



Microbial resistance and resilience to drought in contrasting cropping systems

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Johan Six¹, Jochen Mayer³, and Martin Hartmann¹

1 **ETH** zürich 2 **FiBL** 3  **Agroscope**

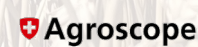
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MICROSERVICES

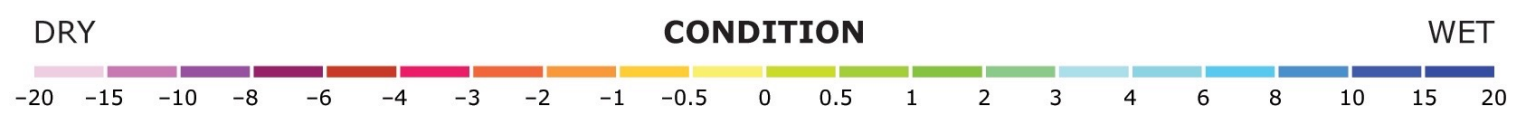
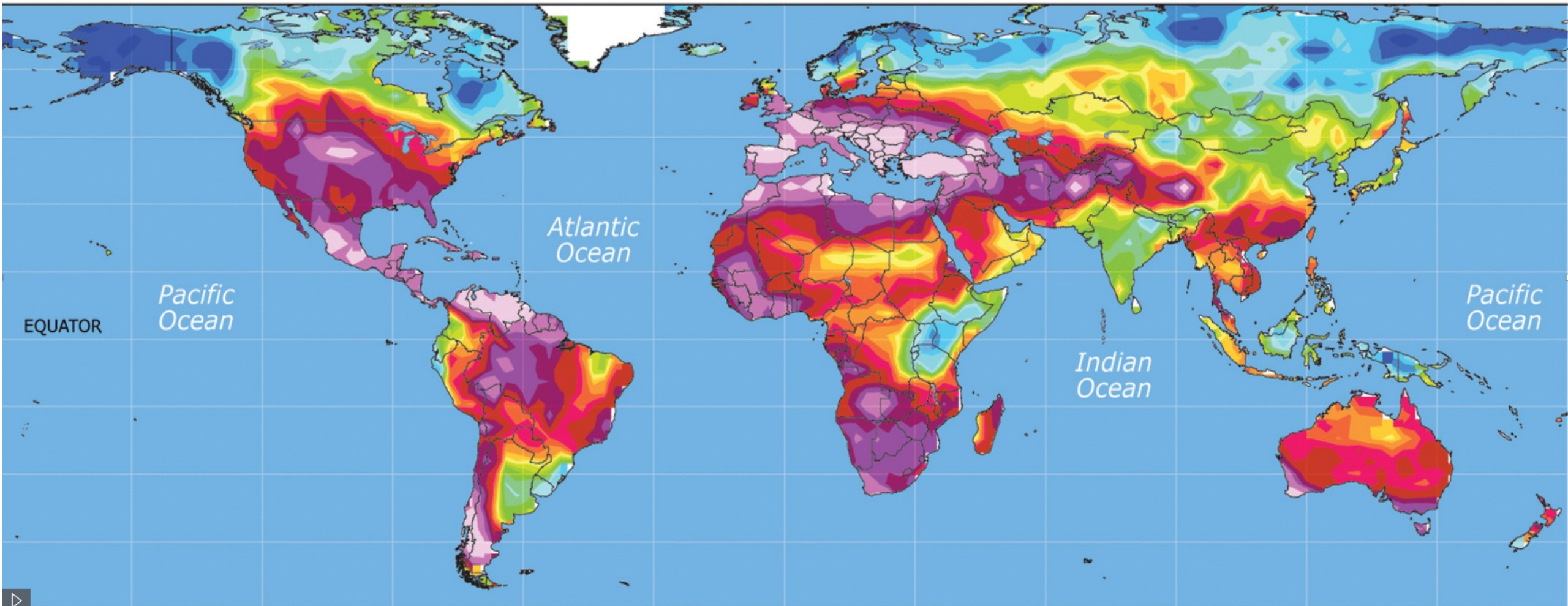


This research was funded through the 2019-2020 BiodivERsA joint call for research proposals, under the BiodivClim ERA-Net COFUND program, and with the funding organizations Swiss National Science Foundation SNSF (31BD30_193666), Agencia Estatal de Investigación AEI (SPCI202000X1206791V0), Agence nationale de la recherche ANR (ANR-20-EBI5-0006), Federal Ministry of Education and Research BMBF (16LC2023A), and General Secretariat for Research and Innovation GSRI (T12EPA5-00075).



Droughts are increasing due to climate change

2090–2099



Dai et al. 2011 (Wiley Interdisciplinary Reviews)
Image: University Corporation for Atmospheric Research

Soil microbes are important for soil functioning and crop growth

Hartmann & Six 2022
(Nature Reviews Earth & Environment,
credit Joshua Binswanger)

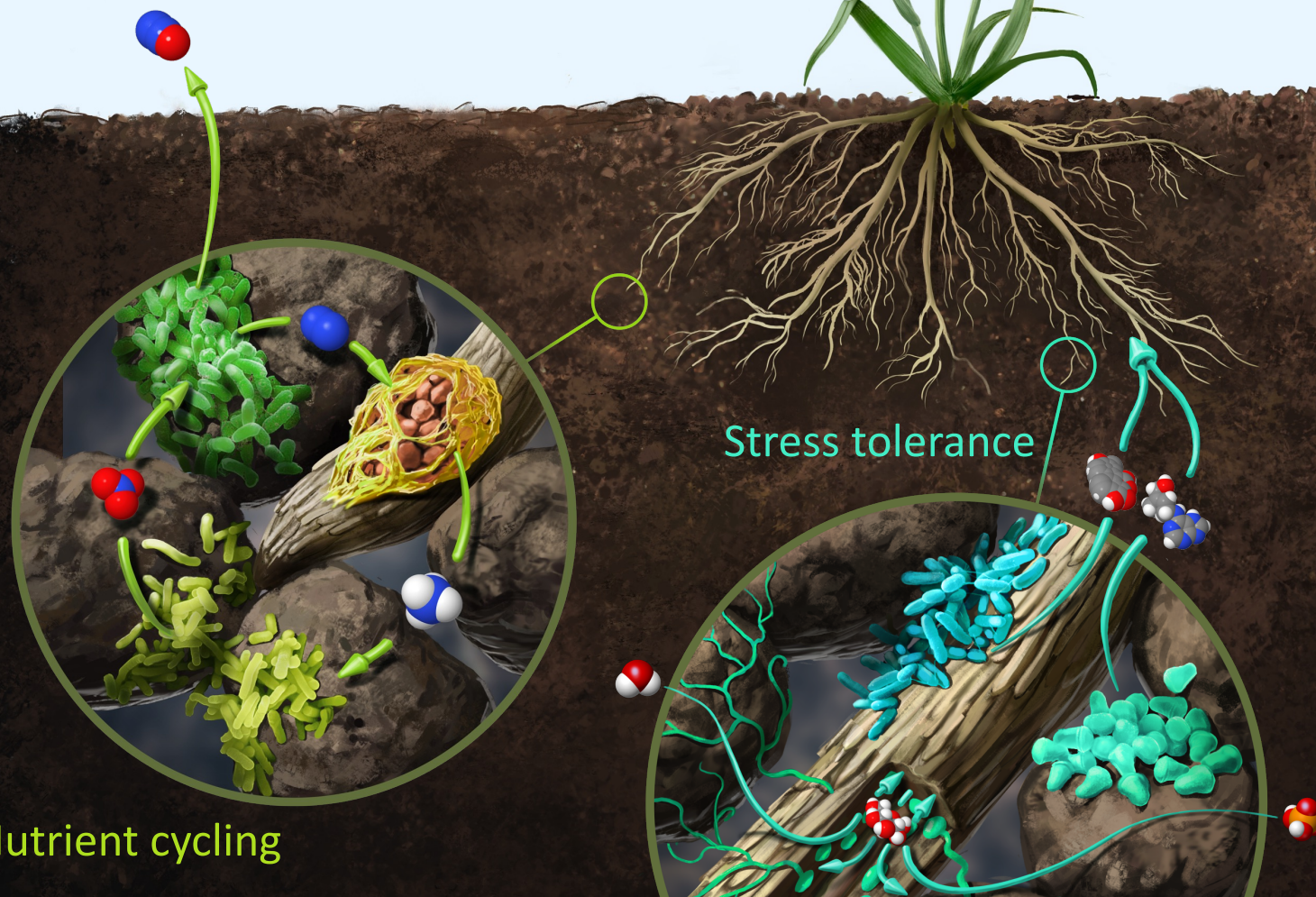


Soil microbes are important for soil functioning and crop growth



Nutrient cycling

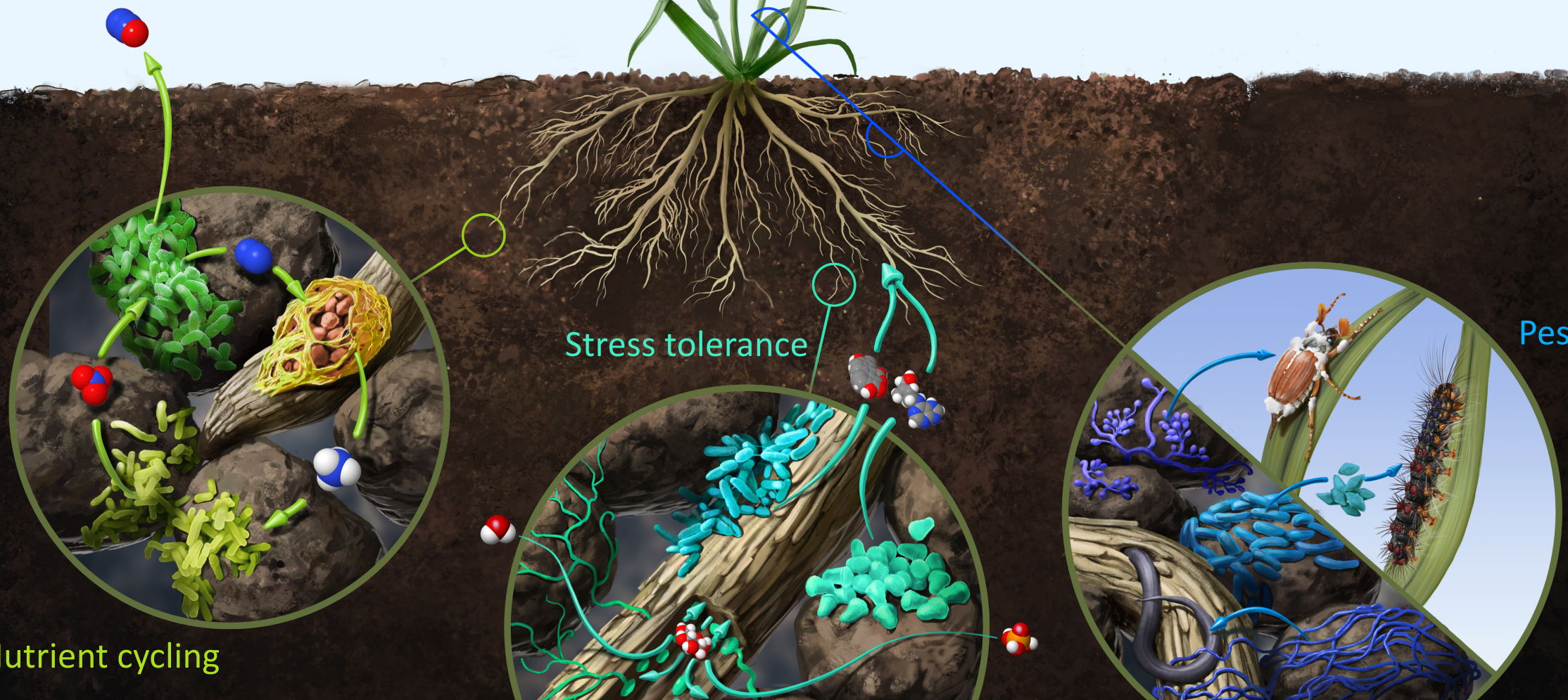
Soil microbes are important for soil functioning and crop growth



Nutrient cycling

Stress tolerance

Soil microbes are important for soil functioning and crop growth



Nutrient cycling

Stress tolerance

Pest control

DOK long-term trial

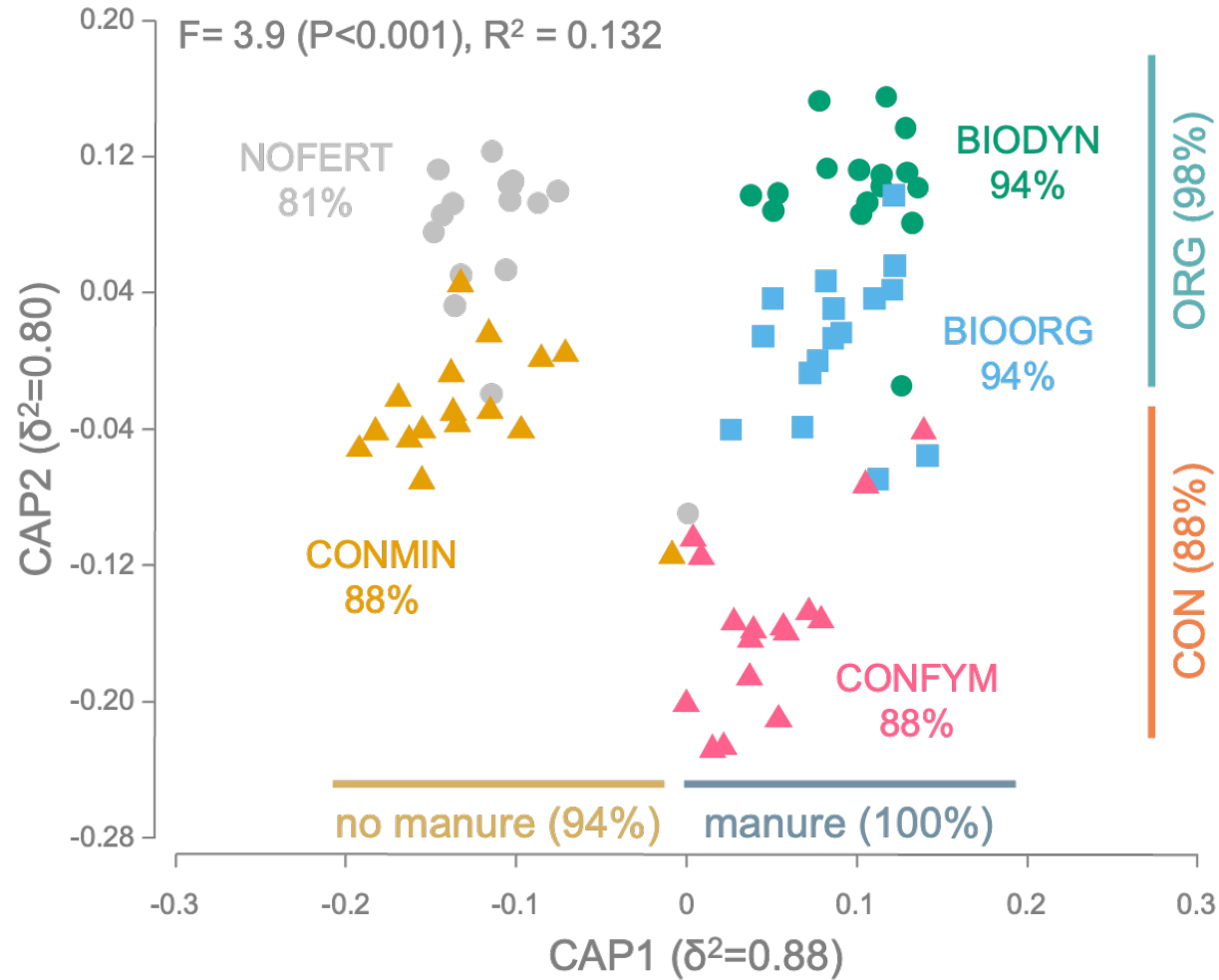


- Established in 1978
- Haplic Luvisol
- 791 mm MAP, 11°C MAT
- 5 systems, 4 replications
- 3 temporally shifted 7-yr crop rotations
- In 7th crop rotation (2020-2027)

Cropping system	Unfertilized NOFERT	Bio-dynamic BIODYN	Bio-organic BIOORG	Conventional mixed CONFYM	Conventional mineral CONMIN
Fertilization	no fertilizer	composted manure	rotten manure	stacked manure & mineral fertilizer	mineral fertilizer
Crop protection	mechanical	mechanical, indirect, beneficials bio-dynamic preps		insecticides, fungicides, herbicides (thresholds) CuSO4	

Contrasting biological soil parameters

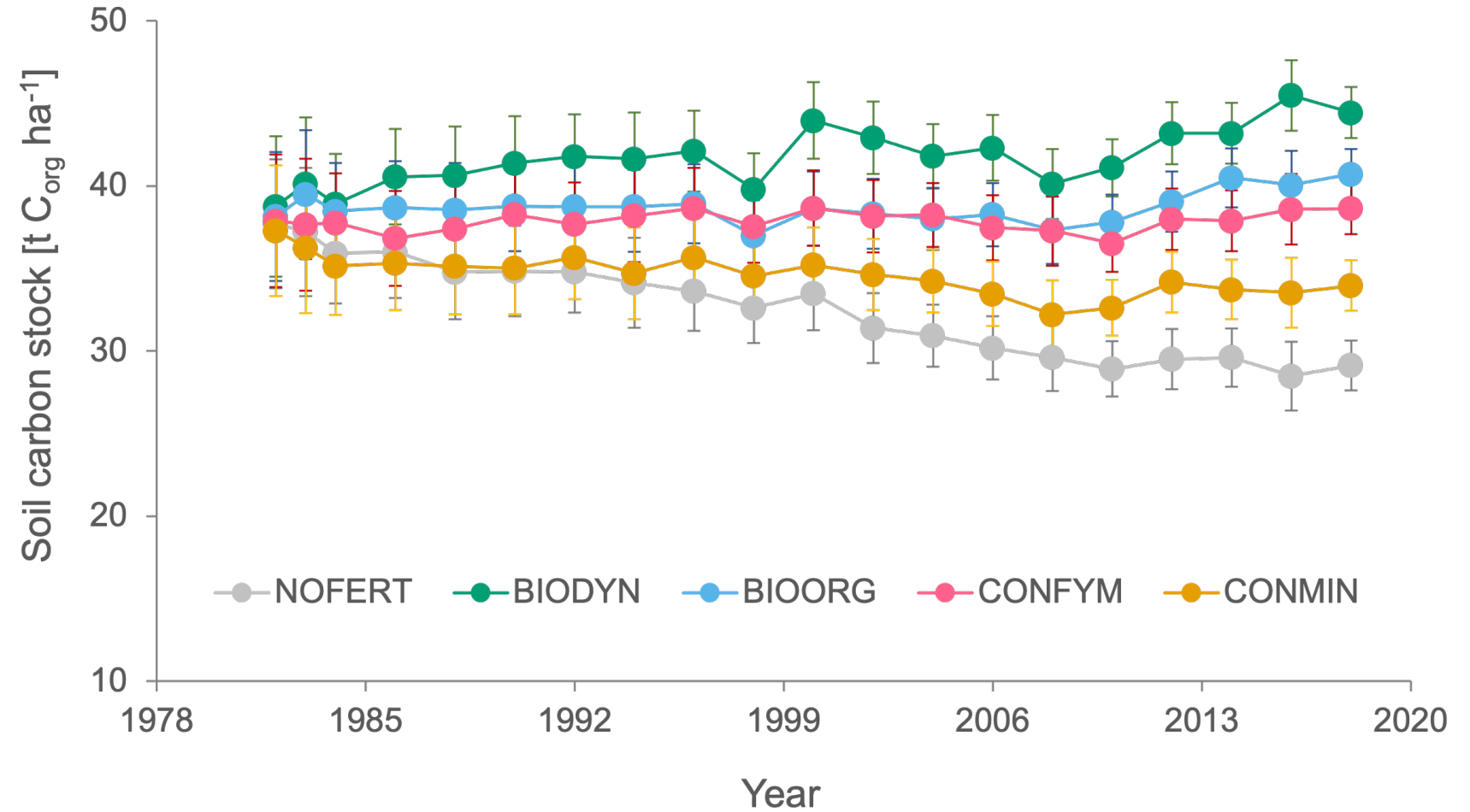
Beta-diversity
(bacteria, archaea, fungi)



Distinct soil microbiomes

Contrasting chemical soil parameters

Distinct soil organic carbon contents



1

How does
severe drought affects
**prokaryotic and
fungal community
structure in cropping
systems** in bulk soil,
rhizosphere and root?

2

2

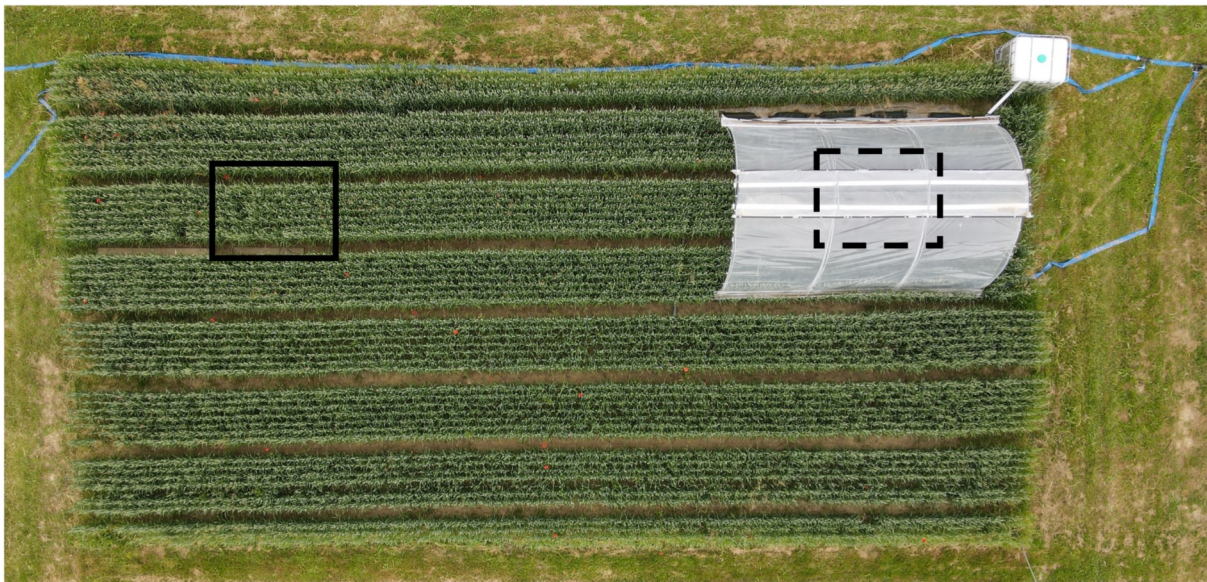
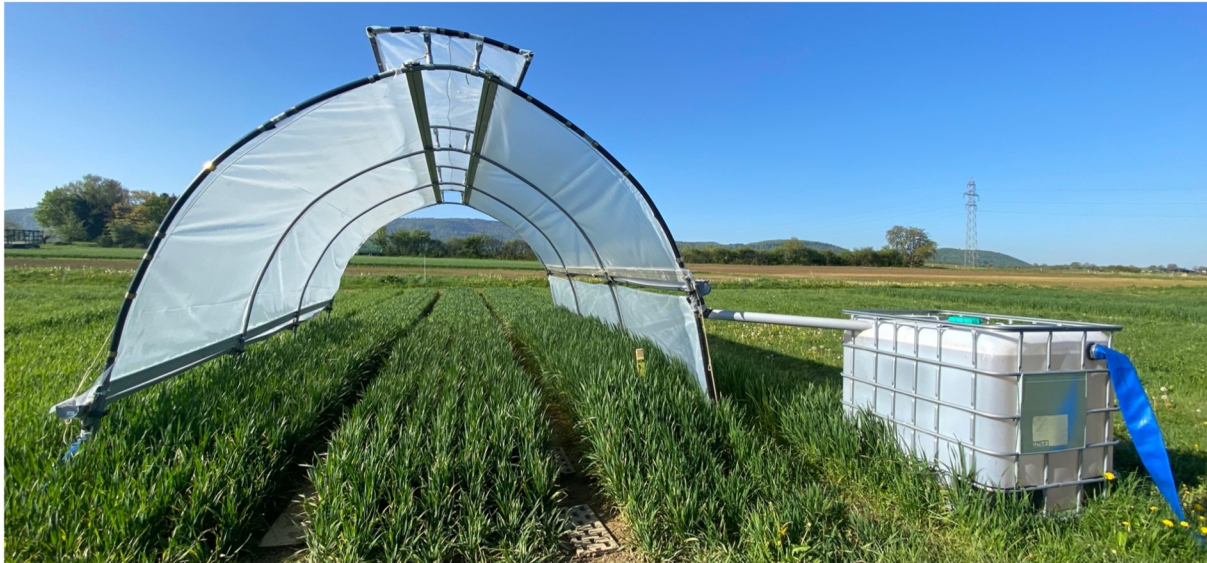
1






How does severe drought affect prokaryotic and fungal community structure in cropping systems in bulk soil, rhizosphere and root?

Does the resistance and resilience of soil microbes towards severe drought differ between organic and conventional cropping systems?

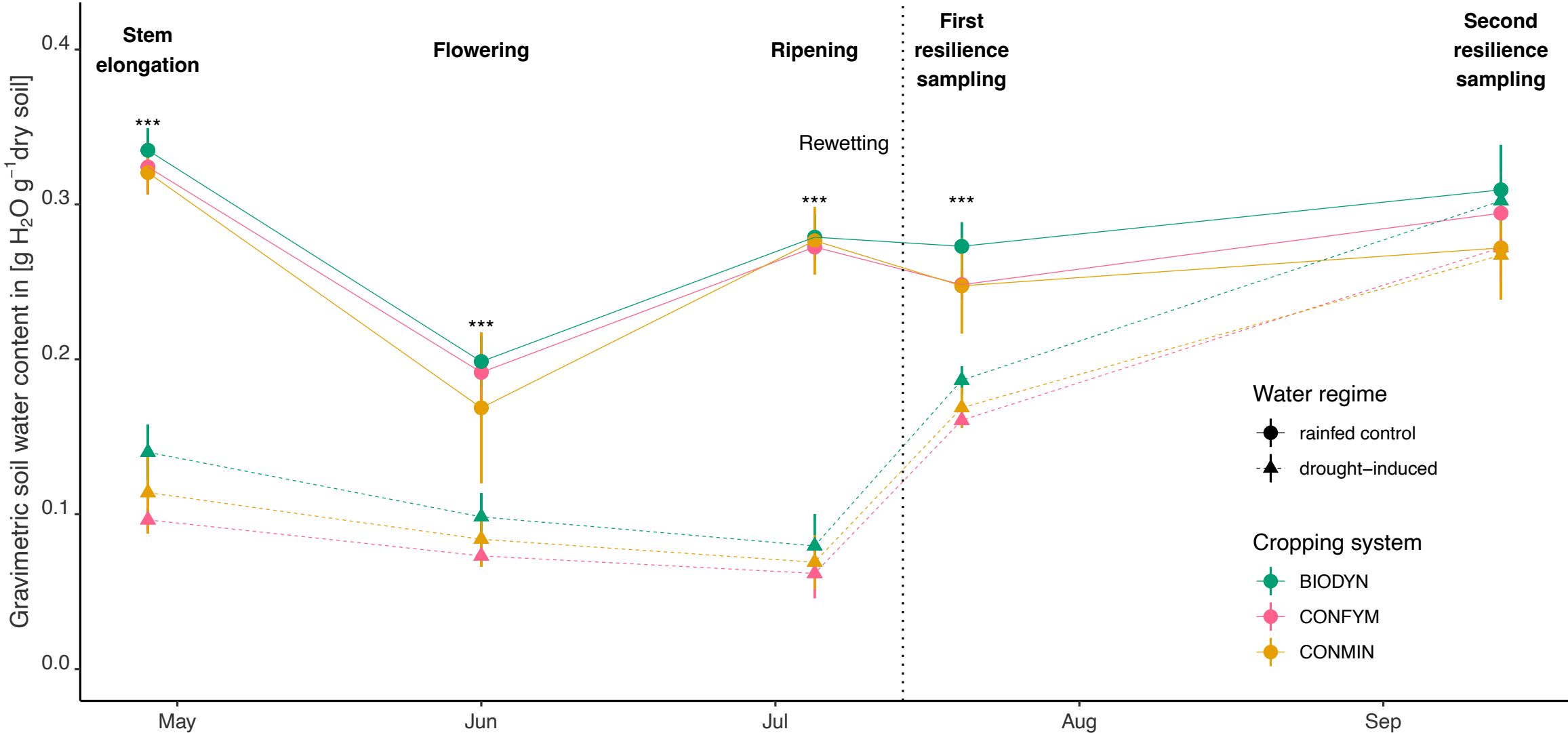
2

On-field drought simulation experiment



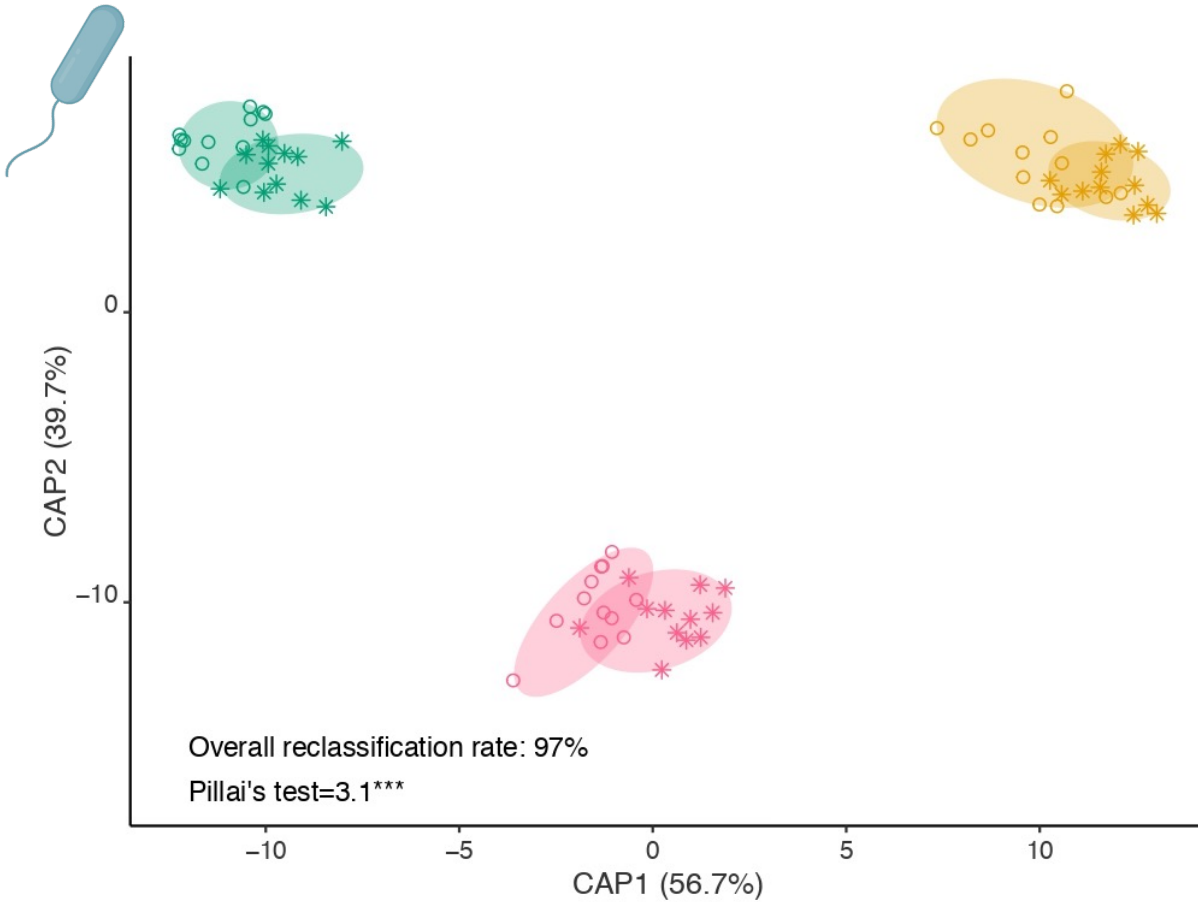
	BIODYN		Control plot
	CONFYM		Drought-induced plot
	CONMIN		

Drought could be implemented

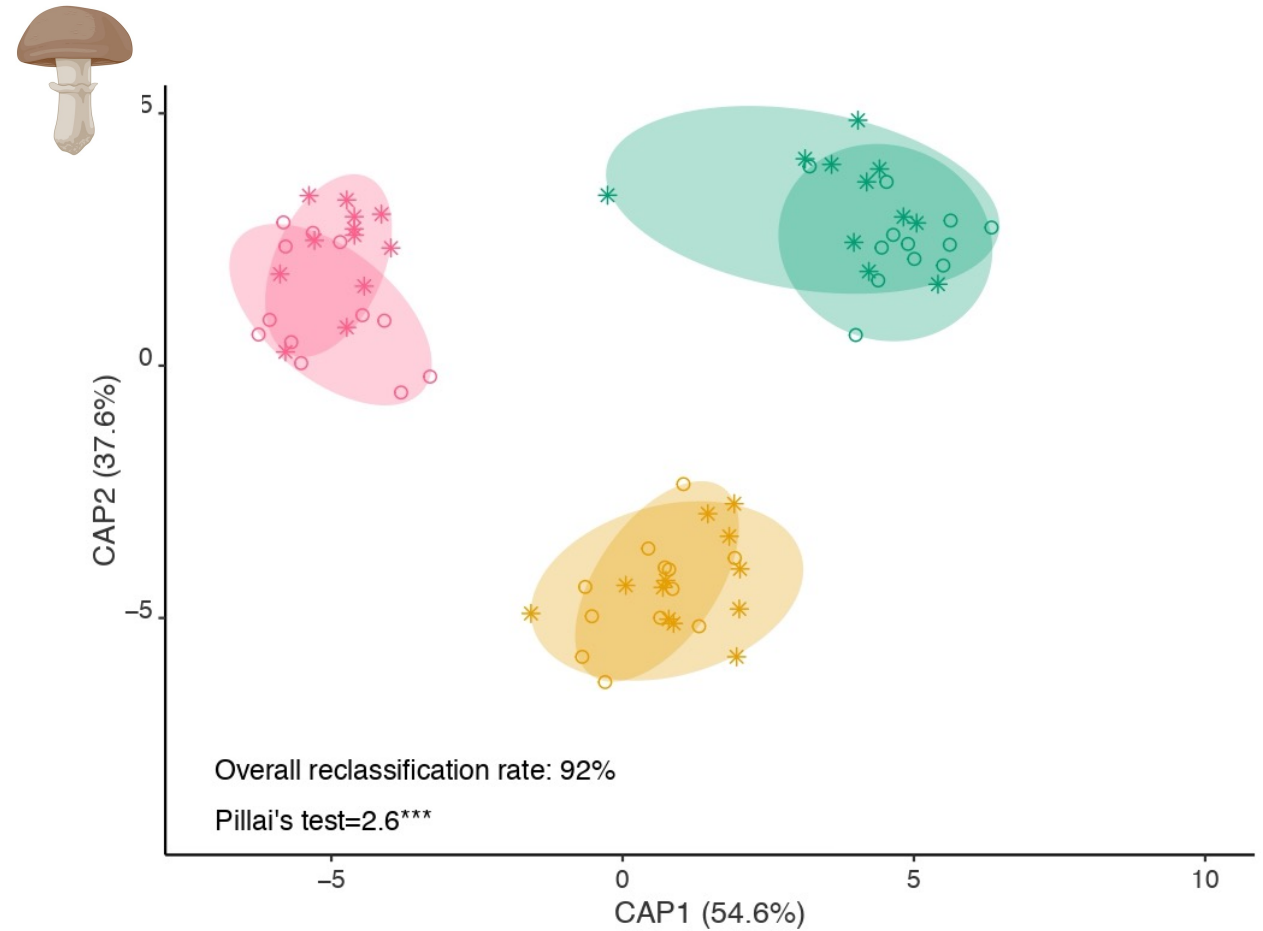


Drought effect in bulk soil

Cropping system ● BIODYN ● CONFYM ● CONMIN
 Water regime * rainfed control ○ drought-induced



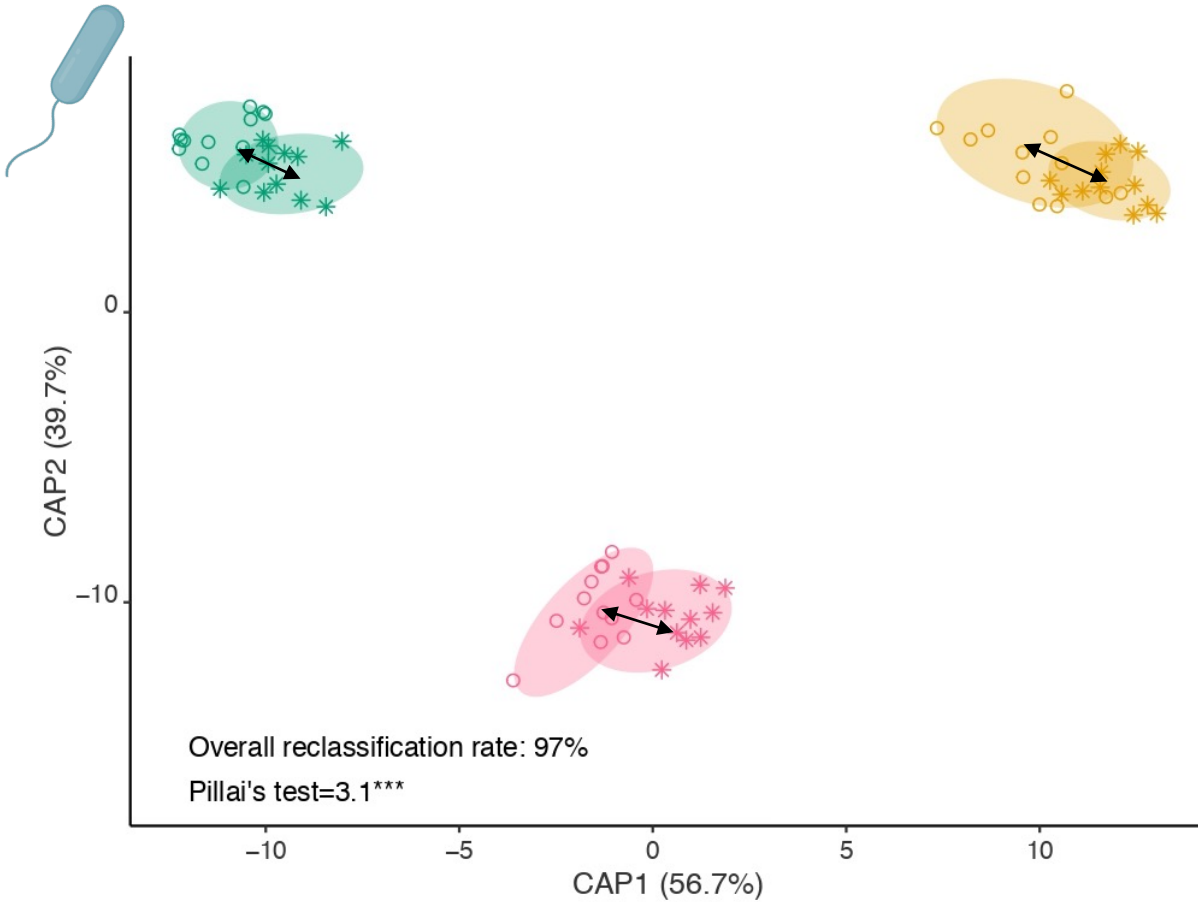
	F (p)	R ²
Water regime (W)	1.4 (0.1297)	0.015
Cropping system (C)	15.1 (0.0001)	0.307
W x C	0.9 (0.5698)	0.018



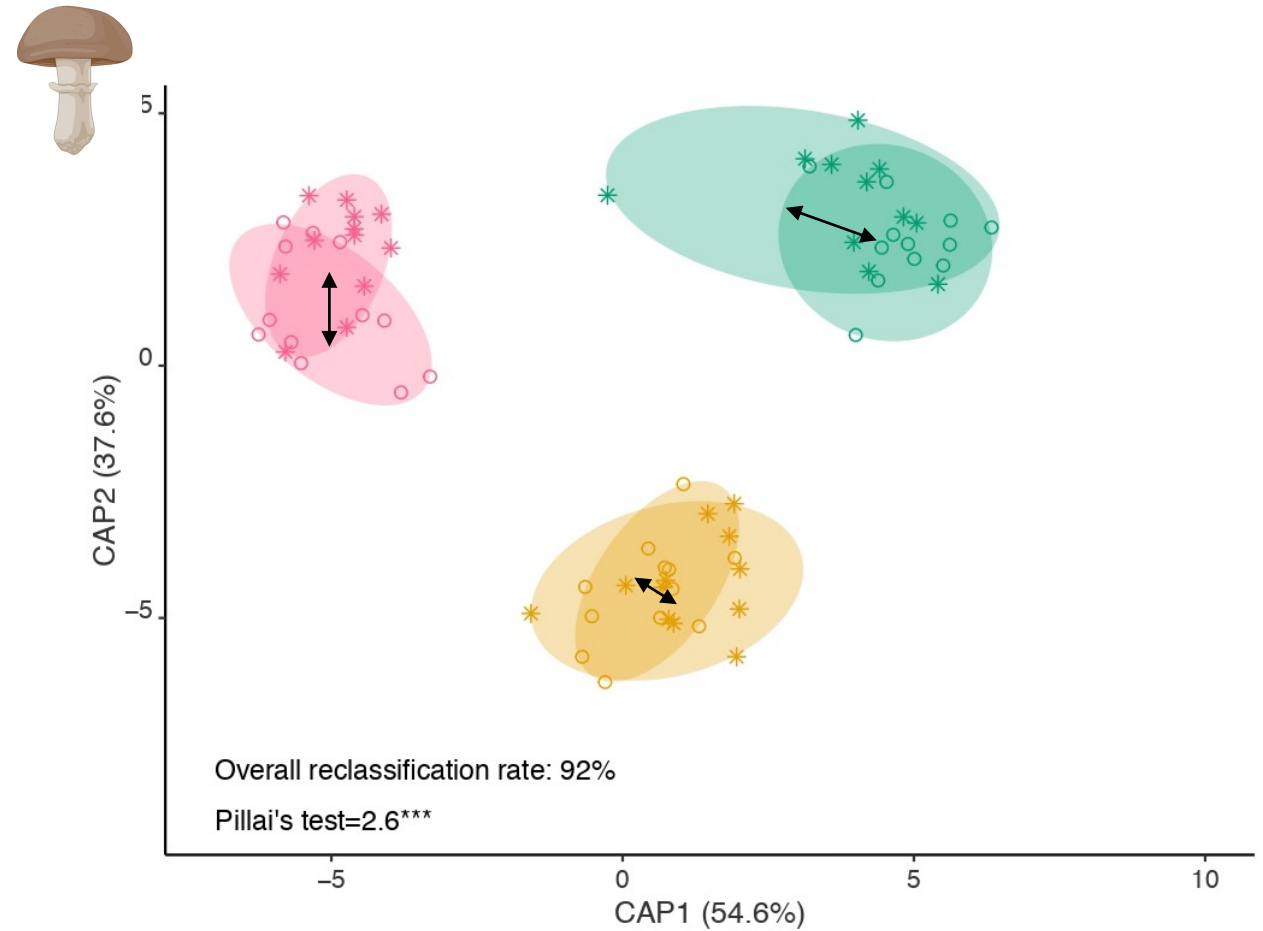
	F (p)	R ²
Water regime (W)	5.4 (0.0001)	0.057
Cropping system (C)	10.7 (0.0001)	0.225
W x C	1.1 (0.3042)	0.023

Drought effect in bulk soil

Cropping system ● BIODYN ● CONFYM ● CONMIN
 Water regime * rainfed control ○ drought-induced



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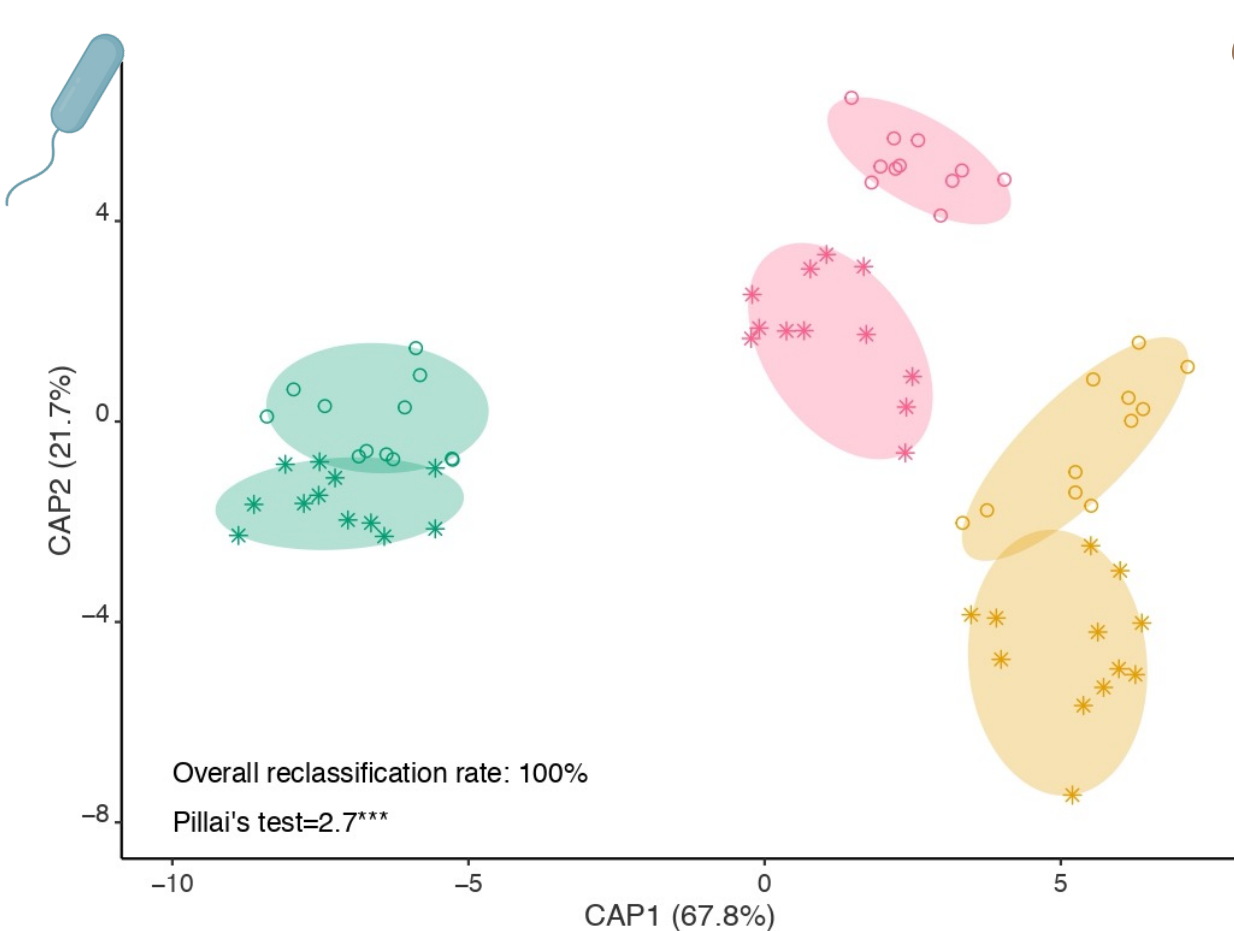


	F (p)	R ²
Water regime (W)	5.4 (0.0001)	0.057
Cropping system (C)	10.7 (0.0001)	0.225
W x C	1.1 (0.3042)	0.023

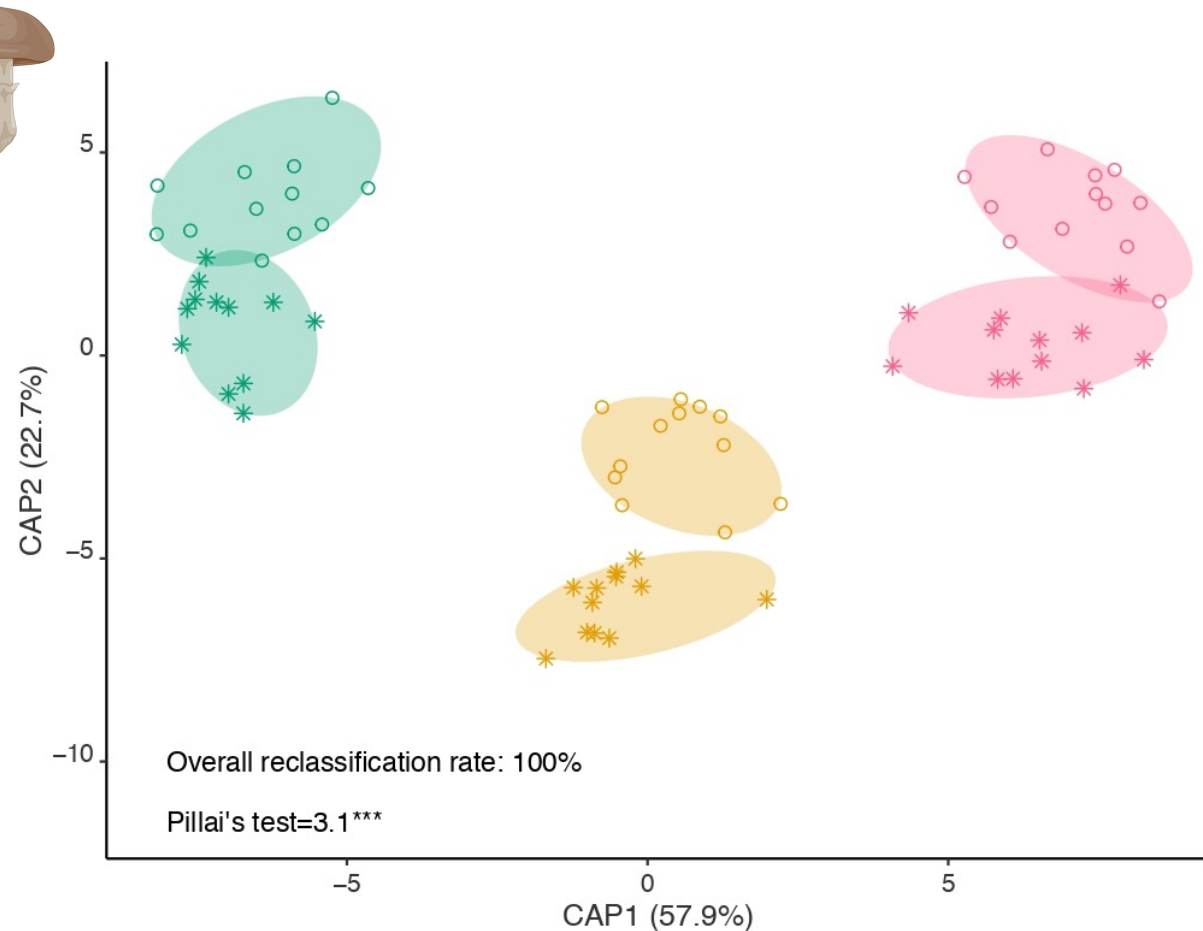
Drought effect in rhizosphere soil

Cropping system ● BIODYN ● CONFYM ● CONMIN

Water regime * rainfed control ○ drought-induced



	F (p)	R ²
Water regime (W)	3.0 (0.0069)	0.031
Cropping system (C)	14.5 (0.0001)	0.298
W x C	1.1 (0.3161)	0.022

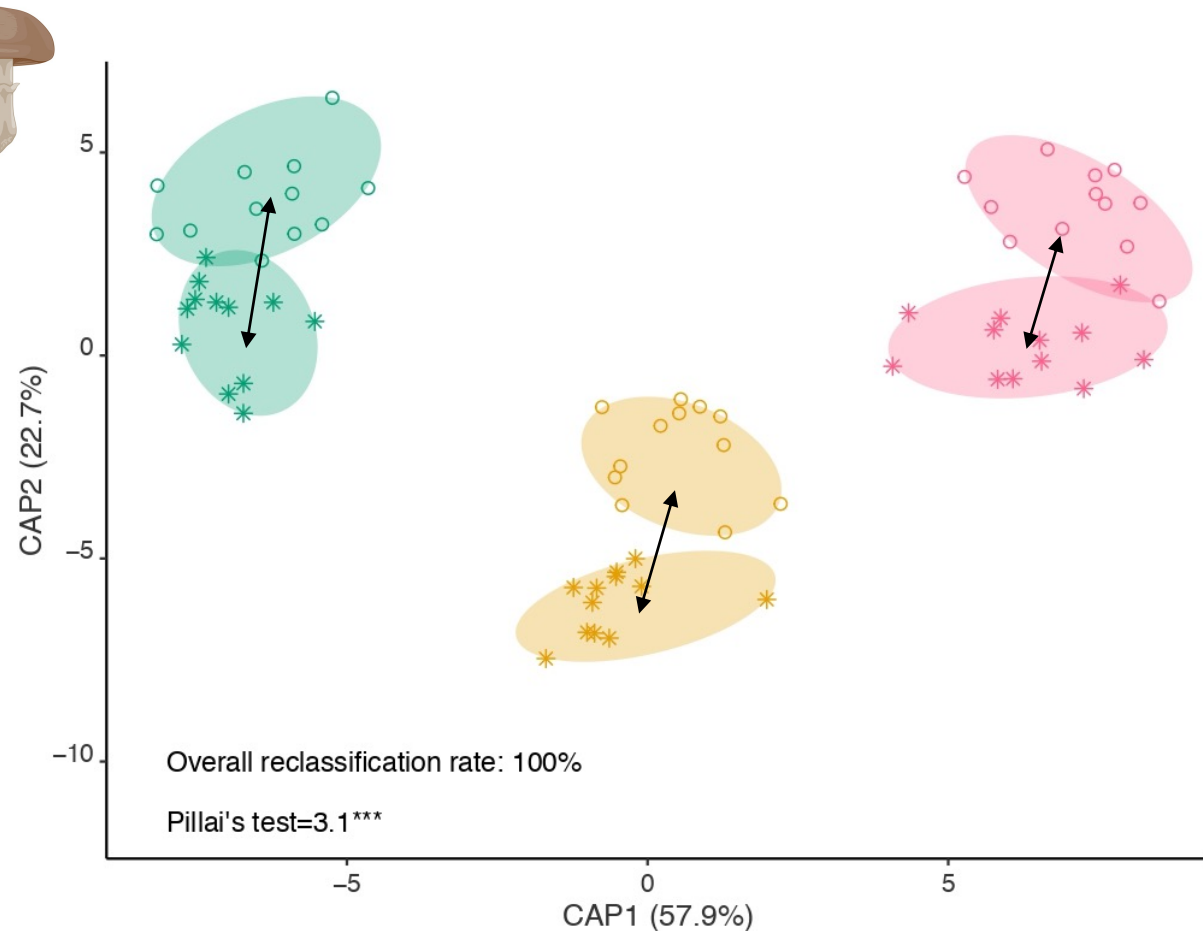
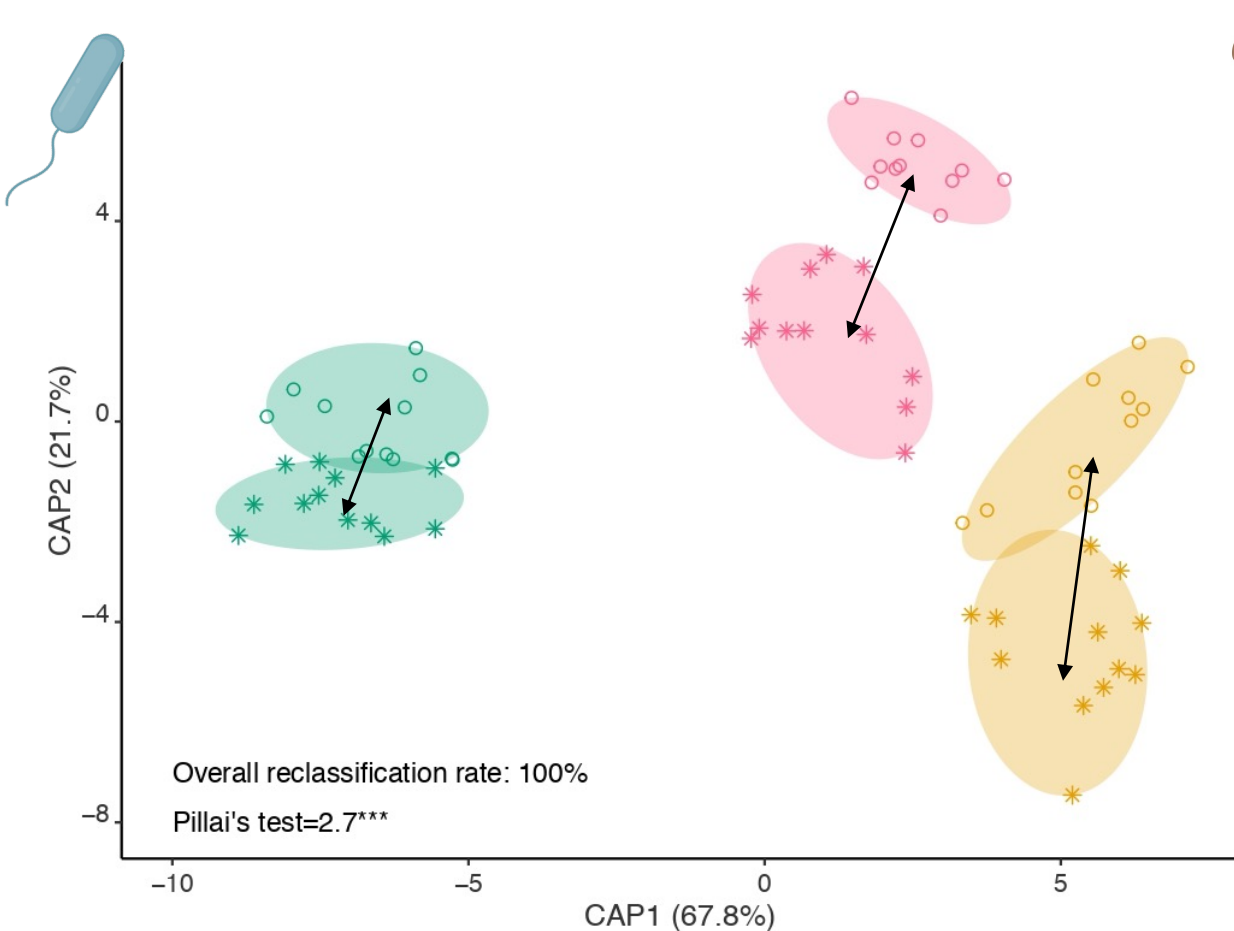


	F (p)	R ²
Water regime (W)	7.7 (0.0001)	0.078
Cropping system (C)	9.0 (0.0001)	0.181
W x C	1.2 (0.1424)	0.024

Drought effect in rhizosphere soil

Cropping system ● BIODYN ● CONFYM ● CONMIN

Water regime * rainfed control ○ drought-induced



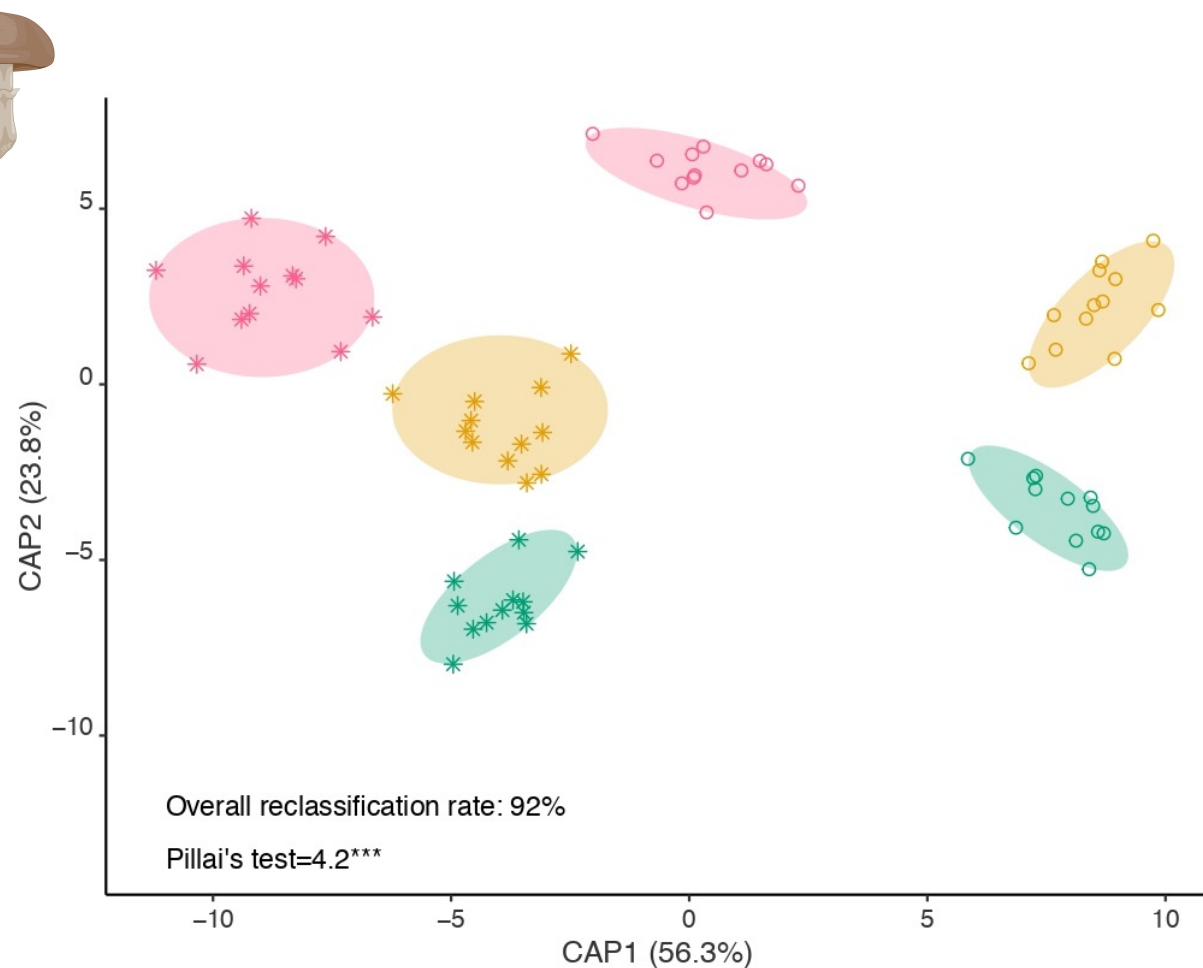
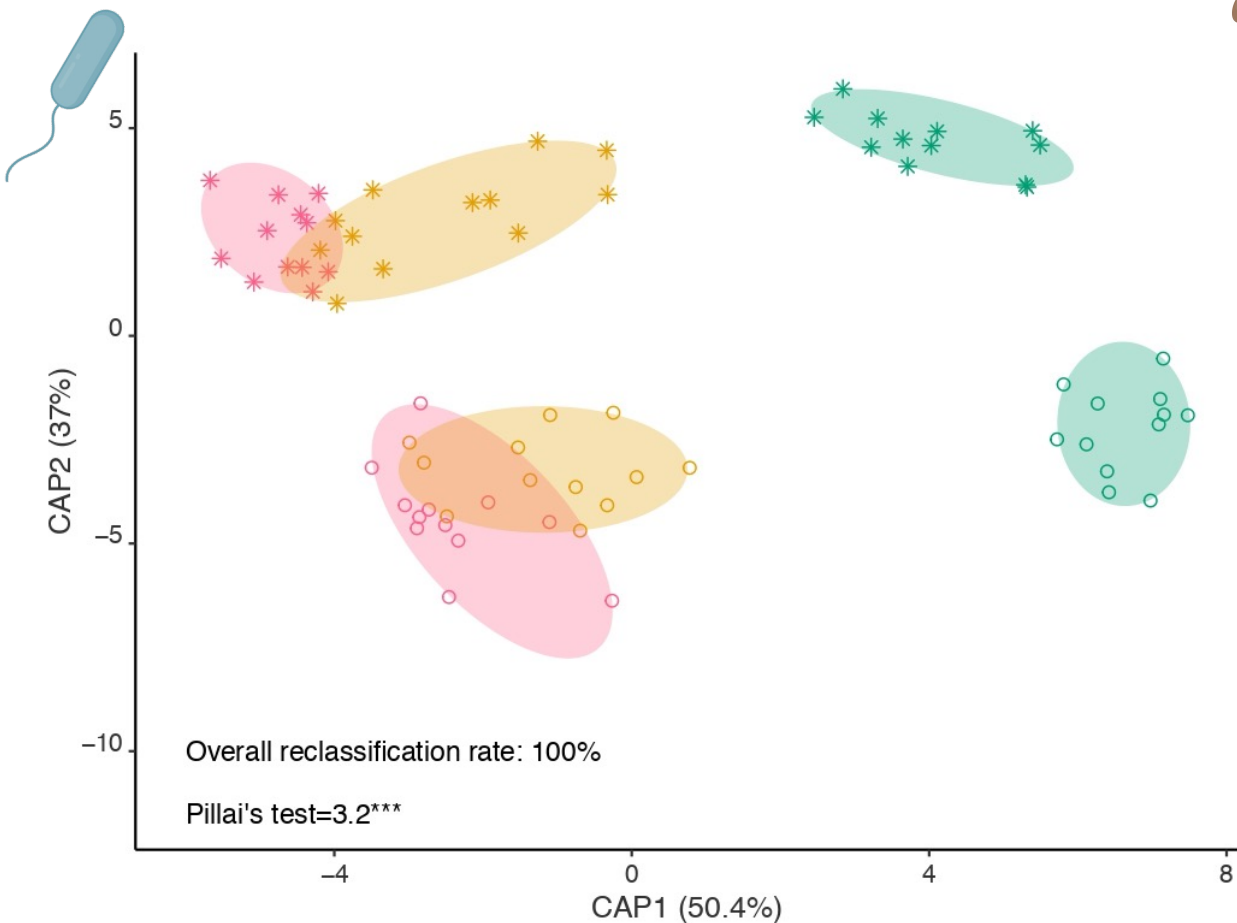
	F (p)	R ²
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Drought effect in root

Cropping system ● BIODYN ● CONFYM ● CONMIN

Water regime * rainfed control ○ drought-induced

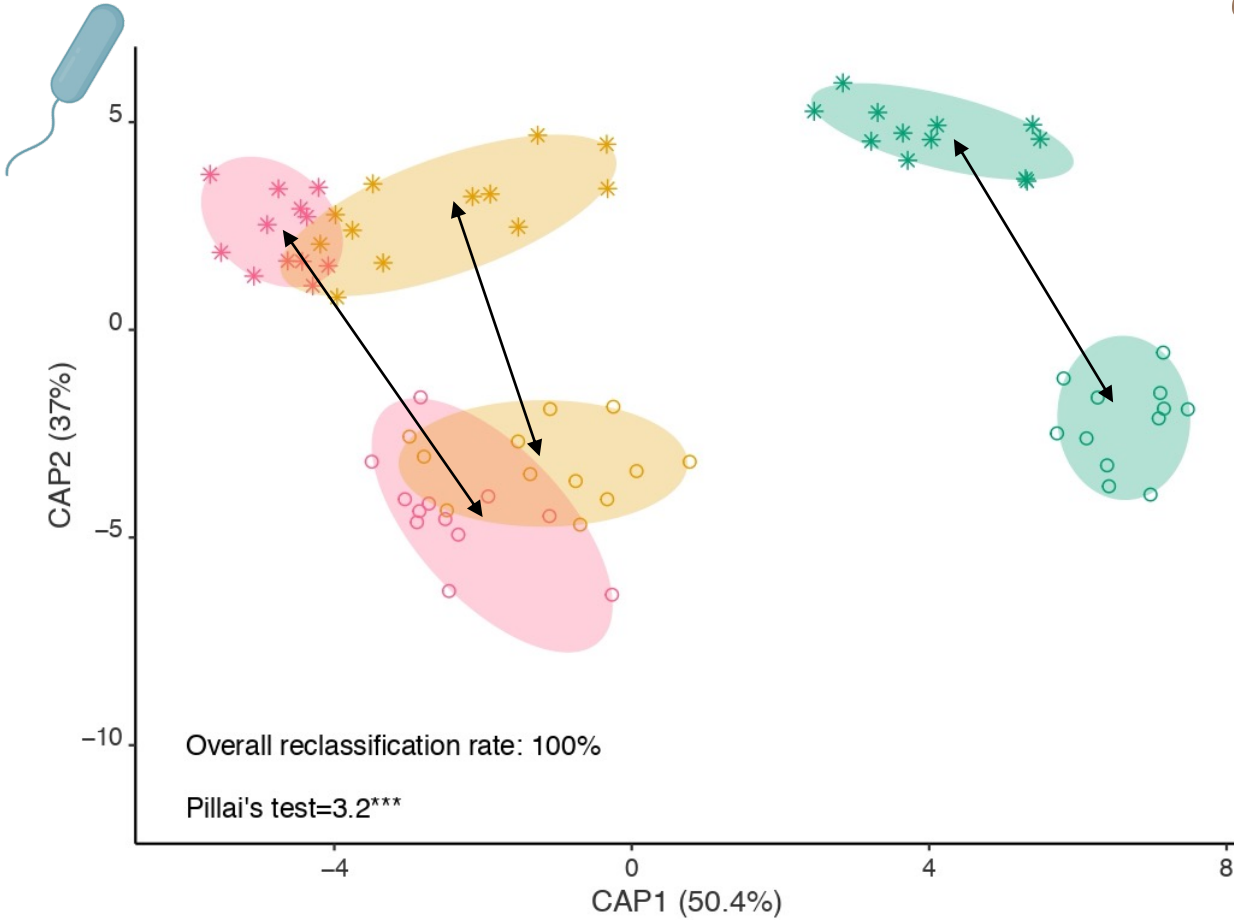


	F (p)	R ²
Water regime (W)	13.3 (0.0001)	0.115
Cropping system (C)	11.5 (0.0001)	0.200
W x C	2.0 (0.0049)	0.035

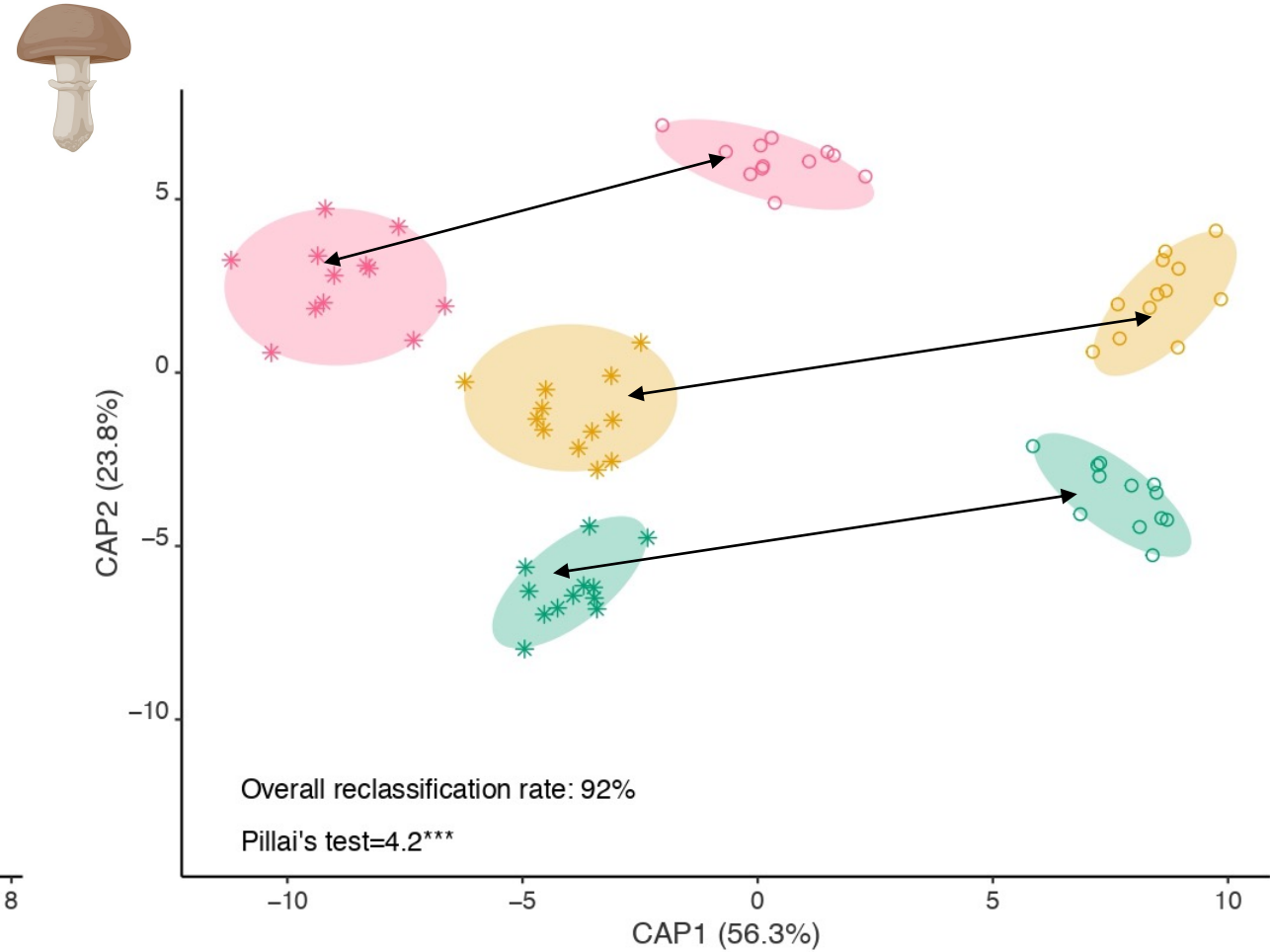
	F (p)	R ²
Water regime (W)	6.2 (0.0001)	0.068
Cropping system (C)	4.5 (0.0001)	0.099
W x C	1.2 (0.0927)	0.027

Drought effect in root

Cropping system ● BIODYN ● CONFYM ● CONMIN
 Water regime * rainfed control ○ drought-induced

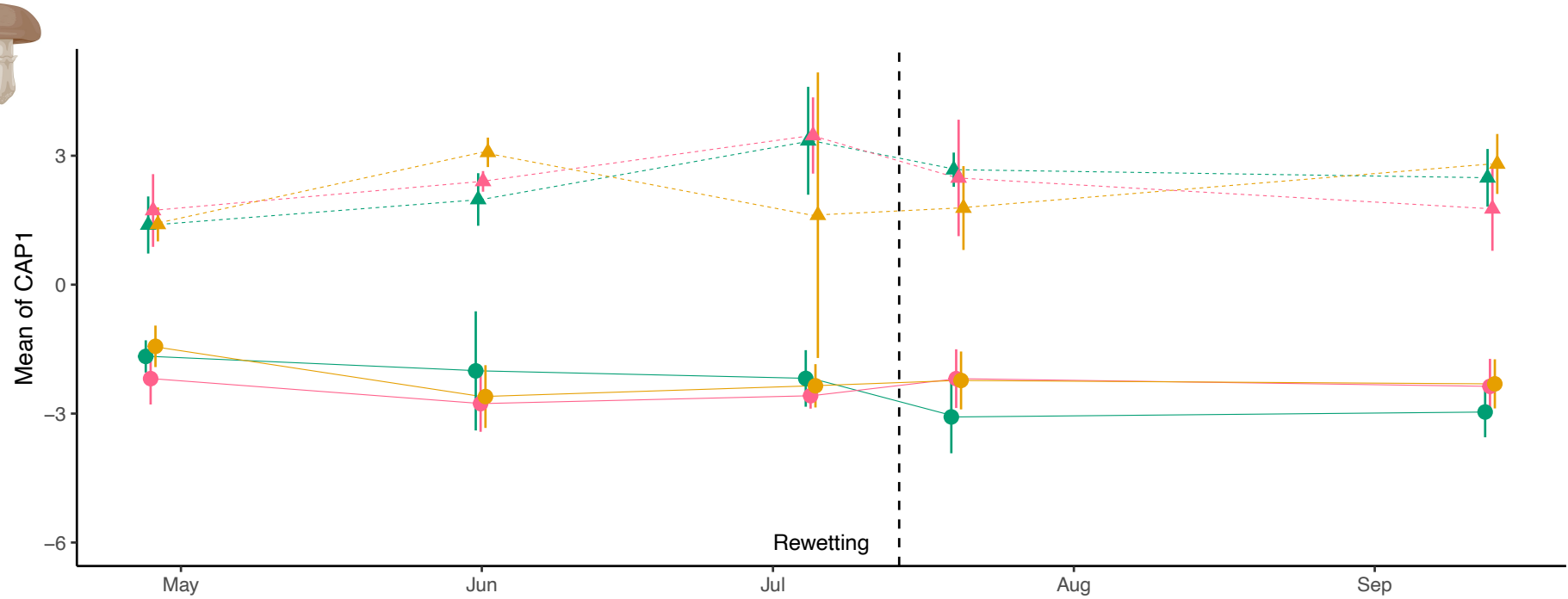
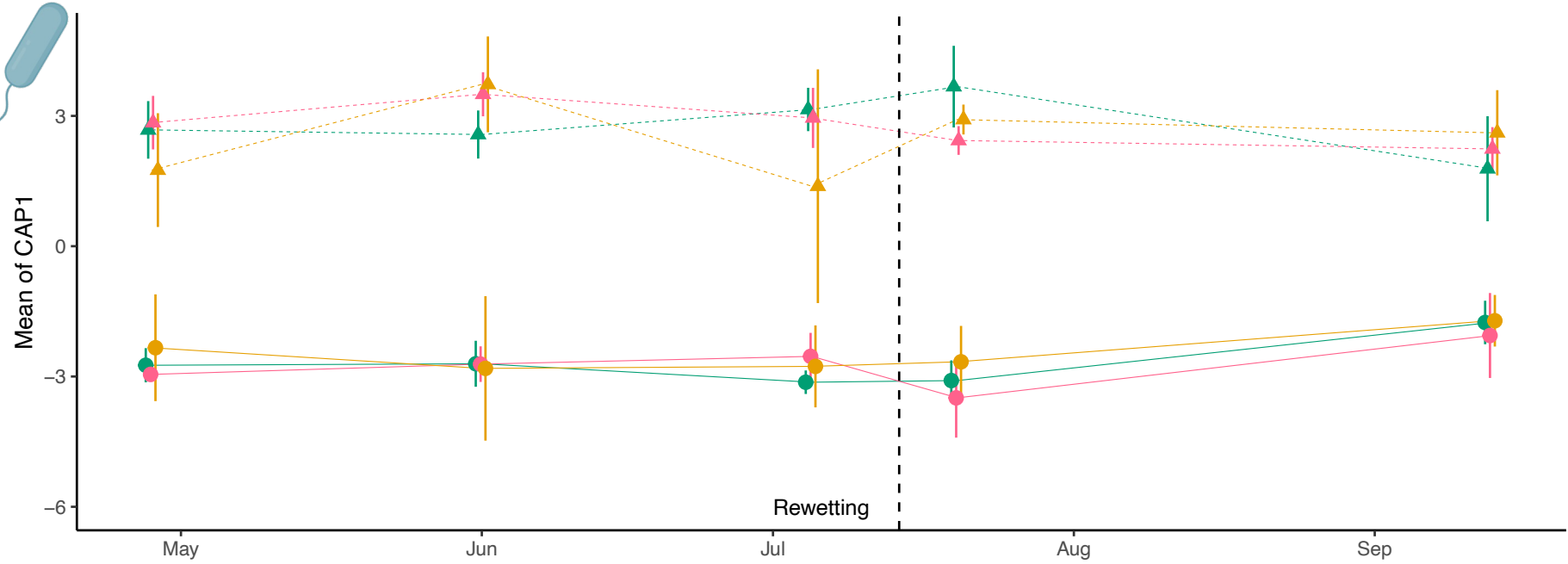
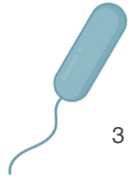


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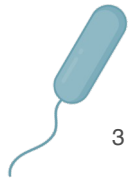
Resistance and resilience bulk soil communities



Water regime ● rainfed control ▲ drought-induced

Cropping system ● BIODYN ● CONFYM ● CONMIN

Resistance and resilience bulk soil communities



Mean of CAP1

-6

-3

0

3

May

Jun

Rewetting

Jul

Aug

Sep



Mean of CAP1

-6

-3

0

3

May

Jun

Rewetting

Jul

Aug

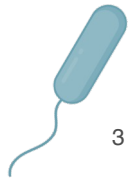
Sep

Resistance:
ability to tolerate
disturbances

Water regime ● rainfed control ▲ drought-induced

Cropping system ● BIODYN ● CONFYM ● CONMIN

Resistance and resilience on bulk soil communities



Mean of CAP1

-6

-3

0

3

May

Jun

Jul

Aug

Sep

Rewetting



Mean of CAP1

-6

-3

0

3

May

Jun

Jul

Aug

Sep

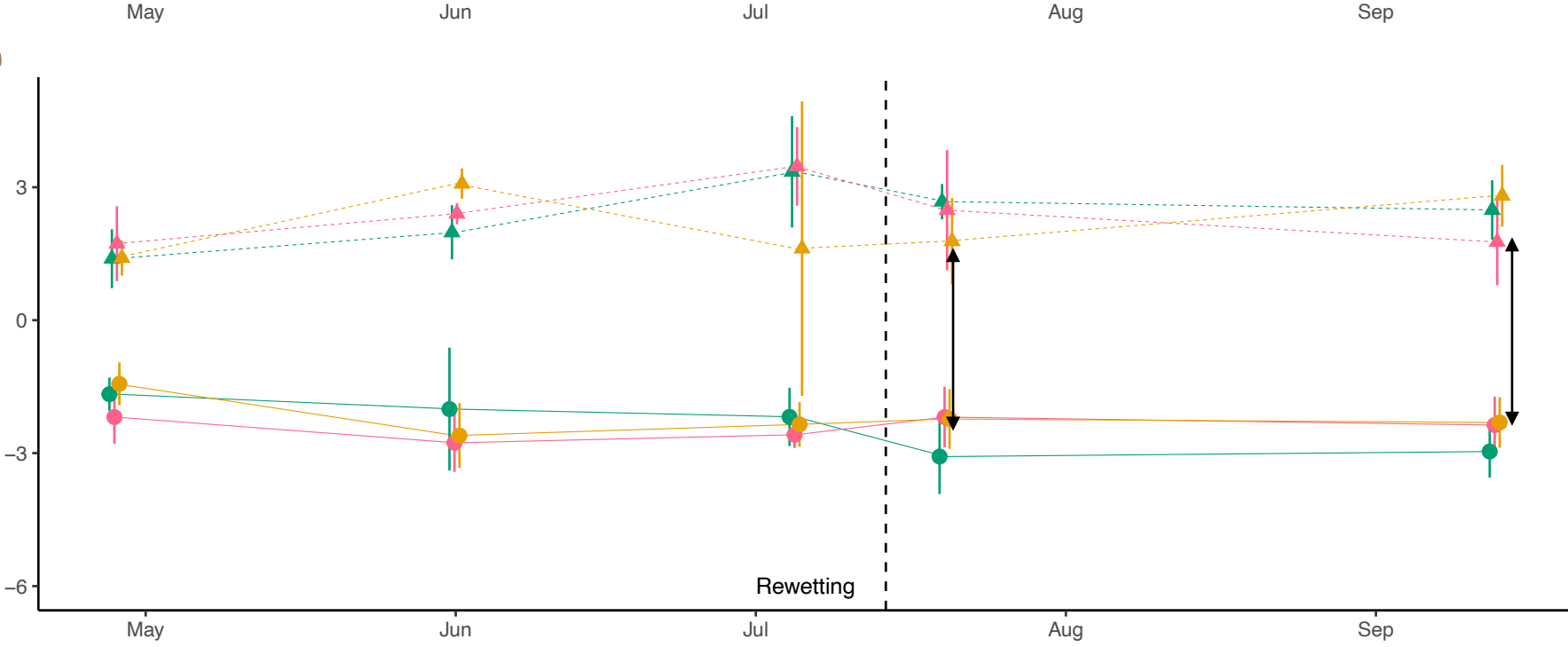
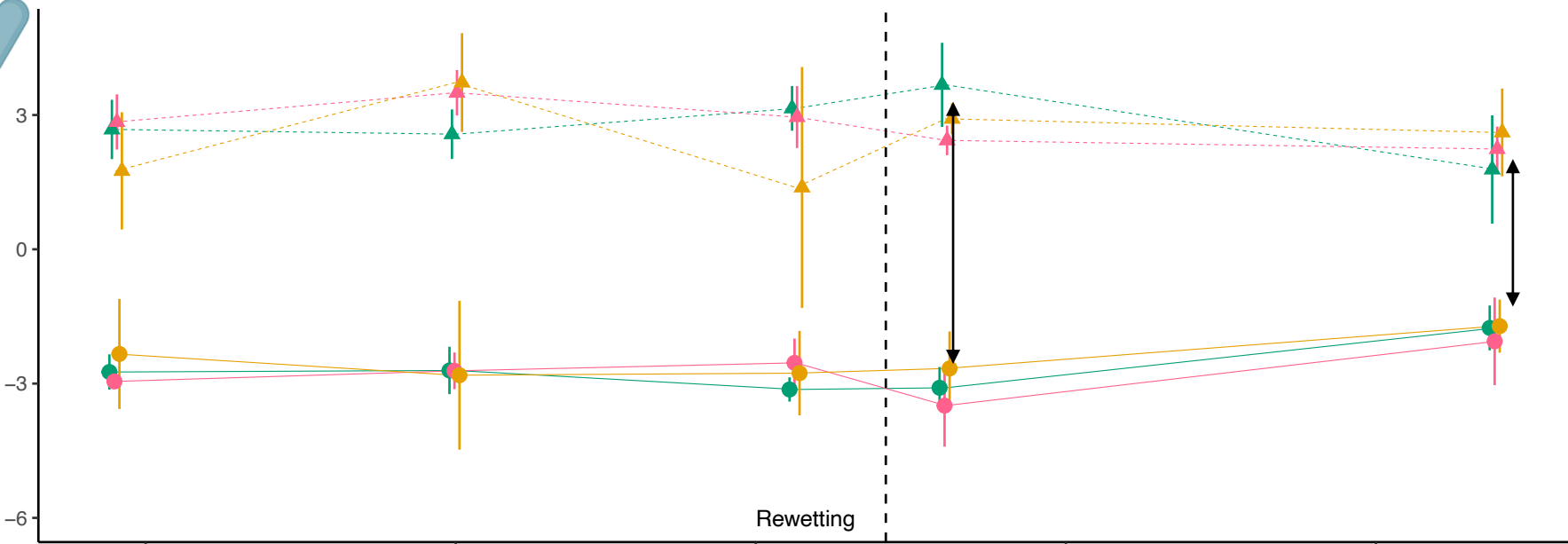
Rewetting

Water regime ● rainfed control ▲ drought-induced

Cropping system ● BIODYN ● CONFYM ● CONMIN

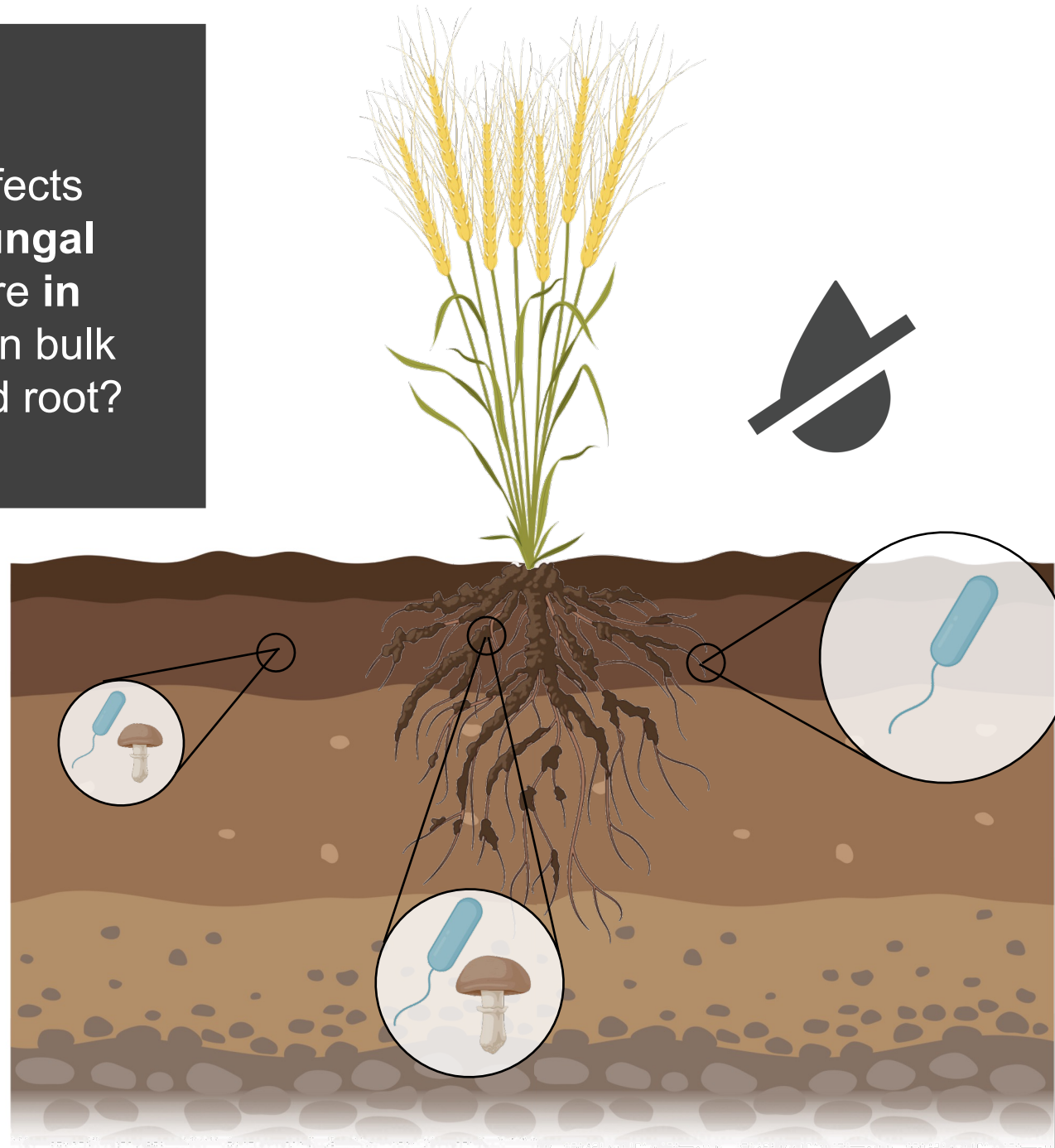
Kost et al. (in prep)

Resilience:
Ability to recover
from disturbances



1

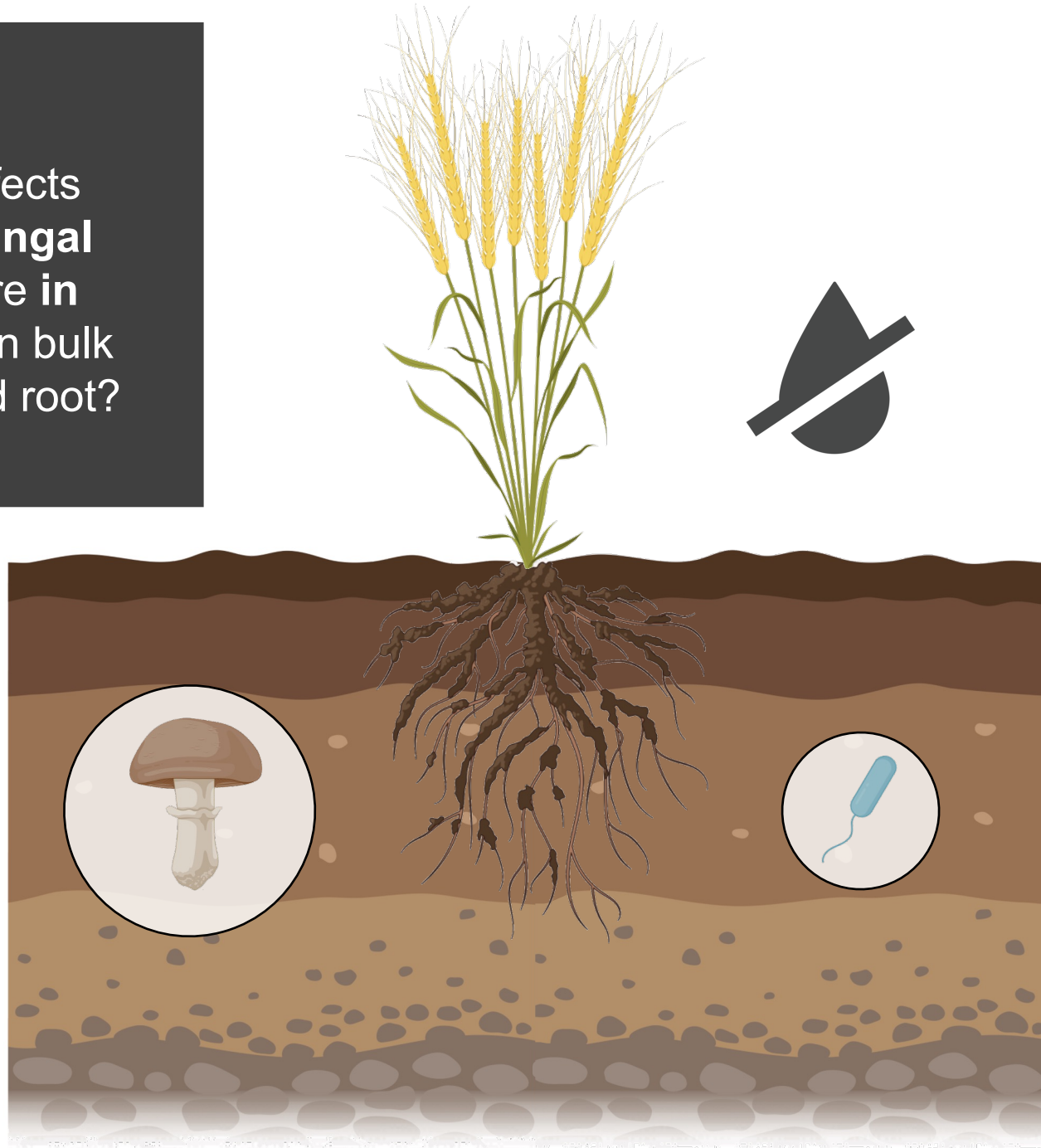
How does severe **drought** affect **prokaryotic and fungal** community structure in **cropping systems** in bulk soil, rhizosphere, and root?



Drought effect increases with **closer plant-microbial association**

1

How does severe **drought** affect **prokaryotic and fungal** community structure in **cropping systems** in bulk soil, rhizosphere, and root?



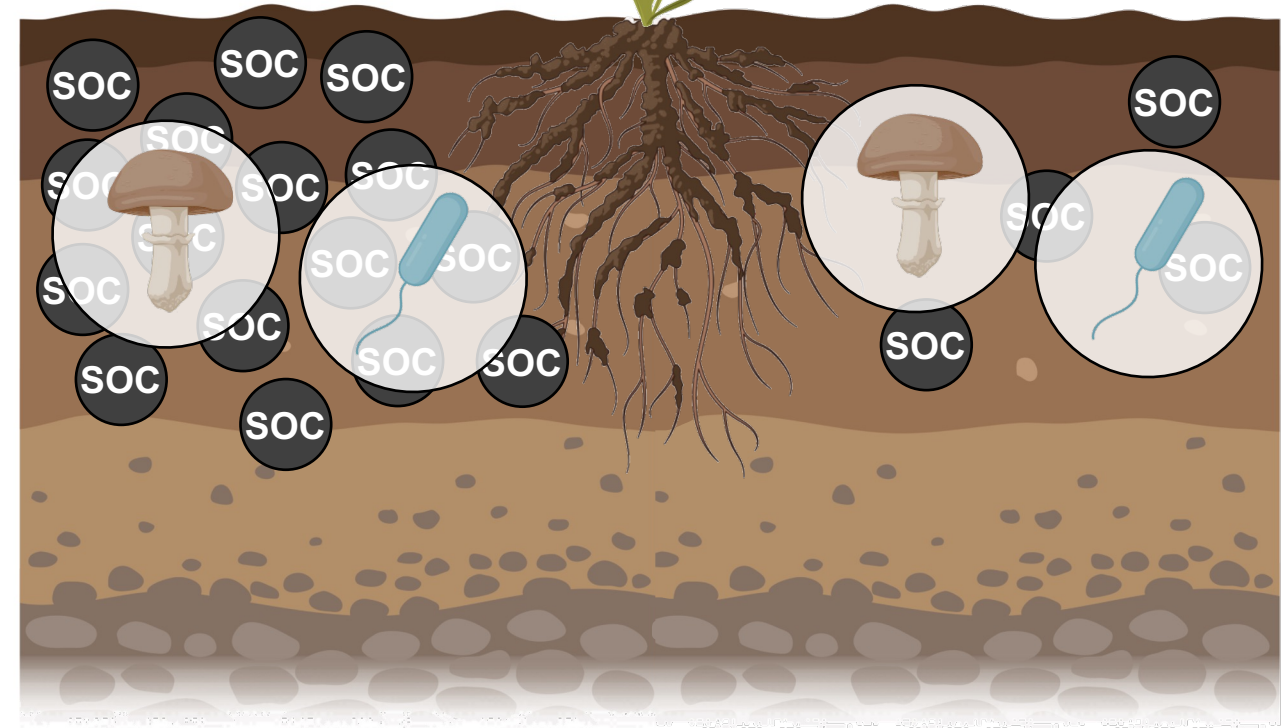
Stronger drought effect on **fungi** compared to prokaryotes

No indication that **organic fertilization with farmyard manure** could enhance the **resistance** and **resilience** to severe drought



Does the **resistance and resilience** of soil microbes towards severe drought differ between **organic and conventional cropping systems**?

2



Acknowledgments

Implementation and maintenance DOK

Field teams FiBL & Agroscope

Frédéric Perrochet, Moritz Sauter, Hansueli

Zbinden, Adrian Lustenberger

Advising farmers

Sequencing facility

Functional Genomics Center Zürich

Computational facilities ETH Zurich

Department of Health Sciences and Technology

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SCHWEIZERISCHER NATIONALFONDS
FONDO NAZIONALE SVIZZERO
SWISS NATIONAL SCIENCE FOUNDATION



Federal Ministry
of Education
and Research



GENERAL SECRETARIAT FOR
RESEARCH AND INNOVATION

Lease of the experimental area

Agrico Cooperative, Birsmatthof, Therwil

Christian Merian Foundation

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Thank you for your attention!

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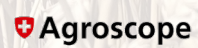
✂ @MICROSERVICES21



MICROSERVICES

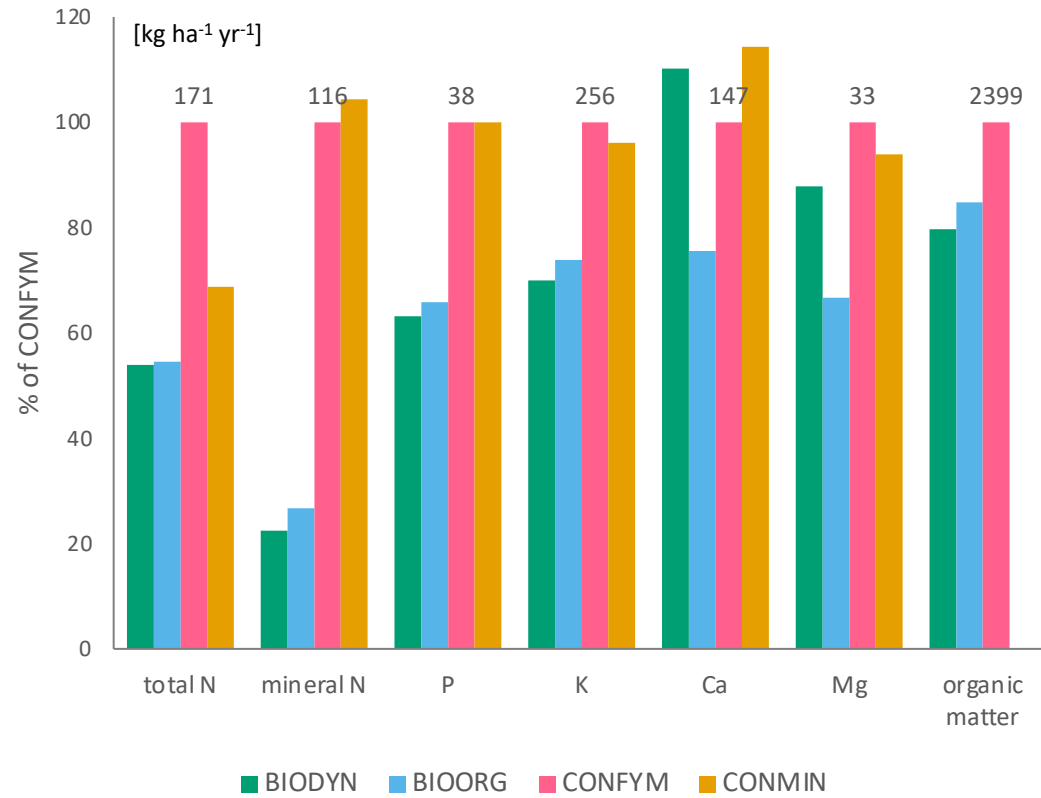


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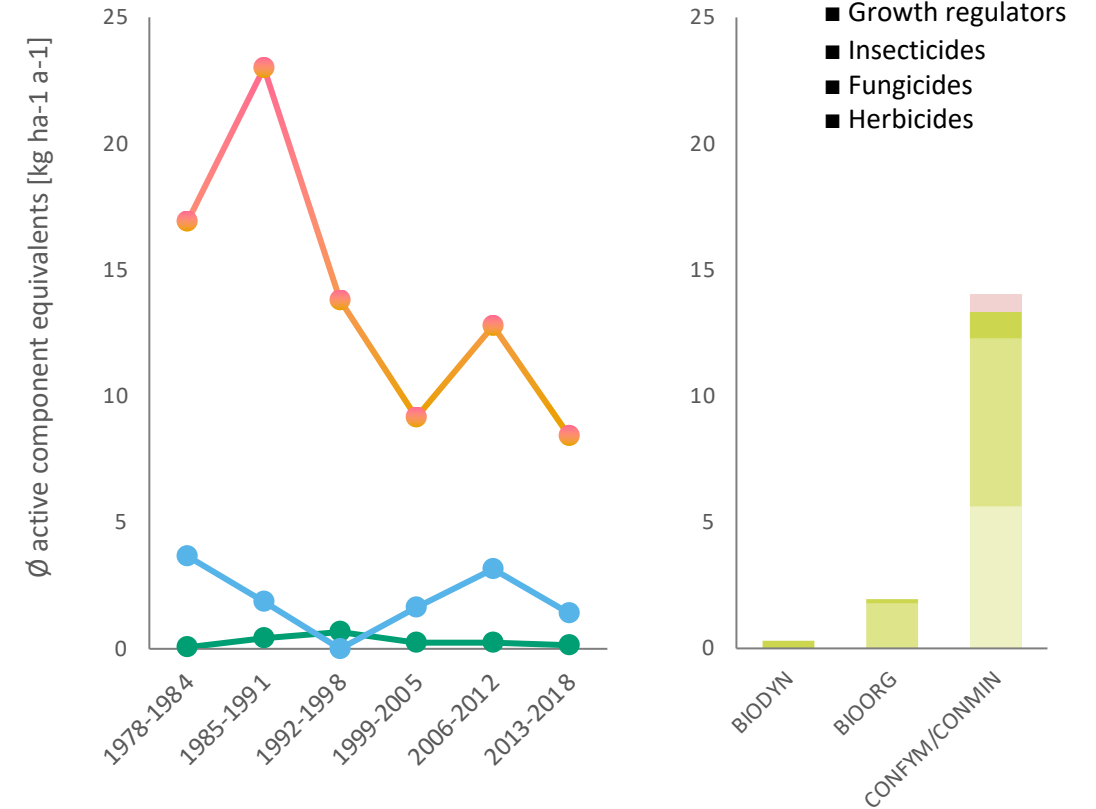


Nutrients and pesticides inputs

Nutrients



Pesticides and growth regulators



Sampling timepoints

Rewetting and
removal of rainout-shelter

Start drought stress

Sampling

Sampling

Sampling

Resilience
sampling

Resilience
sampling

Apr

Mai

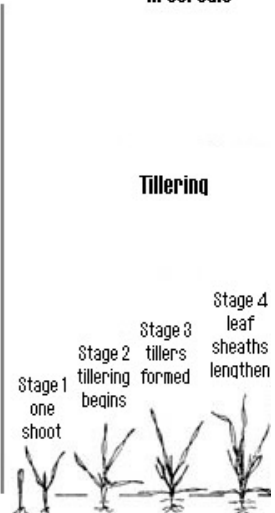
Jun

Jul

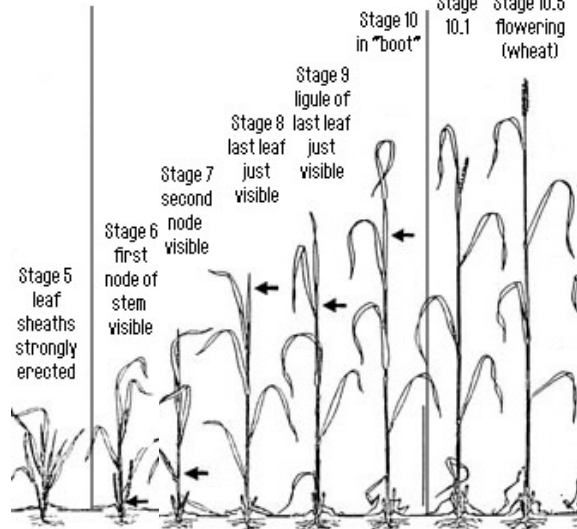
Aug

Sep

Growth Stages
in Cereals



Stem Extension



Heading R

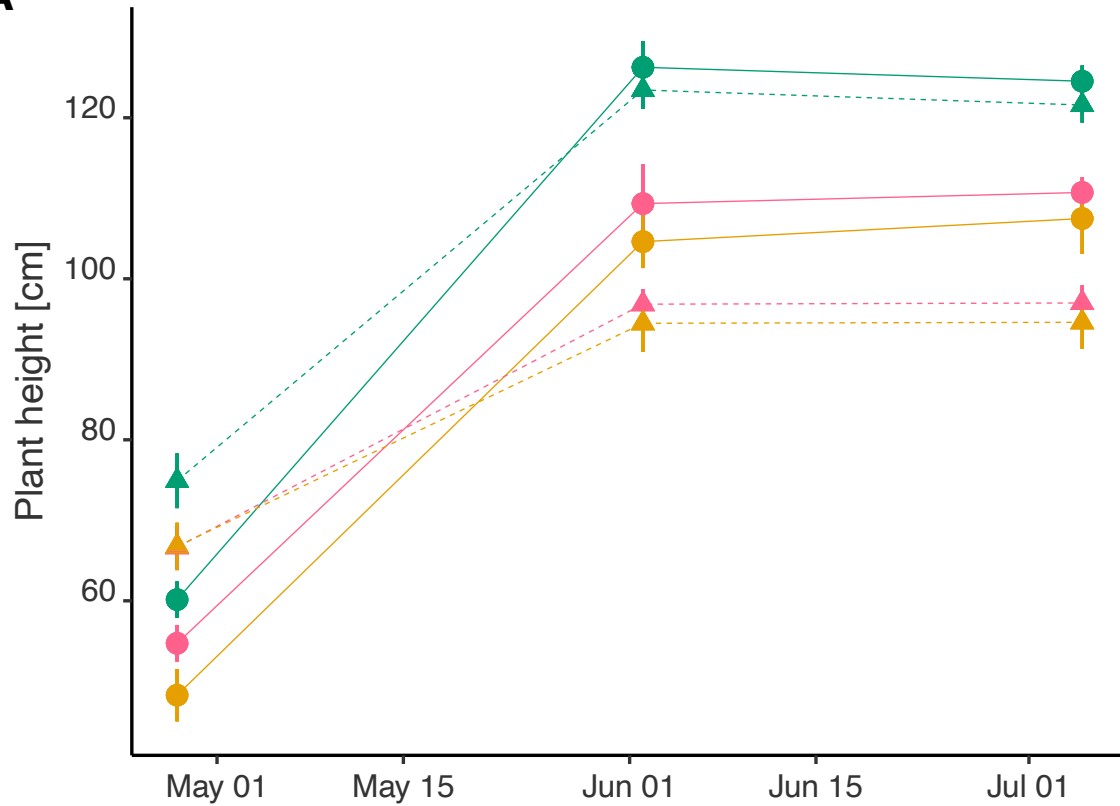


Ripening

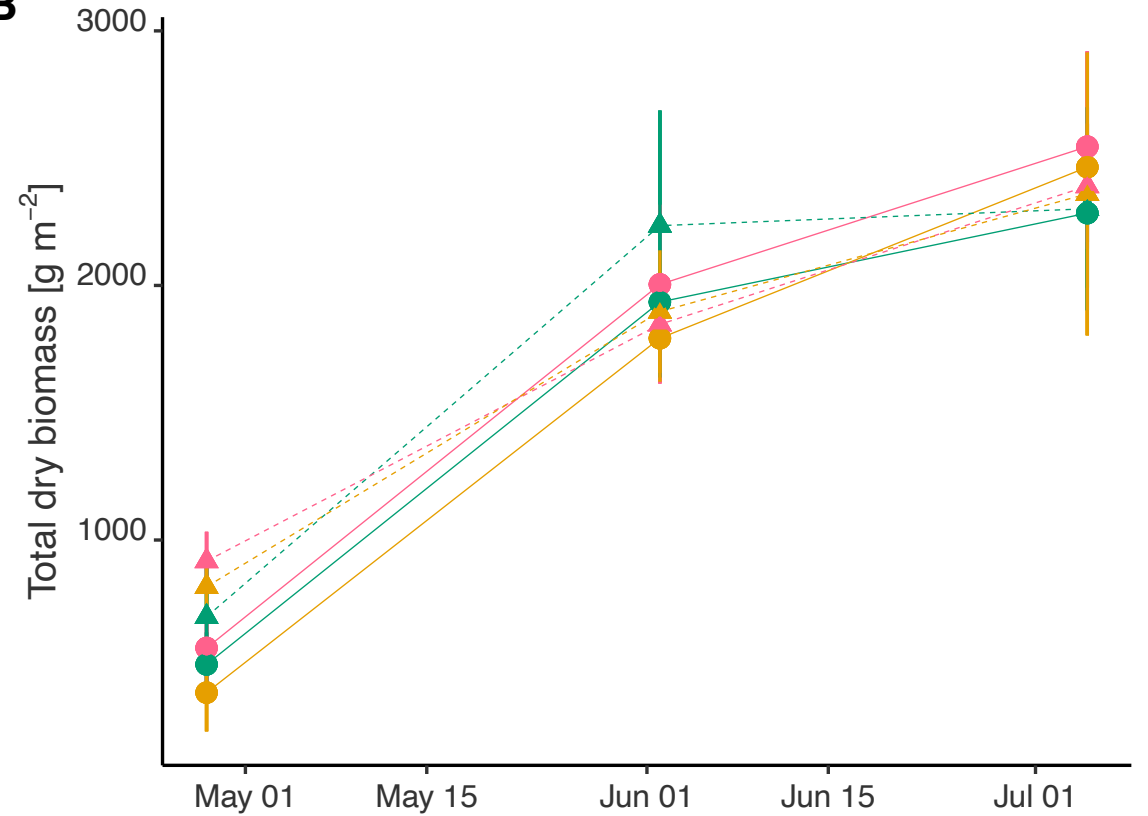


Plant measurements

A



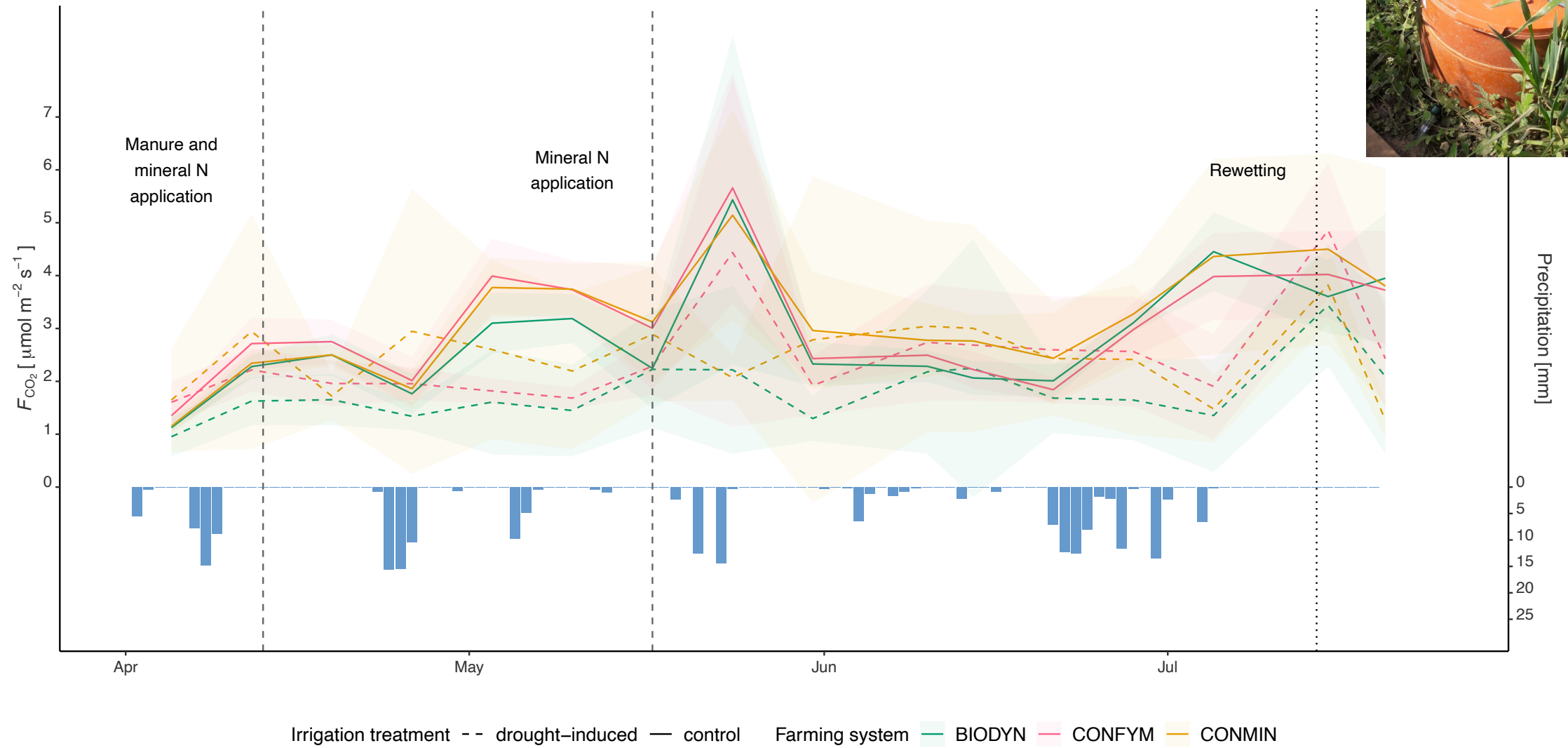
B



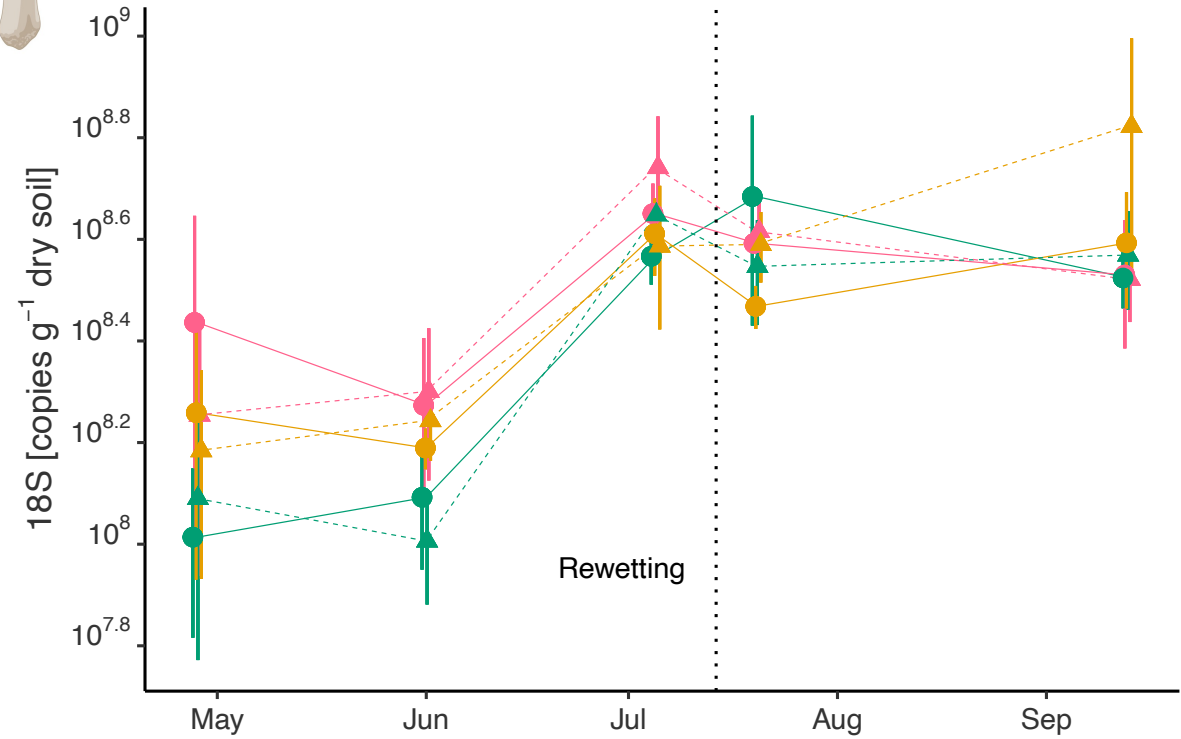
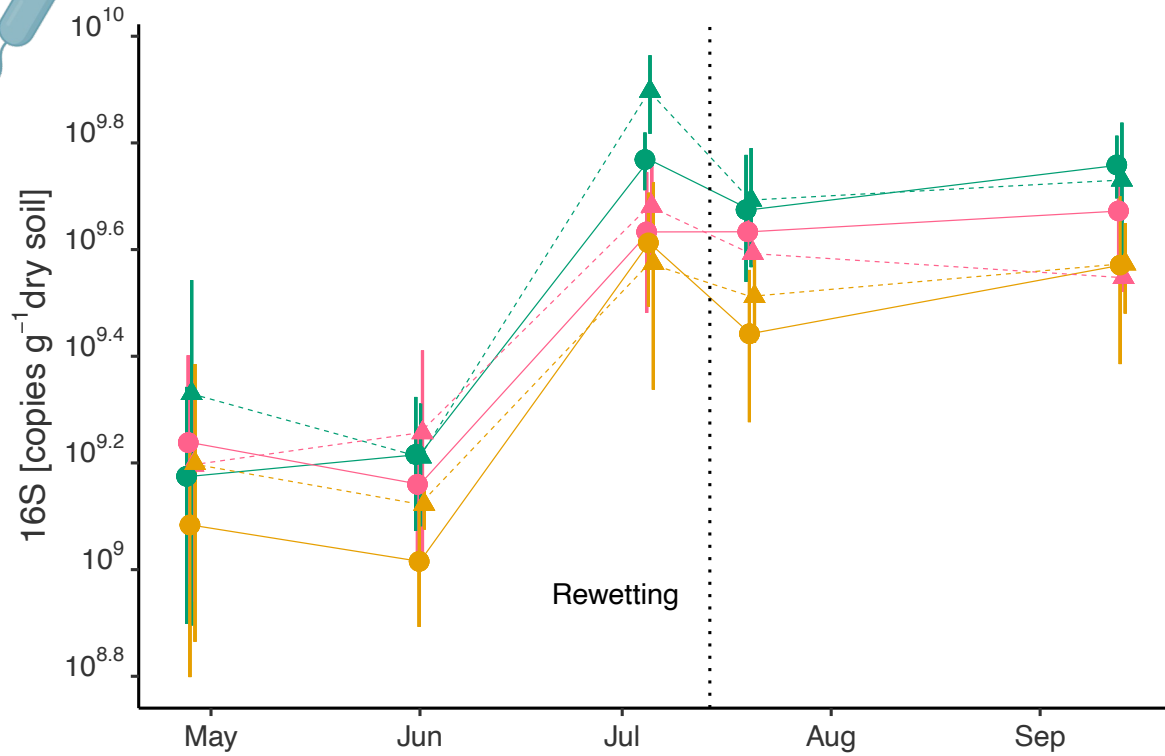
Water regime ● rainfed control ▲ drought-induced

Cropping system ● BIODYN ● CONFYM ● CONMIN

In-situ soil respiration



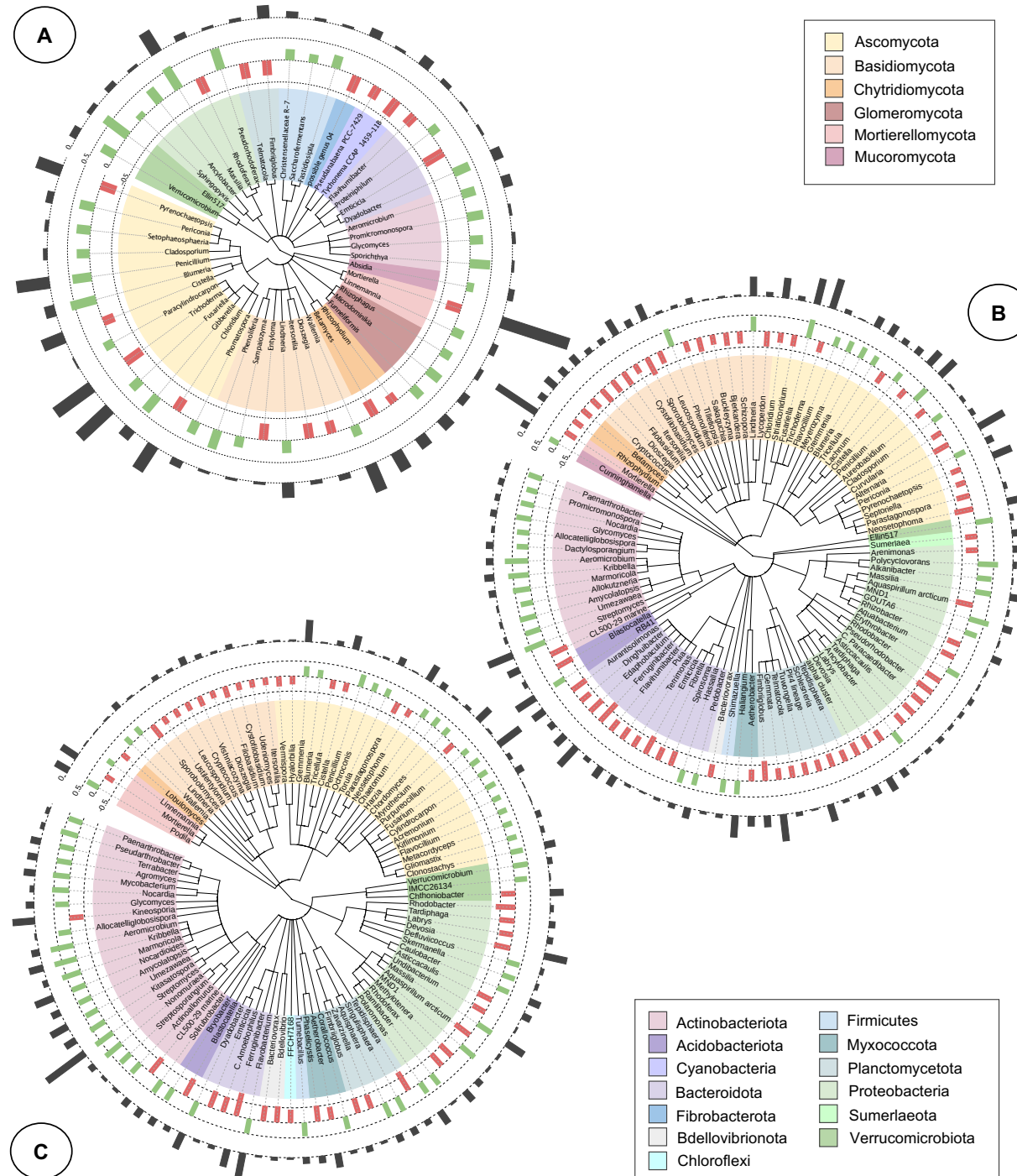
Prokaryotic and fungal abundance



Water regime ● rainfed control ▲ drought-induced

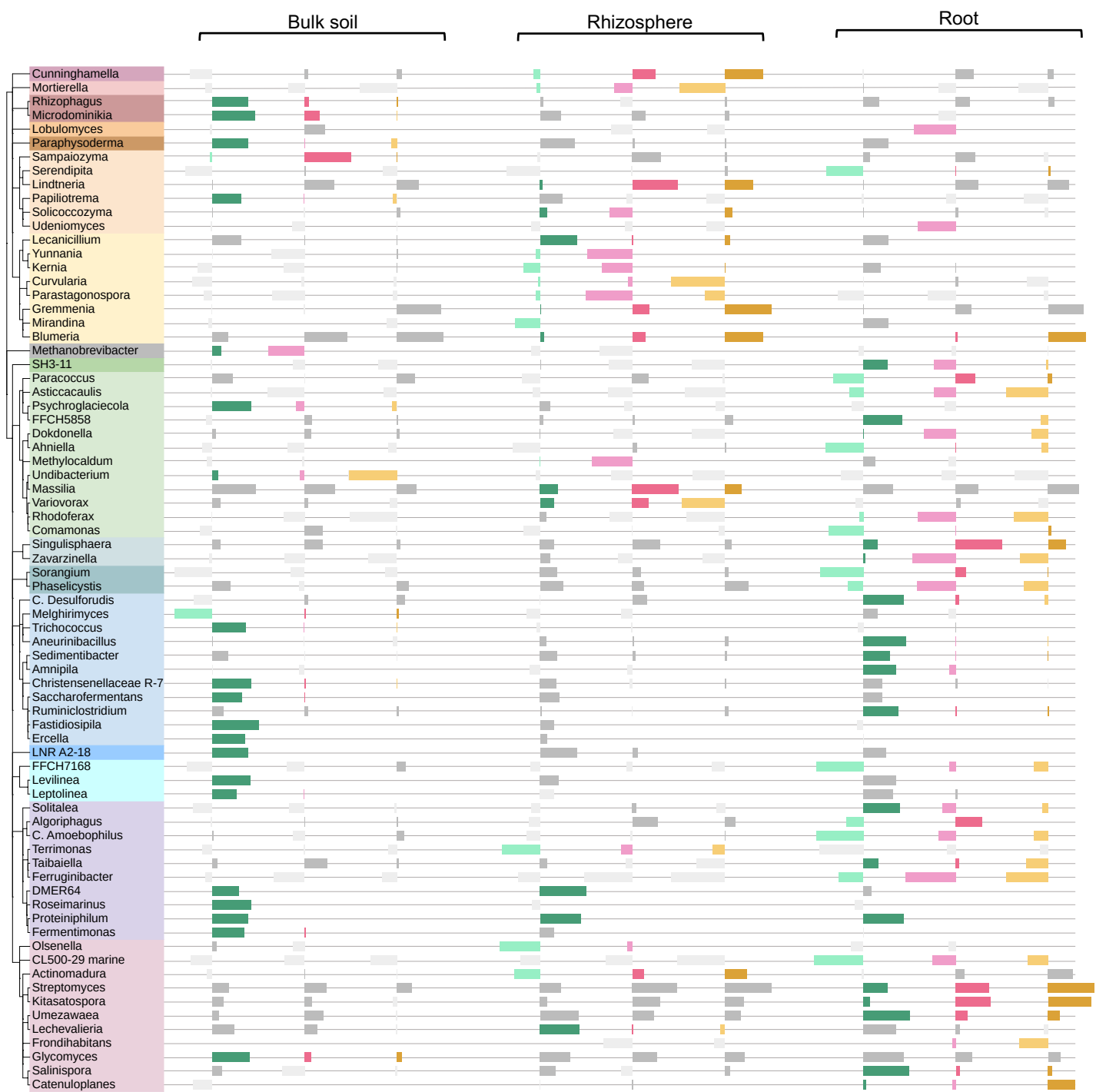
Cropping system ● BIODYN ● CONFYM ● CONMIN

Genera reacting towards drought



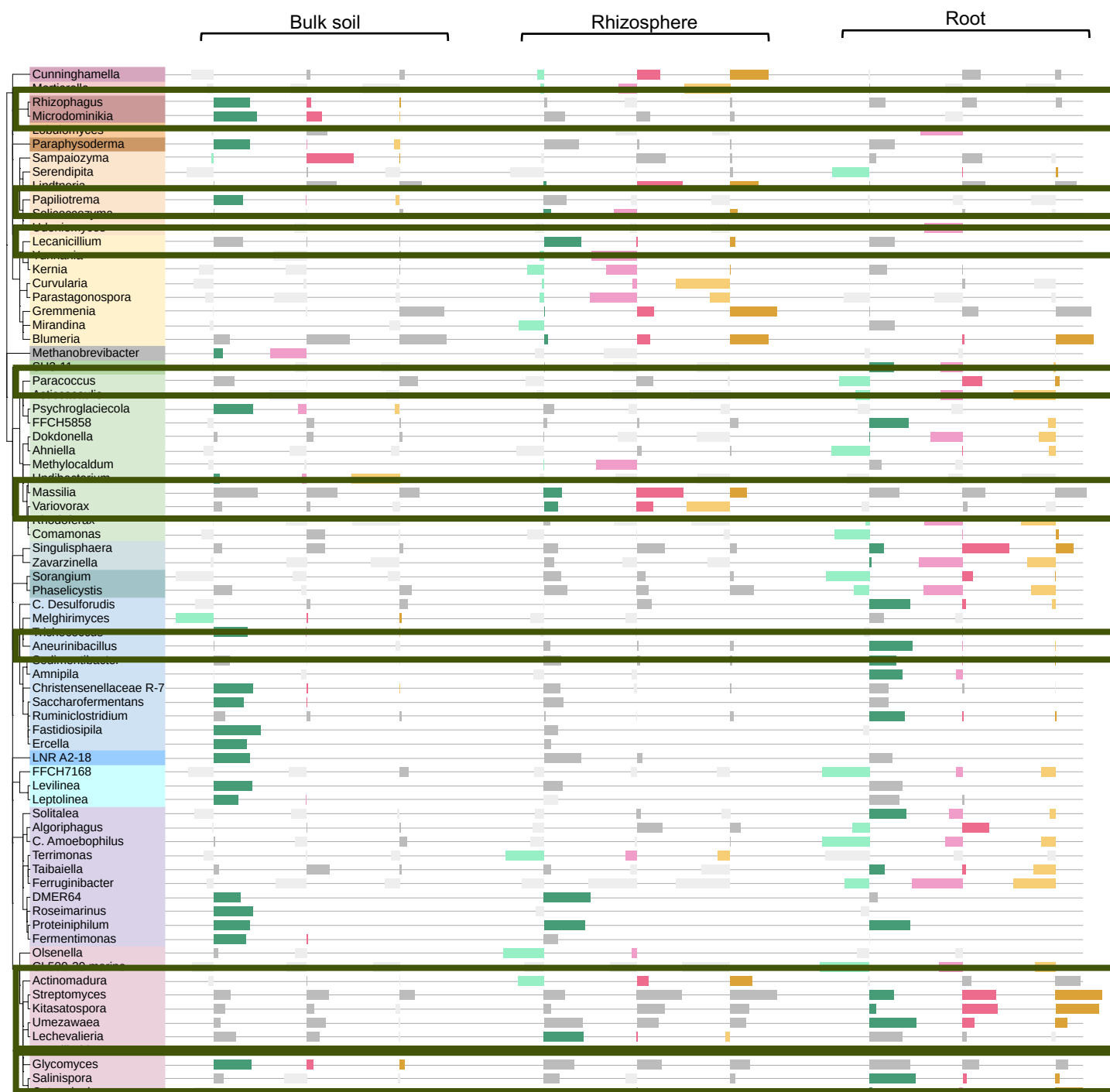
Kost et al. (in prep)

Cropping system specific genera drought response



Cropping system specific genera drought response

Known or potentially plant-growth promoting genera



BIODYN
CONFYM
CONMIN

Ascomycota Chytridiomycota Mucoromycota
Basidiomycota Glomeromycota
Blastocladiomycota Mortierellomycota

Actinobacteriota Cloacimonadota Planctomycetota Euryarchaeota
Bacteroidota Firmicutes Proteobacteria
Chloroflexi Myxococcota Verrucomicrobiota