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Soil organisms and phosphorus dynamics

1. essential
2. finite
3. detrimental

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Outline

Introduction:

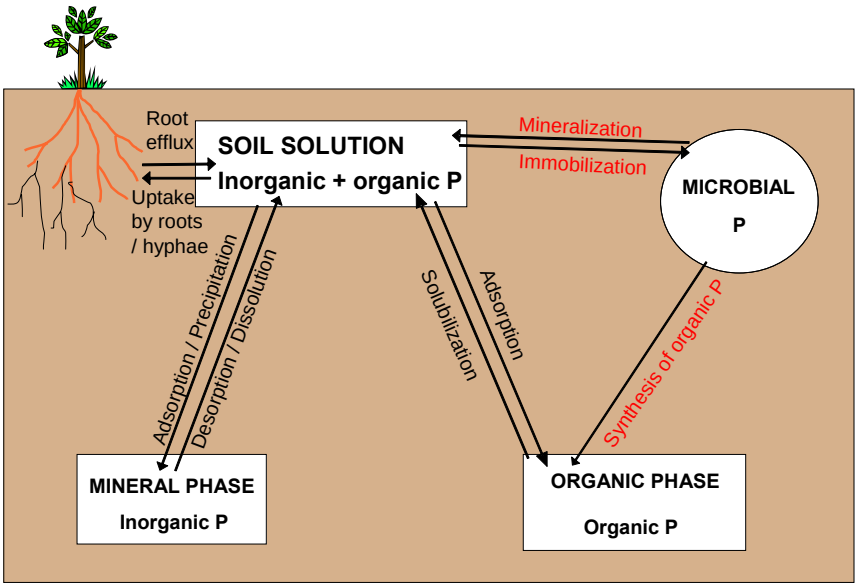
- Soil phosphorus dynamics:

  affected by soil (micro)organisms?

Selected topics:

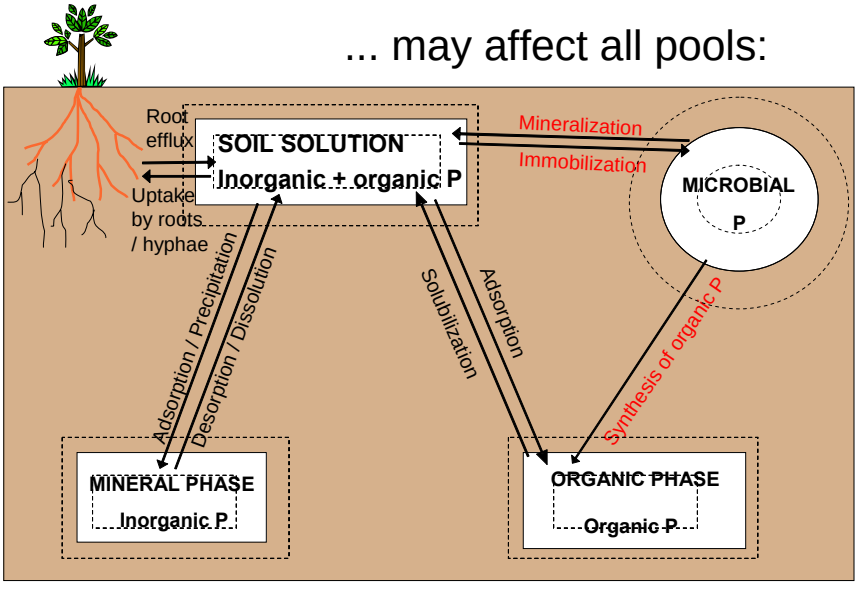
- Soil organic P: C-P relationship; origin
- Microbial P: away from the black box
- Role of flush effects: C-P relationships?

Soil P dynamics



Flush effects...

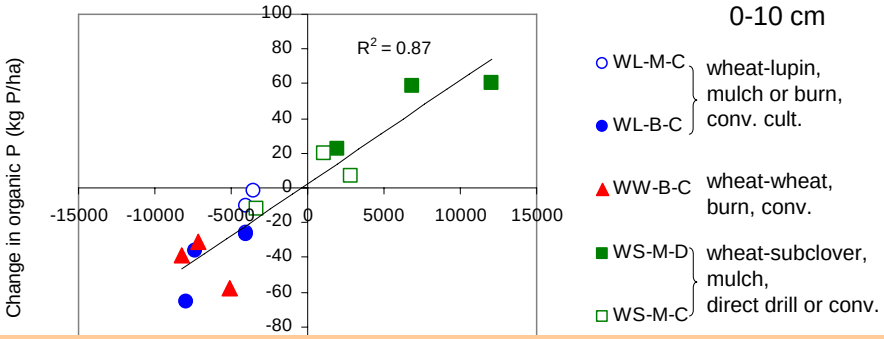
... may affect all pools:



Are changes in organic P related to changes in organic C?

- long-term field experiment in Wagga Wagga, NSW, since 1979
- Chromic Luvisol, pH 4.9, 29% clay, 15% silt
- different crop rotations, stubble management and tillage treatments
- annual addition of 20 kg P/ha to all treatments

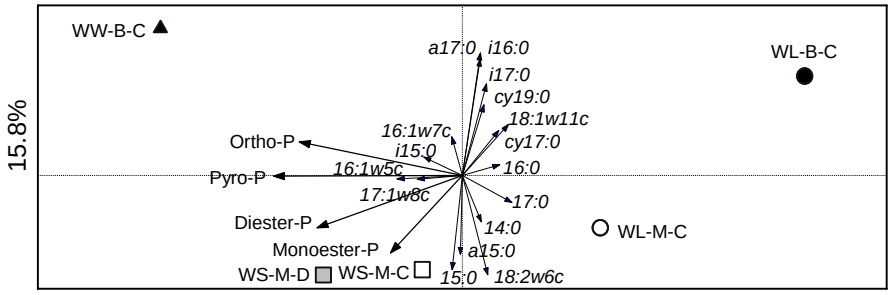
after 24 years; 0-10 cm



Changes in forms of soil organic P? (solution ^{31}P NMR spectroscopy)
=> Similar forms, but different amounts of organic P

Relationship between P forms and microbial community composition?

RDA with relative abundances of fatty acids; amount of P in NMR region as environmental variables:



- positive correlation between pyrophosphate and the fatty acids 16:1w5c and 17:1w8c

=> storage of P in condensed forms in microbial communities with large proportions of these fatty acids?

Bünemann et al. 2008 BFS 44:717-728

Origin of soil organic P ?

In Wagga trial:

- changes in organic P mainly in monoester region (phytate?)
- microbial P only 1.6-4.3 mg P kg^{-1}
- plant residue inputs: similar broad organic P forms as microbes

⇒ Incubation experiment: Repeated additions of C to increase microbial synthesis of soil organic P

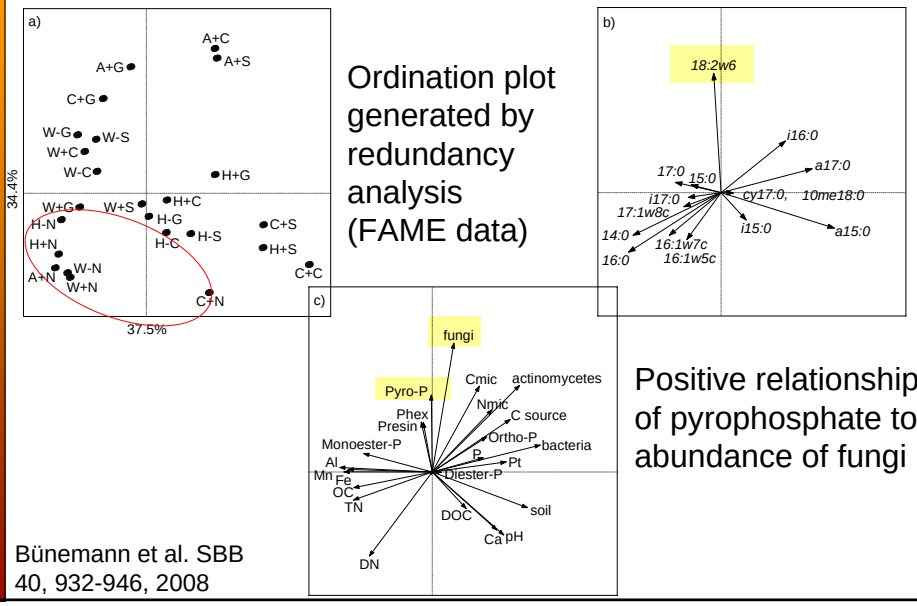
- 4 different soils (acid/calcareous)
- 4 C treatments (none, glucose, starch, cellulose @ 2.5 g C kg^{-1} soil)
- ± inorganic P @ 50 mg P kg^{-1} soil
- 5 amendments, each followed by 5 weeks incubation & leaching before re-amendment
- Analyses after 25 weeks

Changes in P pools

- without C and P addition: no changes during 25 weeks
- C addition decreased inorganic P and increased organic P
- accumulation of organic P: generally 16-48 mg P kg^{-1} soil, in one case 160 mg P kg^{-1} !
- largest increase in organic P generally after glucose addition
- microbially derived P forms similar to soil organic P forms

Bünemann et al. SBB 40, 932-946, 2008

Relationship between P forms and microbial community composition?



Ordination plot generated by redundancy analysis (FAME data)

Positive relationship of pyrophosphate to abundance of fungi

Bünemann et al. SBB 40, 932-946, 2008

Microbial P: Away from the black box

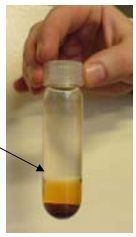
- Fumigation-extraction methods for microbial P: destruction of P species in microorganisms => black box
- Alternative: extraction of bacteria by density gradient centrifugation (Bakken and Lindahl, 1995) => speciation of microbial P forms

Before centrifugation:

Nycodenz is placed under the soil suspension

After centrifugation:

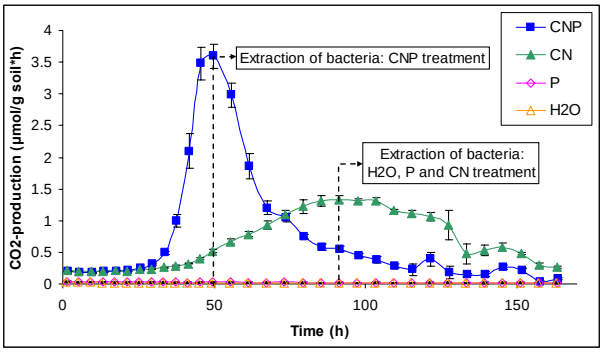
Bacteria are floating on top of the Nycodenz; soil particles form a pellet at the bottom



- Adaptation of the method to a tropical Ferralsol (low P availability, high P sorption): acceptable yield (5%) at sufficient purity and representativeness

Ehlers et al. SBB 40:1940-1946, 2008

Effect of microbial activity and P availability on cell-internal P pools

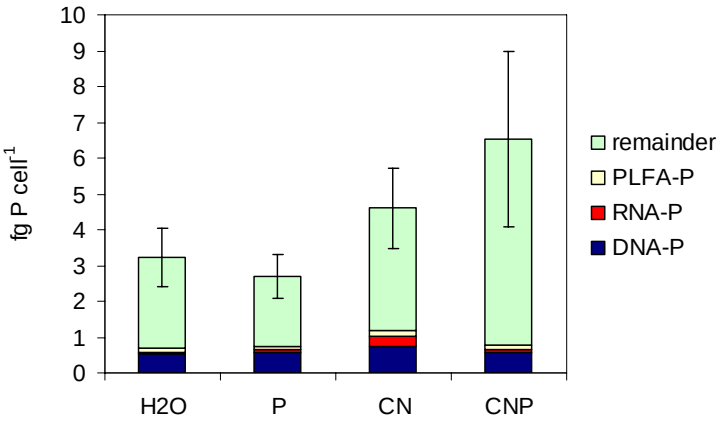


Factorial design with

1) addition of C and N (2.5 g C kg^{-1} and 0.5 g N kg^{-1})
2) addition of inorganic P (0.1 g P kg^{-1})

Ehlers et al. in preparation

Cell-internal P pools



- Carbon & nitrogen addition leads to higher P concentration per cell (presumably also larger cells)
- P addition has no effect
- a large proportion of P per cell still unexplained

Ehlers et al. in preparation

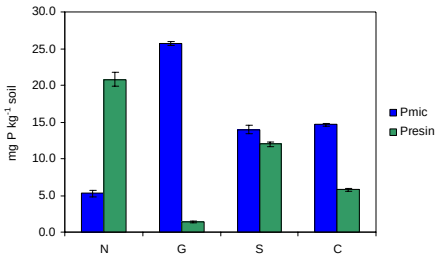
Role of flush effects

Drying and rewetting: known to induce flushes in CO_2 and available nutrients – what is the source?

- Experiment with repeated drying and rewetting:

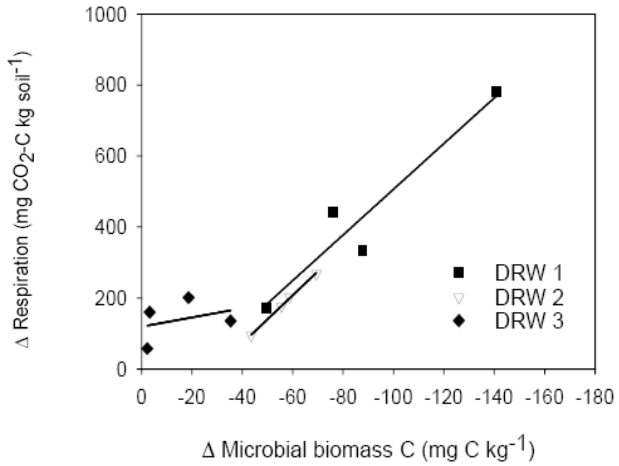
1 week drying down, 1 week moist (3x)

- Acid soil from Wagga, previously non-amended or amended with glucose, starch or cellulose



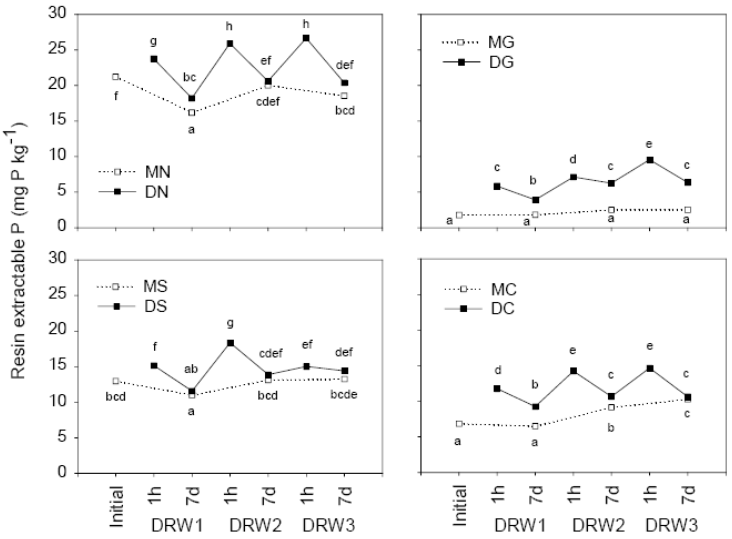
Butterly et al. SBB in revision

Source of the C flush



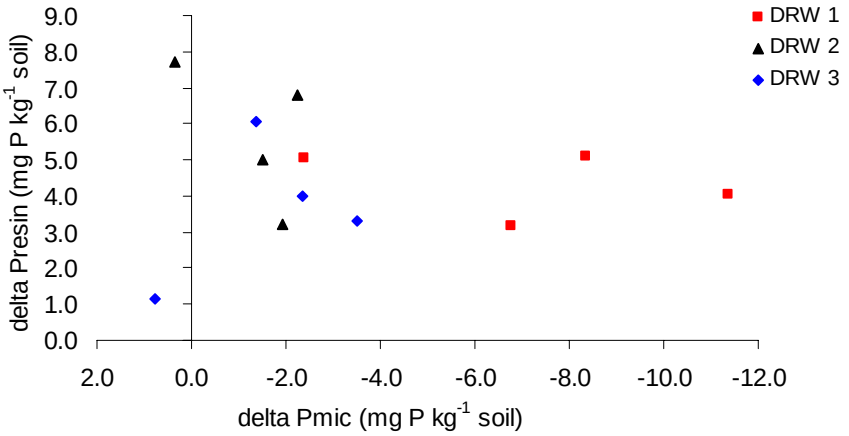
Butterly et al. SBB in revision

Available P



Butterly et al. SBB in revision

Source of the P flush?



- largest decrease in microbial P after first rewetting event
- largest P flushes at small changes in microbial P

=> microbial P is probably not the source of the P flush

Conclusions...

- Strong C-P relationships for soil organic P
- Soil organic P appears to be of microbial origin
- Substrate availability changes microbial P forms and concentrations per cell
- Drying and rewetting: flush effects for C primarily of microbial origin, but not for P

...and outlook:

- ➢ Role of phosphatase enzymes?
- ➢ Better proof and characterization needed
- ➢ Microbial P forms and plant availability
- ➢ Plant availability of P after flush effects