Crop Booster

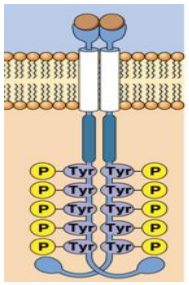
Phosphate

S. Abel[1], F. Degan[2], T. Desnos[3], L., D. Hourcade[2], M. Hothorn[4], L. Nussaume[3*], J. Paz-Ares[5], Y. Poirier[6], C. Plassard[7] H. Rouached[8], J. Zhu[3].

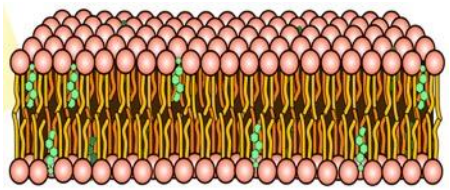
1 Department of Molecular Signal Processing, Leibniz Institute of Plant Biochemistry, 06120 Halle, Germany
2 ARVALIS, Institut du Végétal, Paris, France
3 CEA, CNRS, BIAM, UMR7265, SAVE, Aix Marseille Univ, Saint-Paul lez Durance, France
4 Structural Plant Biology Laboratory, Department of Botany and Plant Biology, University of Geneva, Geneve, Switzerland.
5 Centro Nacional de Biotecnologia, Consejo Superior de Investigaciones Cientificas, Campus de Cantoblanco, Madrid, Spain
6 Department of Plant Molecular Biology, University of Lausanne, Switzerland.
7 INRA, UMR Eco&Sols, 2 Place P. Viala, Montpellier, France
8 Plant, Soil, and Microbial Sciences, Michigan State University, East-Lansing, Michigan, USA

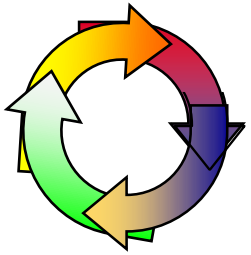
Phosphorus is essential for life

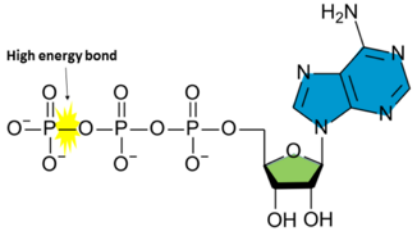
Signaling
(phosphorylation)



Structure of the cells
(Phospholipids)



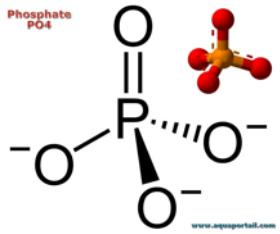




Genetic information
(DNA-RNA)

Metabolic reactions
(ATP)

Inorganic phosphate is the sole source of phosphorus for plants



pH

H_3PO_4

2,1

$H_2PO_4^-$

7,2

HPO_4^{2-}

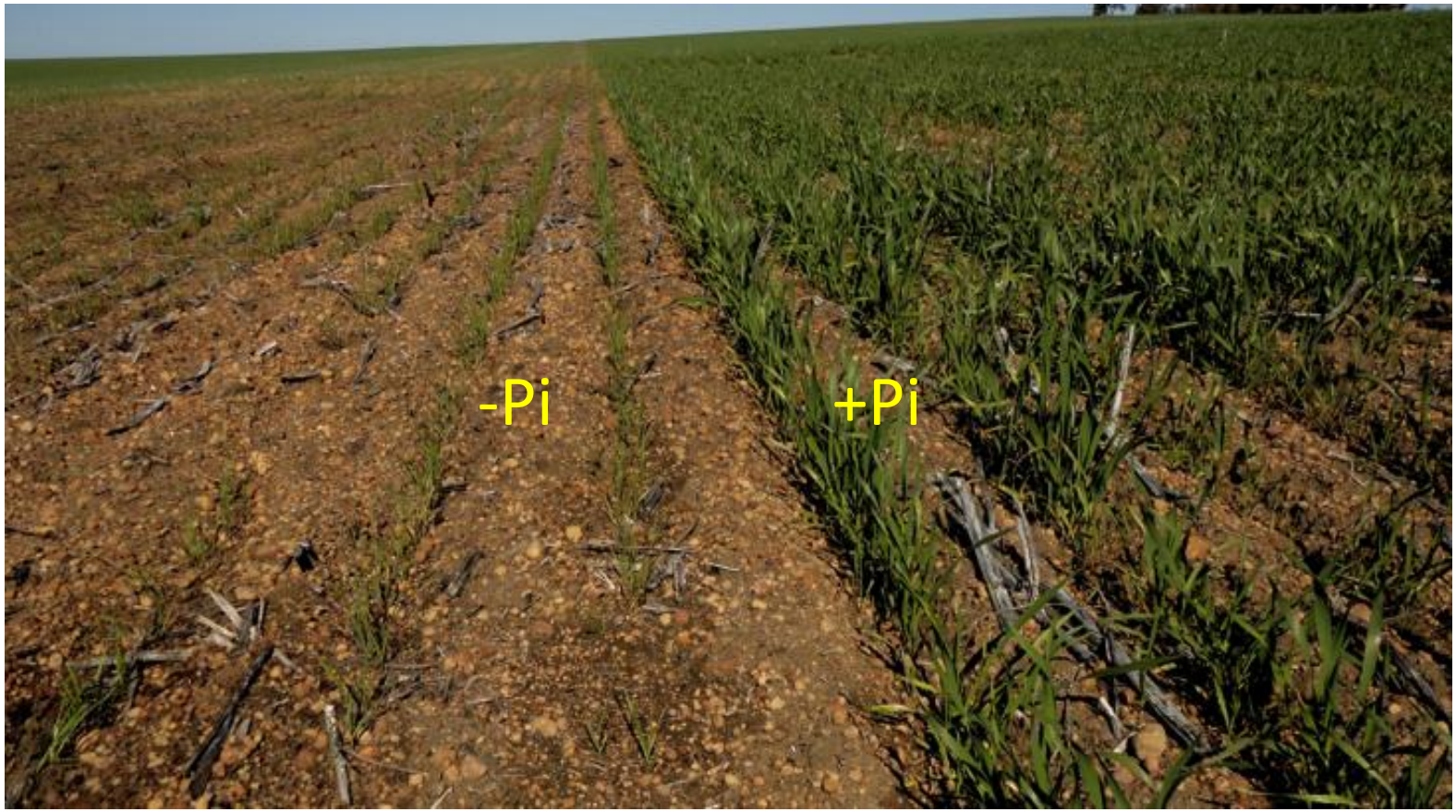
12,3

PO_4^{2-}

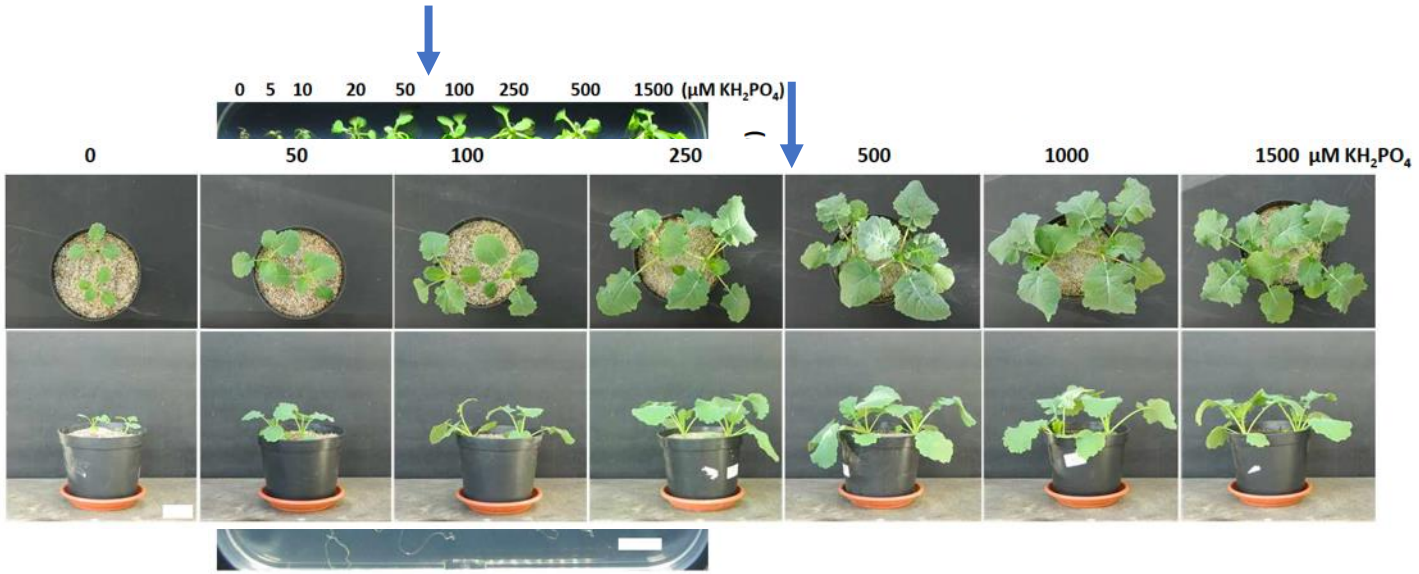
Crucial role of pH!

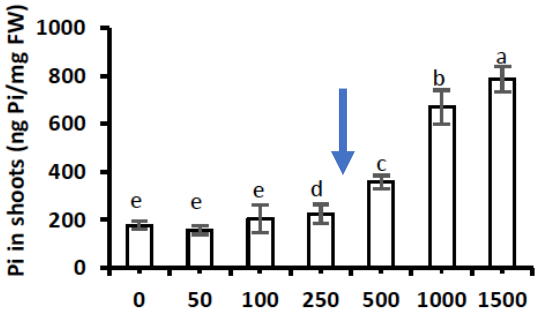
Plants are secreting multiple phosphatases to recover organic Pi

Pi: an essential macronutrient



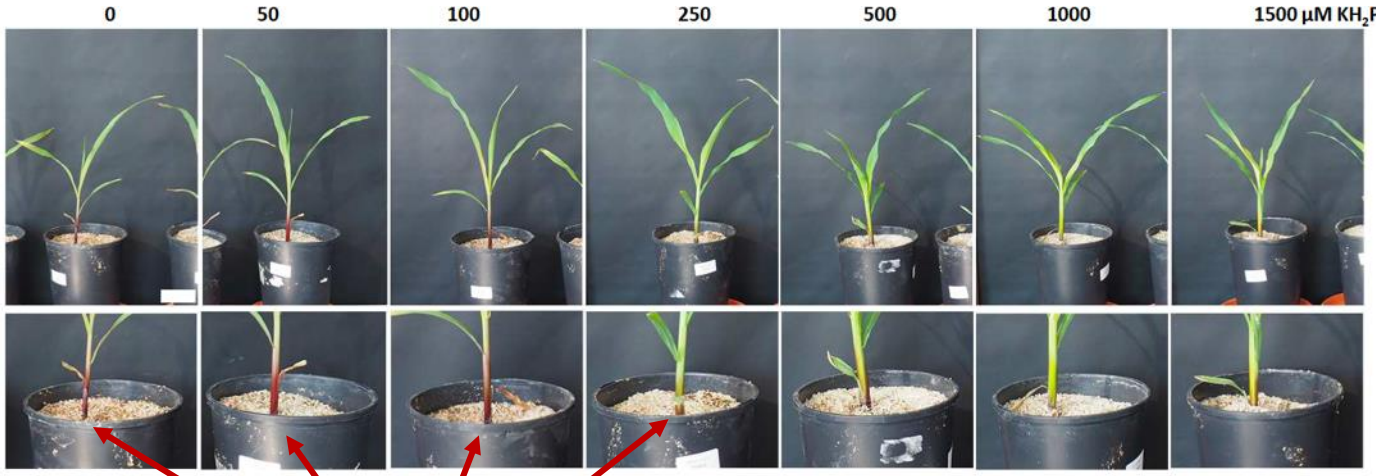
Internal Pi does not reflect Pi deficiency status



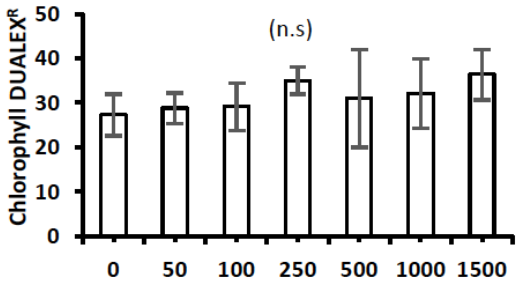


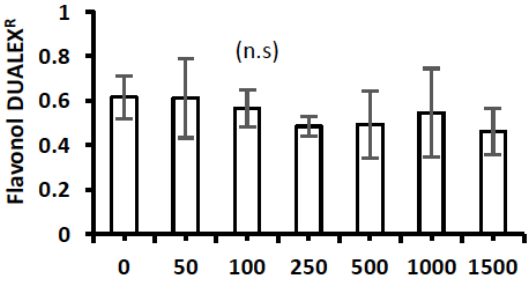
Internal Pi is not a good marker of Pi deficiency!

Symptoms of Pi deficiency are difficult to identify



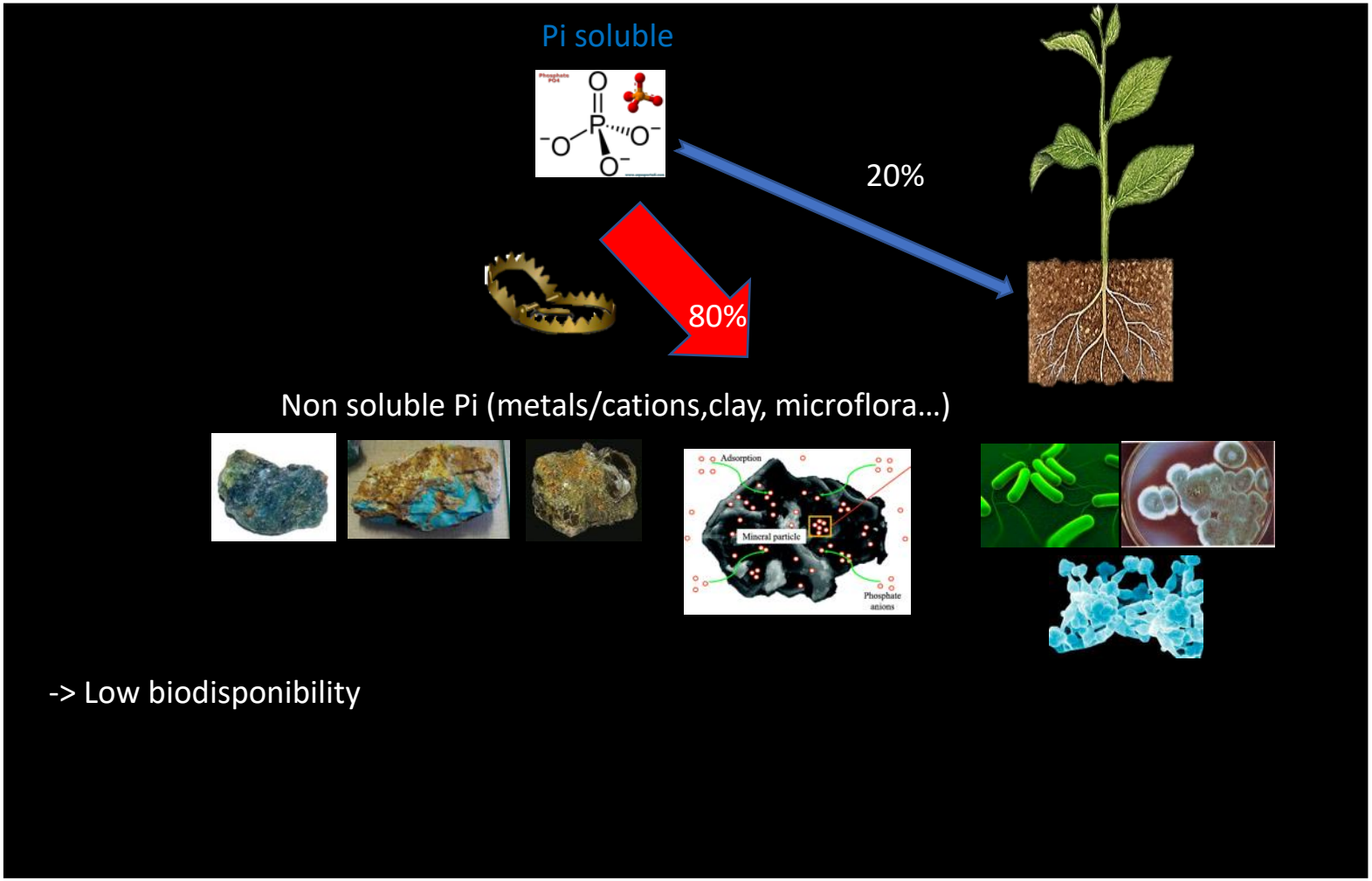
Anthocyan





Anthocyanins accumulation lacks specificity!

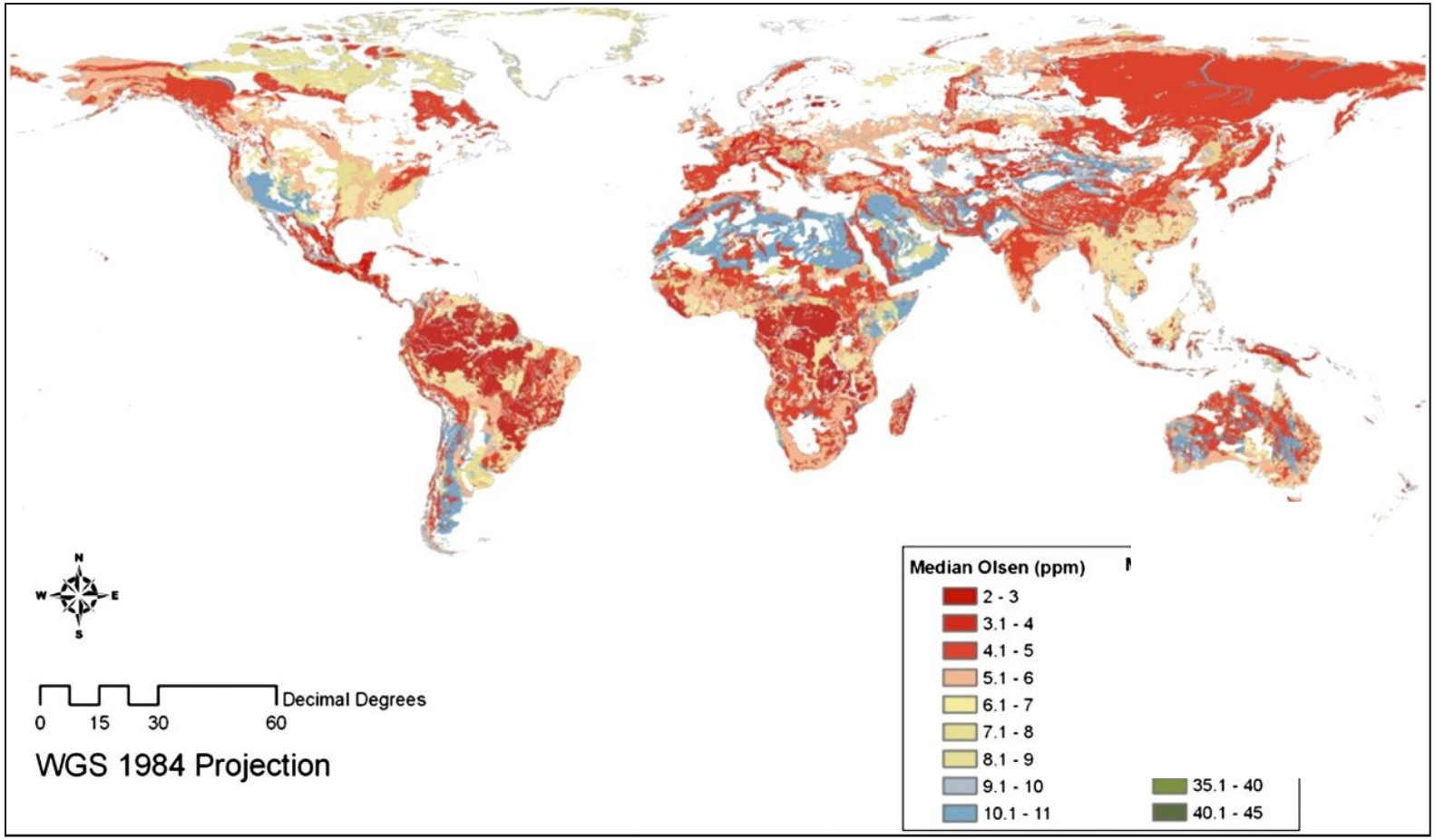
Only a fraction of Pi is recoverd by plants



Difficulty to measure bio-available Pi in a soil!

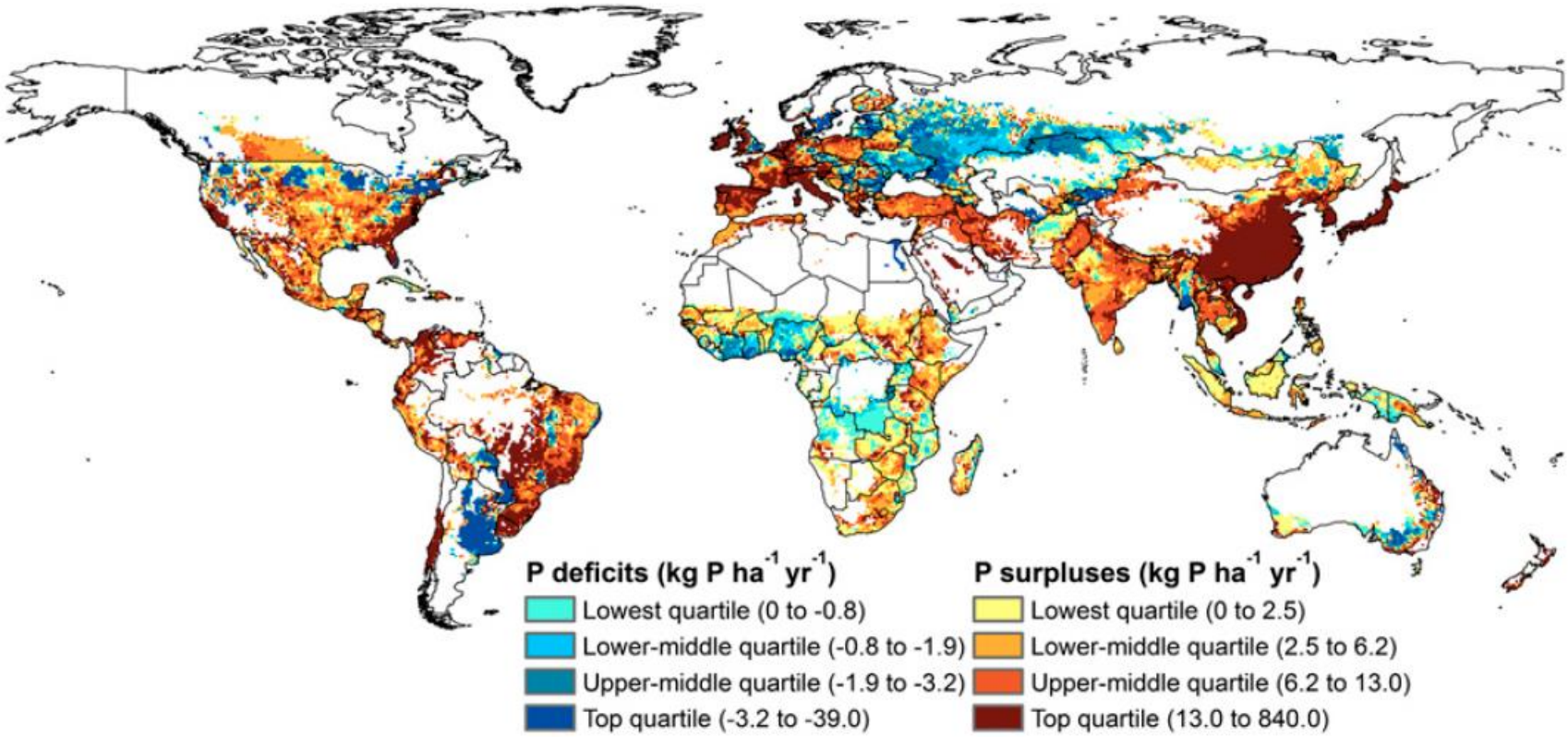
Weak mobility of phosphate in soils

50% of soils are Pi deficient



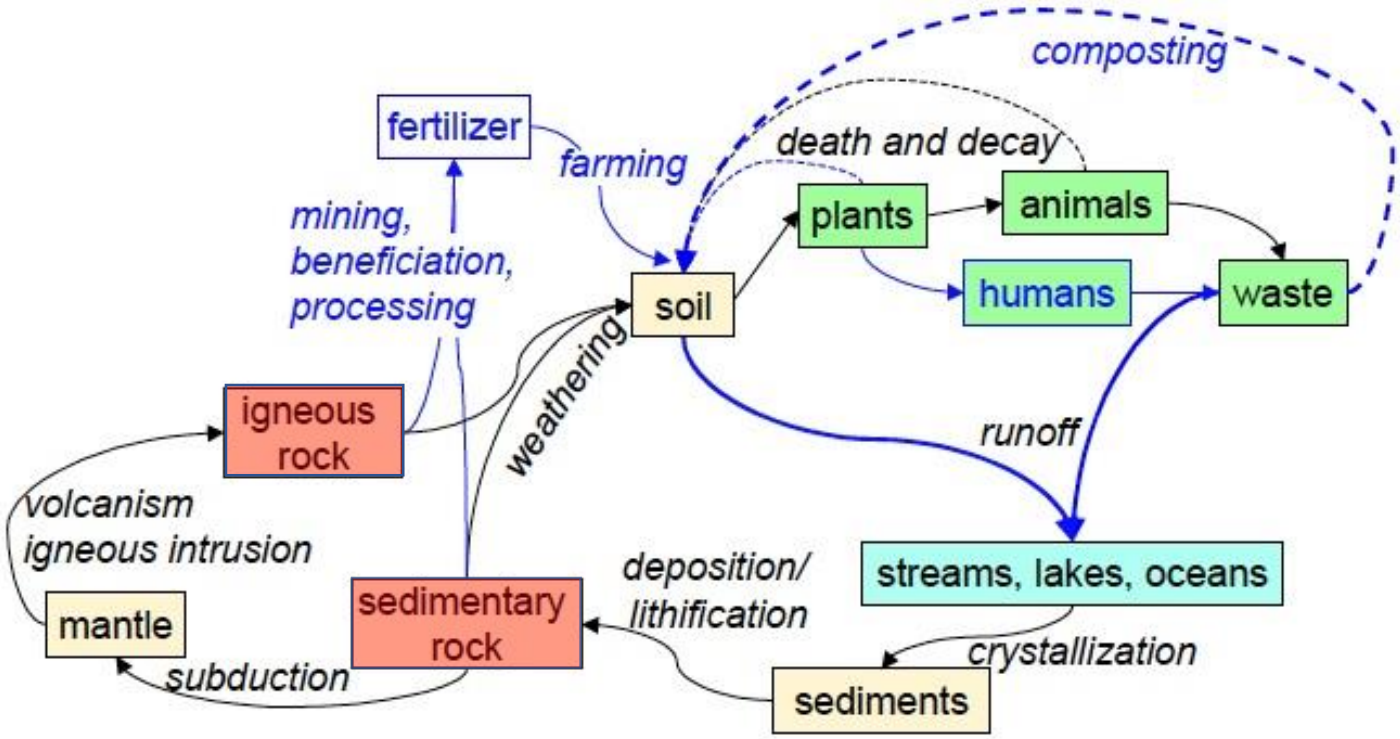
Mc Donald et al., PNAS 2011

29% Cropland have P deficit



(Mc Donalds et al., 2011. PNAS)

Origin of Pi fertilizers

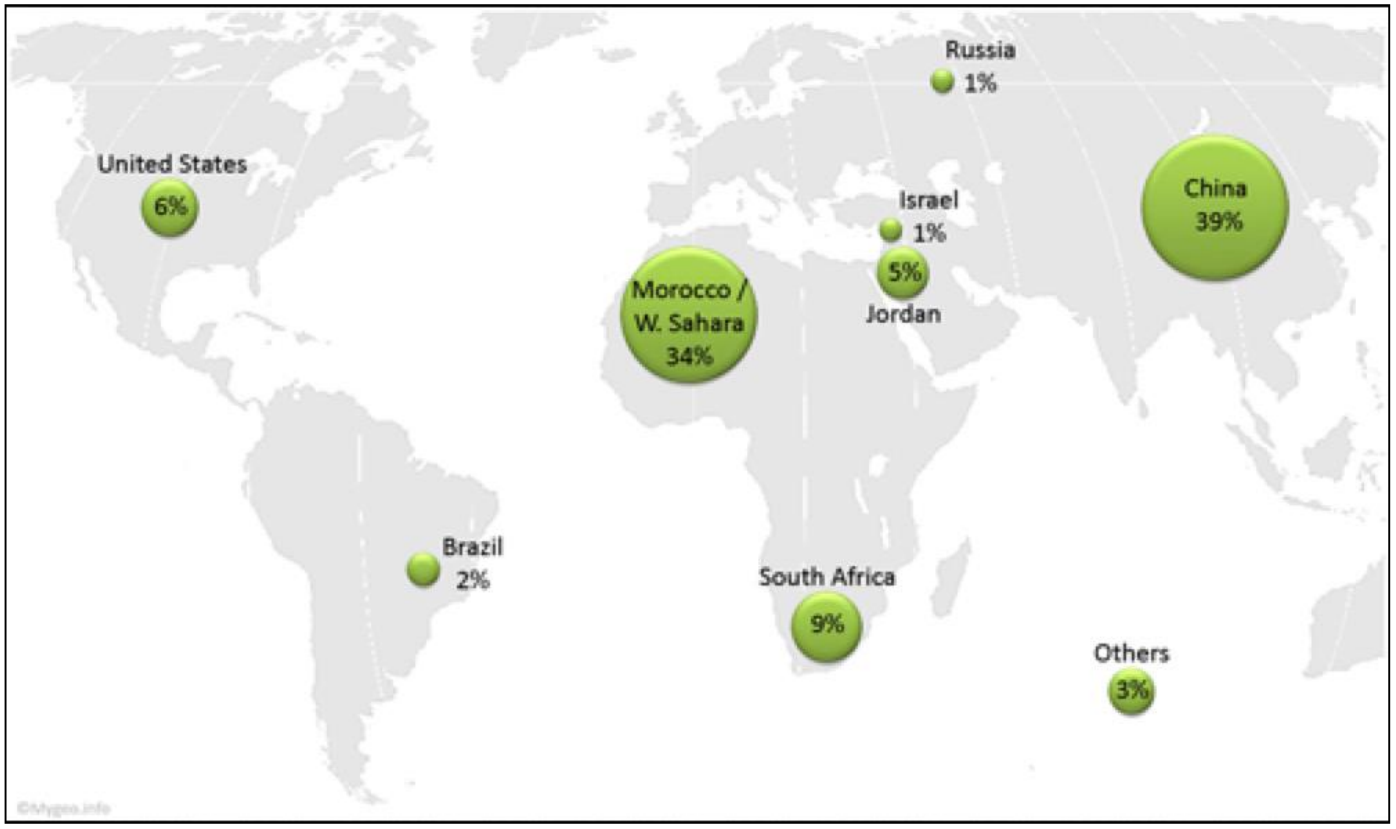


Sediments: 95%

Igneous rock: 5%

Pufahl, 2017 Economic Geology

Phosphorus stocks around the world



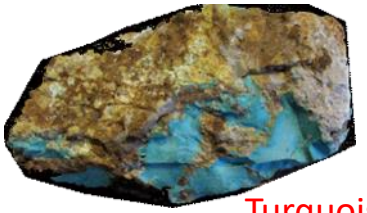
Röhling, S. (2007)

Pi is a source of environmental pollution

Many fertilizers contain metals

-> EC regulation modified

Uranite

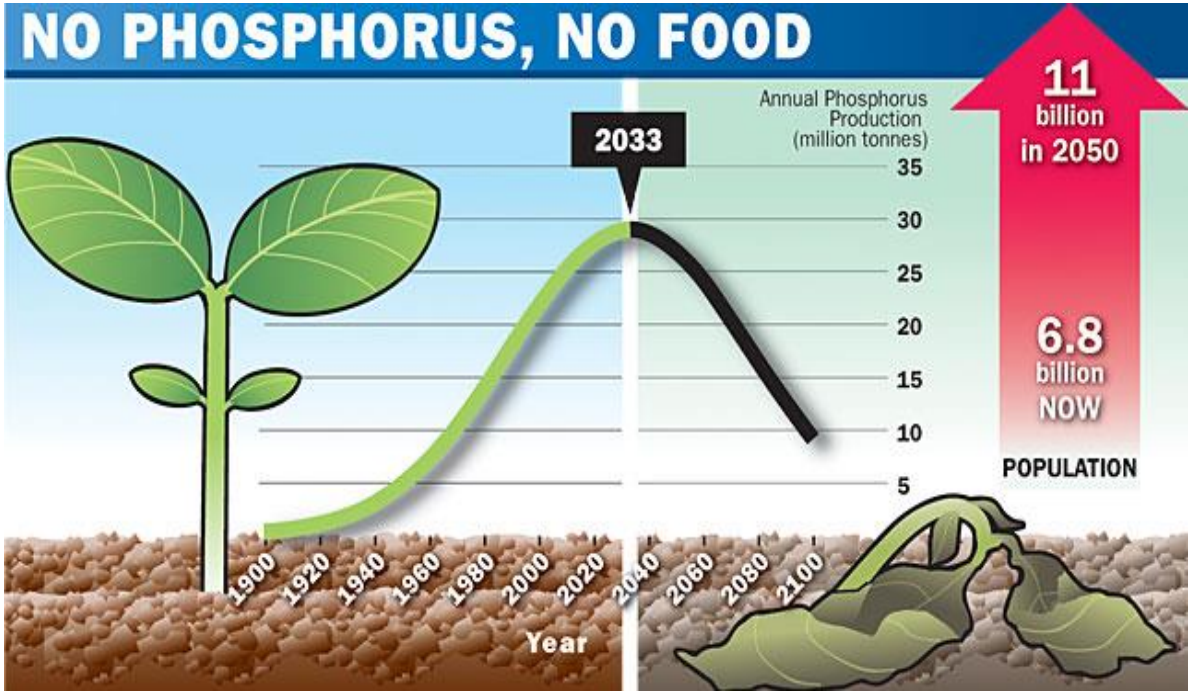


Turquoise

Pollution

->Land (Radioactive Polonium in US Tobacco) « high quality » phosphate ressources will be exhausted in next future

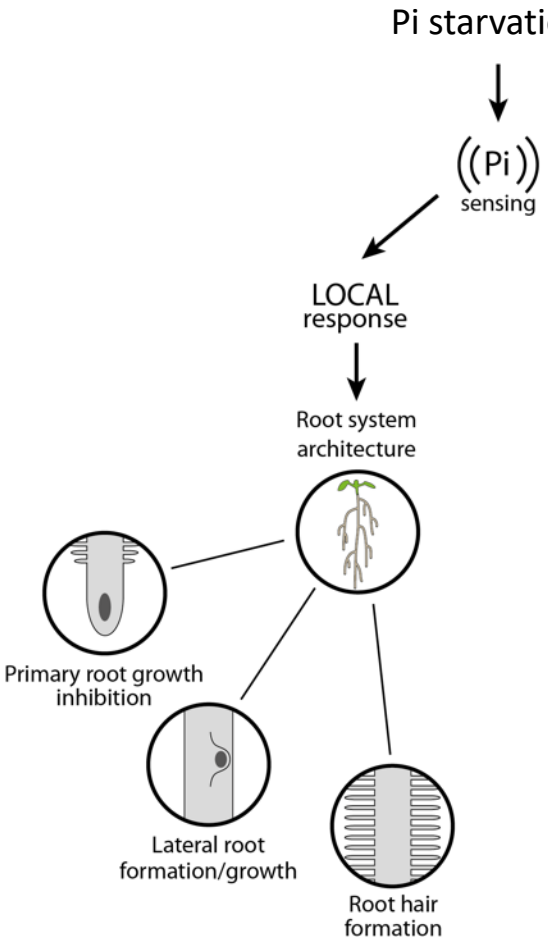
->Water (favors cyanobacteria bloom)

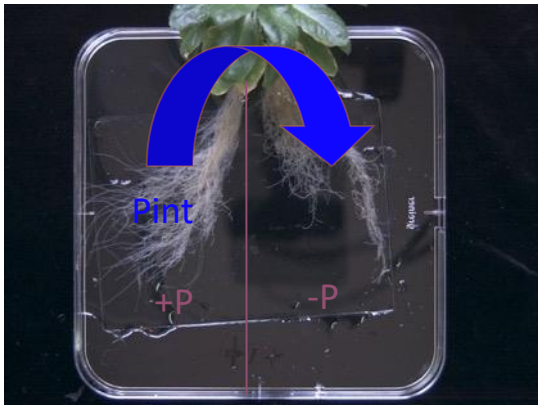


GPRI & Institute for Sustainable Futures (ISF), Sydney; Cordell et al. 2009

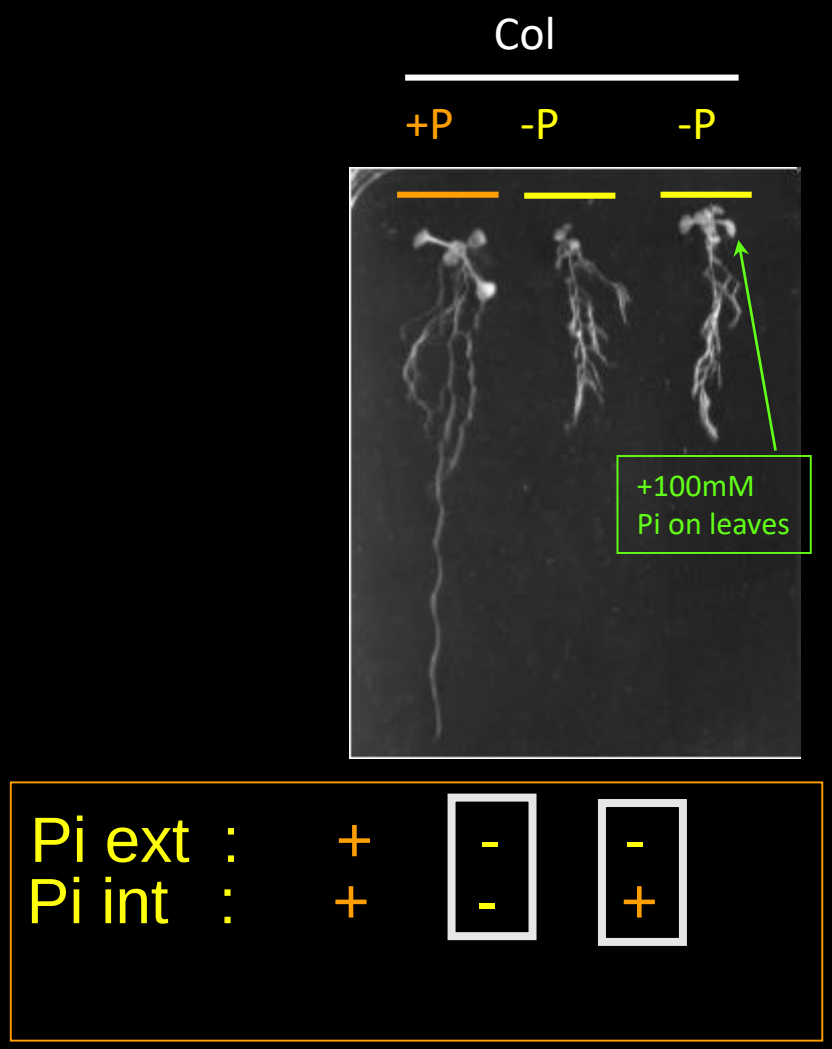
Estimated reserves: 200/300 years (US Geological survey)
But all are not high quality grade!

Phosphate starvation





(Péret *et al.*, 2011 Trends Plant Sci; Thibaud et al., Plant J. 2010)

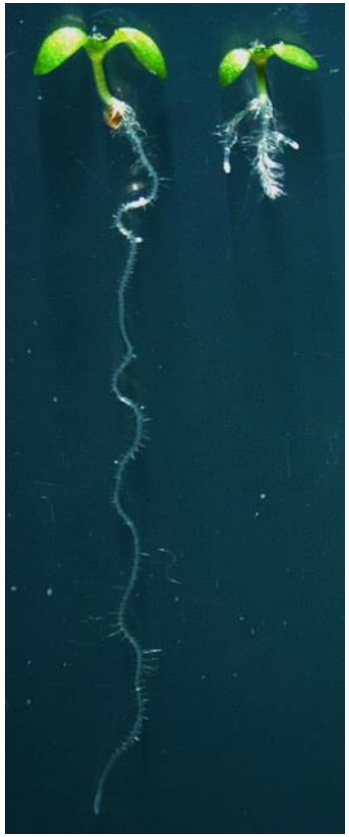


Root architecture is linked with external Pi concentration

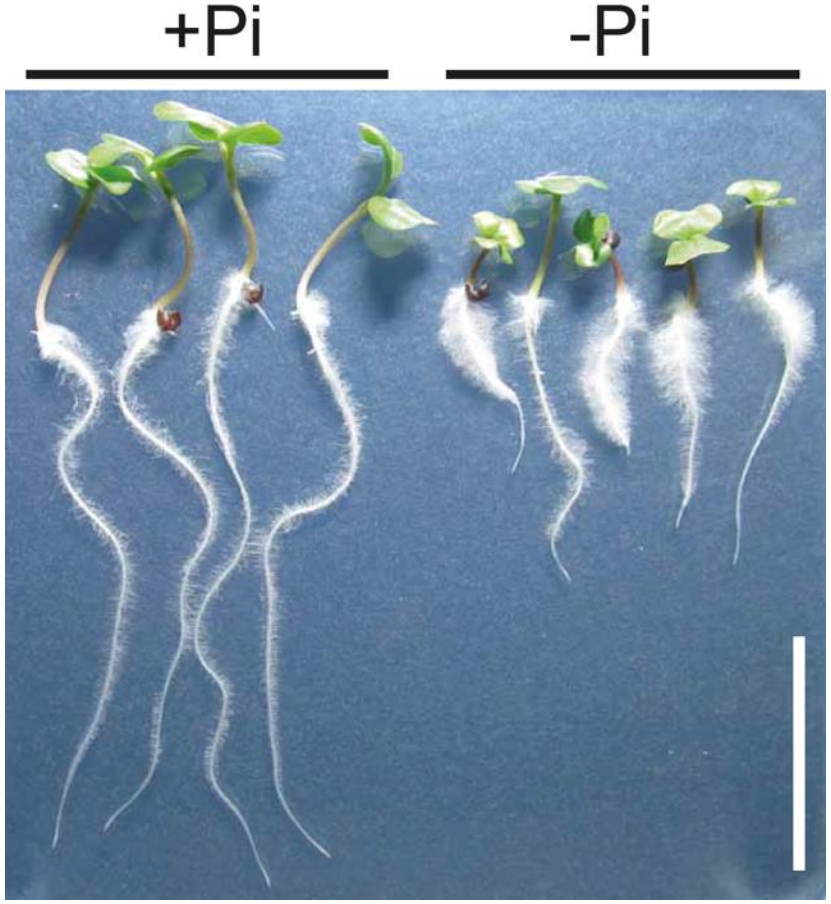
Primary root inhibition in response to Pi deficiency Pi

Arabidopsis thaliana

+Pi -Pi

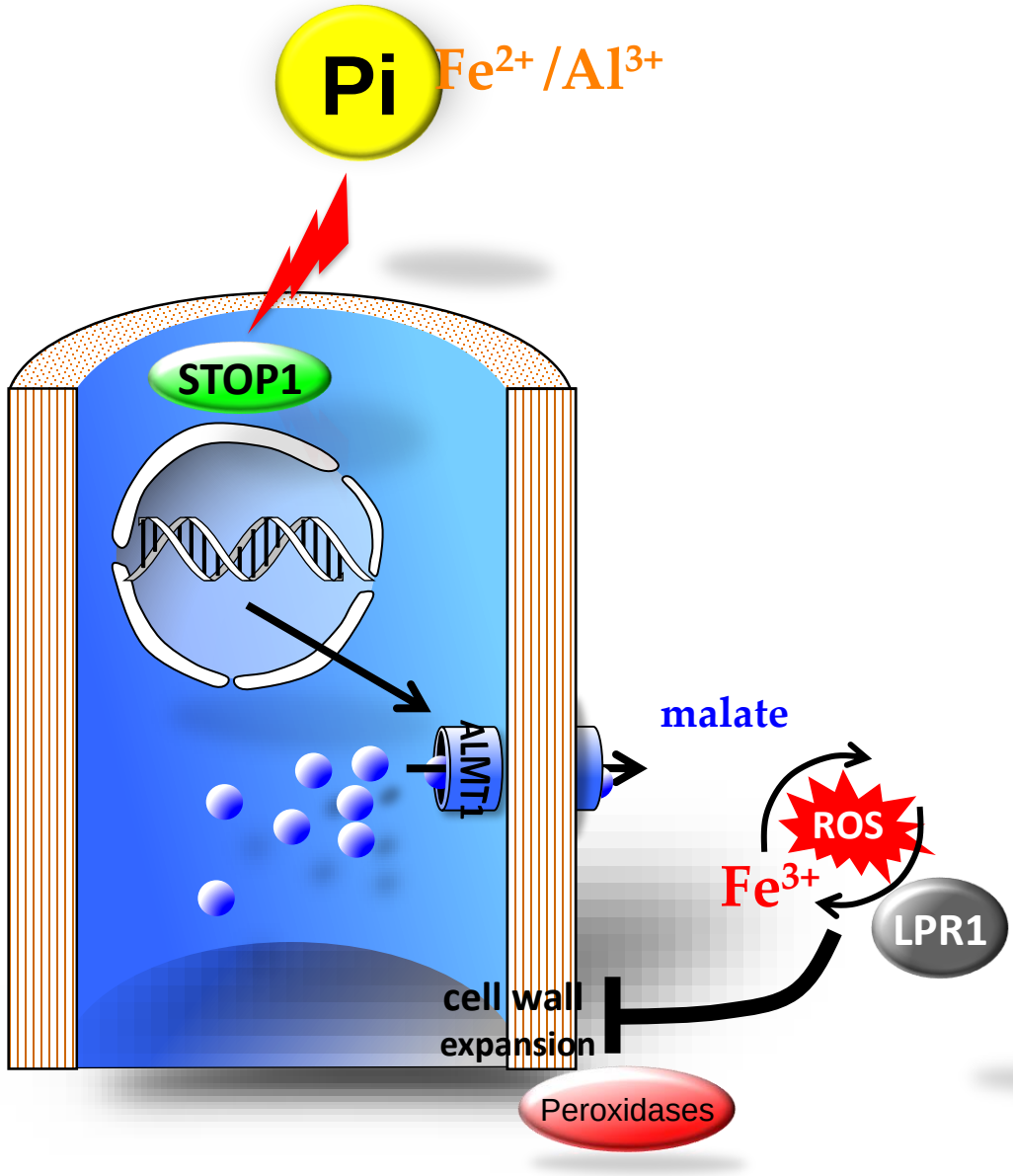


Brassica napus



Balzergue *et al*. *Nature Communications* (2017)

Primary root inhibition highlights links between Pi and metals (Fe,Al)



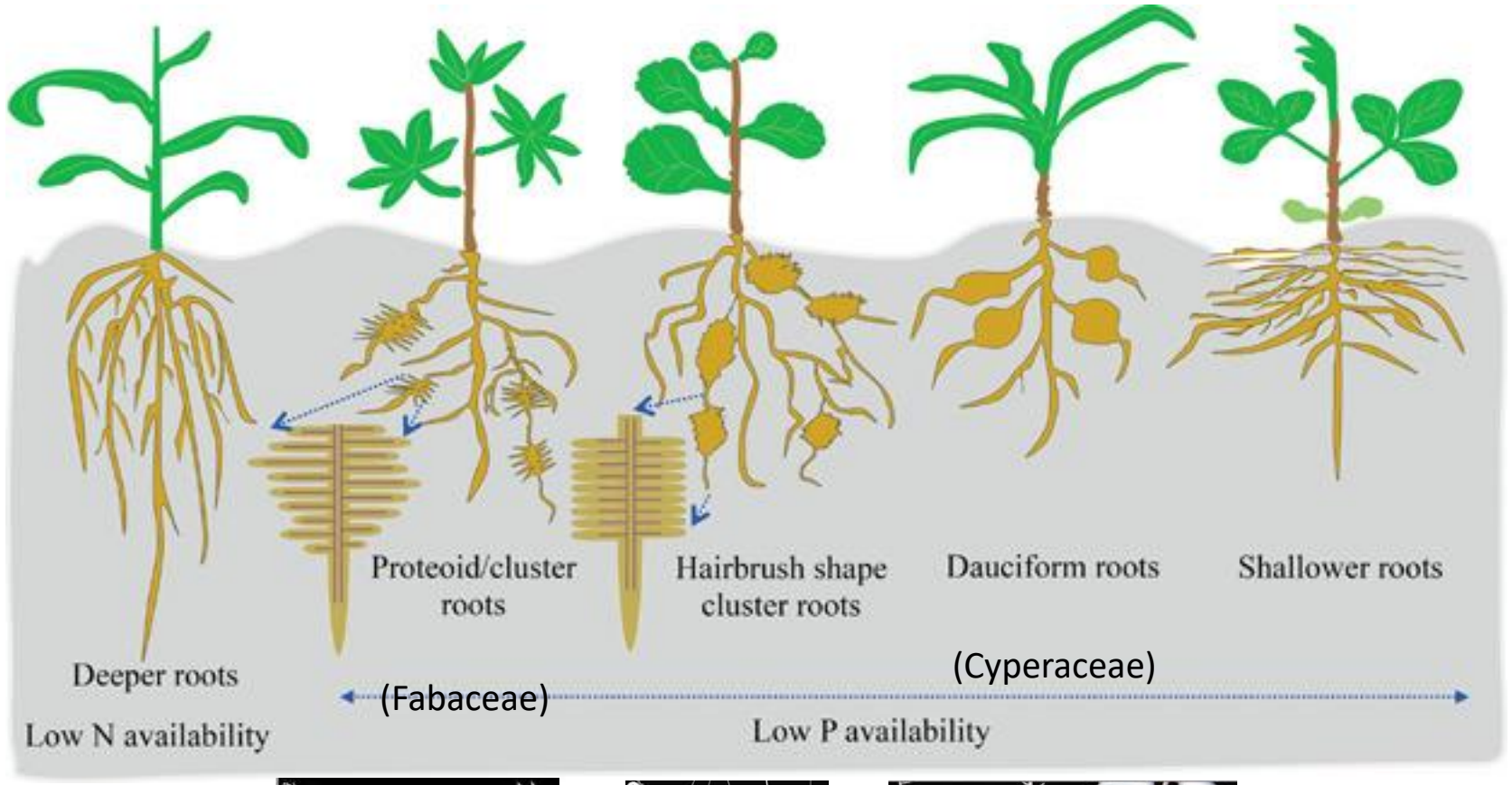
Reducing Pi increase metals availability

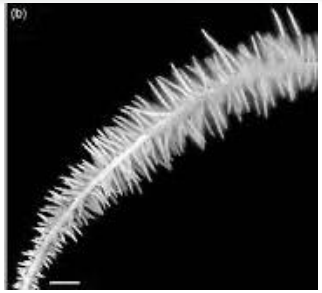
It triggers:

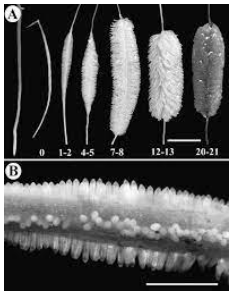
-modification of root architecture

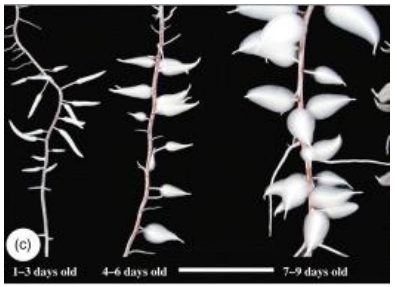
-malate secretion

Cluster root strategies



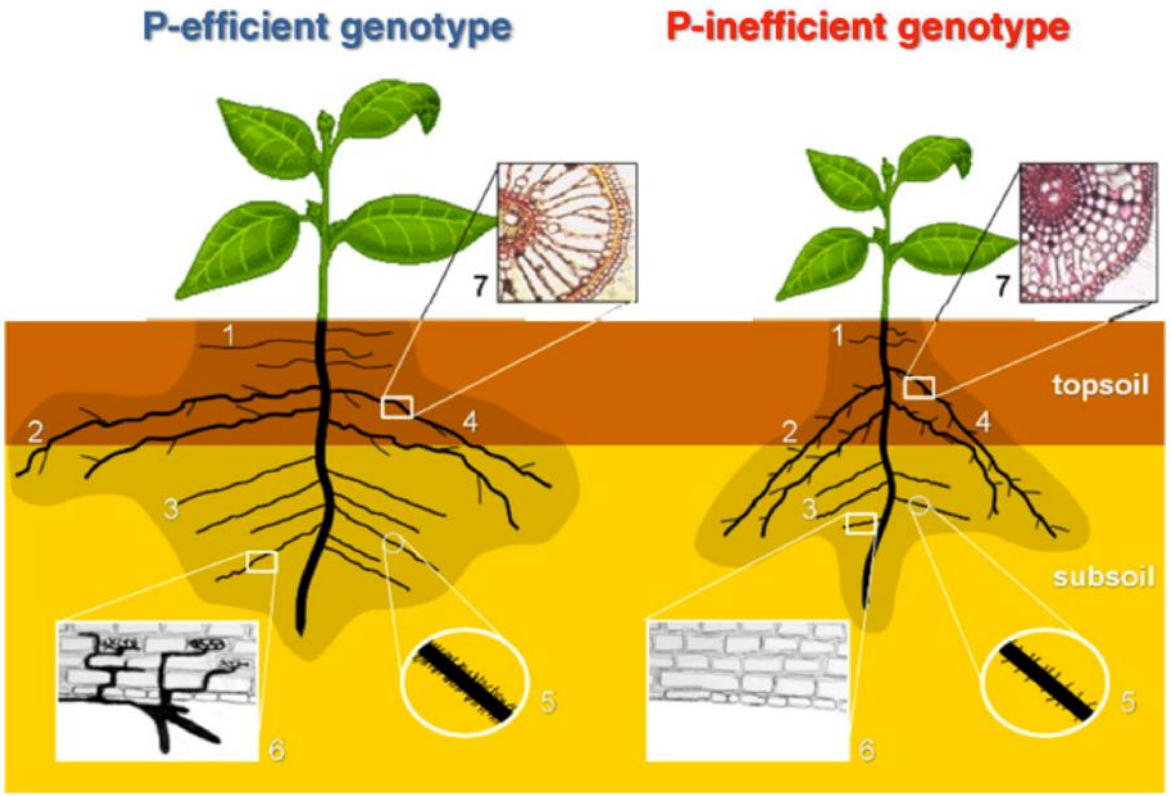






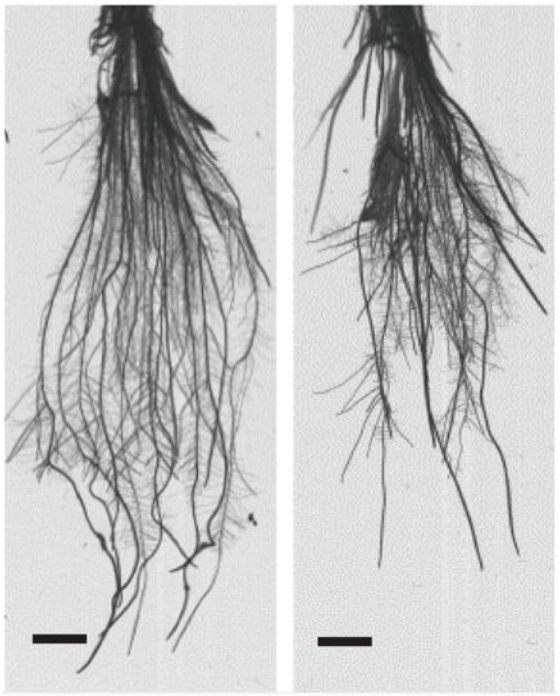
Very efficient but number of species limited

Top soil foraging: a strategy to cope with Pi deficient soils



Ramaekers et al. *Field Crops Research* 2010

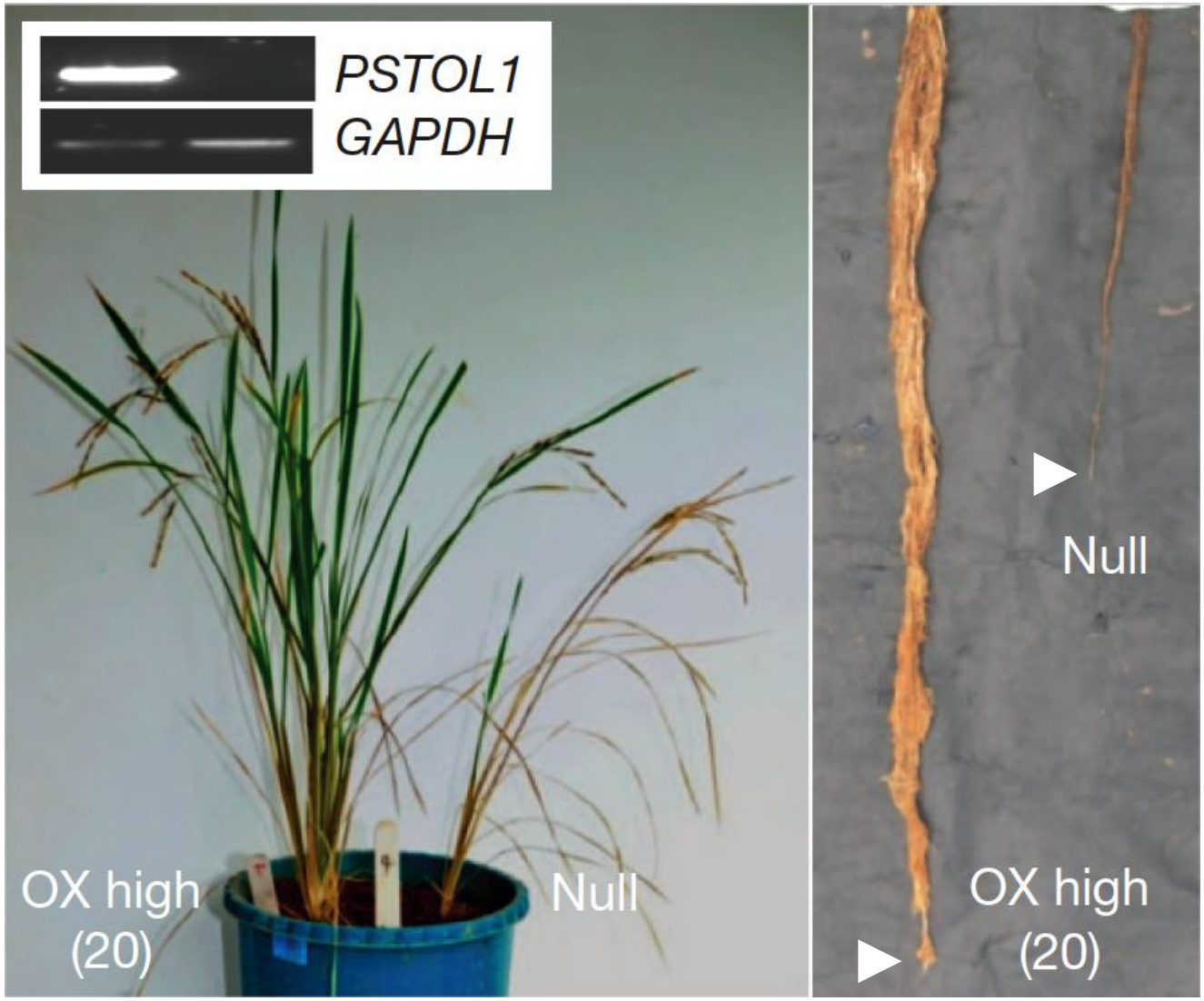
Rice



PSTOL1 *pstol1*

Gamuyao et al. *Nature* 2012

PSTOL1 augmente le rendement du riz en sol carencé en Pi

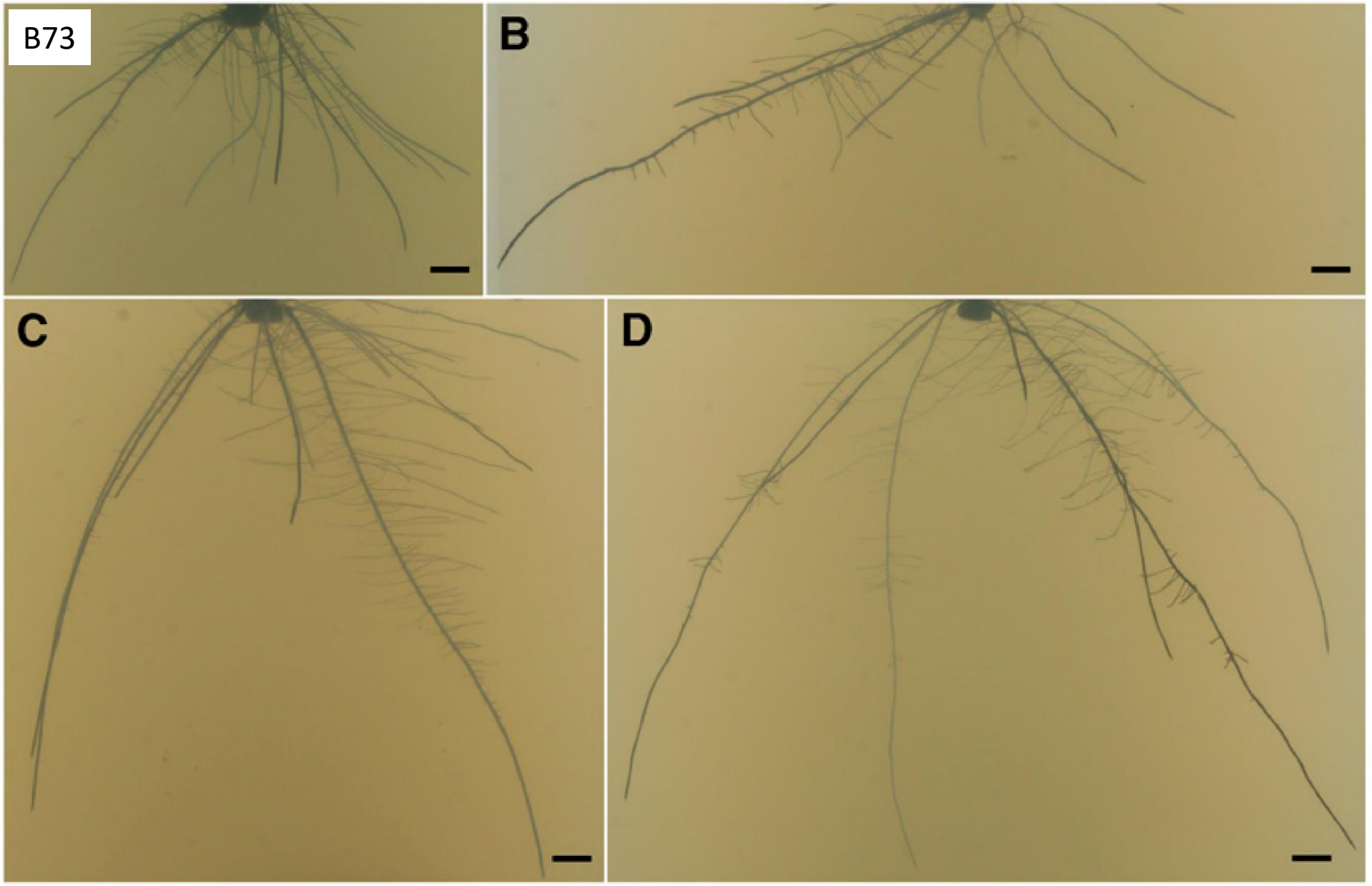


P-deficient soil

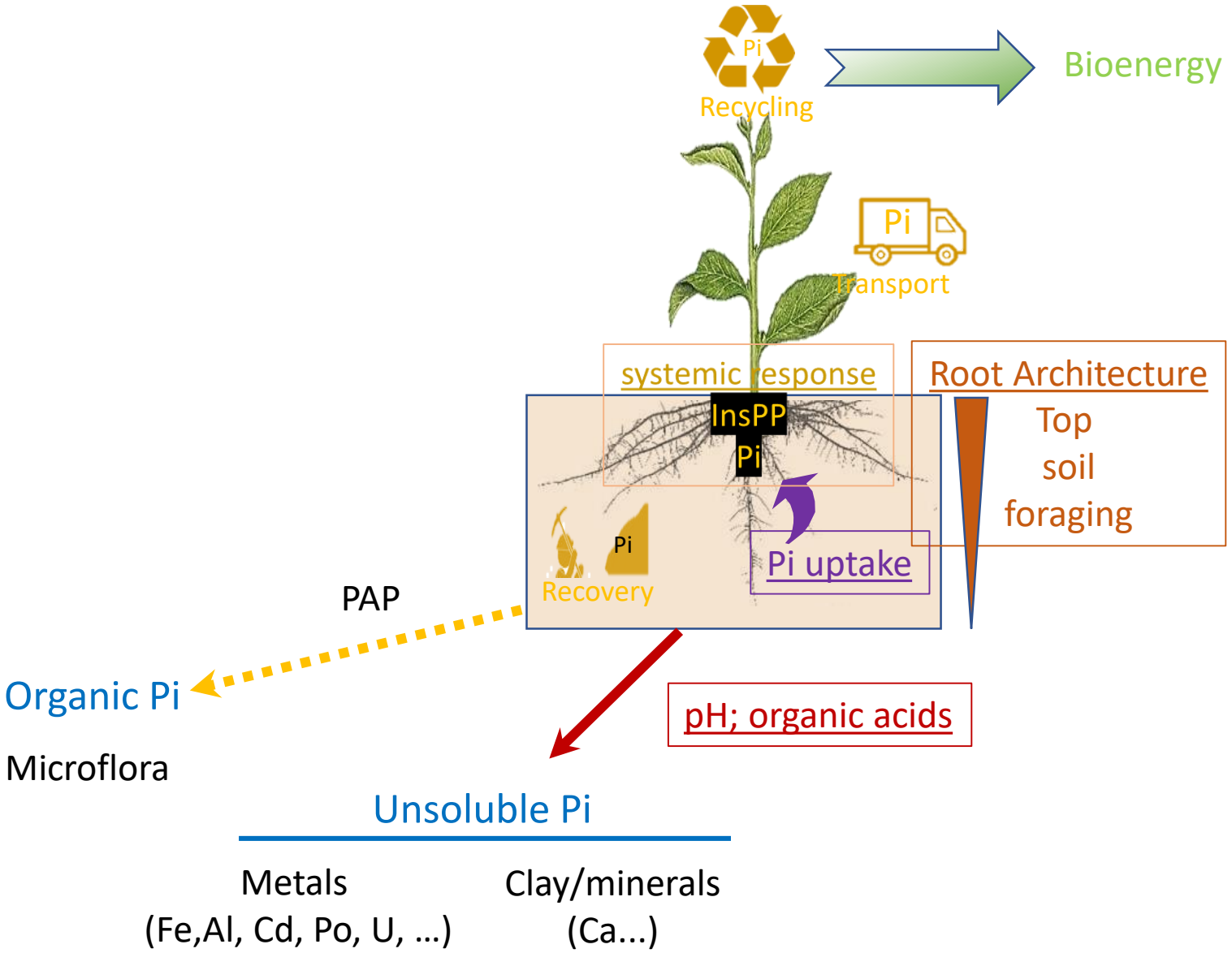
PSTOL1 is lost in modern rice cultivar

Nature (2012) 488:535

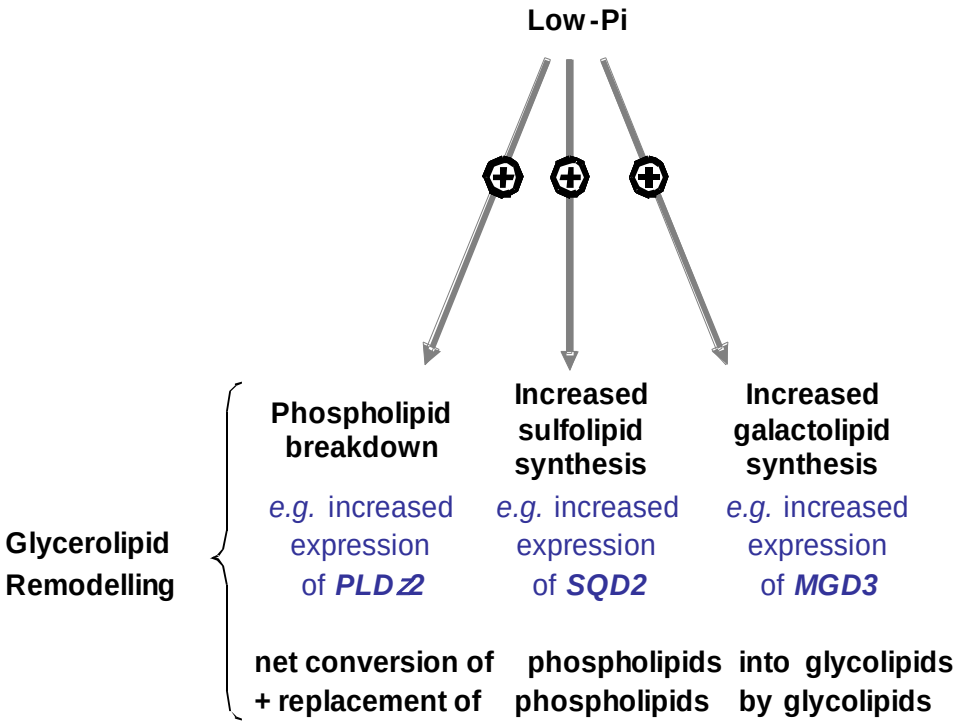
Maize root architecture variability (mapping lines)



Zurek et al *Plant Physiol.* 2015 Apr;167(4):1487-96.


Pi
Recycling
Bioenergy
Pi
Transport
systemic response
Root Architecture
InsPP
Pi
Top
soil
foraging
Pi
Recovery
Pi uptake
PAP
Organic Pi
Microflora
pH; organic acids
Unsoluble Pi
Metals
(Fe,Al, Cd, Po, U, …)
Clay/minerals
(Ca...)

Interest of controling the metabolism: ex lipids

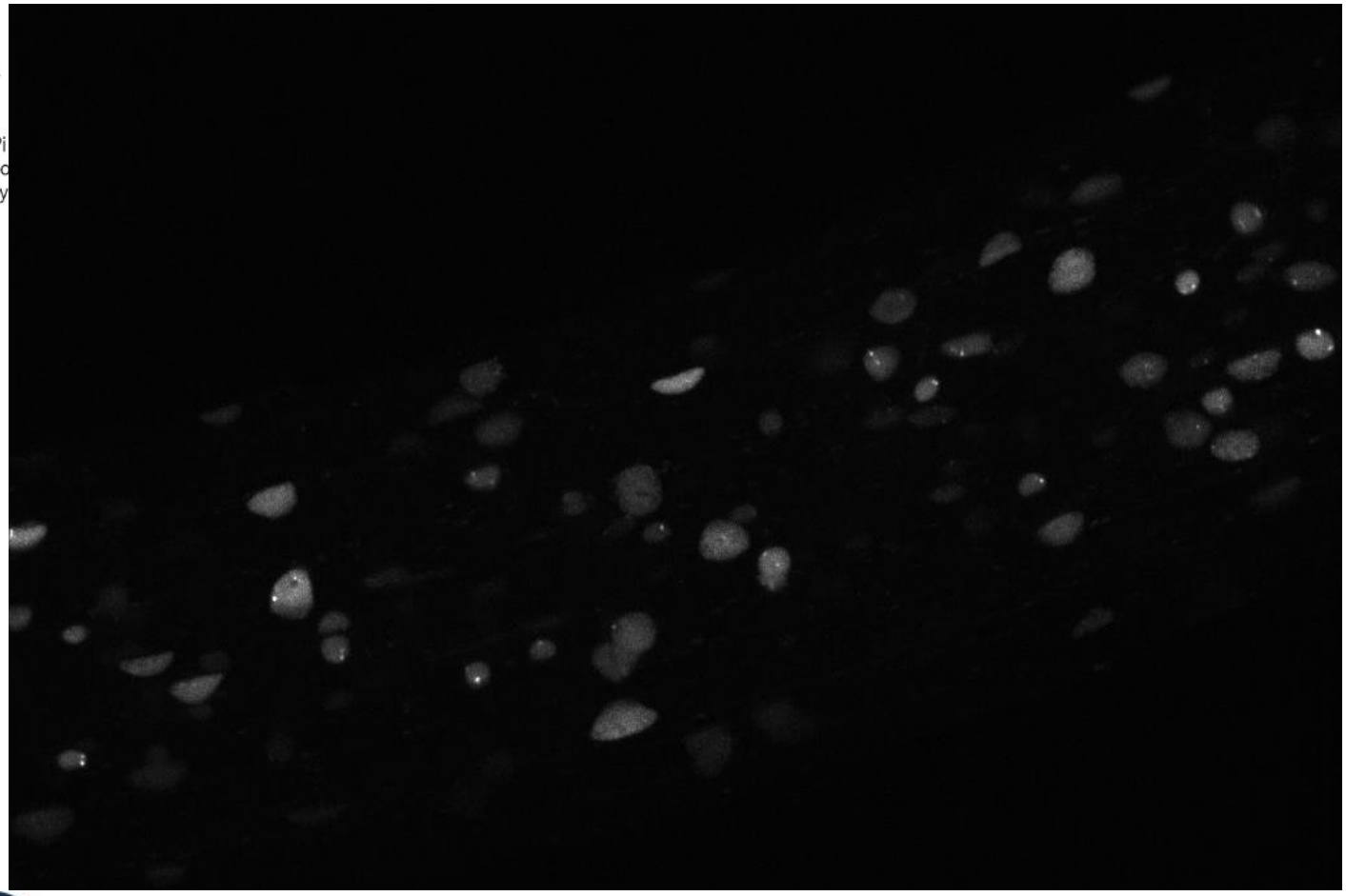


Phospholipids:

Source of P for animal nutrition

Ex lecithin (Phospho Choline) emulsifier

Pi systemic signaling



Conclusion

Rationalize Pi fertilizer use:

Europe lacks Pi ressources

-Necessary to meet EC regulation (to reduce Cd in fields)

-Measure bioavailable Pi in soils (Olsen methods to develop)

-Identify fast reliable markers for plant Pi deficiency

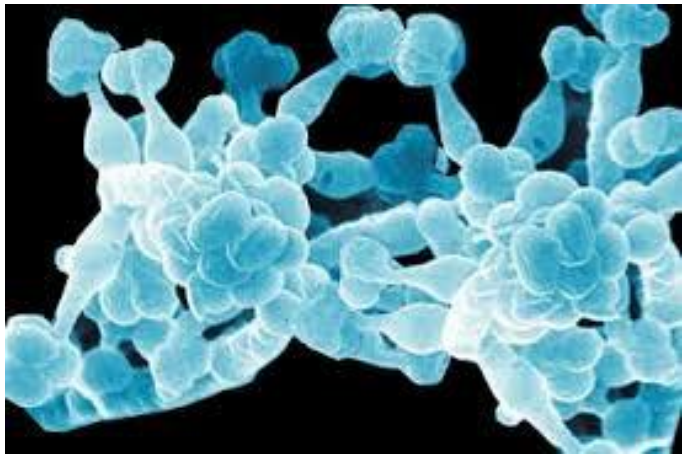
-New generations of fertilizers (precision, micro-dose, delayed release)

-Improve basic knowledge on Pi starvations:

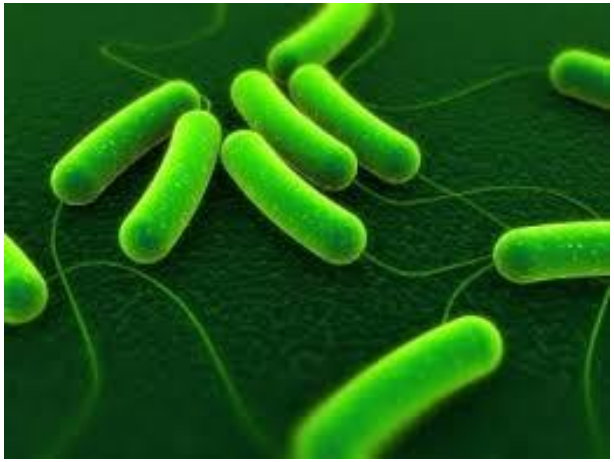
-Selection of crop tolerant to reduce Pi (request adapted field trial)

-Identify the genes behind the QTL

-Exploit biodiversity for Pi deficiency adaptation



-Microorganisms:



-Strong contribution of myccorhizae

-Interactions very difficult to control in field

-> Good application: Greenhouse