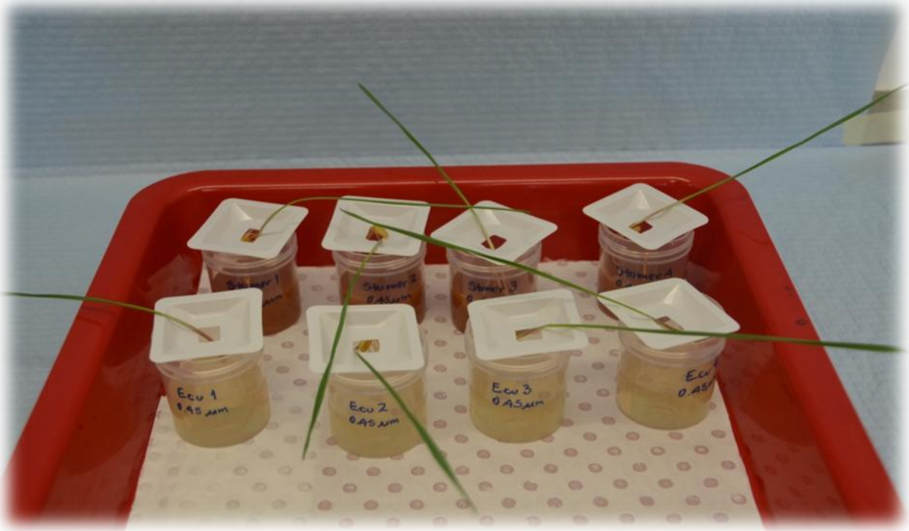
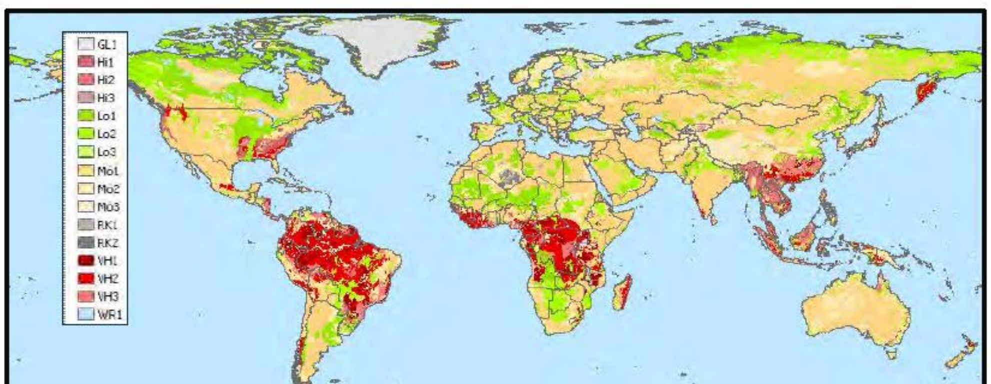


Colloidal phosphorus contributes to plant nutrition

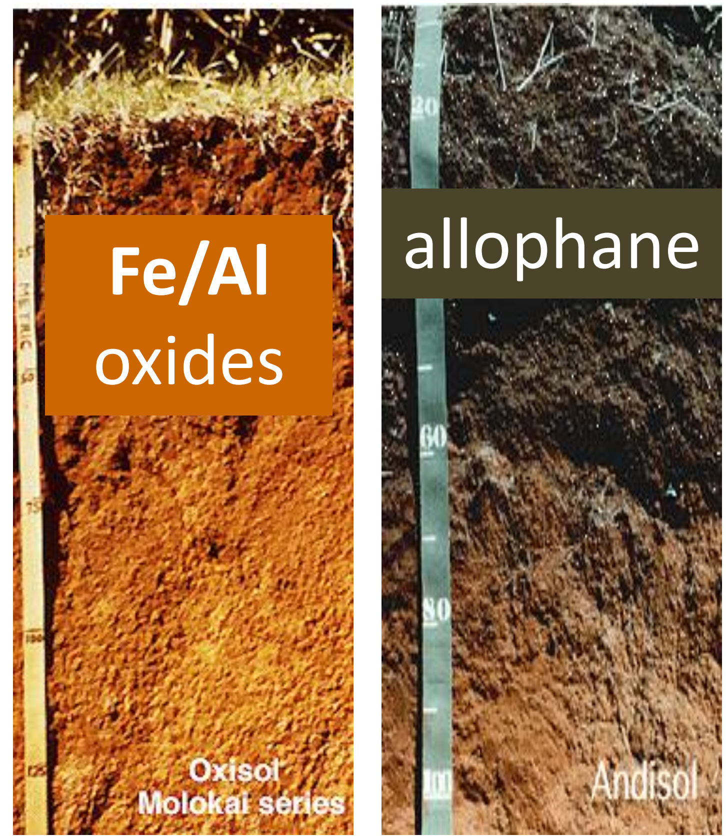
Daniela Montalvo, Fien Degryse, Mike McLaughlin

Andisols and Oxisols: highly P-sorbing soils

- P strongly bound to high P-sorbing minerals
- P unavailable to plants
- Highly P-sorbing soils mainly found in Africa, South America



(Batjes 2011)



(Uehara et al. 2001)

Phosphorus in soils

Plant uptake

Solid-phase (>90% of soil P)

Solution-phase (µM)

- $H_2PO_4^-$ HPO_4^{2-} (plant-available P)
- Mobile colloidal P complexes (P-Fe/Al/C of size range: 1-1000 nm)

Soil-solution phosphorus

- Bioavailability of soil-solution P related to:
  - concentration
  - speciation
- Membrane filtration (0.45 µm) operationally differentiates *“particulate”* and *“dissolved”* P
- Colloidal P < 0.45 µm has been reported
- Natural colloidal P may play a role in plant nutrition, yet has not been considered

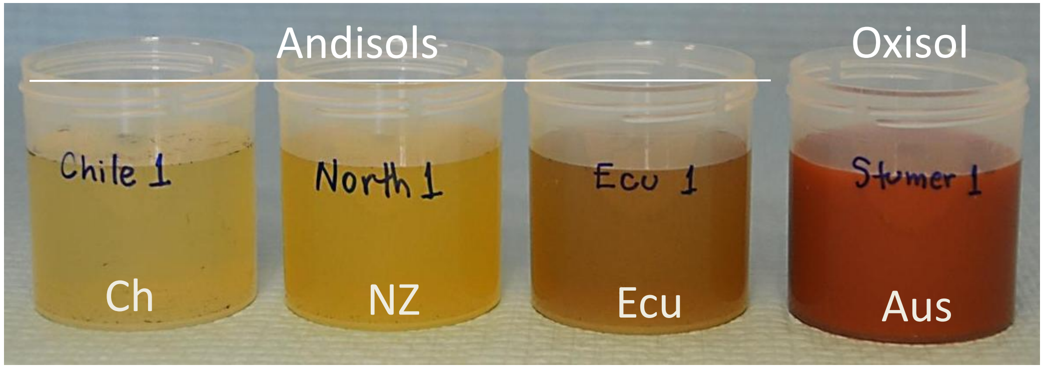
Research question

- Synthetic P-loaded Al_2O_3 nanoparticles used as mobile P buffer enhanced the uptake of P by *Brassica napus* with increasing P buffering at low free P concentration (Santner et al. 2012)
- Colloidal P can comprise a large amount of total solution P in Andisols and Oxisols

Is colloidal P from Andisols and Oxisols plant available?

Solutions for plant P uptake experiment

- 1:10 soil-water extracts from Andisols (3) & Oxisol (1) obtained by centrifugation
- Soil-solutions spiked with ^{33}P and equilibrated for 3 days
- Radiolabeled solutions divided in fractions:
  - Non-filtered (NF)
  - 0.45 µm
  - 3 kDa



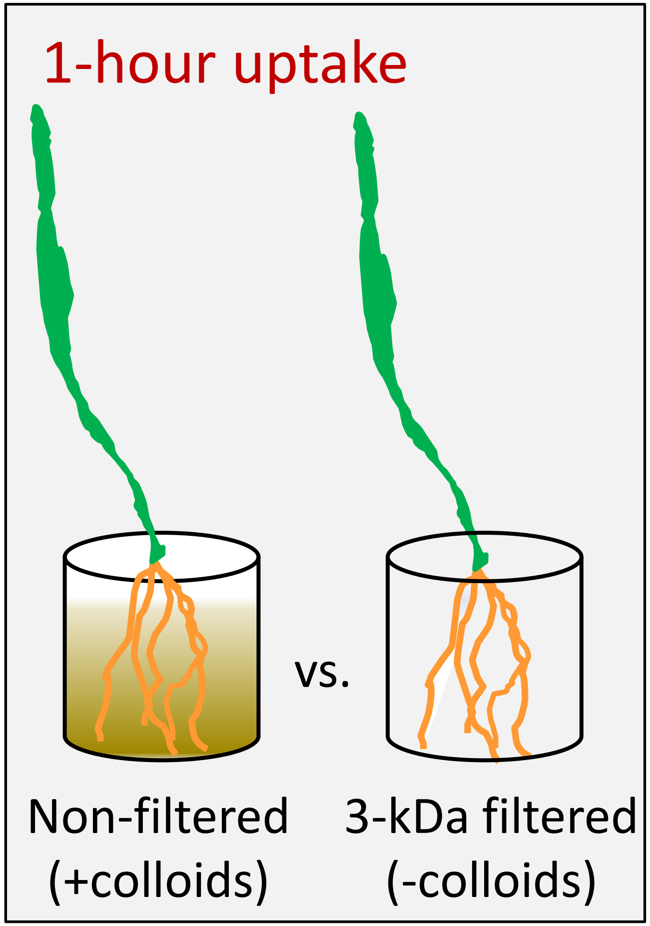
Colloidal P in the uptake solutions

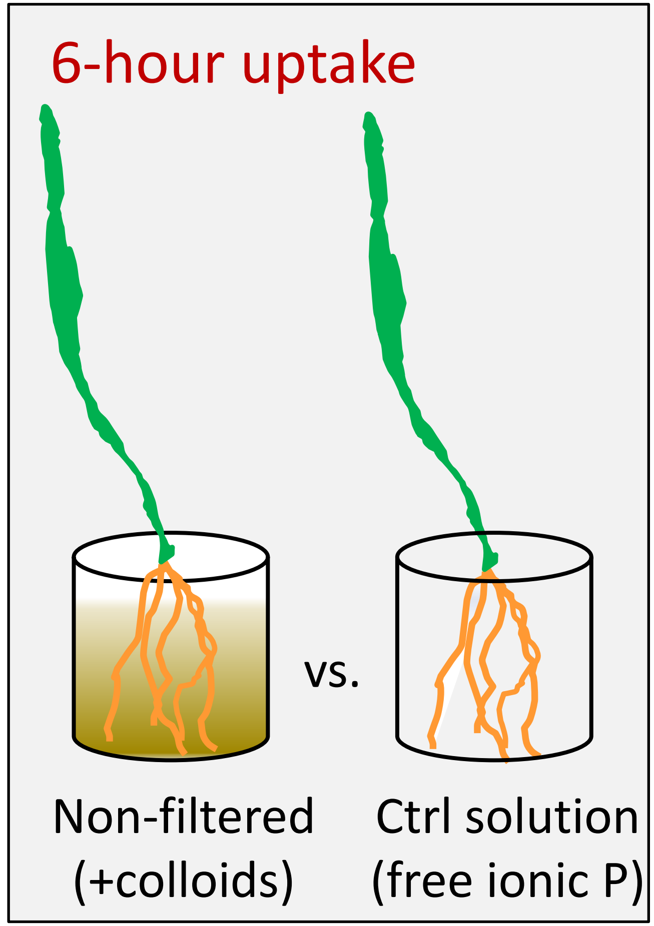
- P associated with Al/Fe
- Different nature of colloidal P between soil groups:

Molar ratio	Al:P	Fe:P
Andisols	16-34	2-7
Oxisol	165	60

- ^{33}P activities of soil-water extracts significantly decrease with filtering: NF >> 0.45 µm > 3 kDa
- Size range of colloids: Andisols 30-240 nm and Oxisols 10-60 nm (high speed disk centrifuge)

Short-term plant P uptake experiments



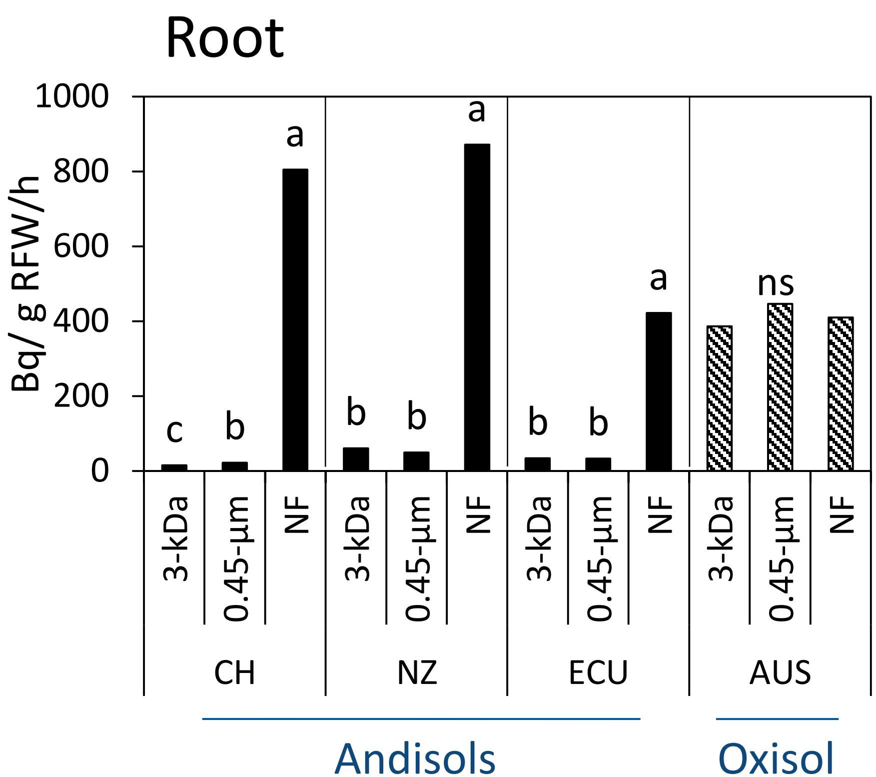


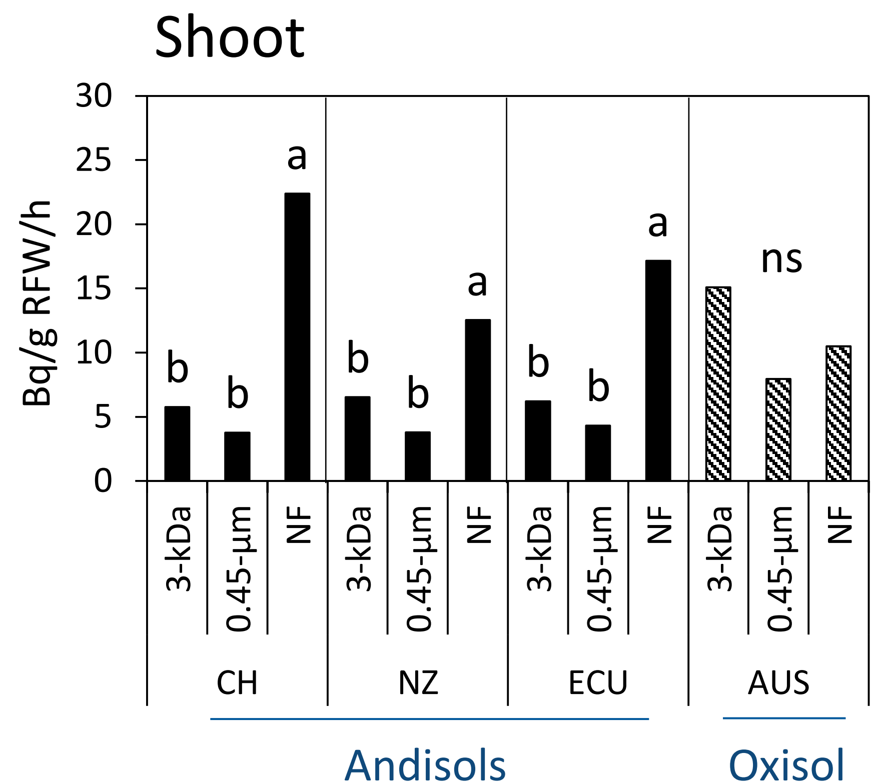
<u>Analysis</u>

- Shoot/root acid extracted
- ^{33}P activity measured in plant extracts and uptake solutions

Similar findings ⇒ only results of 1-hour uptake experiment discussed

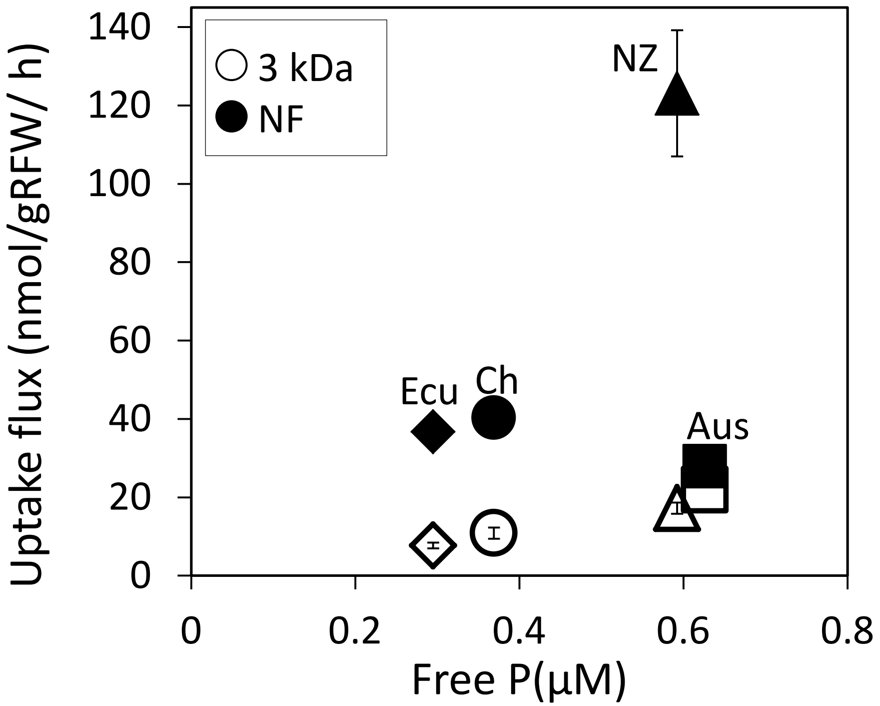
^{33}P activity in shoot and root

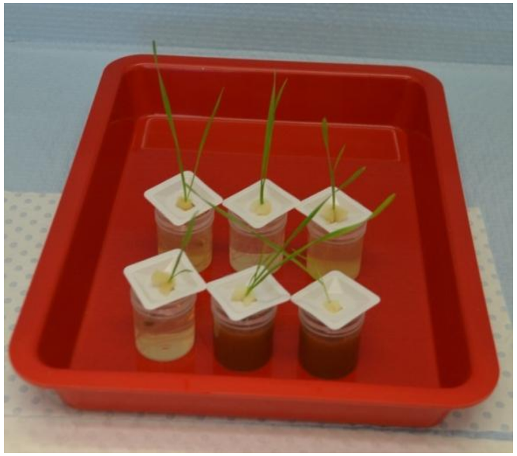




Significantly higher ^{33}P activity in shoots from plants exposed to NF solutions indicates true absorption followed by translocation

Uptake fluxes: non-filtered vs. 3-kDa filtered

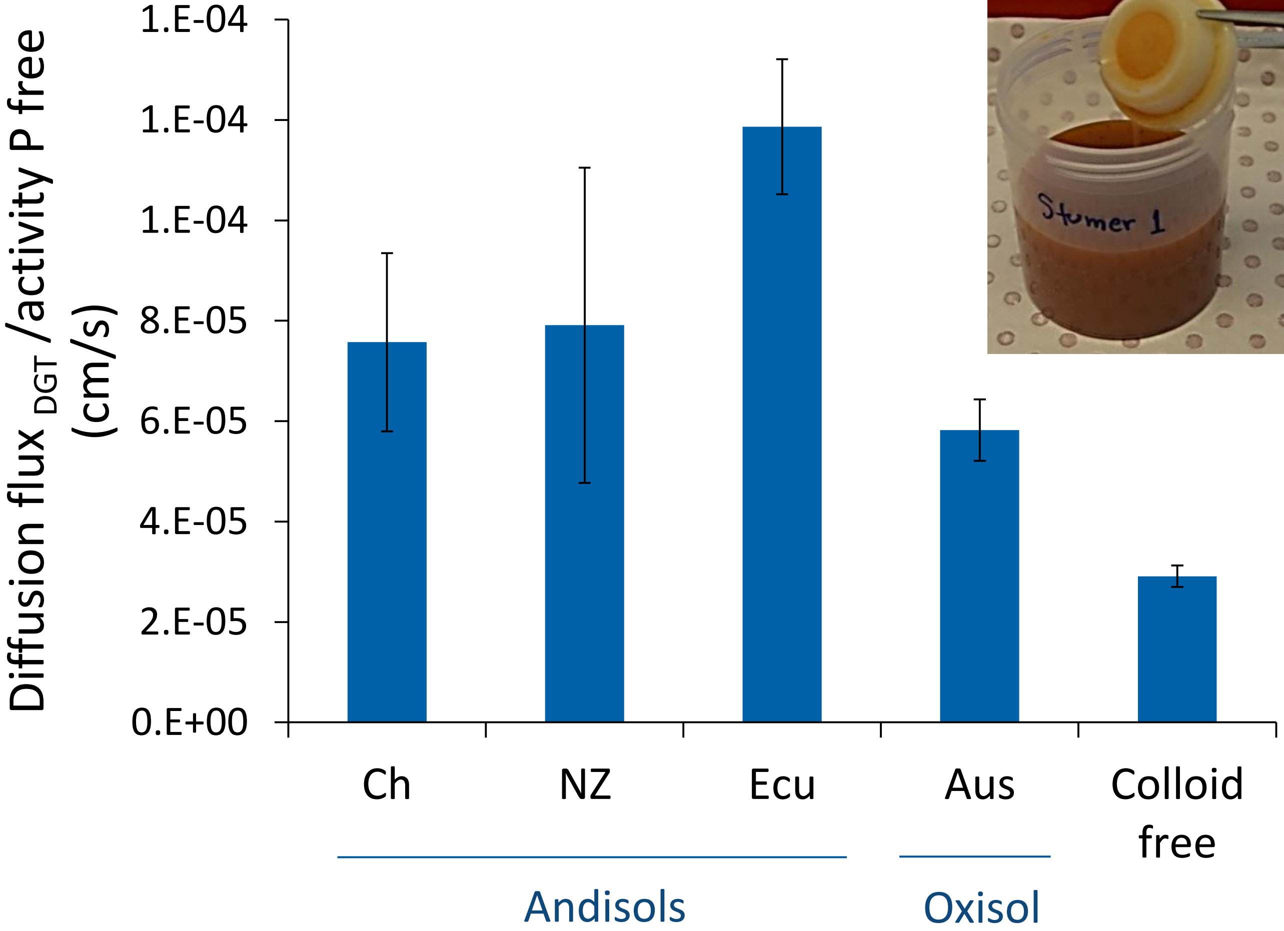


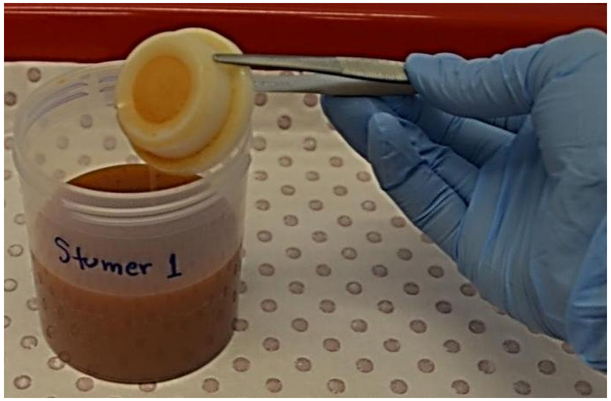


NZ	Solution P (µM)	Uptake flux (nmol/g/h)
NF	30	123
3 kDa	0.6	17
Ratio	50	7

- Uptake flux from NF solutions (Andisol) up to 7-fold higher than the 3 kDa filtered solution (at same free P concentration)

P diffusion fluxes with DGT measurement





Reasons for higher P uptake in NF solutions

- Direct uptake of colloids

Disk centrifuge data showed presence of small colloids

There is evidence in literature of root uptake of synthetic nanoparticles (20nm)

- Enhancement of P diffusive transport

Colloidal P act as mobile buffer of free ionic P

(DGT data support this)

Summary

- Colloidal P increased up to 7-fold the uptake flux in Andisols
- Contribution most likely through enhanced diffusion of the free P in presence of labile complexes, although direct uptake cannot be completely excluded
- Higher contribution of colloids for Andisols than for Oxisol likely related to the different nature of colloids: P in humic-Al/Fe-P complexes (P-species abundant in Andisols) probably more labile

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