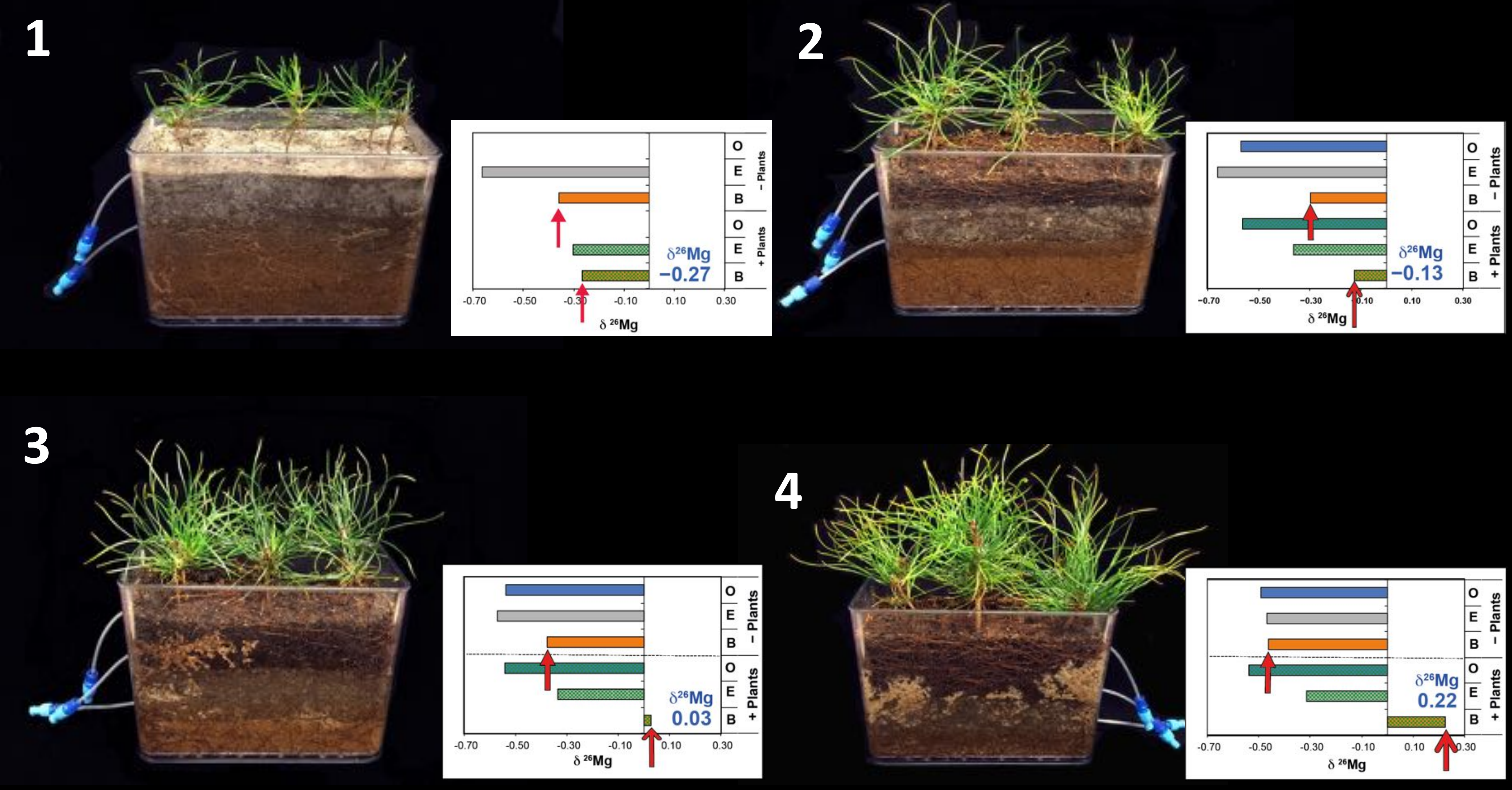


Fungi appear to discriminate against uptake of heavy Mg isotopes with mycorrhizal fungi showing stronger discrimination (more strongly negative mycelial signatures) related to higher total amounts of Mg uptake

Fahad *et al.* 2016. *Env. Microbiol. Rep.* 8: 956–965.



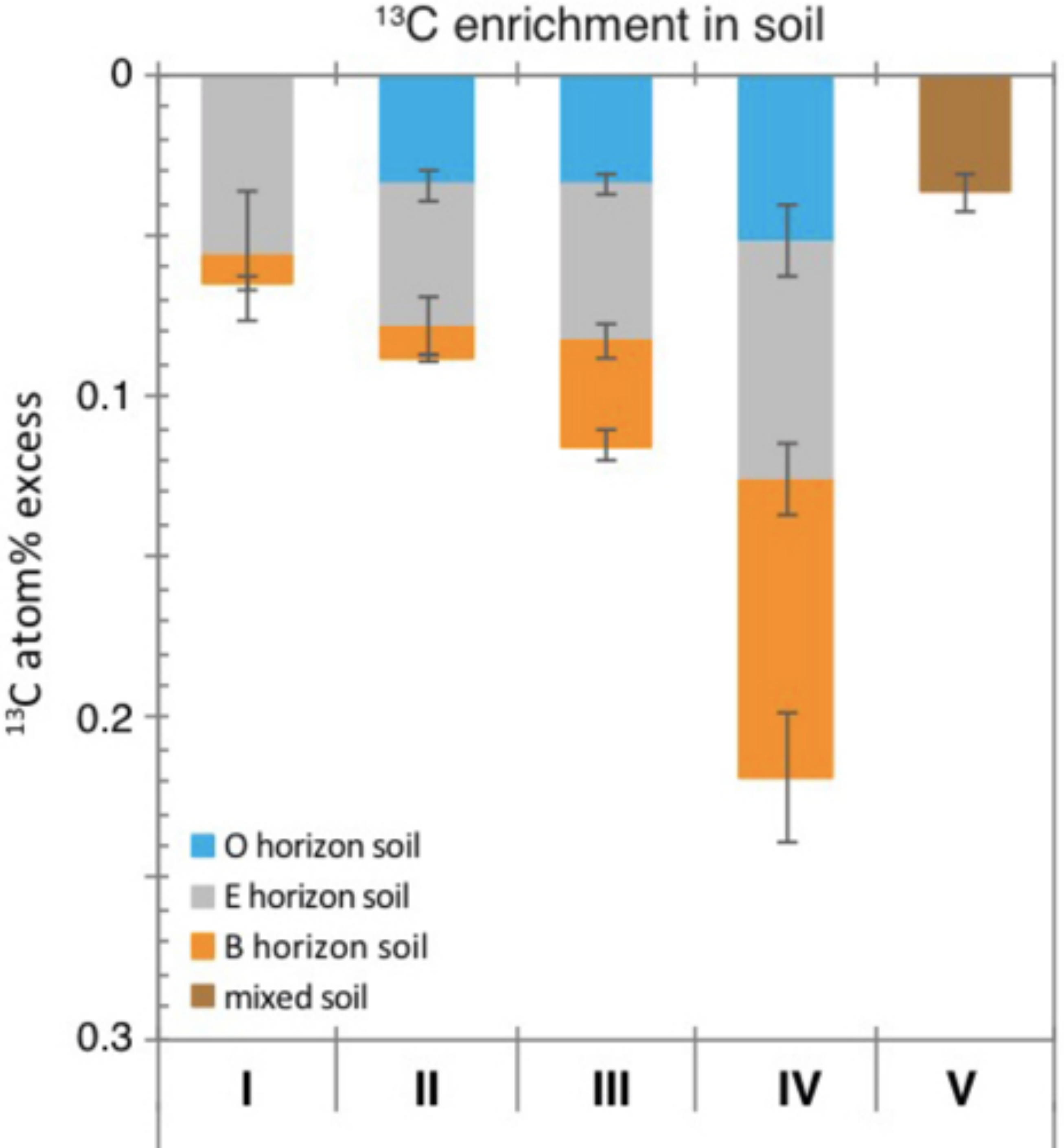
INCREASING INTENSITY OF FORESTRY
4
O x 1.5
3
"natural"
2
O x 1/2
1
no organic horizon
O
E
B
E
B
Mineral weathering
Decomposition



1
O
E
B
− Plants
O
E
B
+ Plants
δ26Mg
−0.27
-0.70 -0.50 -0.30 -0.10 0.10 0.30
δ 26Mg
2
O
E
B
− Plants
O
E
B
+ Plants
δ26Mg
−0.13
−0.70 −0.50 −0.30 −0.10 0.10 0.30
δ 26Mg
3
O
E
B
− Plants
O
E
B
+ Plants
δ26Mg
0.03
-0.70 -0.50 -0.30 -0.10 0.10 0.30
δ 26Mg
4
O
E
B
− Plants
O
E
B
+ Plants
δ26Mg
0.22
-0.70 -0.50 -0.30 -0.10 0.10 0.30
δ 26Mg

- Microcosm experiments suggest Mg is mobilised primarily in the B horizon and that significant enrichment of ^{26}Mg in the B horizon soil solution is associated with higher total uptake of Mg by increased biomass associated with additions of organic matter

- Removal of organic residues containing N accessed by mycorrhizal fungi restricts plant growth and carbon allocation to mycorrhizal fungi colonising mineral substrates – restricting mobilisation of base cations through weathering.



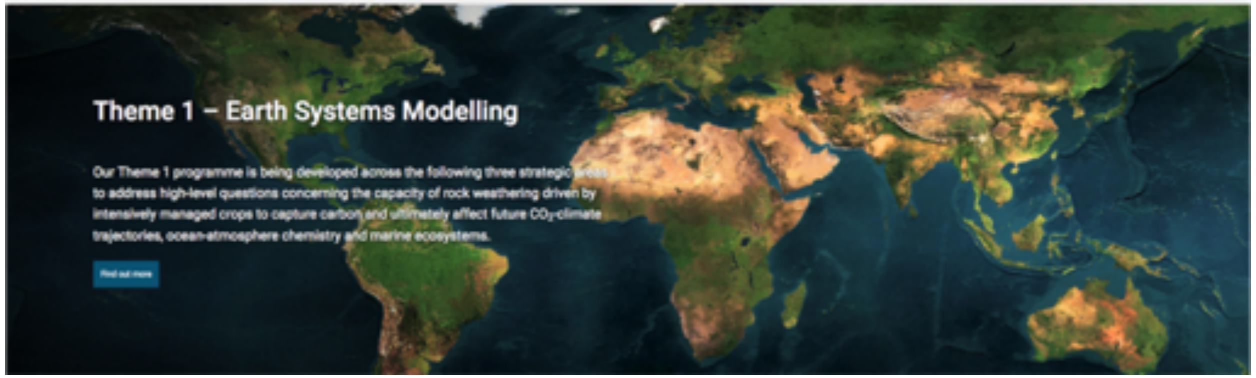
Pine seedlings were $^{13}CO_2$ pulse labelled and flow of ^{13}C was examined in podzol O, E and B horizon soils.

^{13}C-enrichment in mineral horizon soils significantly greater than in O horizon soils. (particularly in B horizon - treatment IV, where Mg uptake is greatest)

LETTERS
PUBLISHED ONLINE: 14 DECEMBER 2015 | DOI: 10.1038/NCLIMATE2882
nature climate change

Enhanced weathering strategies for stabilizing climate and averting ocean acidification

Lyla L. Taylor[1], Joe Quirk[1], Rachel M. S. Thorley[1], Pushker A. Kharecha[2,3], James Hansen[2], Andy Ridgwell[4,5], Mark R. Lomas[6], Steve A. Banwart[7] and David J. Beerling[1]*



BIOLOGY LETTERS
rsbl.royalsocietypublishing.org

Introduction

Check for updates

Cite this article: Beerling DJ. 2017 Enhanced rock weathering: biological climate change mitigation with co-benefits for food security? *Biol. Lett.* **13**: 20170149.
http://dx.doi.org/10.1098/rsbl.2017.0149

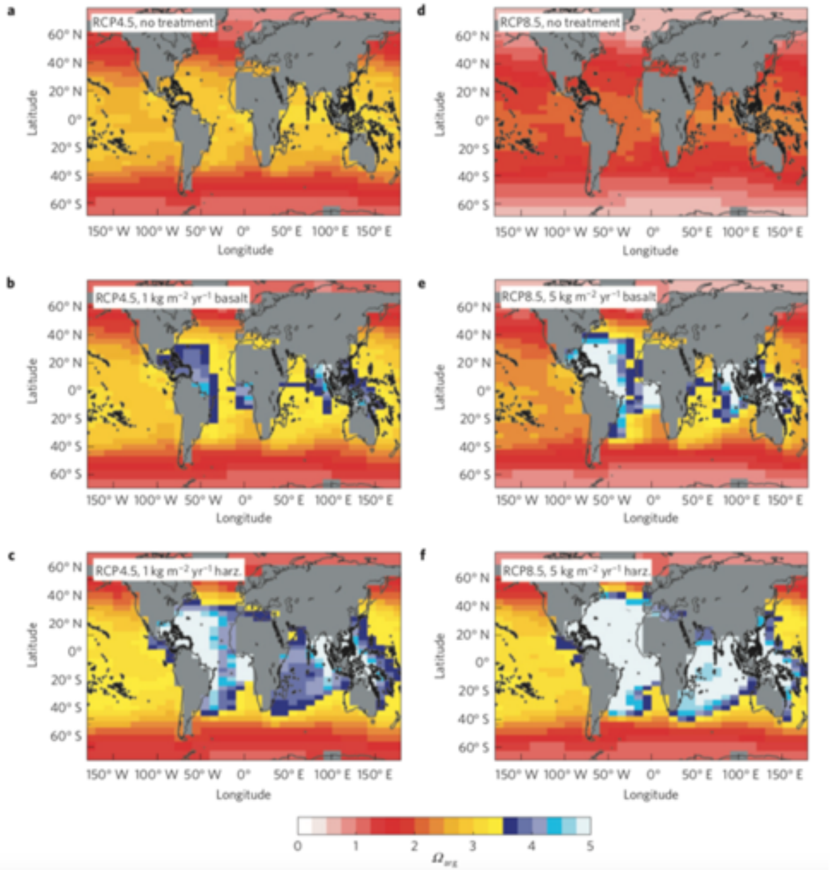
Global change biology

Enhanced rock weathering: biological climate change mitigation with co-benefits for food security?

David J. Beerling

Leverhulme Centre for Climate Change Mitigation, Department of Animal and Plant Sciences, University of Sheffield, Sheffield S10 2TN, UK

DJB, 0000-0003-1869-4314

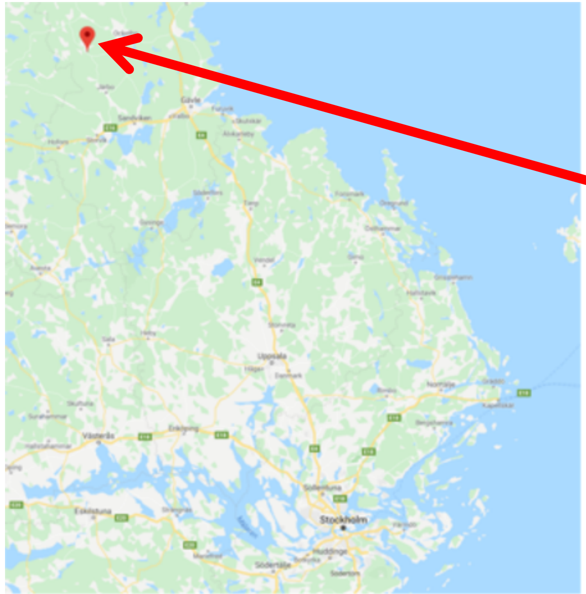


PERSPECTIVE
https://doi.org/10.1038/s41477-018-0108-y
nature plants
Corrected: Publisher Correction

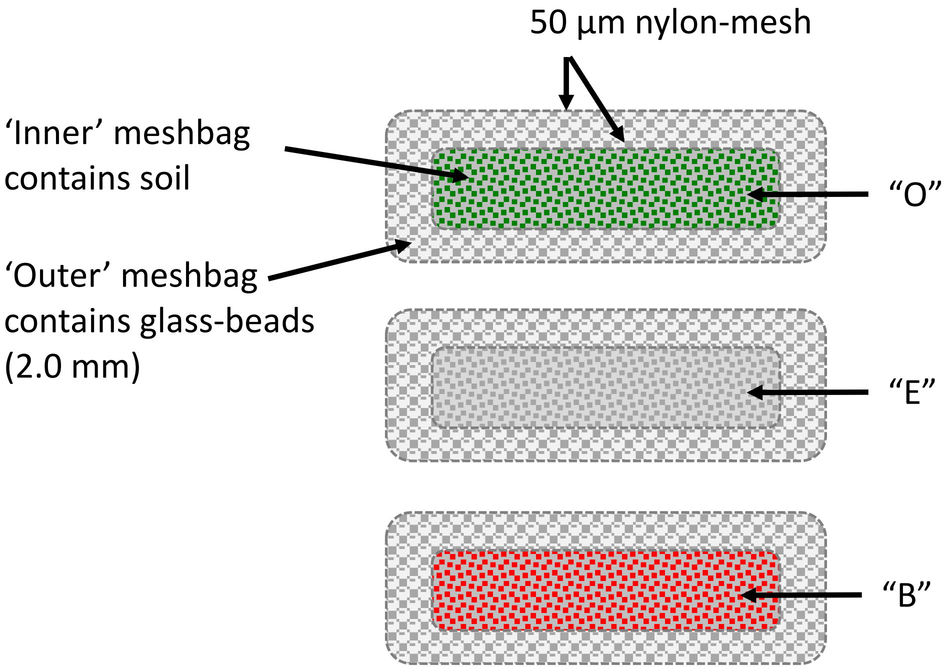
Farming with crops and rocks to address global climate, food and soil security

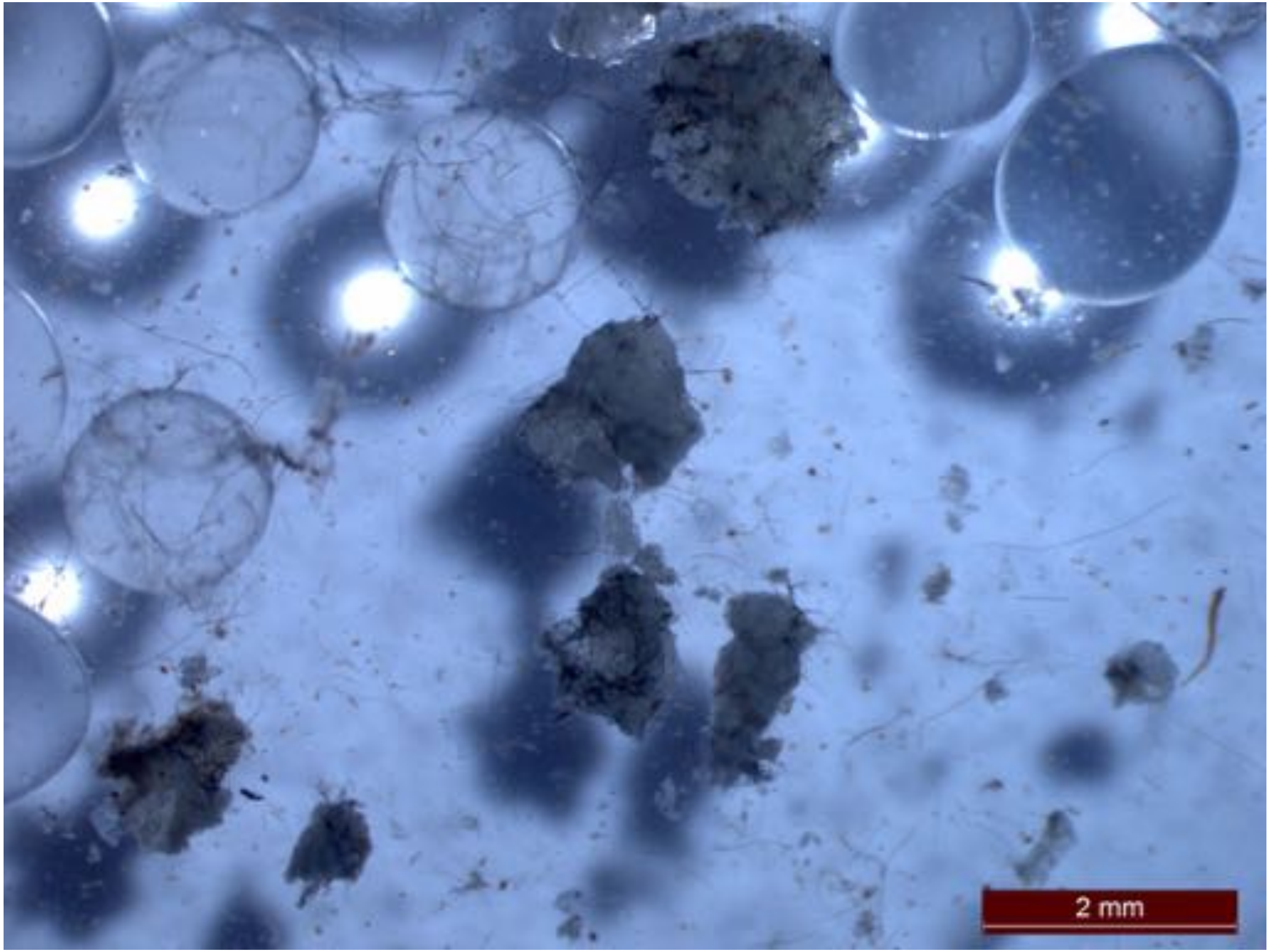
David J. Beerling[1*], Jonathan R. Leake[1], Stephen P. Long[2,3,4], Julie D. Scholes[1], Jurriaan Ton[1], Paul N. Nelson[5], Michael Bird[5], Euripides Kantzas[1], Lyla L. Taylor[1], Binoy Sarkar[1], Mike Kelland[1], Evan DeLucia[2,3], Ilsa Kantola[2], Christoph Müller[6], Greg H. Rau[7] and James Hansen[8]

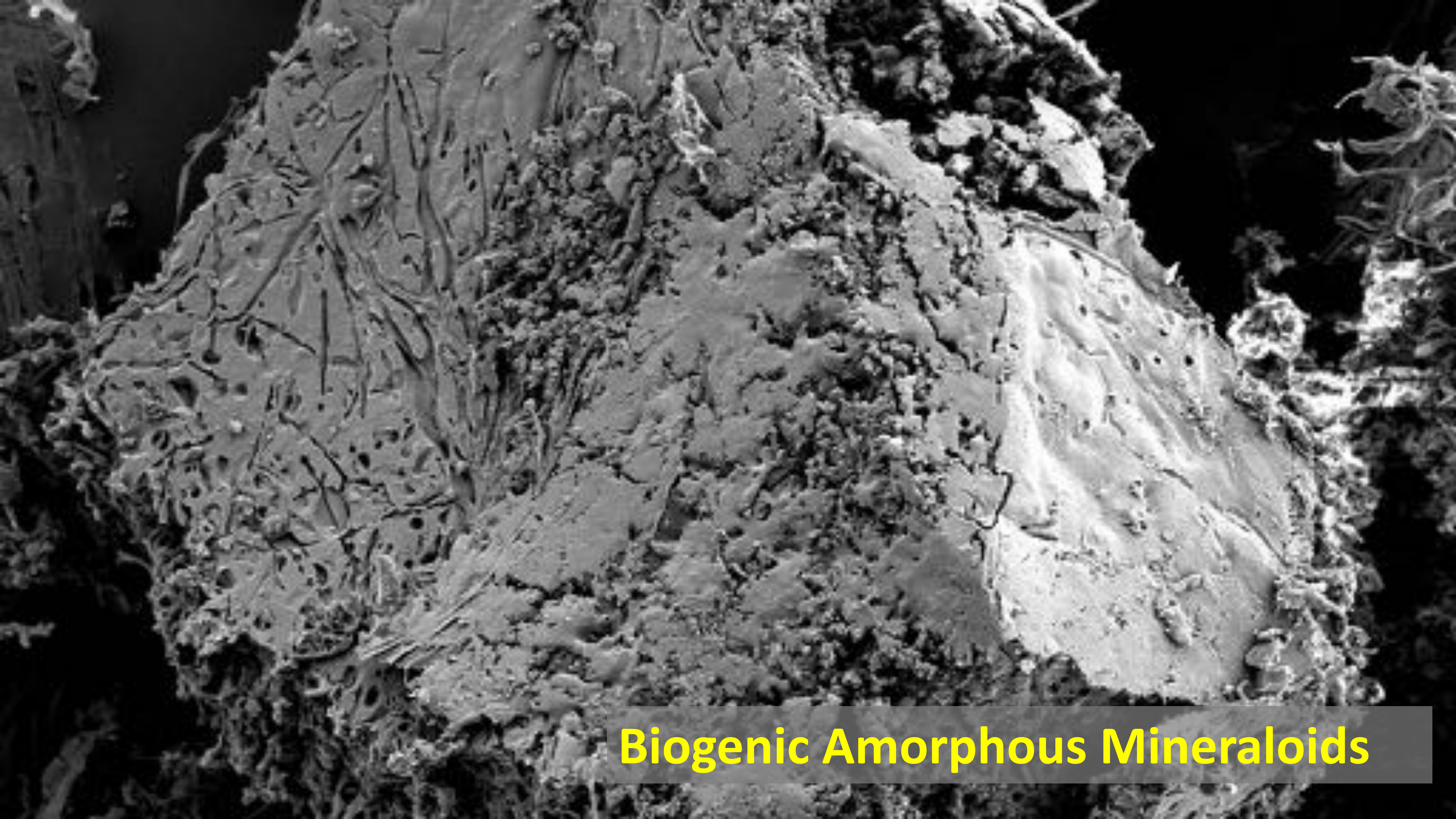
The magnitude of future climate change could be moderated by immediately reducing the amount of CO_2 entering the atmosphere as a result of energy generation and by adopting strategies that actively remove CO_2 from it. Biogeochemical improvement of soils by adding crushed, fast-reacting silicate rocks to croplands is one such CO_2-removal strategy. This approach has the potential to improve crop production, increase protection from pests and diseases, and restore soil fertility and structure. Managed croplands worldwide are already equipped for frequent rock dust additions to soils, making rapid adoption at scale feasible, and the potential benefits could generate financial incentives for widespread adoption in the agricultural sector. However, there are still obstacles to be surmounted. Audited field-scale assessments of the efficacy of CO_2 capture are urgently required together with detailed environmental monitoring. A cost-effective way to meet the rock requirements for CO_2 removal must be found, possibly involving the recycling of silicate waste materials. Finally, issues of public perception, trust and acceptance must also be addressed.

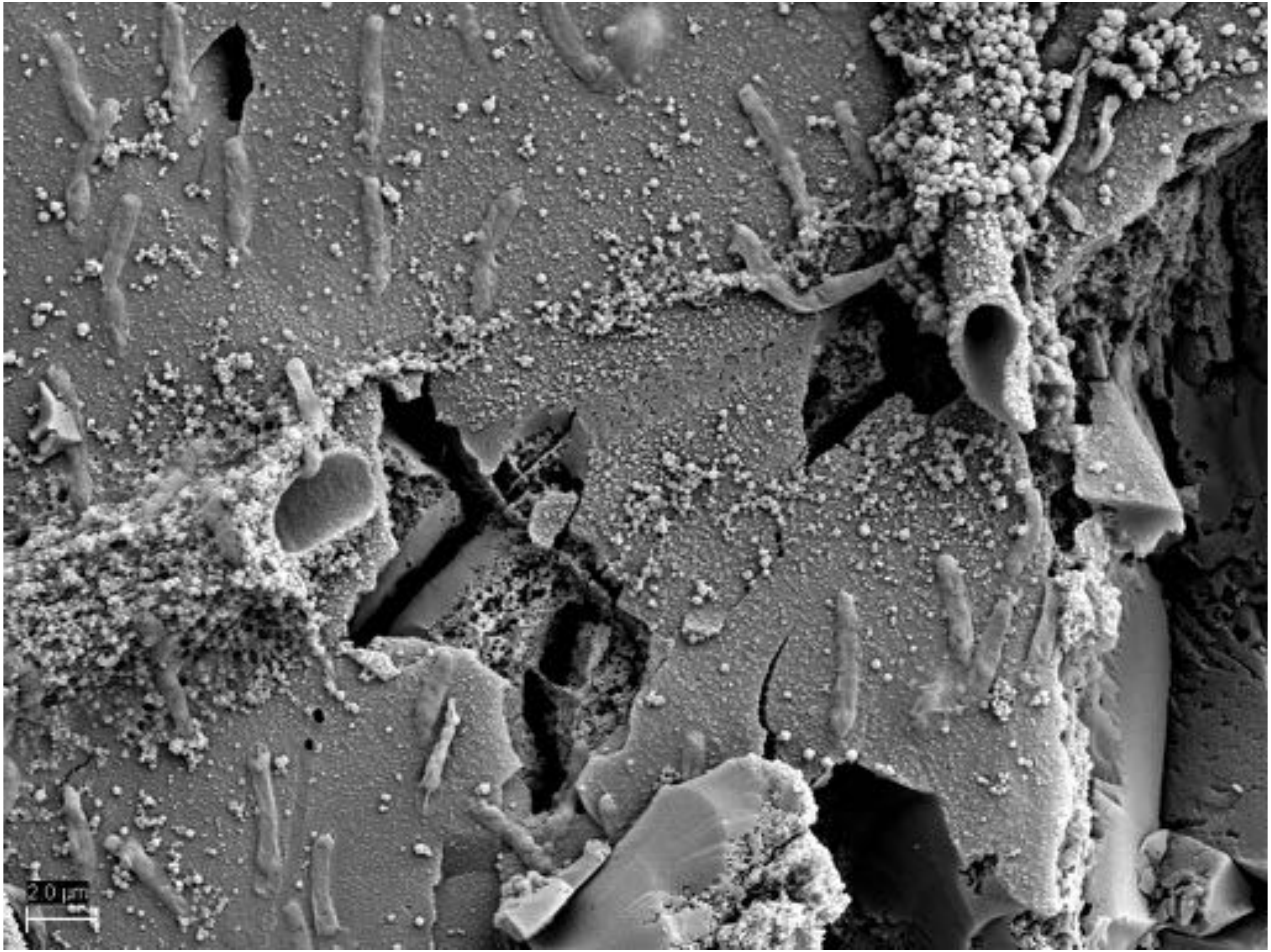


Two-compartment mesh bags Sep 2014-Sep 2015



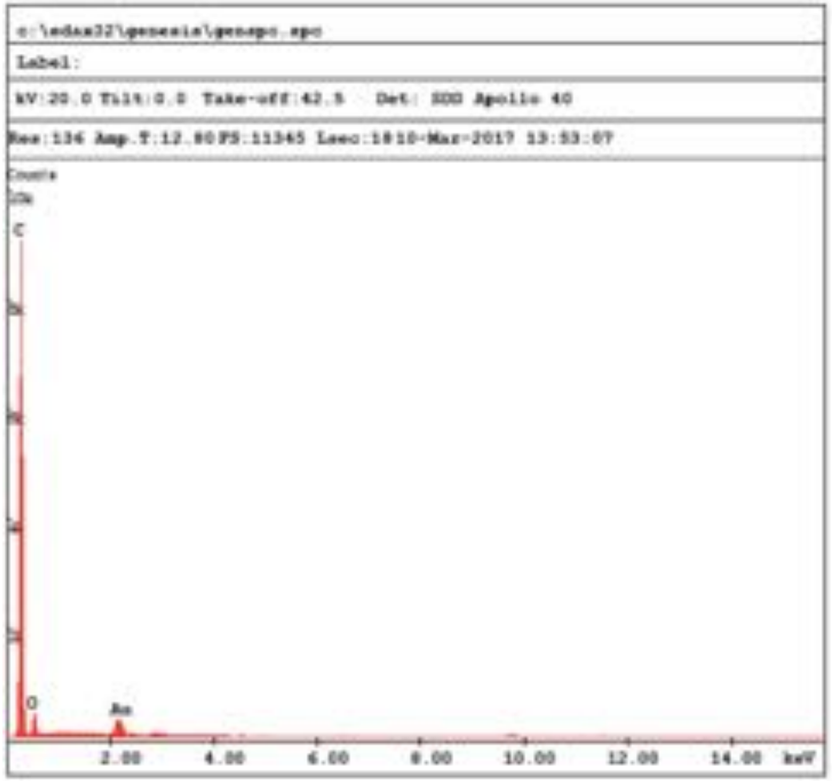

2 mm


Biogenic Amorphous Mineraloids


2.0 µm

NanoSIMS – biogenic amorphous mineraloids (BAMs)

- **Production of secondary minerals and BAMs may result in significant (long-term) sequestration of C from the atmosphere.**
- **Ongoing studies using nanoSIMS, NMR and FTIR spectroscopy will determine the chemical composition of BAMs**
- **High-throughput community profiling and ^{13}C- SIP will be used to determine the microbial taxa involved in BAM production and how this is influenced by different forestry management practices.**



BAMs contain a lot of carbon
Resistant to dissolution by acids
Need to determine chemical composition

Publications 2019

★ **<u>Finlay RD</u>, Thorn RG. 2019.** The Fungi in Soil. In: *Modern Soil Microbiology*, 3rd edition. (ed. by JD. van Elsas, J. Trevors, A Rosado & P Nannipieri). CRC Press, Taylor & Francis, Boca Raton, FL. pp. 65-89. ISBN 9781498763530.

★ **Moreau D, Bardgett RD, <u>Finlay RD</u>, Jones DL, Philippot L. 2019.** A plant perspective on nitrogen cycling in the rhizosphere. *Functional Ecology* **33**: 540-552.

★ **Sun Q, Li J, <u>Finlay RD</u>, Lian B. 2019.** Oxalotrophic bacteria assemblages in the ectomycorrhizosphere of forest trees and their effects on oxalate degradation and carbon fixation potential. *Chemical Geology* **514**: 54-64.

★ **Sun Q, Ziyu F, <u>Finlay RD</u>, Lian B. 2019.** Transcriptome analysis provides novel insights into the response of the ectomycorrhizal fungus *Amanita pantherina* to deficiencies of soluble potassium and phosphorus. *Applied and Environmental Microbiology* 85:e00719-19.

★ **Kluting K, Clemmensen K, Jonaitis S, Vasaitis R, <u>Finlay RD</u>, Rosling A. 2019.** Microhabitat shapes fungal community composition in a sand dune pine forest. *FEMS Microbiology Ecology* 95, 2019, fiz149.

★ **Rosenstock N, van Hees PAW, Fransson PMA, <u>Finlay RD</u>, Rosling A. 2019.** Biological enhancement of mineral weathering by *Pinus sylvestris* seedlings - effects of plants, ectomycorrhizal fungi, and elevated CO_2. *Biogeosciences* **16**: 3637-3649

★ **Akselsson C, Belyazid S, Stendahl J, <u>Finlay RD</u>, Bengt Olsson, Erlandsson Lampa Martin, Håkan Wallander, Gustafsson, J-P, Bishop Kevin. 2019.** Weathering rates in Swedish forest soils. *Biogeosciences* **16:** 4429-4450.

★ **<u>Finlay RD</u>, Mahmood S, Rosenstock N, Bolou-Bi E, Köhler S, Fahad Z, Rosling A, Wallander H, Belyazid S, Bishop K, Lian B. 2020.** Biological weathering and its consequences at different spatial levels – from nanoscale to global scale. *Biogeosciences* **16:** 0000-0000.

Shahid Mahmood- *SLU, Uppsala, Sweden* Community profiling, ^{13}C SIP

Alf Ekblad – *Örebro University, Sweden* $^{13}C/^{15}N$ MS

Emile BOLOU BI - *IEES, Paris, France* ^{26}Mg MS

Bin Lian - *Nanjing, China* Transcriptome profiling, SEM-EDS, XRD

Andras Gorzas - *Umeå University, Sweden* FTIR spectroscopy

Carsten Müller, Carmen Höschen, Ingrid Kögel-Knabner -

Technical University of Munich, Freising, Germany NanoSIMS

SEVENTH FRAMEWORK PROGRAMME

EcoFINDERS

IMPRESS

FORMAS

QWARTS

SLU