Plants possibility to control gas exchanges via mucilage

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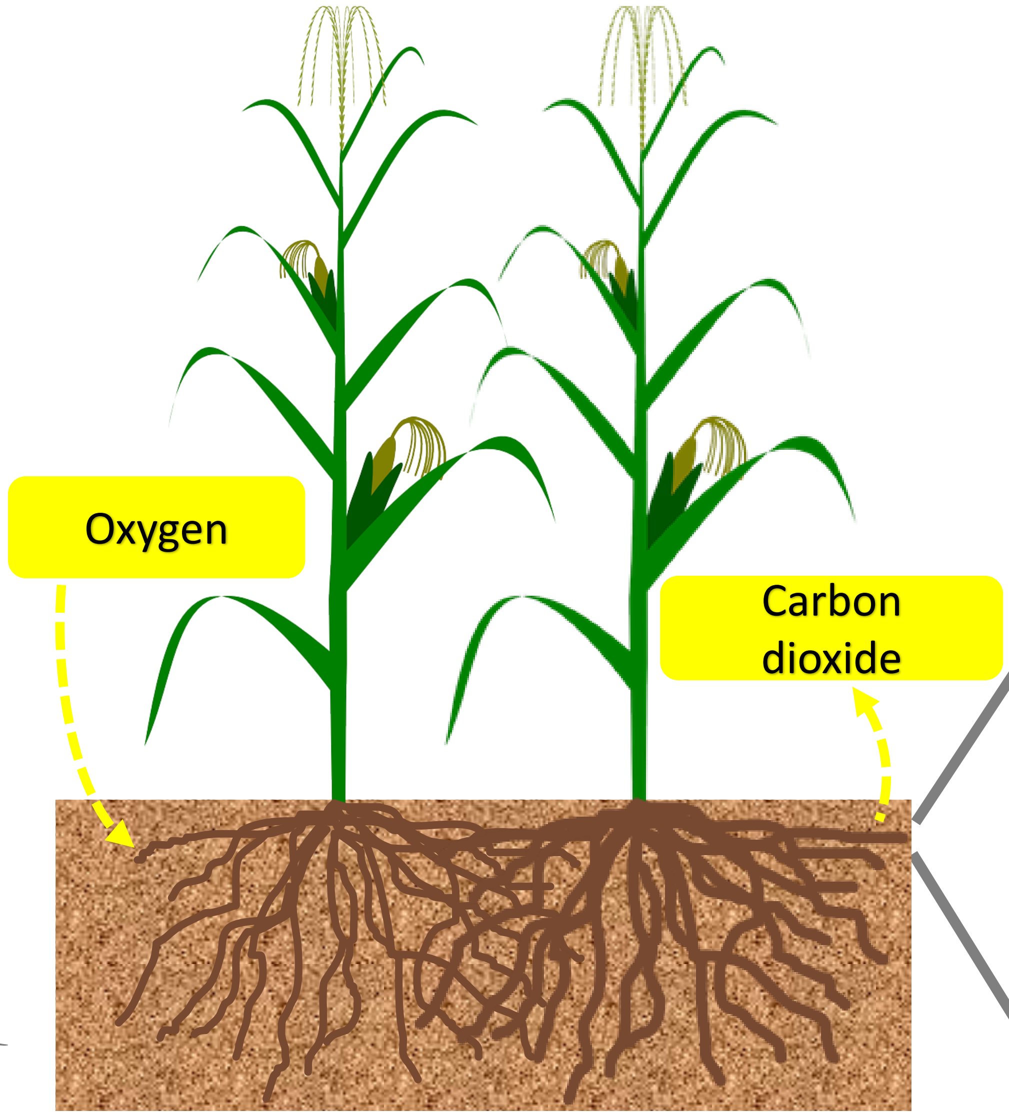
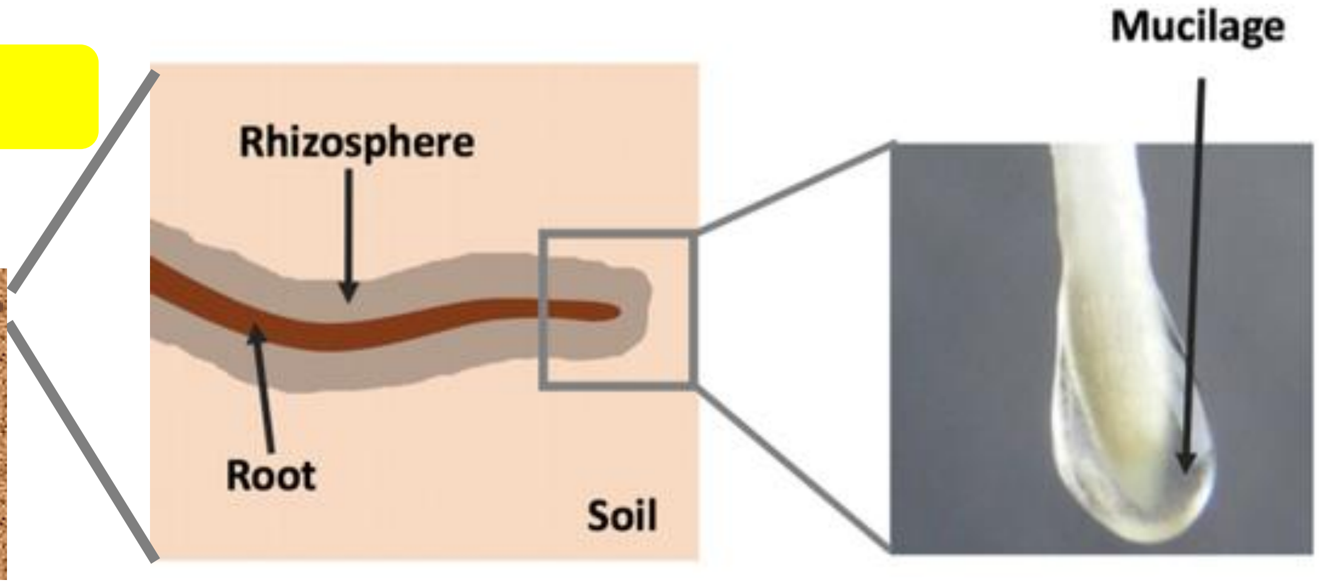
Motivation

- Soil respiration is an important factor for plant growth and soil O_2 and CO_2 exchanges with atmosphere.
- Mucilage plays a key role in shaping the physical properties of the rhizosphere.

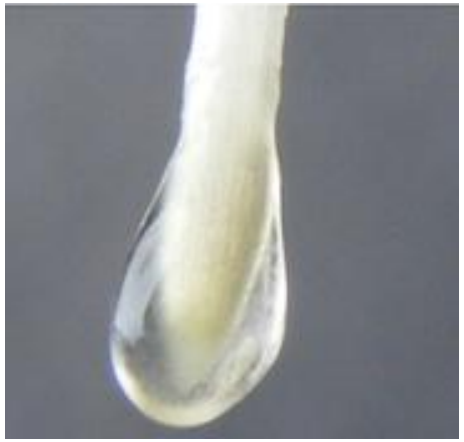
How does mucilage affect soil gas diffusion?

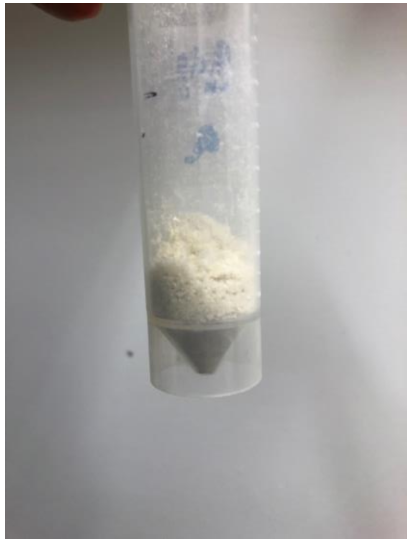




Mucilage – a rhizodeposition

- **Chia seed mucilage** as a model for plant mucilage
- Similar physical properties as plant mucilage:
  - Can hold large amounts of water
  - More **viscous** as maize or barley mucilage
- Freeze-dried and pulverized after collection





State of the art

Diffusion:

- Main process for gas movement in soil.
- **Most important factor** for controlling soil-gas diffusion is the **gas diffusion coefficient D** $(\mathrm{cm}^2/\mathrm{s}^{-1})$
- **D highly depends** on **air-filled pore-connectivity** and **tortuosity**.

Model for root respiration (Ben-Noah and Friedman, 2018 VZJ):

- Diffusive resistance of the **mucilage** layer is one of the **dominant factors** in determining **respiration rate**.
- Thickness of **mucilage** is **limiting respiration** rate
- But **increasing viscosity** of drying mucilage is expected to have a much higher influence -> **diminishing** positive effect of **reducing mucilage thickness** at lower water potentials

Existing models treat mucilage as an uniform layer coating the root

Environmental Scanning Electron Microscopy

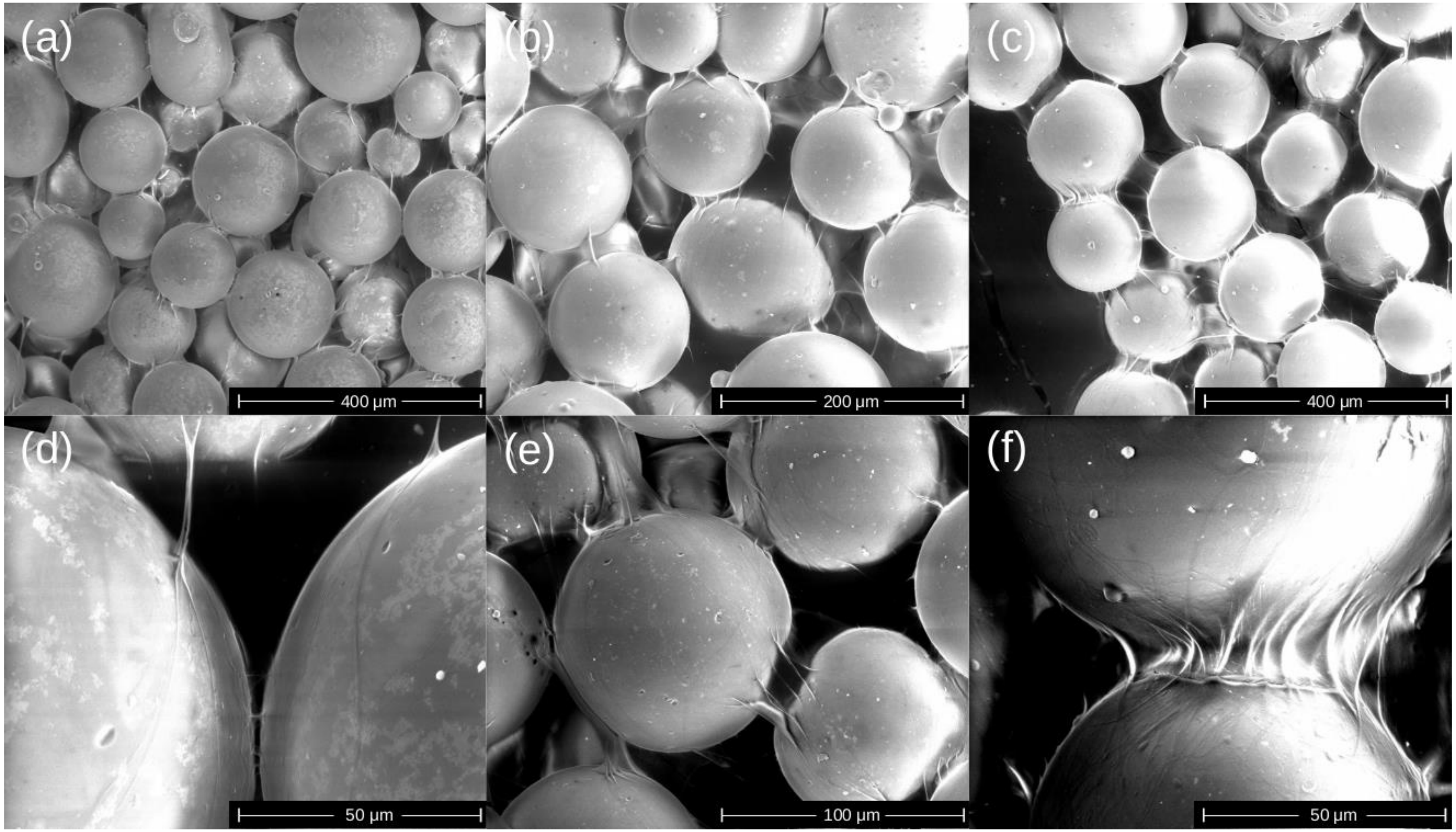
- Glass beads, diameter: 0.2mm
- Mixed with chia seed mucilage
- Oven-dried for 24h at 30° C
- Concentrations : 0.16%; 0.25%; 0.49%
- Chamber pressure: 60 – 80 Pa
- Acceleration voltage: 12.5 – 15 kV

https://www.fei.com/products/sem/quanta-sem/

Environmental Scanning Electron Microscopy

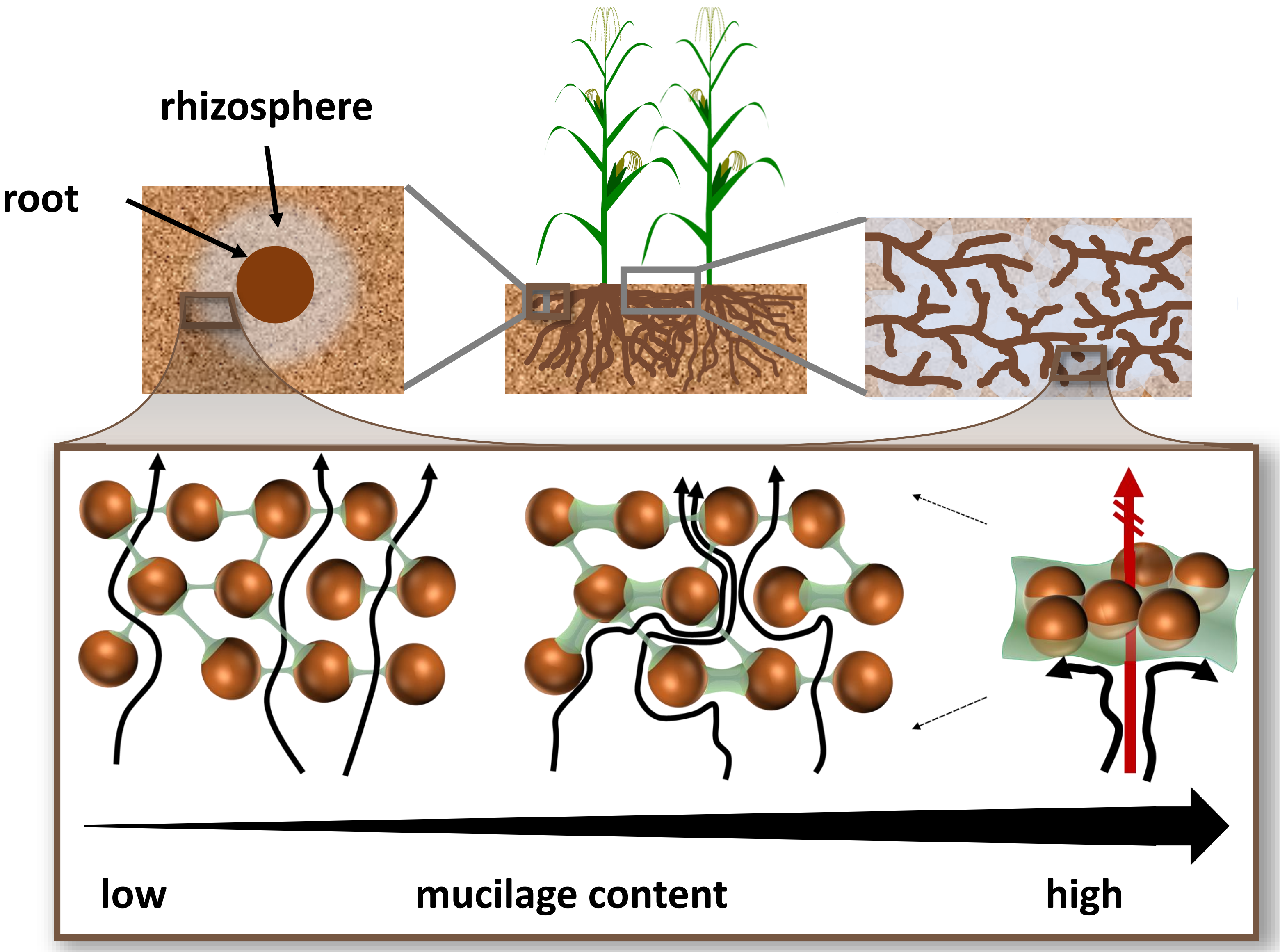
(a), (d) **0.16%** :
thin filaments span throughout the pore space

(b), (e) **0.25%**; (c), (f) **0.49%** :
mucilage forms **hollow cylinders up to interconnected surfaces**



During drying mucilage forms liquid bridges between particles

Conceptual model



Hypothesis:

- At **low concentration** of mucilage, thin filaments have a **small effect** on gas diffusion
- At **high concentration,** mucilage is able to block pores, disconnecting the gas phase and **reduce gas diffusion significantly**

Soil samples

- Soil particle size: 500-630 µm
- Mixed with chia seed mucilage
- Dry chia seed mucilage was diluted in water
- Amount of water was according to soil maximum water capacity
  ➡ **No change in porosity during drying**
- Concentrations: **0%; 0.1%; 0.3%; 0.6%**
- Drying for 48 h at 20°C ± 1°C
  ➡ **Gravimetric water content < 1%**

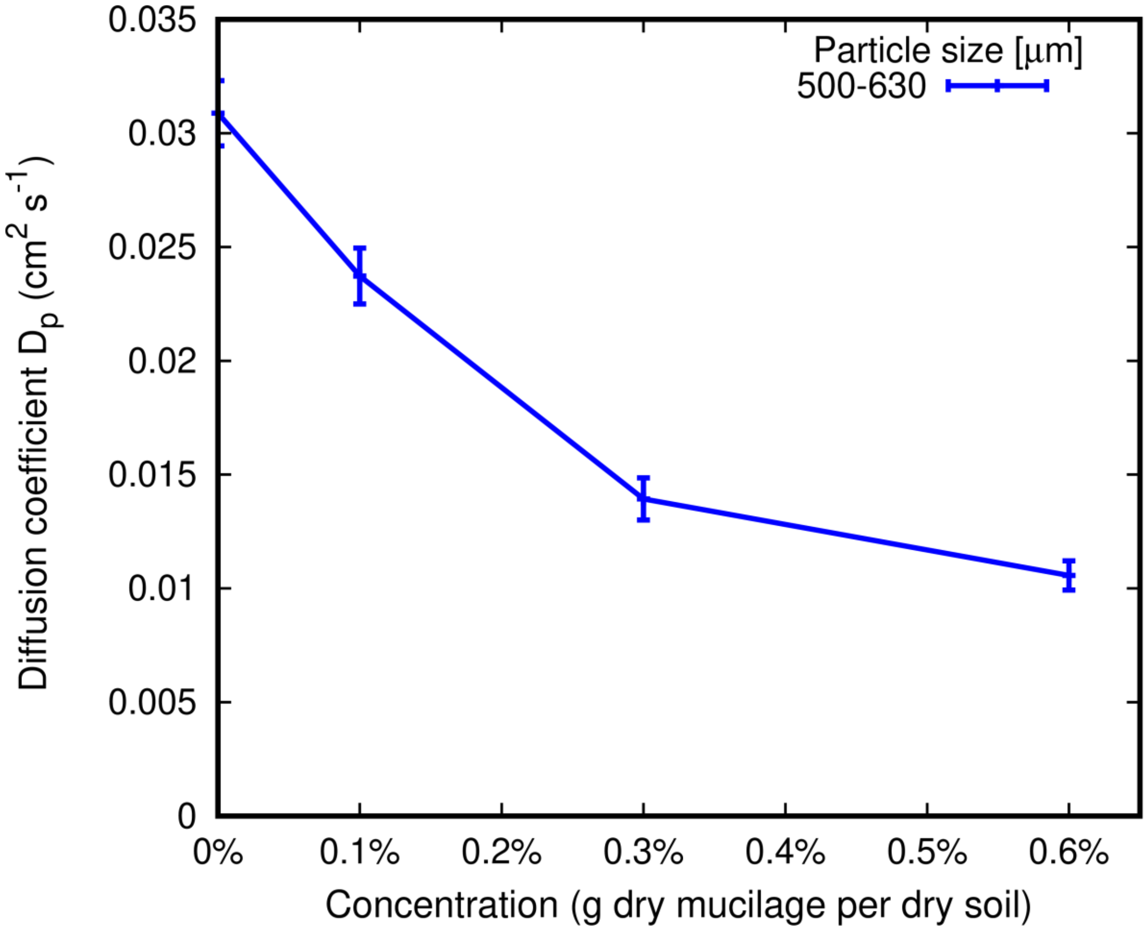
Weight	Volume	Area	Height	Bulk density	Porosity
10 g	5.77 cm^3	9.62 cm^2	0.6 cm	1.74±0.01 gcm^{-3}	0.34±0.01 cm^3cm^{-3}

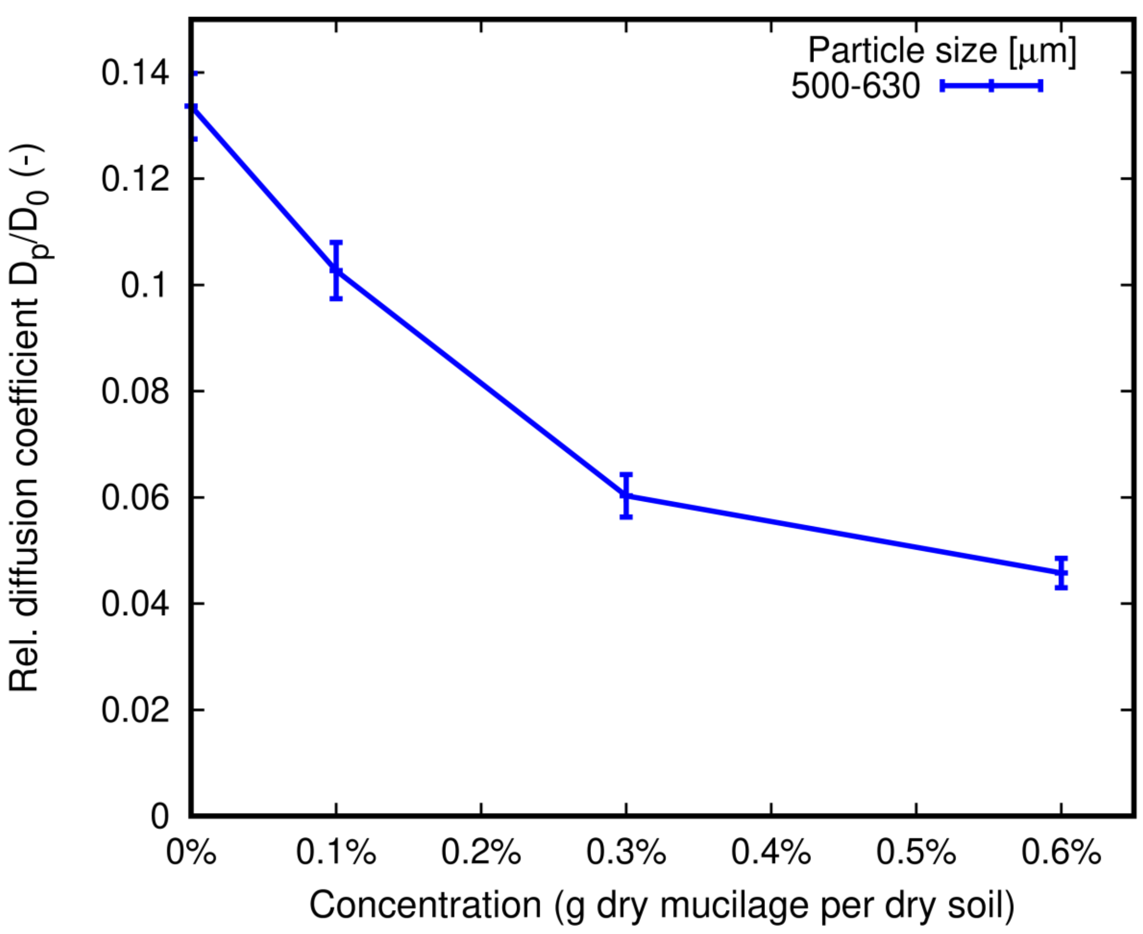
Gas diffusion measurements

- **Gas diffusion coefficient D_p** as a function of mucilage
- Diffusion chamber method (Rolston and Moldrup 2002)
- Tracer gas: **Oxygen**; diffusion coefficient in free air D_0= 0.231 $cm^2 s^{-1}$
- Temperature: **20°C ± 1°C**

Gas diffusion measurements

Gravimetric water content < 1%





Diffusion coefficient decreases with increasing mucilage concentration

Summary

- During drying mucilage forms liquid bridges between soil particles
- With increasing mucilage concentration gas diffusion coefficient decreases

Next Steps

- We look forward to gain a better understanding of the influence of mucilage on soil gas diffusion using experimental and modelling techniques
- Variation of soil and mucilage properties, e.g. particle size distribution, water content, mucilage type,…
- How interactions with microbial communities additionally alter how plants control soil gas exchanges