Phosphorus efflux from maize roots is highly localised to the root tip

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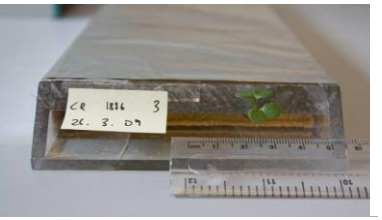
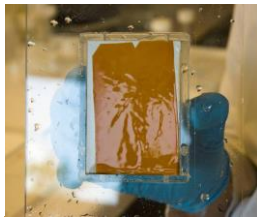
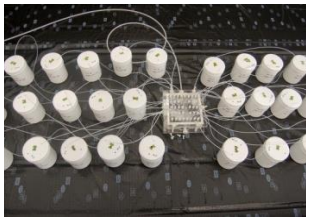
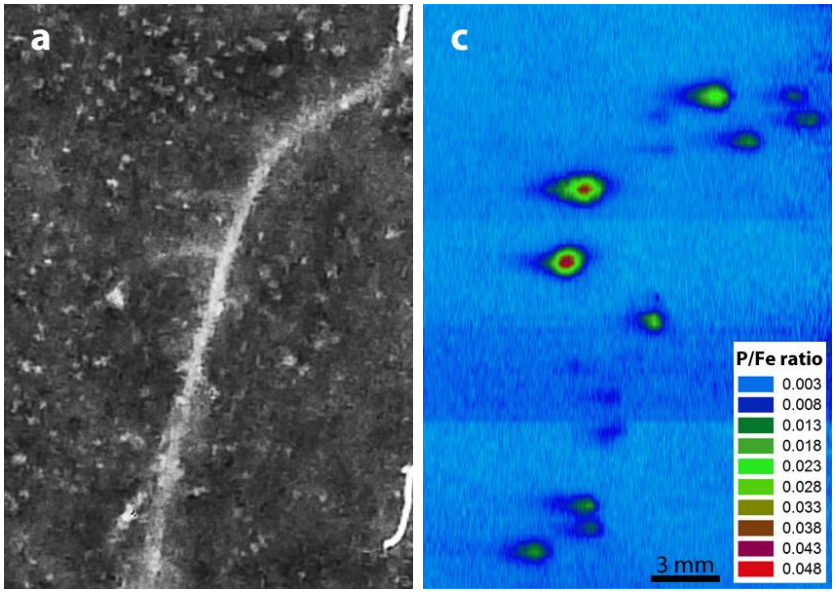
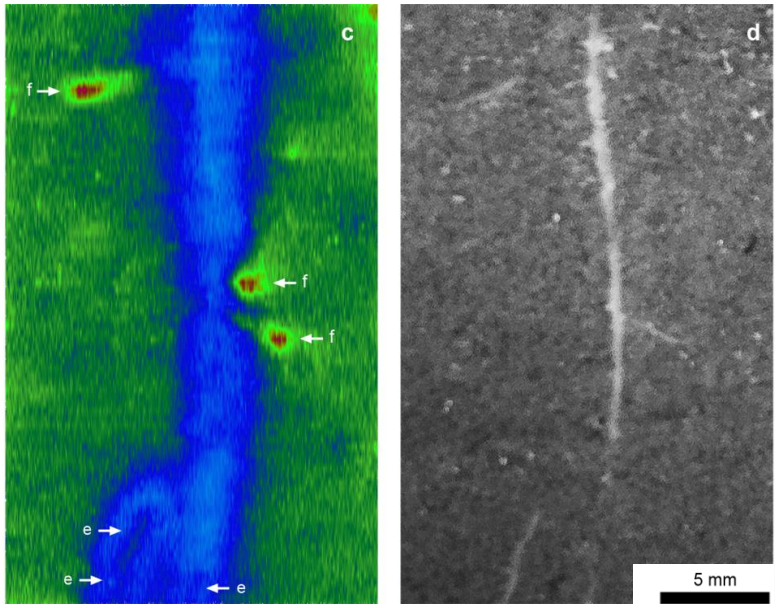





Phosphorus uptake & release in rapeseed and maize



Maize

Santner et al., unpublished.



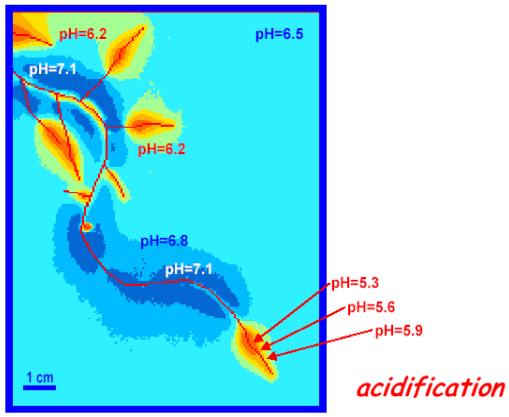
Rapeseed

Santner et al. 2012, Exp. Env. Bot.

What causes the P hotspots?

P released from soil by root exudates (H^+, carboxylates)?

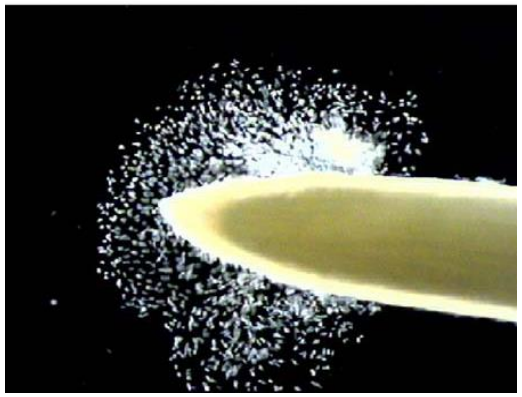
- Desorption from soil?
- Dissolution of PO_4 minerals?



Ruiz 1992 – PhD thesis

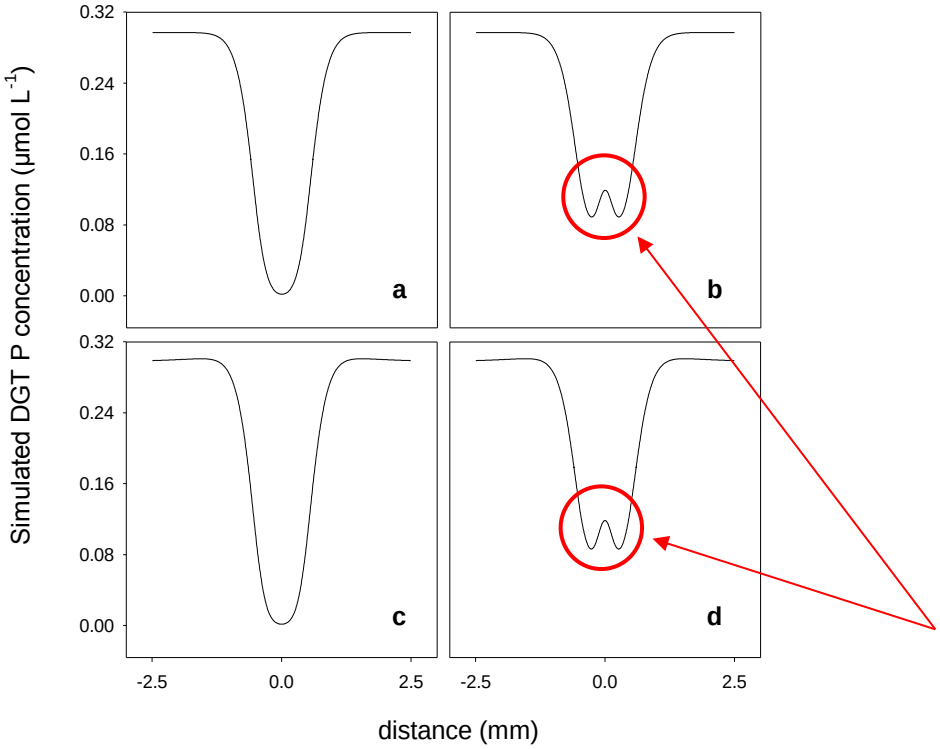
P released from directly from roots?

- Casparian strip permeable at root tip (Efflux)?
- Crushed root border cells?



Hinsinger et al. Plant & Soil 321, 2009

Numerical simulation points at efflux



Simulations:

a) No efflux, no citrate exudation

b) Efflux only

c) Citrate exudation only

d) Efflux & citrate exudation

Peaks caused by direct P release (efflux)

Santner et al. 2012, Exp. Env. Bot.

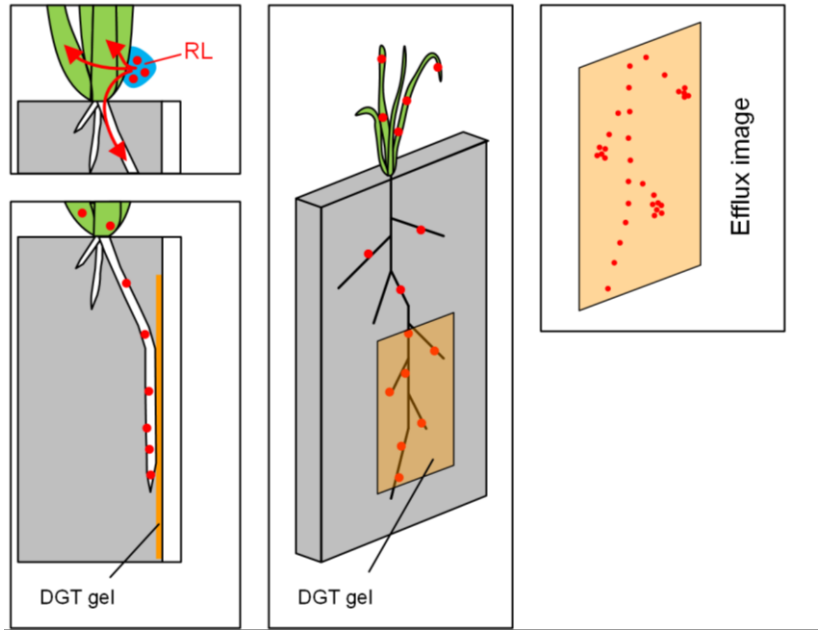
Question Do we see efflux?

Anything else?

Aim Image ^{33}P release from plant roots.

Methods

^{33}P labelling of plant shoot & Efflux imaging



(1) ^{33}P-containing droplet onto lesion (needle sting) on the coleoptile to radiolabel shoot P of maize.

(2) ^{33}P is redistributed via the phloem.

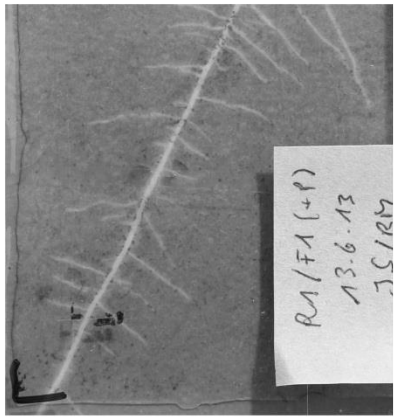
(3) Imaging of potential ^{33}P release from roots using the 'diffusive gradients in thin films' technique.

Results

Localisation of P efflux from maize roots

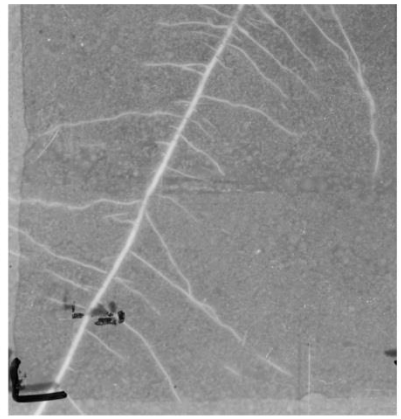
t_0

^{33}P label. & DGT app.



t_{48h}

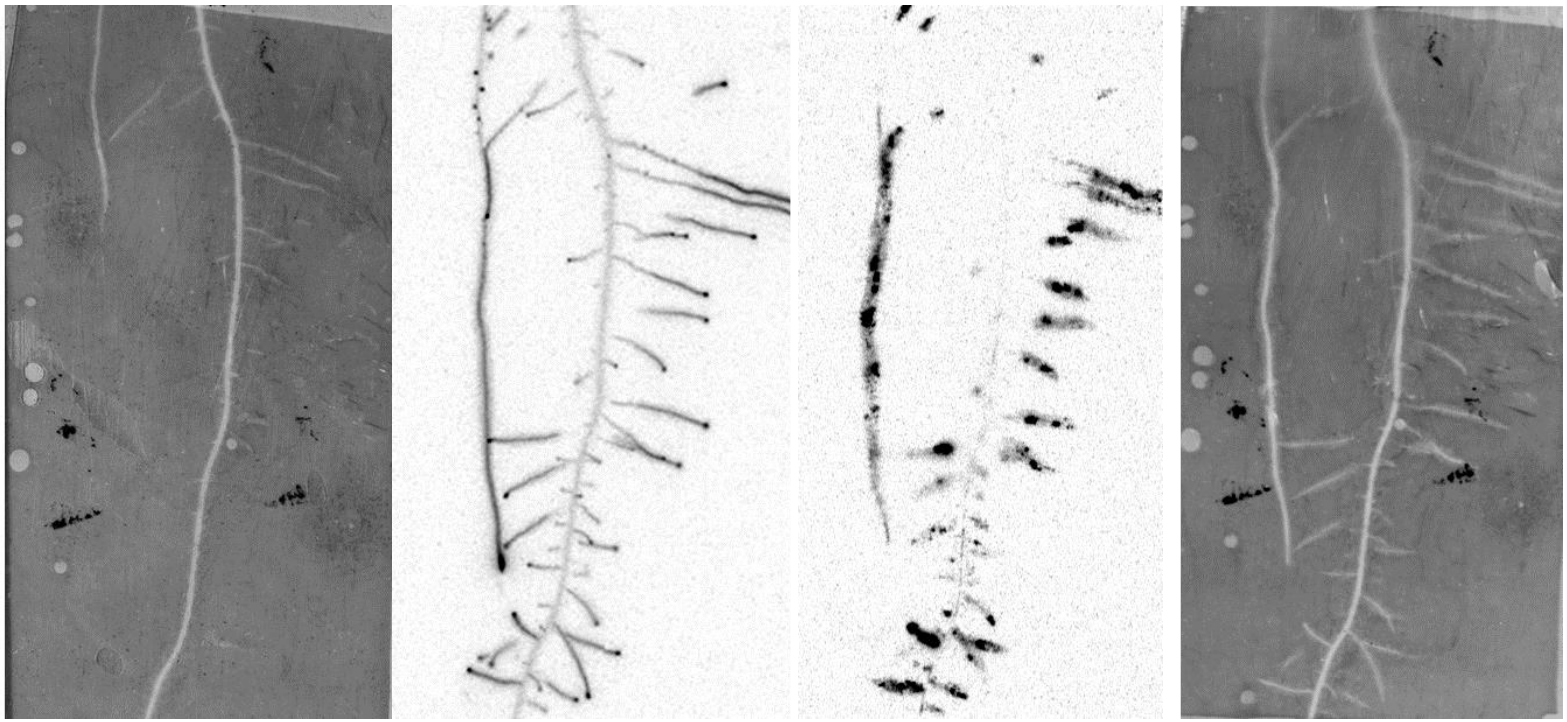
Note root growth!



Results

Localisation of P efflux from maize roots

t_0	t_{48h}	t_0-t_{48h}	t_{48h}
^{33}P label. & DGT app.	total ^{33}P in the root	^{33}P on the DGT gels	

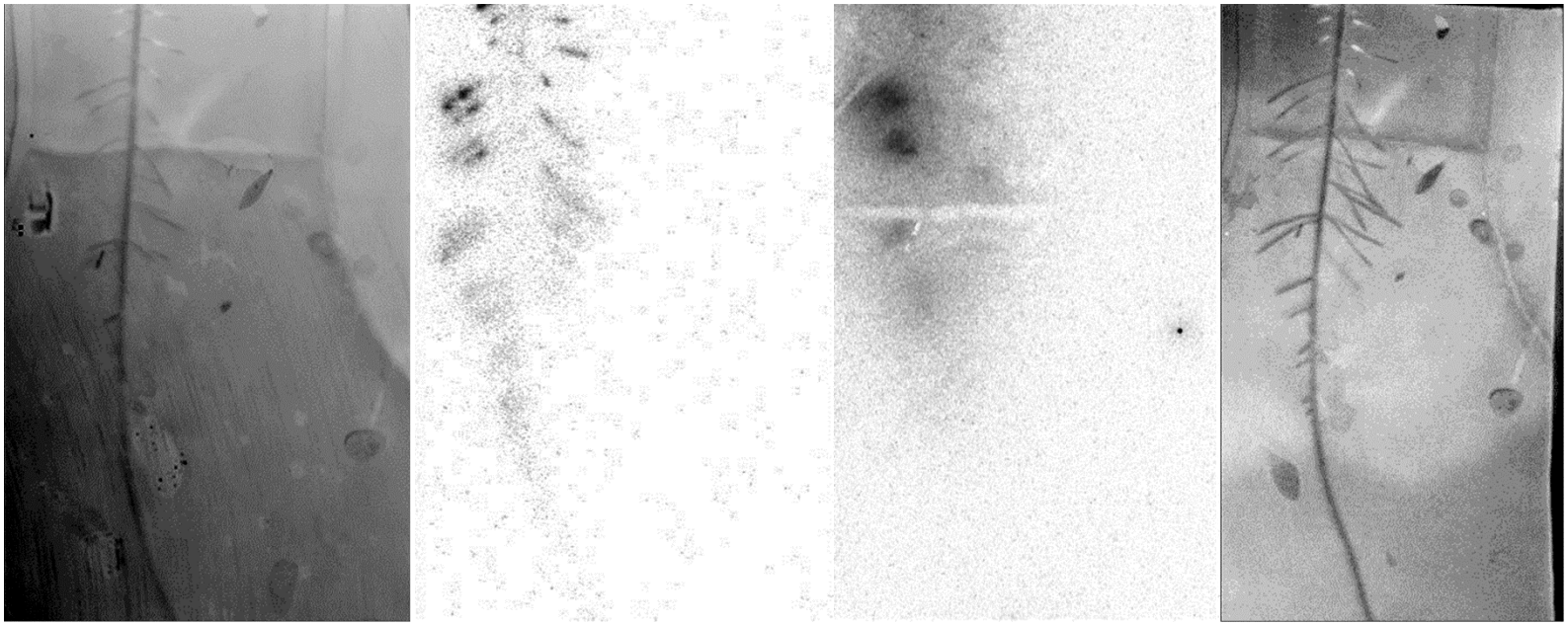


Results

Artefacts due to root injury?

Plant cultivation in agar medium to reduce risk of root injury.

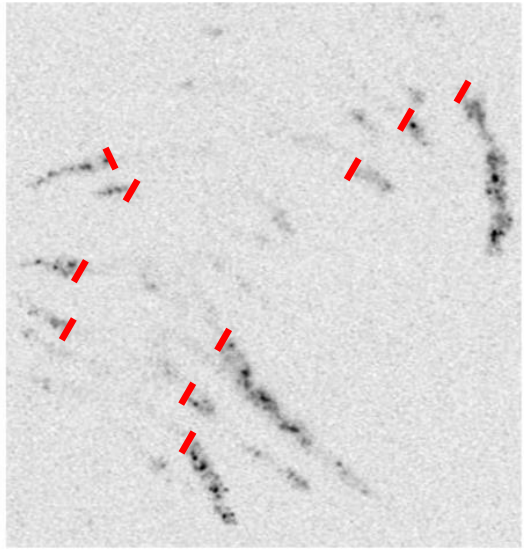
t_o	t_{48h}	t_o-t_{48h}	t_{48h}
^{33}P label. & DGT app.	total ^{33}P in the root	^{33}P on the DGT gels	



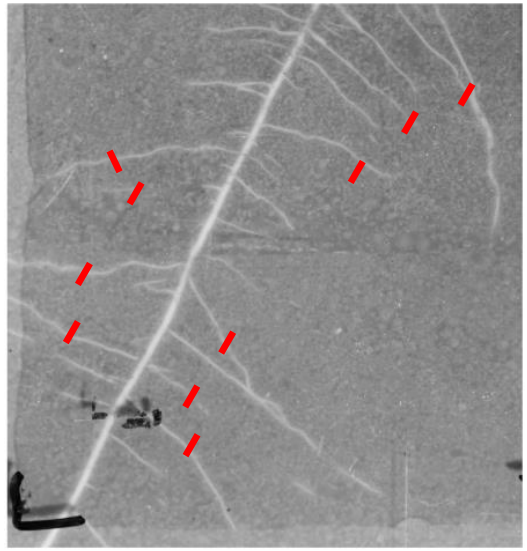
What's the size of the effluxing region?

Root growth: Efflux along newly grown area or confined to the very tip?

Start of Exp.



End of Exp. (48 h)



Almost all efflux from roots grown during sampling.

→ Indication for efflux from a very small area at the tip.

Discussion

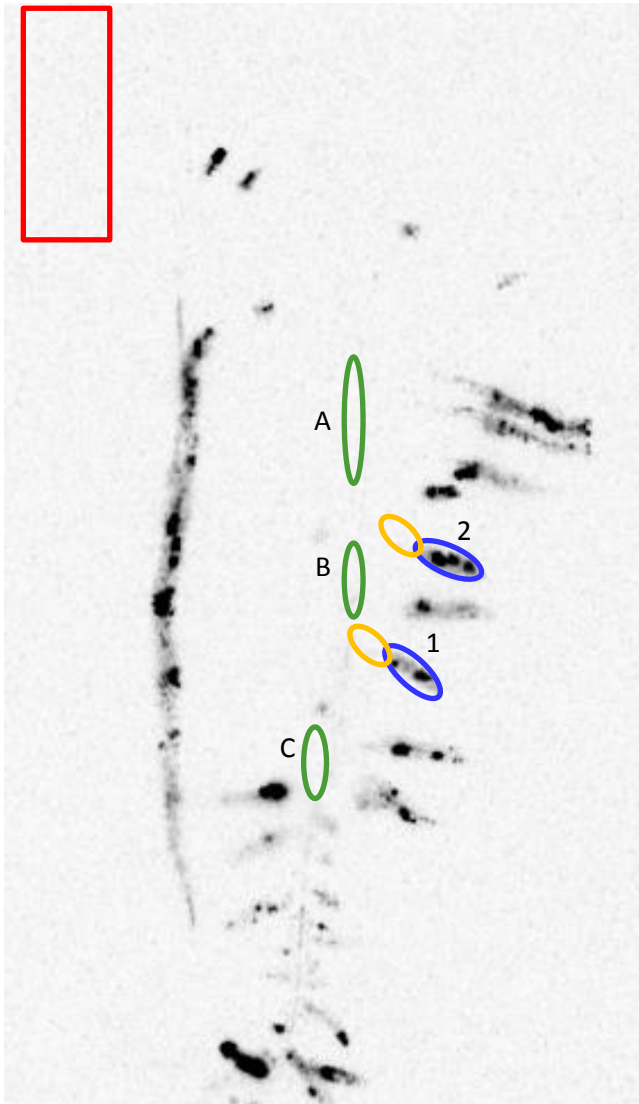
Ratio of tip efflux to efflux along axes

Measurement of ^{33}P efflux quantity in distinct image areas.

$$\frac{\text{efflux rate of root tip (cpm/cm}^2\text{)}}{\text{efflux rate of root axis (cpm/cm}^2\text{)}} \approx 300$$

Assumption: very small (1 mm²) effluxing root tip area

Virtually all P is effluxed at the tip areas!



Discussion — Consequences for Michealis-Menten uptake kinetics

- Efflux was assumed to be homogeneously distributed across the root surface.

  Classens & Barber 1974 Plant Phys.

$$I = \frac{I_{max}\, c}{K_m + c} - E \qquad I = \frac{I_{max}\,(c - c_{min})}{K_m + (c - c_{min})}$$

- P uptake (influx) along major parts of the root axis is well documented.

  Rubio et al. 2004 J. Exp. Bot., Rovira & Bowen 1968 Nature, …

- BUT: Efflux cannot be subtracted from influx if both processes are not co-localised.

Discussion — Consequences for Michealis-Menten uptake kinetics

- c_{min} much lower than assumed along the majority of absorbing root surfaces.

- Earlier work showed overestimation of K_m values due to diffusion-limitated supply to the sites of apoplastic uptake.

  (Santner et al. 2012, PCE; Degryse et al, 2012, Plant Phys.)

Further questions:

- **Roots practically zero-sinks for P?**
- **Are MM kinetics unnecessary?**
- **Is it more important to accurately model soil P supply for modelling plant P uptake?**

Thanks for your attention