Root exudates affecting P phytoavailability in soils - biogeochemical mechanisms and experimental approaches

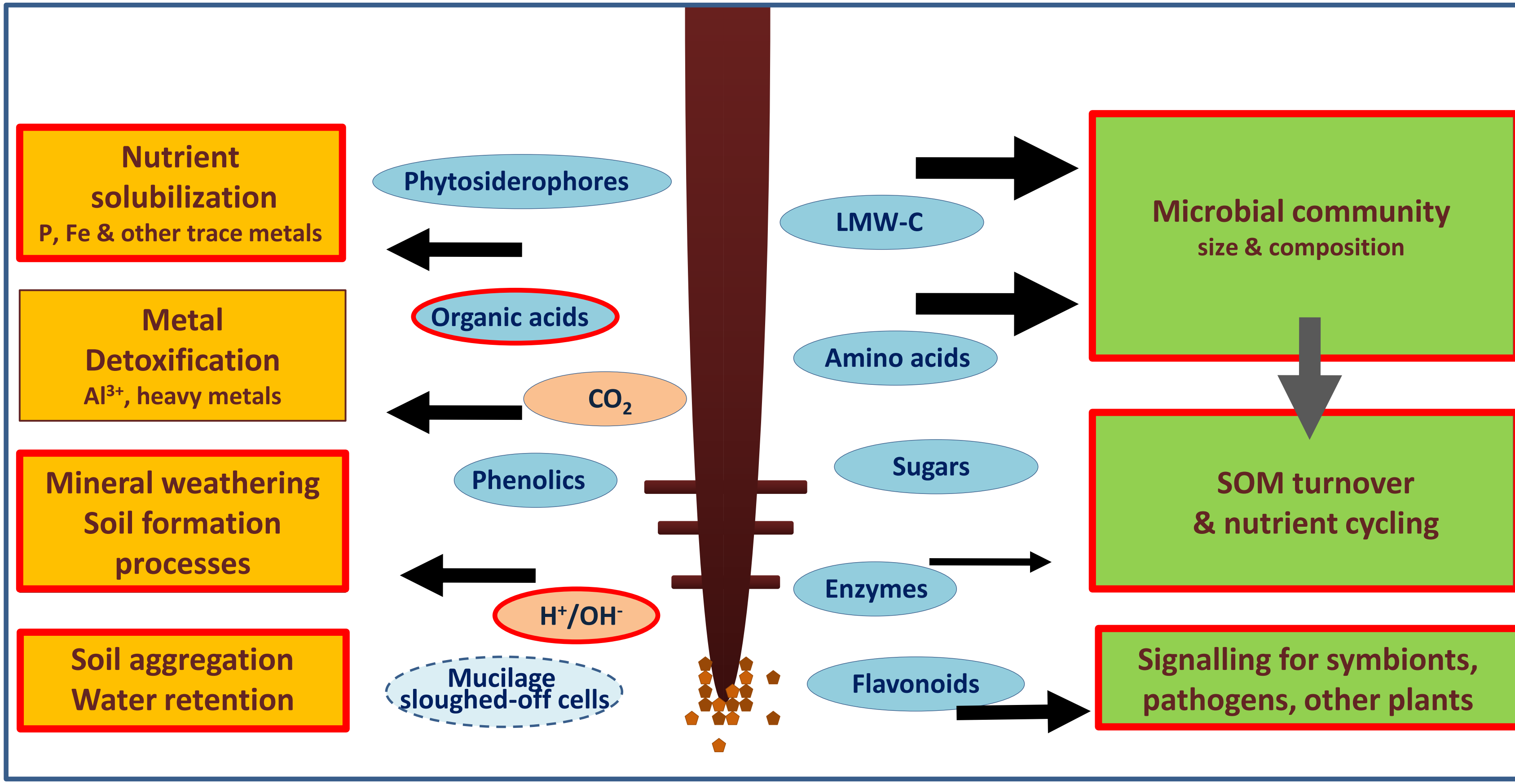
University of Natural Resources and Life Sciences, Department of Forest- and Soil Sciences, Vienna, Austria

Eva Oburger[1], Markus Puschenreiter[1], Stephan Hann[2], Davey Jones[3], Walter Wenzel[1]

[1]*University of Natural Resources and Life Sciences, Department of Forest and Soil Sciences, Institute of Soil Research*
[2]*University of Natural Resources and Life Sciences, Department of Chemistry, Division for Analytical Chemistry*

[3]*School of Environment,Natural Resources & Geography, Bangor University, Bangor, UK*

Root exudates triggering important soil/rhizosphere processes



modified from Oburger et al., 2013

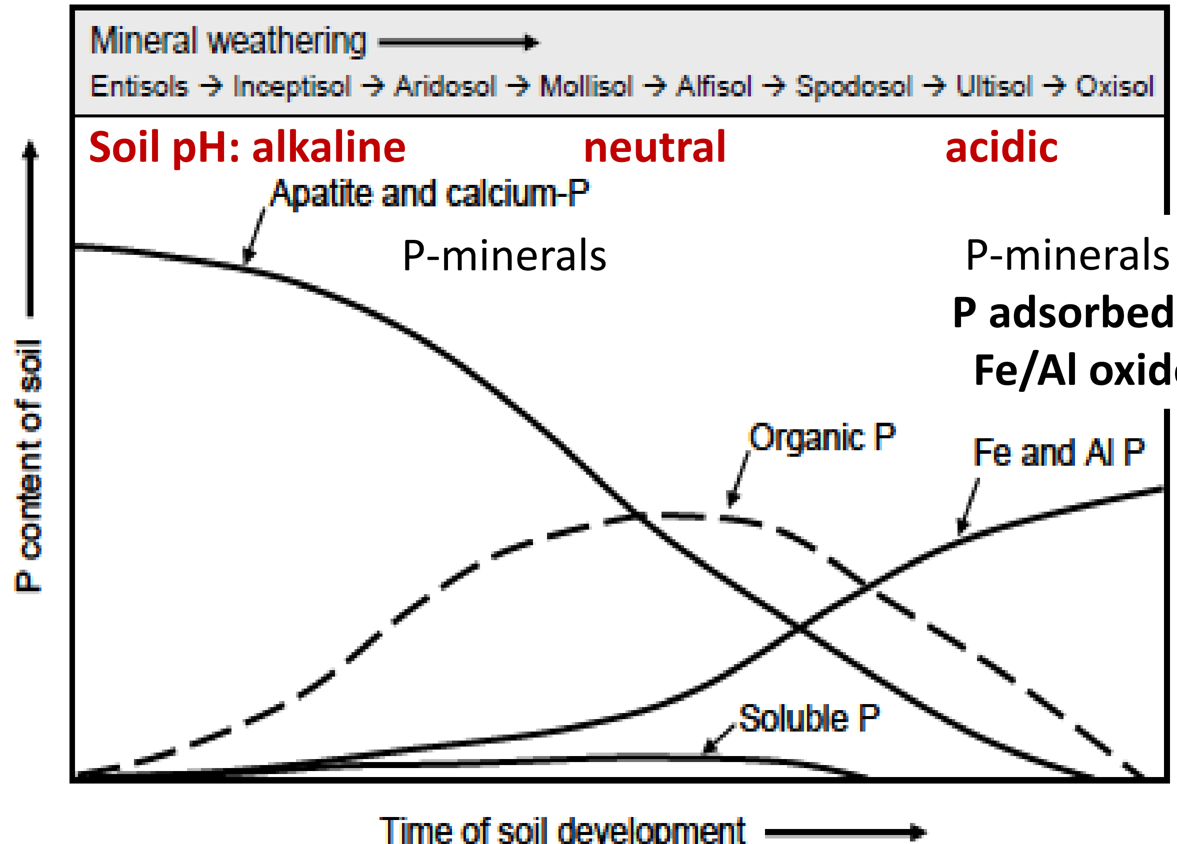

FIGHTING

Chemical froms of P in soil

- ...depend on parent material, soil pH, vegitation, extent of pedogenesis

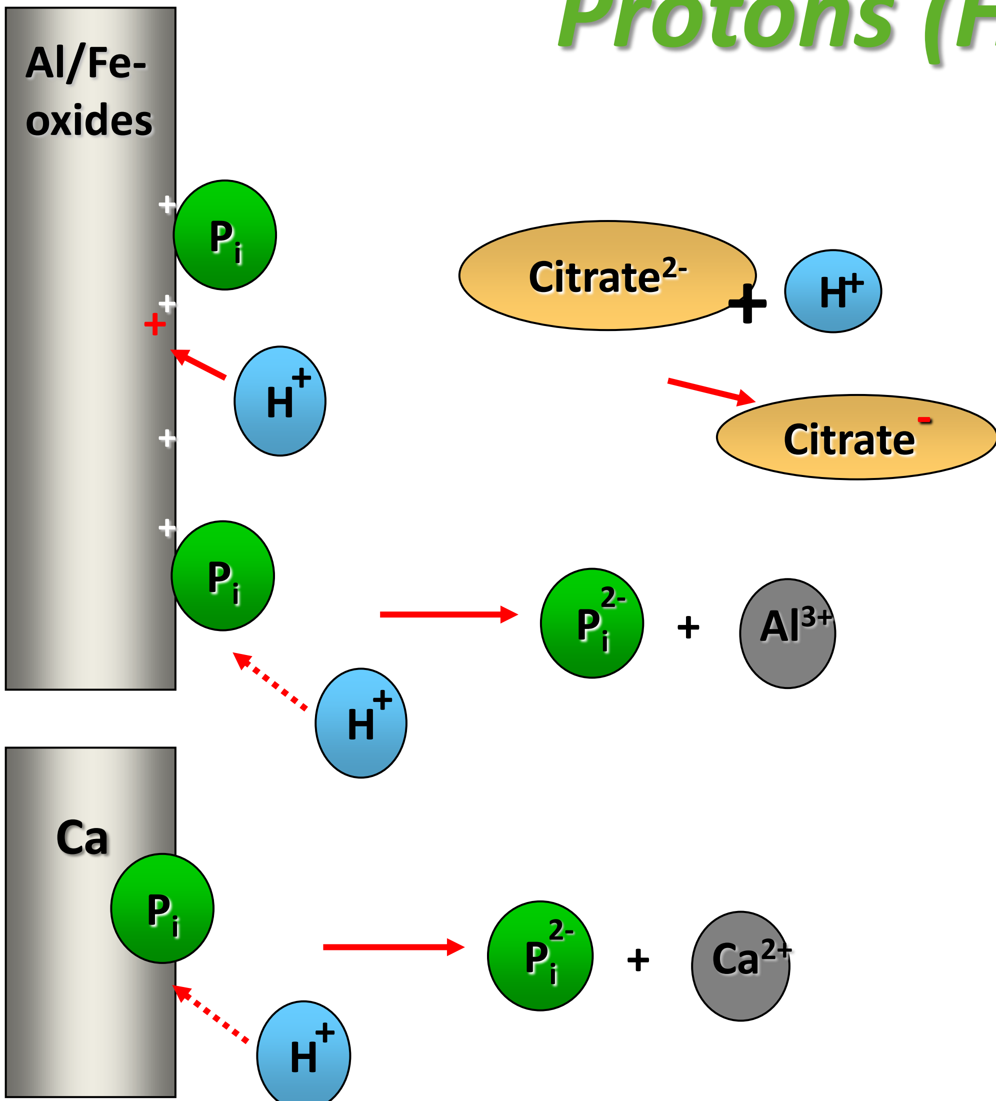
- P_i 50-75%
- P_o 30-65%

P speciation will determine the P solubilizing efficiency of root exudate compounds!



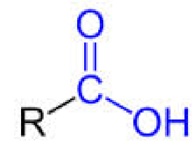
Jones and Oburger 2010

P Solubilization mechanisms
Protons (H+)

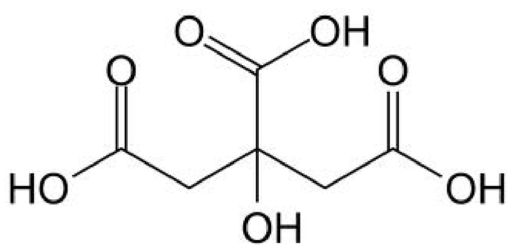


- Solution species protonation
- Surface protonation
- Proton-promoted mineral dissolution (Fe/Al-P & Ca P)

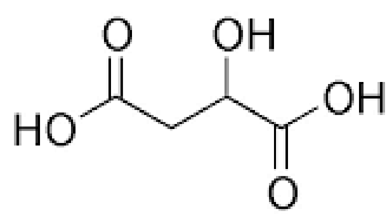
Organic acids

- Root exudate compound class associated with increasing P solubility
- LMW- organic compounds
- Posess one or more carboxylic group 

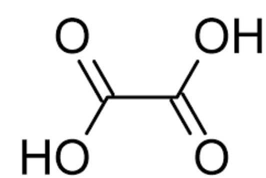
- E.g. citric, malic, oxalic, malonic, succinic, gluconic, …acid



Citric acid

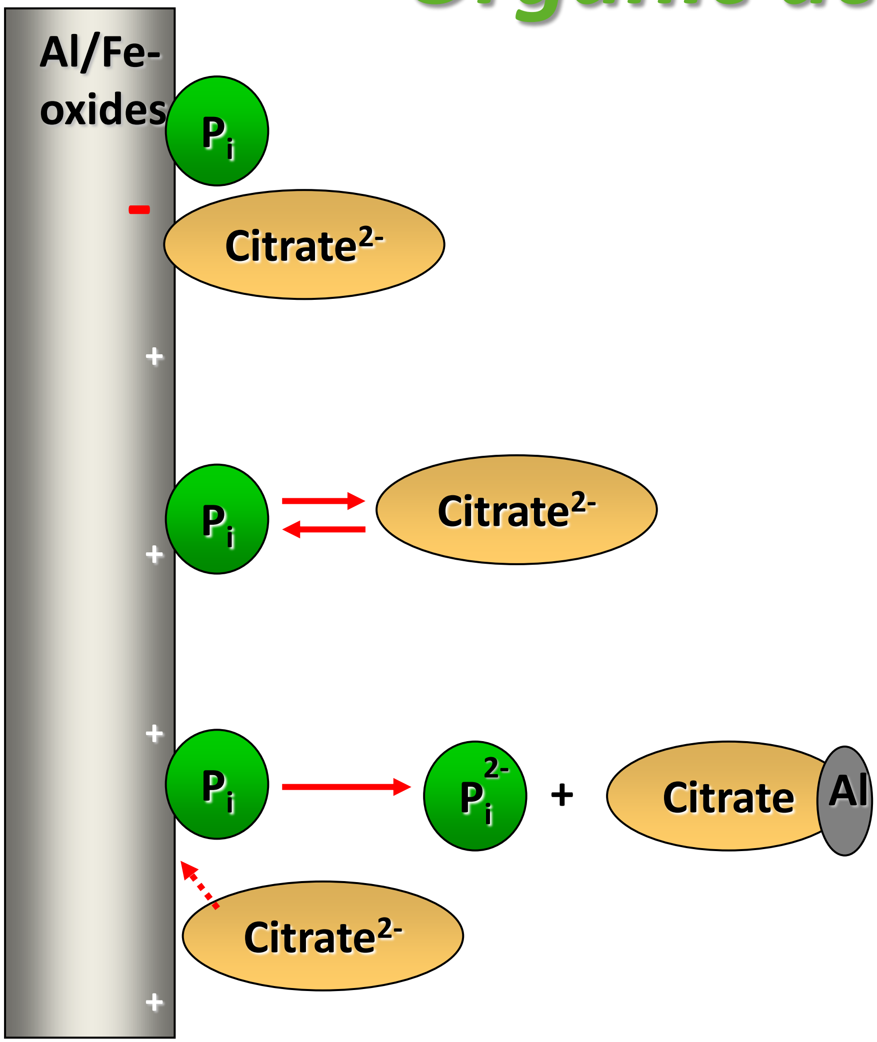


Malic acid



Oxalic acid

P_i solubilization mechanisms Organic acid anions



– Released as dissociated anion!

Fe/Al-P

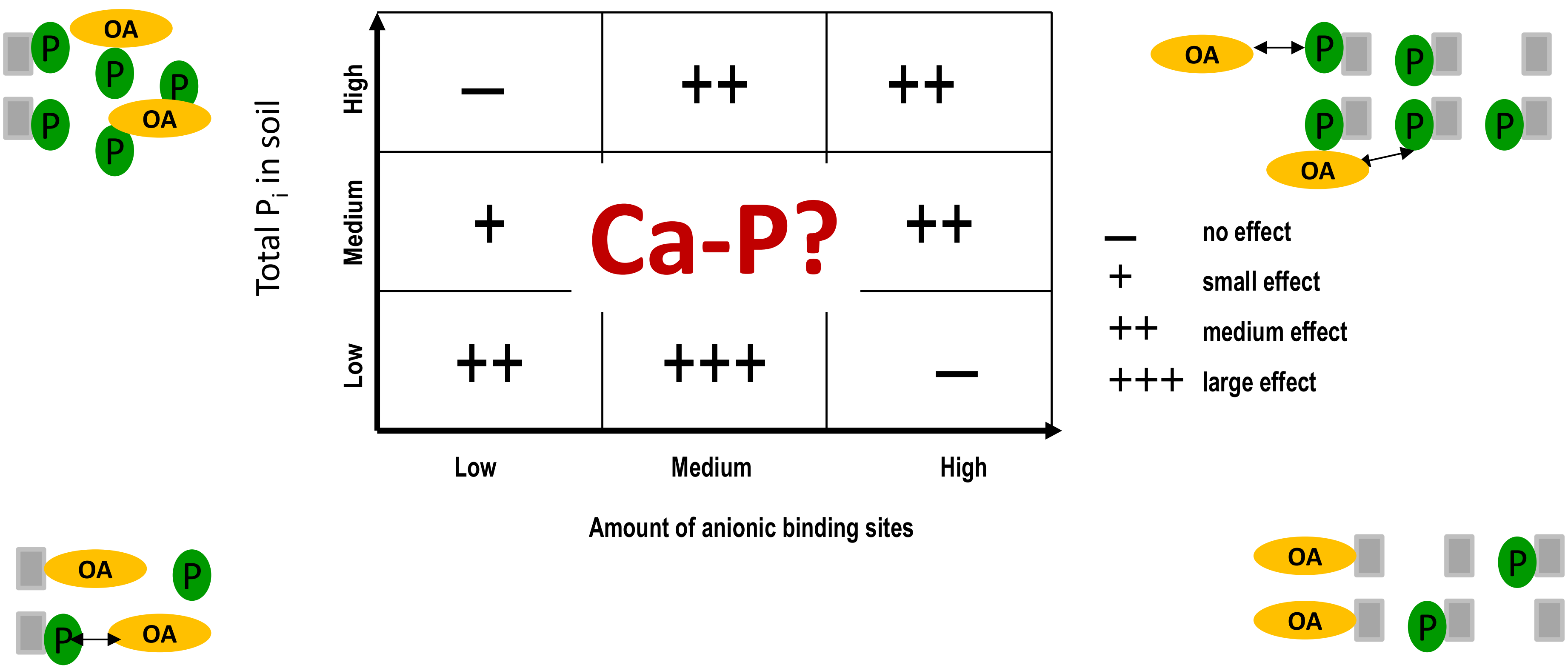
– Adsorption (also to clay minerals)=> change in surface potential ψ

– Ligand exchange

– Ligand-promoted mineral dissolution

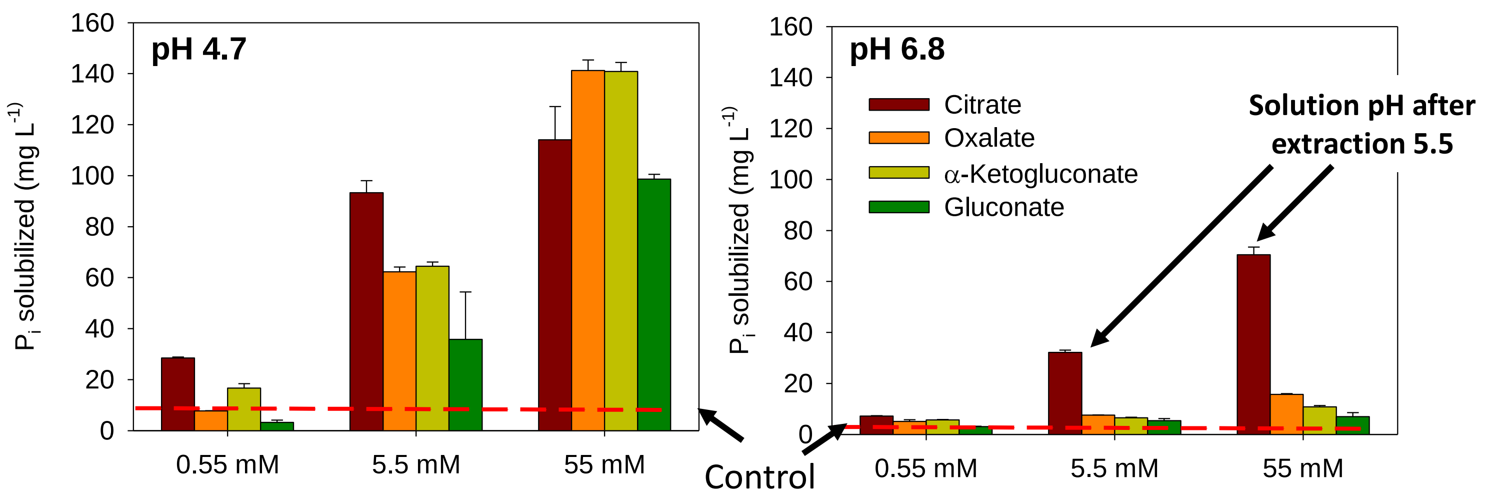
Efficiency of organic acid anions to solubilize Fe/Al-P

..is a function of total P_i and anionic binding sites (i.e. Fe & Al oxides)



Oburger et al. 2011, Plant Soil

Solubilization of Ca-P by organic acids



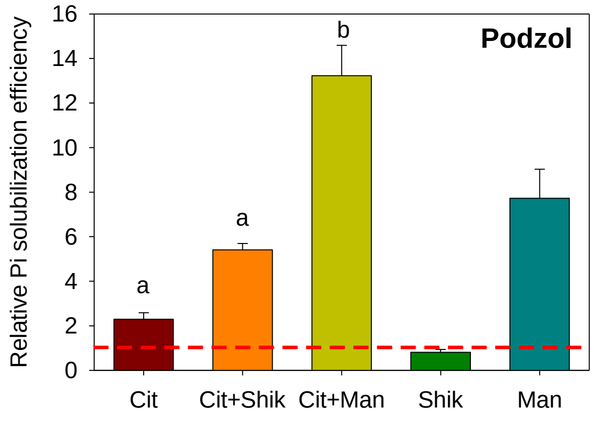
Oburger & Jones, unpublished

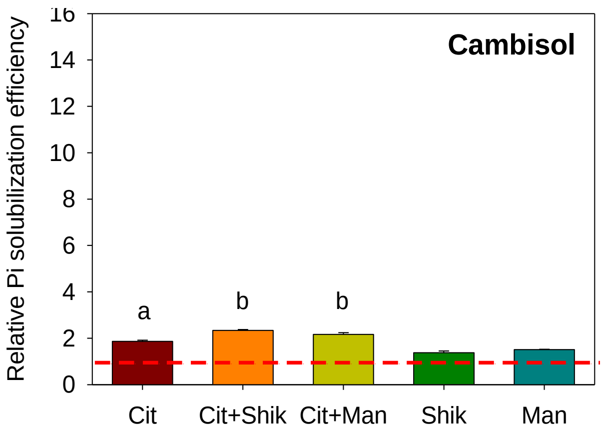
Complex stability constants:
e.g.
Citrate-Fe: 11.5
Citrate-Ca: 4.9

Acidification =>
main solubilization mechanism of Ca-P

Concentration matters!

Some additional apects to consider...



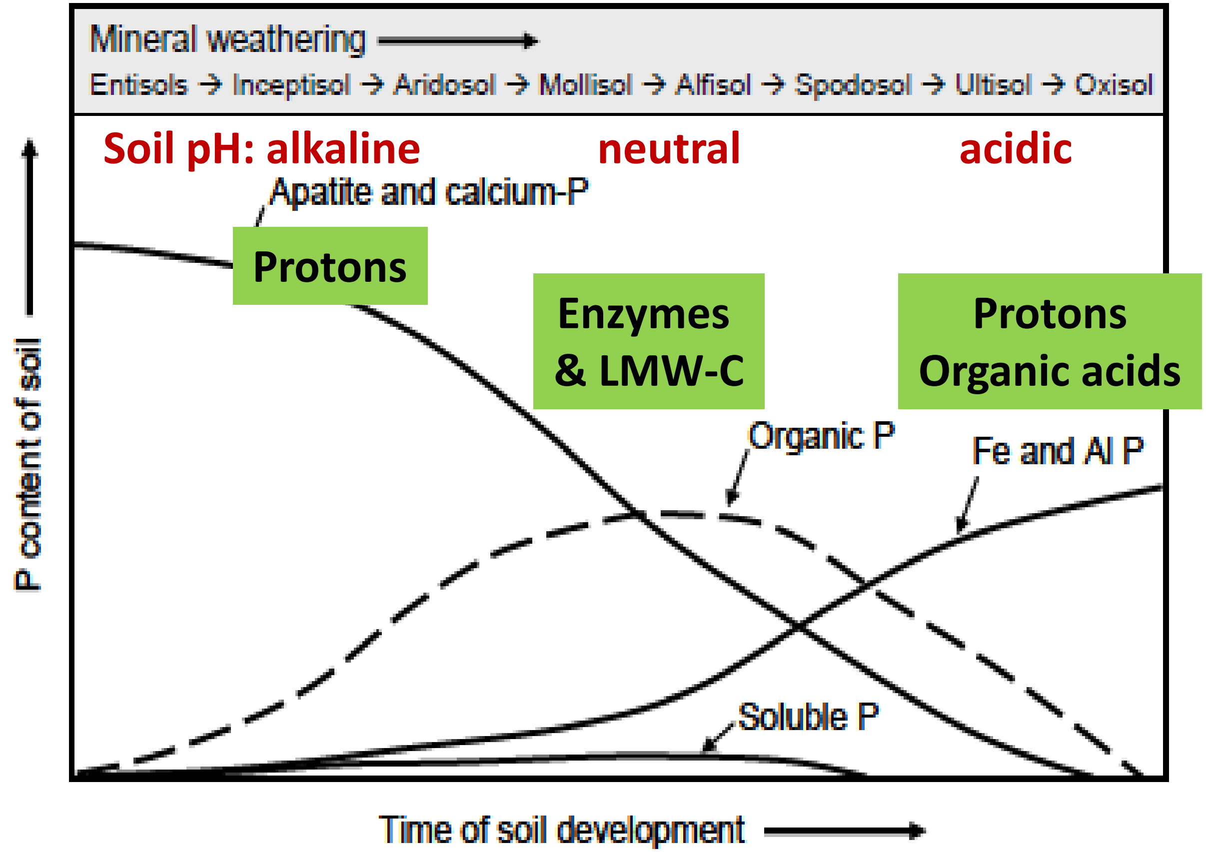


Oburger et al. 2009, Soil Biol.Biochem.

Additive/synergistic/ antagonistic? effects of different root exudates released

Cit – Citrate
Shik – Shikimate
Man – Malonate

P solubilizing efficiency of root exudate compounds depending on soil P speciation



Do plants adapt?

Jones and Oburger 2010

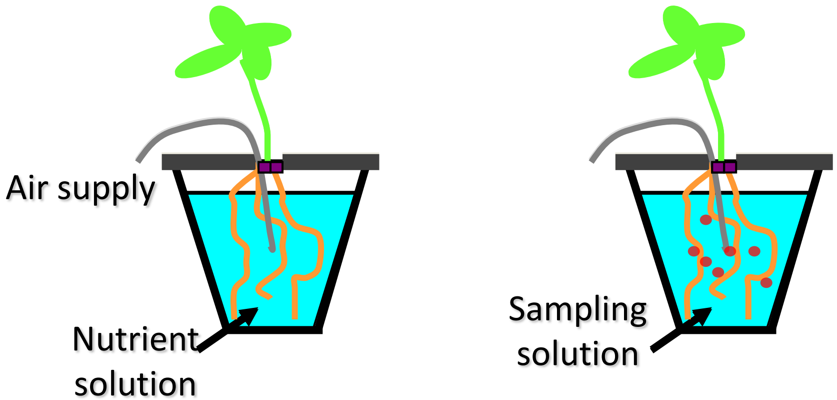
The Problem...

...with sampling root exudates:

- Root architecture
- Localized exudation
- Soil
  - Sorption processes
  - Microbial degradation

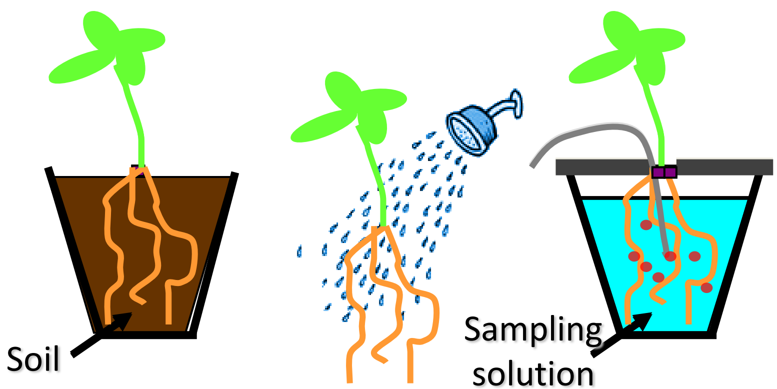
Sampling approaches I

- Nutrient solution (hydroponic) growth & sampling



Simple but realistic?

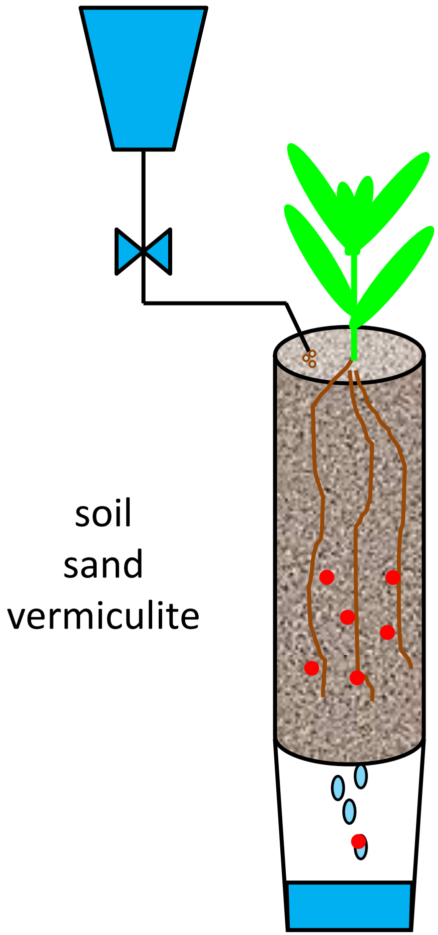
- Soil growth & hydroponic sampling



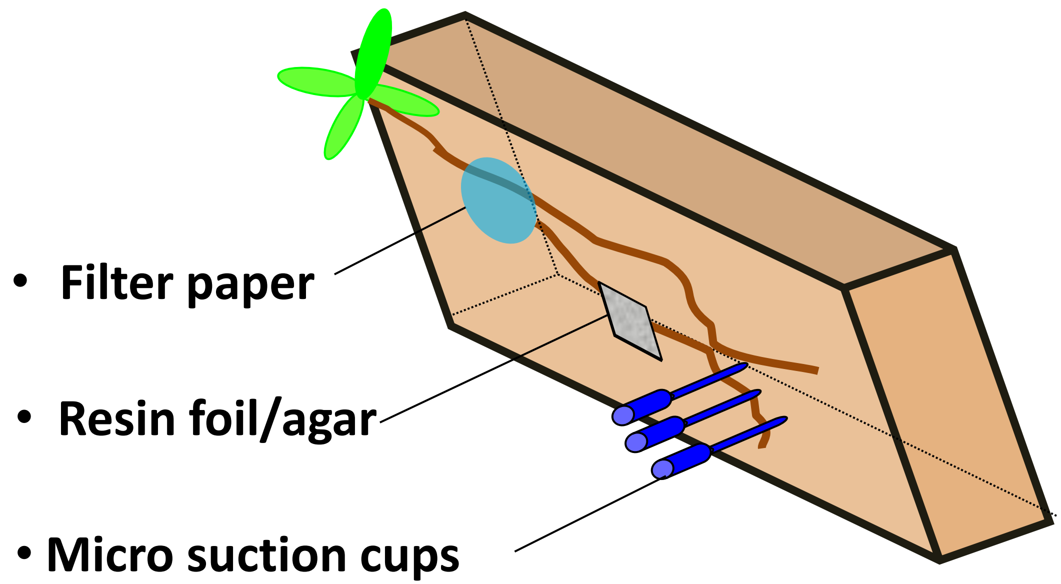
Natural growth condition but root shock/damage

Sampling approaches II

- Leaching columns



- Rhizoboxes in combination with

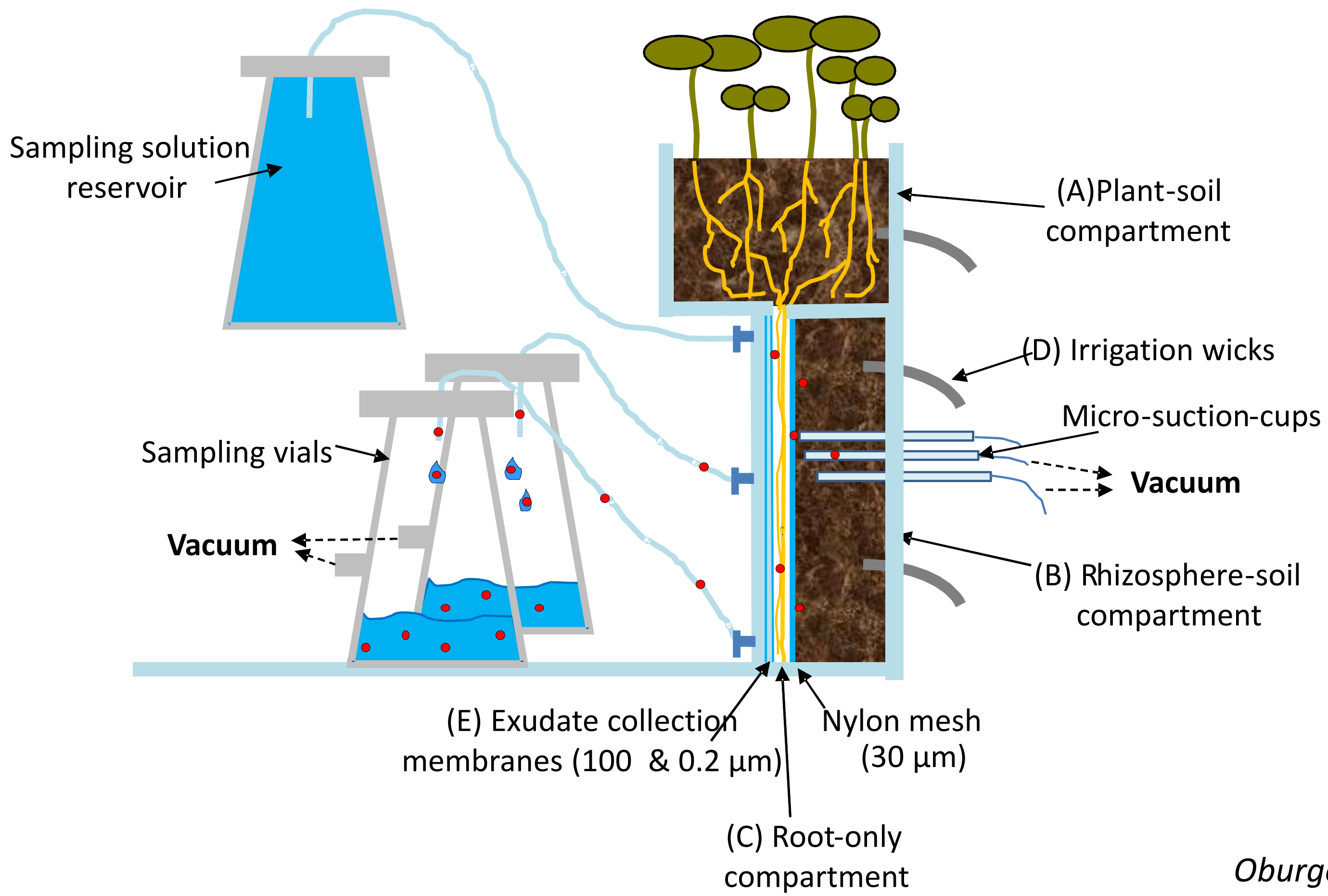


Sorption processes
Microbial degradation

For example:
Göttlein et al. (1996)
Kham et al. (1998)
Dinkelaker et al. (1997)
Neumann & Römheld (2001)
Mimmo et al. (2011)

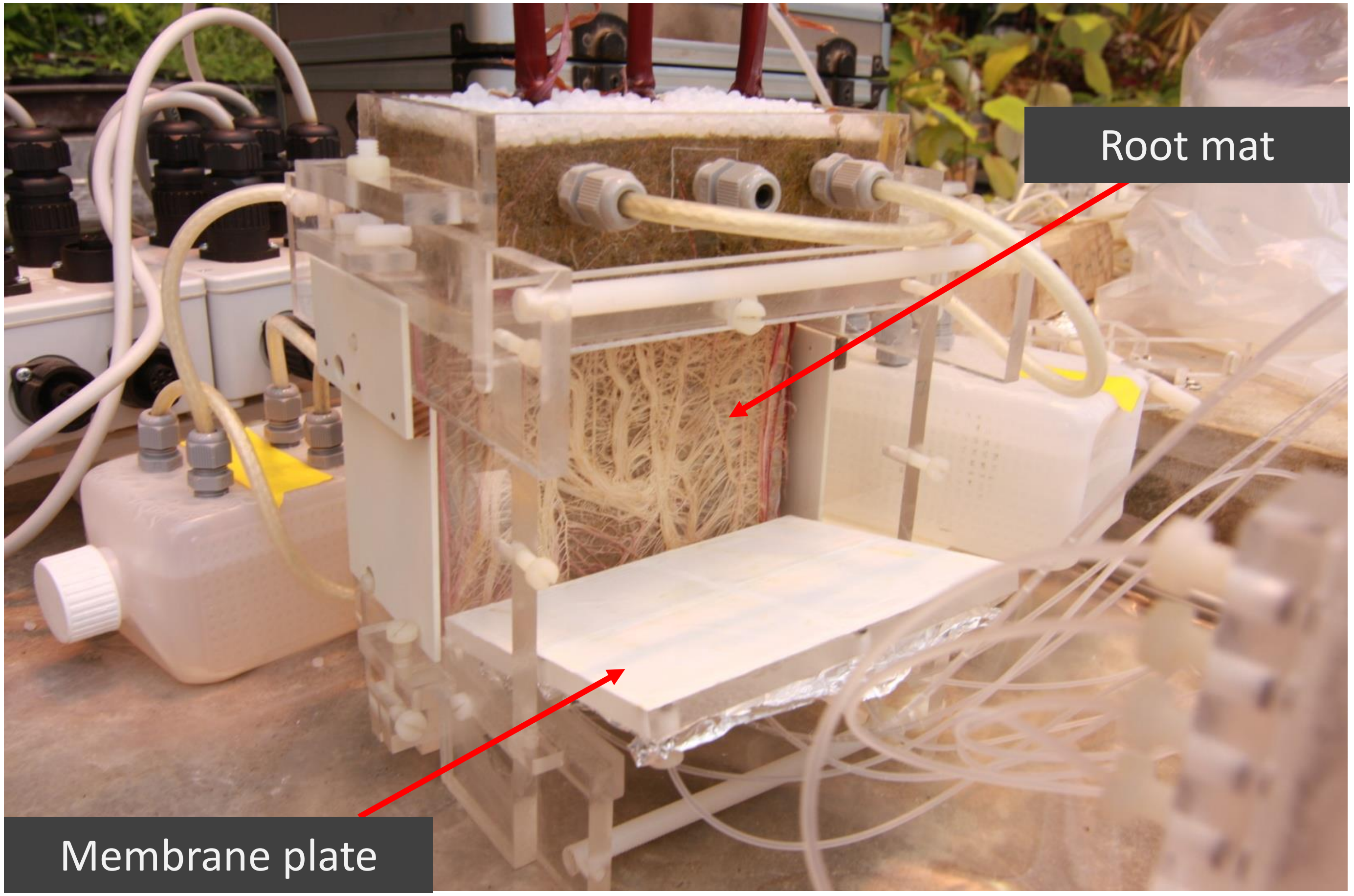
A new approach

Rhizoboxes combined with an *in-situ* root exudate collecting tool (REC)



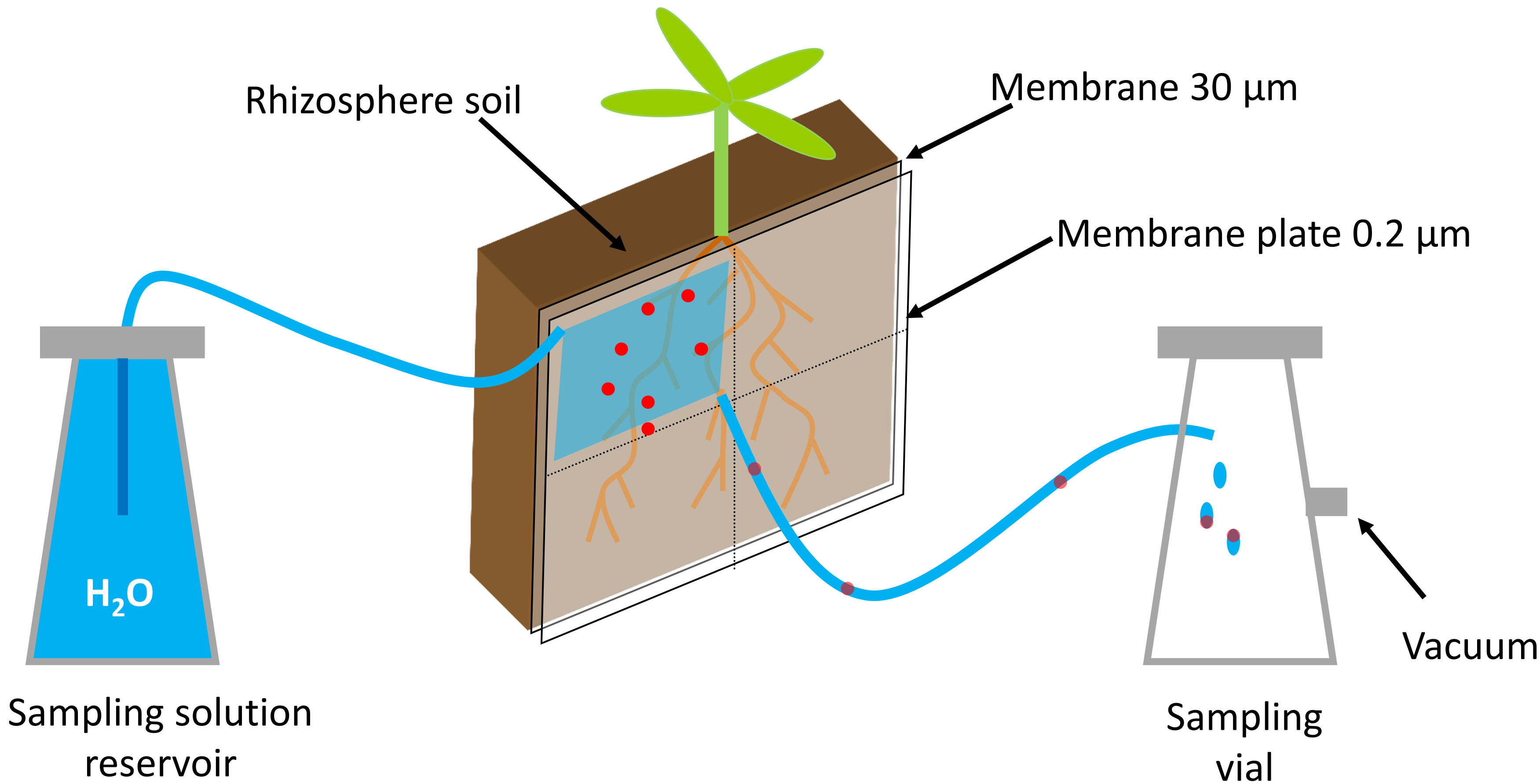
Oburger et al., 2013, Env.Exp.Bot.

Rhizobox & REC

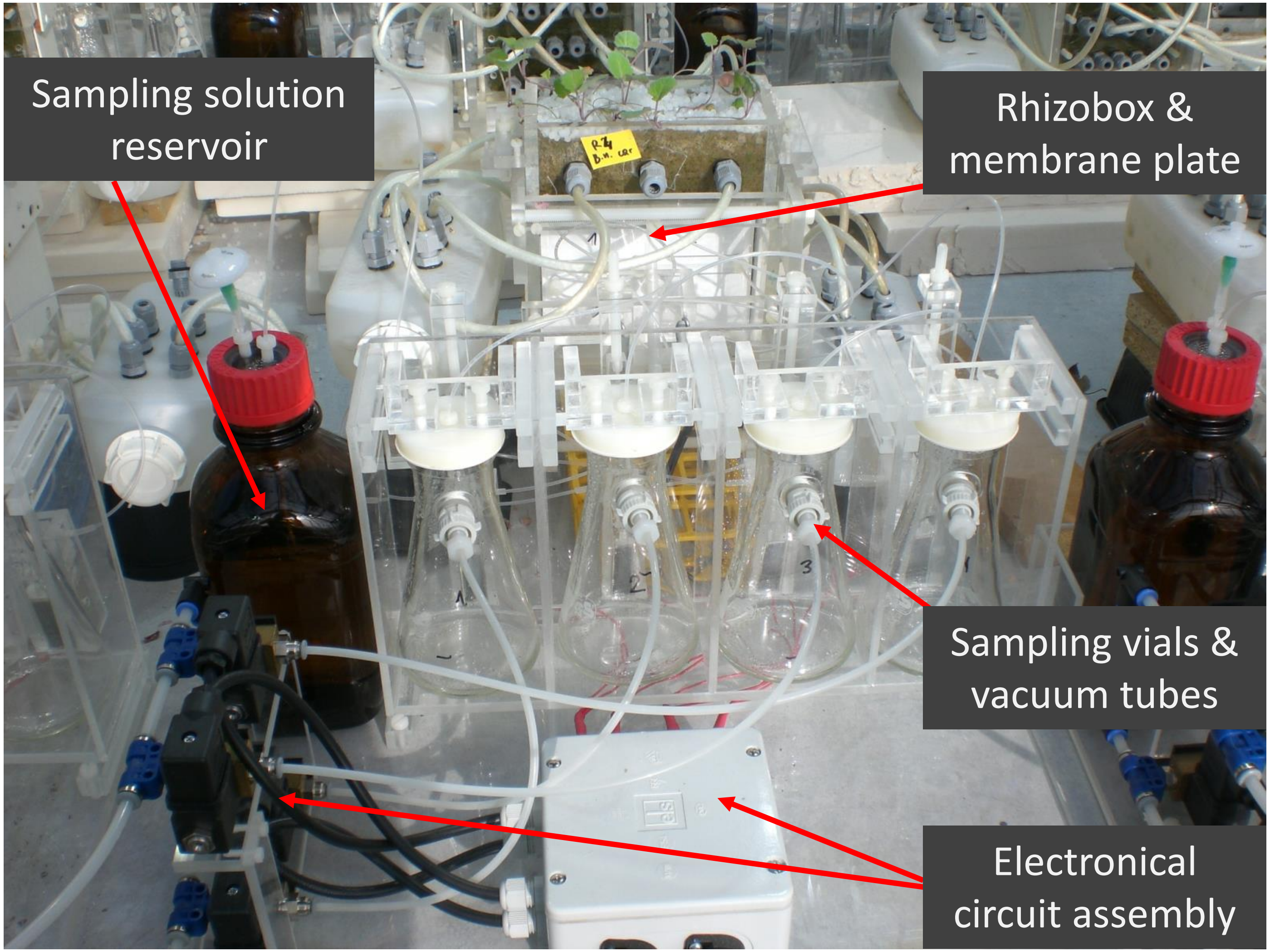


Oburger et al., 2013, Env.Exp.Bot.

Root exudate collector

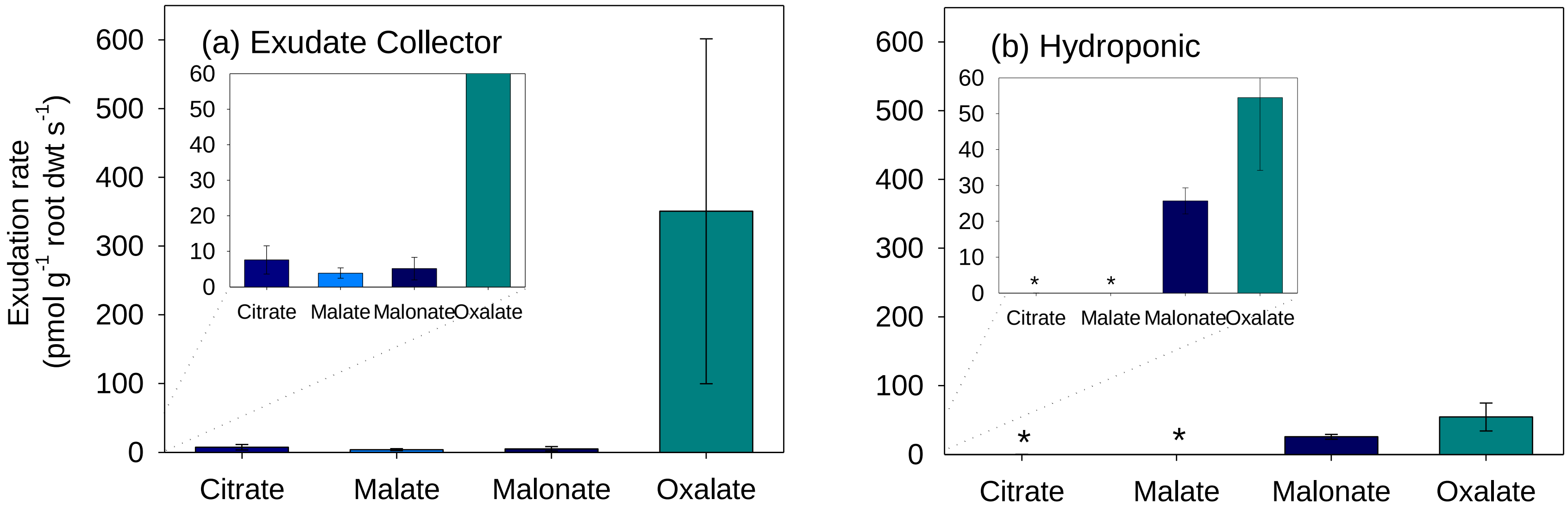


Rhizobox & REC



Oburger et al., 2013, Env.Exp.Bot.

Exudation rates of organic acids by Zea mays L.



Growth and sampling conditions will significantly effect quality and quantity of root exudates released!

- Release rates ~ **5x higher** in soil than in hydroponic culture

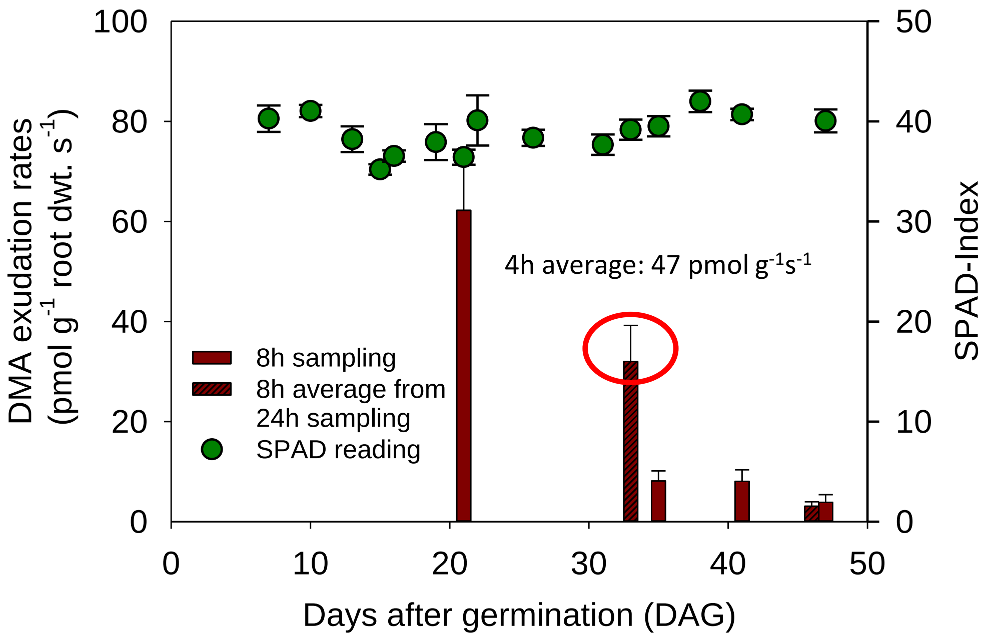
* < LOQ

Sampling period 24 h

Oburger et al., 2013, Env.Exp.Bot.

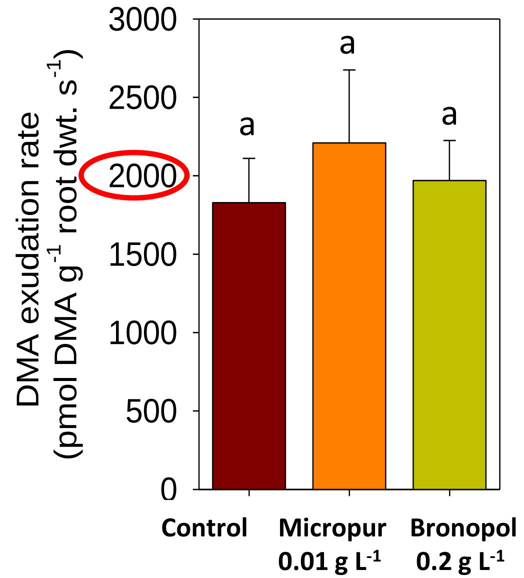
Phytosiderophore exudation rates of soil grown wheat

Rhizoboxes + REC sampling



Wheat (*Triticum aestivum* cv. Tamaro)
Fe deficient soil (50% $CaCO_3$)

Hydroponic, 28 DAG, 4h sampling



Wheat (*Triticum aestivum* cv. Tamaro)
Nutrient solution culture - zero Fe

- Phytosiderophore exudation rate in soil ~ **50 times lower** than in zero Fe nutrient solution

Oburger et al., 2014, New Phytol.

Conclusion

- Root exudates & P phytoavailability -
  It‘s complicated!

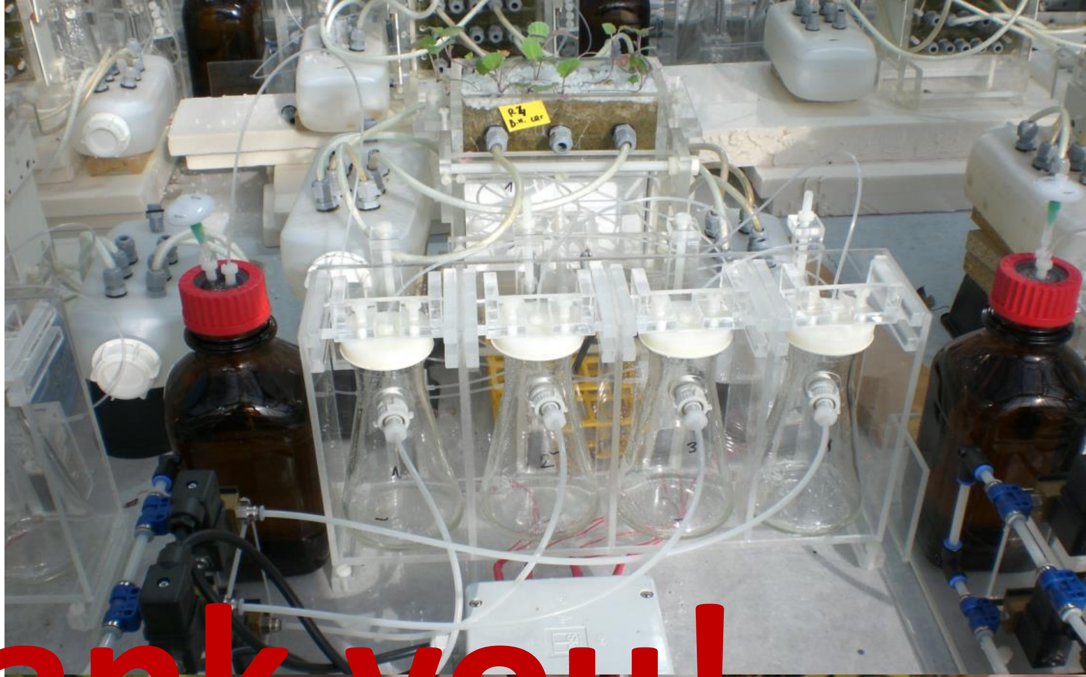
- Testing solubilizing efficiency
  - Experimental conditions (exudate concentration, pH, sterility, kinetics)
  - Soils are different (P speciation)!
  - Not only effect but also mechanisms (solubilization of Al, Fe, Ca)

- Root exudate sampling – move from hydroponic to soil
  - Experimental concentrations of solubilizing efficiency tests
  - Modeling rhizosphere processes

Acknowledgements

<u>*BOKU Vienna*</u>
Markus Puschenreiter
Barbara Gruber
Walter Wenzel
Grottfried Wieshammer
Madeleine Dellmour
Yvonne Schindlegger
Stephan Hann

<u>*University of Wales, Bangor UK*</u>
Davey Jones



Thank you!