Phosphorus & soil biology

(bound together by chemistry)

DR CASSANDRA SCHEFE

SCHEFE CONSULTING & MONASH UNIVERSITY

Outline:

- Why is phosphorus (P) important?
- The P cycle in our soils
- Why is P availability an issue in our soils?
- Can soil biology increase P availability or ‘unlock’ P?
- Can we change it?
- What can we do?

Why is P important?

- P is necessary for all life
- It is a key ingredient in genetic molecules (DNA and RNA)
- Required for cellular energy production (ATP)
- Key component of cell membranes
- High P content in bones – early P source for fertiliser

- Required for plant growth – more productive plant species need more P to support increased biomass production

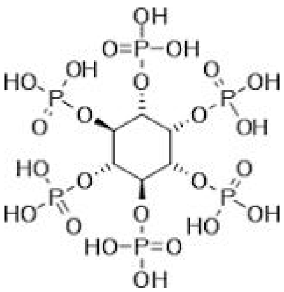
Key point: Australian soils are very old and weathered, and low in P

The P cycle - a love triangle at extreme pH

The key players:

Organic P

- P compounds containing carbon and oxygen
- Plant or microbial origin
- Cannot generally be taken up by plants
- Refers to chemical structure

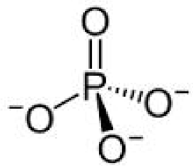


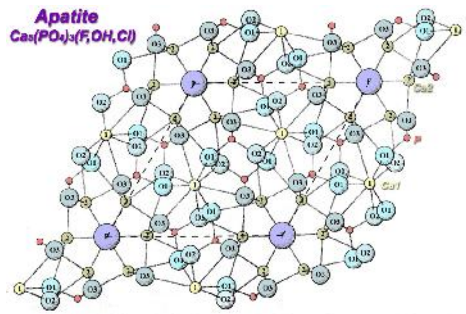
mineralisation

immobilisation

Inorganic P

- P compounds with no carbon
- Include plant-available and insoluble

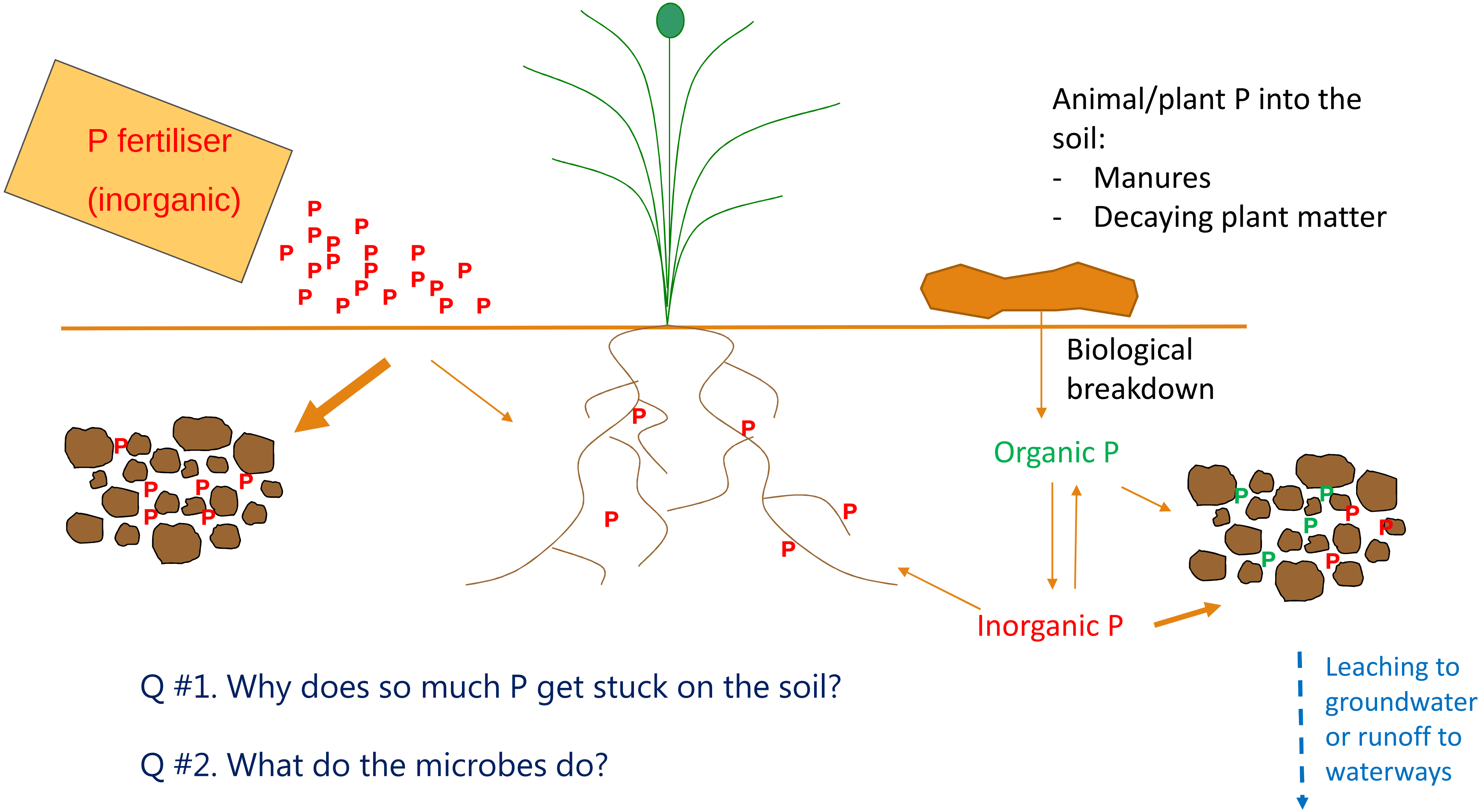




Adsorption/ precipitation

Acid soil/Calcareous alkaline soil

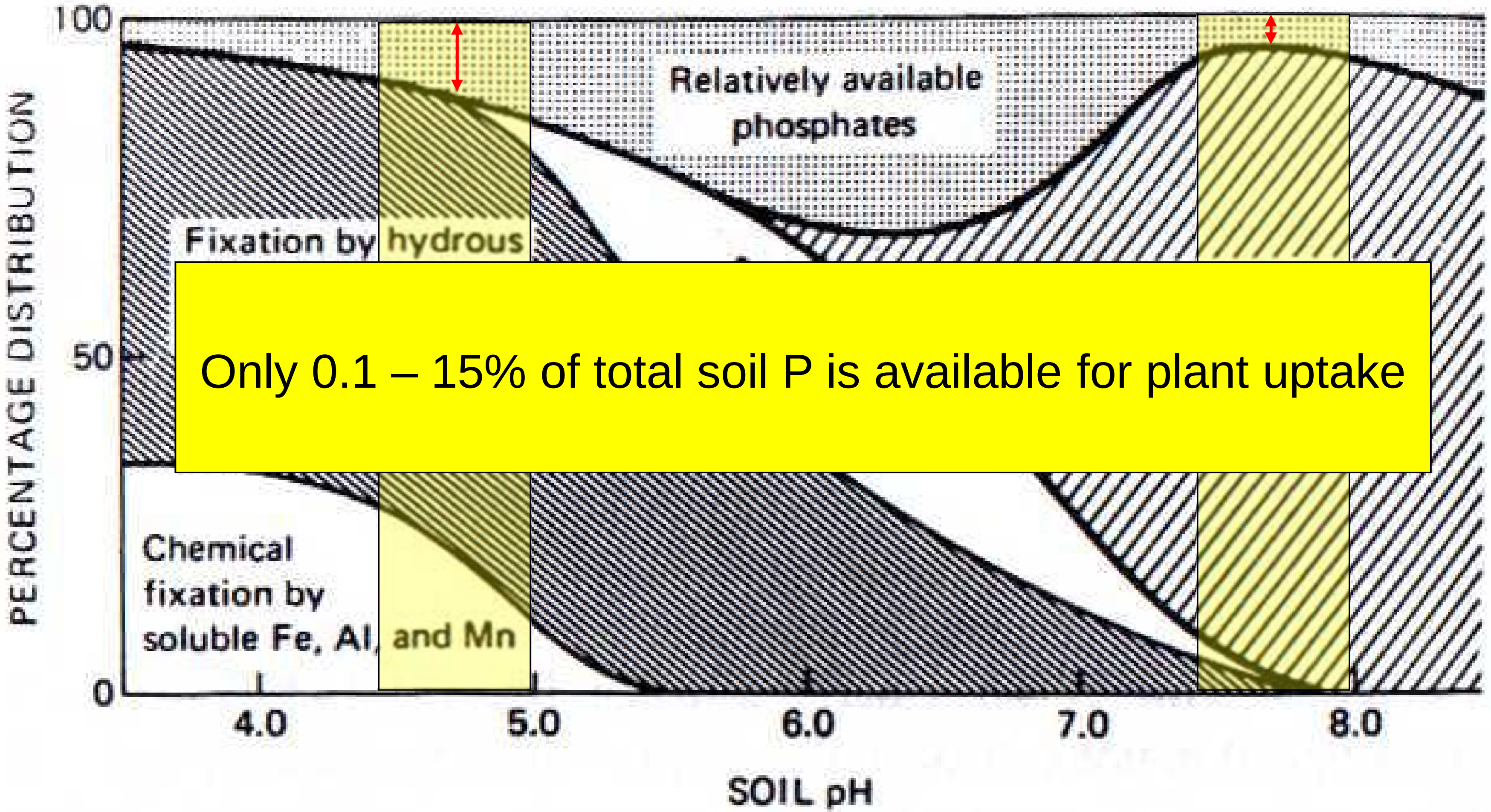
- **LOVES** P (inorganic and organic)
- Won't give it up easily



Q #1. Why does so much P get stuck on the soil?

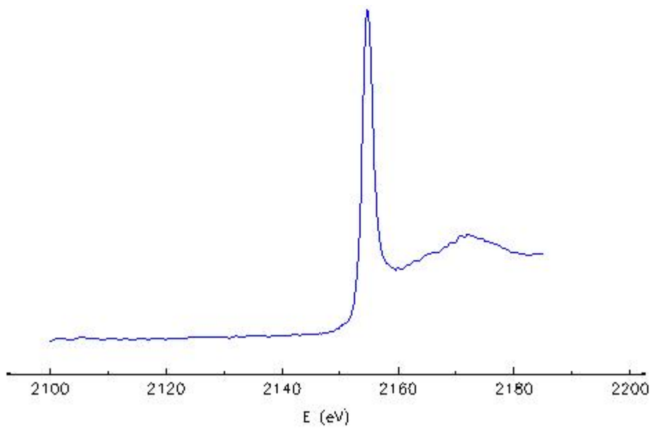
Q #2. What do the microbes do?

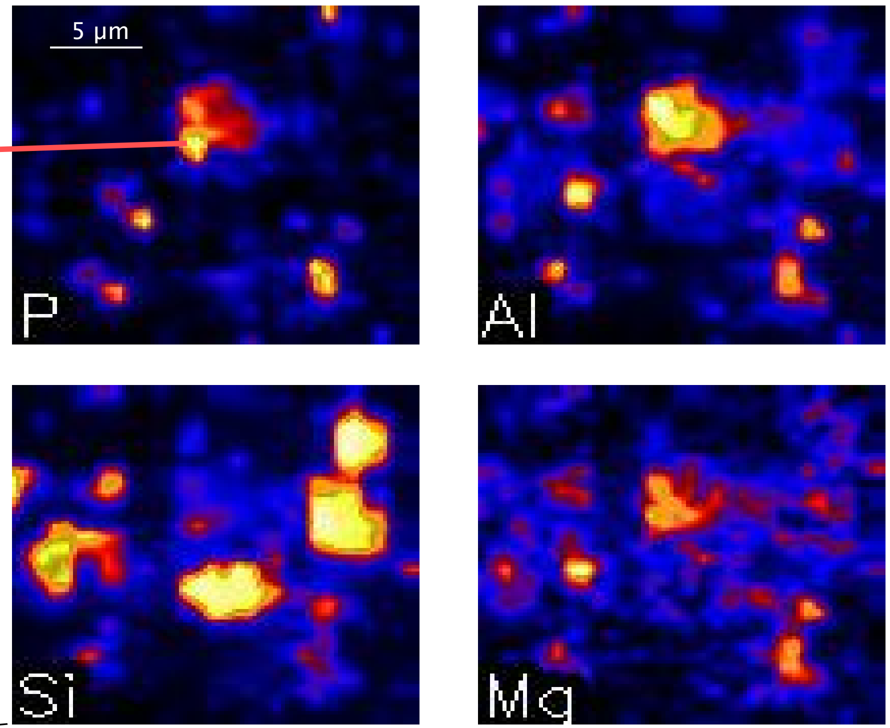
Q #3. What can we do to change it?

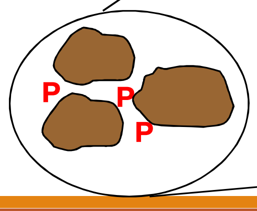


Only 0.1 – 15% of total soil P is available for plant uptake

Q #1. Exactly how does P get stuck in acid soil?







Schefe et al, (2011) *Soil Science Society of America Journal*

Q #2. What do the microbes do?

- A range of P-related microorganisms (microbes) are present in soil

Breakdown of large organic matter/manure

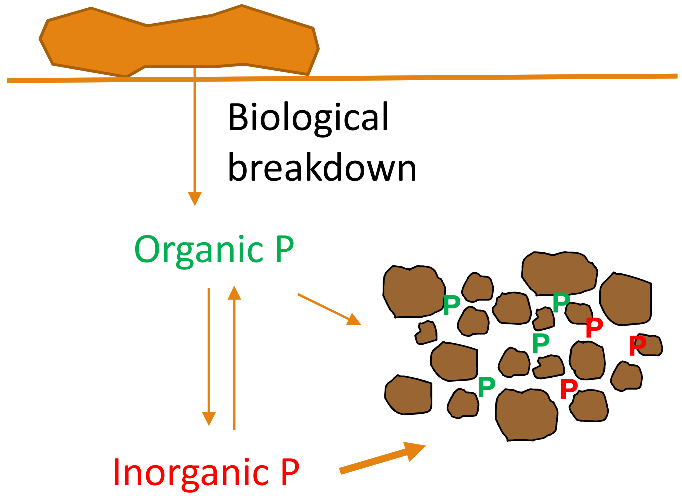
Cellulases

Organic P

Phosphatases

Inorganic P

Immobisation (microbes eat P to balance their diet – P stored within microbial biomass, available for slow release)



Q. Is P-release related to a specific microbial group?

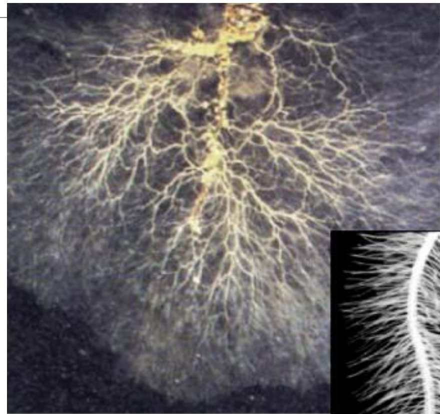
Biodiversity of Phosphate solubilising microorganisms

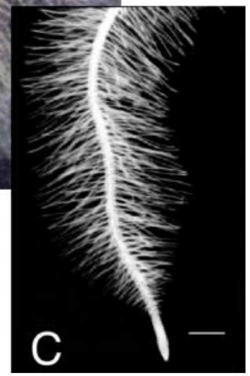
Bacteria	*Alcaligenes sp., Aerobactor aerogenes, Achromobacter sp., Actinomadura oligospora, Agrobacterium sp., Azospirillum brasilense, Bacillus sp., Bacillus circulans, B.cereus, B.fusiformis, B. pumils, B. megaterium, B. mycoides, B. polymyxa, B. coagulans B,chitinolyticus, B. subtilis, Bradyrhizobium sp., Brevibacterium sp., Citrobacter sp., Pseudomonas sp., P putida, P. striata, P. fluorescens, P. calcis, Flavobacterium sp., Nitrosomonas sp., Erwinia sp., Micrococcus sp., Escherichia intermedia, Enterobacter asburiae, Serratia phosphoticum, Nitrobacter sp., Thiobacillus ferroxidans, T. thioxidans, Rhizobium meliloti, Xanthomonas sp.*
Fungi	*Aspergillus awamori, A. niger, A. tereus, A. flavus, A. nidulans, A. foetidus, A. wentii. Fusarium oxysporum, Alternaria teneius, Achrothcium sp. Penicillium digitatum, P lilacinium, P balaji, P. funicolosum, Cephalosporium sp. Cladosprium sp., Curvularia lunata, Cunnighamella, Candida sp., Chaetomium globosum, Humicola inslens, Humicola lanuginosa, Helminthosporium sp., Paecilomyces fusisporous, Pythium sp., Phoma sp., Populospora mytilina, Myrothecium roridum, Morteirella sp., Micromonospora sp., Oideodendron sp., Rhizoctonia solani, Rhizopus sp., Mucor sp., Trichoderma viridae, Torula thermophila, Schwanniomyces occidentalis, Sclerotium rolfsii.*
Actinomycetes	*Actinomyces,, Streptomyces.*
Cyanobacteria	*Anabena sp., Calothrix braunii, Nostoc sp., Scytonema sp.,*
VAM	*Glomus fasciculatum.*

Sharma et al. SpringerPlus 2013, 2:587

Q #2. What *else* do the microbes do?

- Increase root growth through:
  - Extending P exploration through mycorrhizal association (VAM fungi), *or*
  - Hormonal stimulation of root growth, branching or root hair development
- Change P balance in soil through microbial consumption/storage of P in microbial biomass – diffusion of orthophosphate from soil surfaces
  - Microbial biomass is a sink for plant-available P, for slow release
  - Turnover of P in microbial biomass could be 10 – 42 days
- Directly solubilising and mineralising P from sparingly soluble forms of soil P
  - **from inorganic P forms** via organic acids and other complexing/mineral-dissolving compounds
  - **From organic P forms** via extracellular *phosphatase* enzymes (also produced by plant roots)





Zhang *et al* (2003)
J Exp Botany

Q #3. What can we do to change it?

Evaluation of the performance of *Penicillium bilaii* inoculant on wheat crops across 47 field experiments:

> *"No consistent benefit in terms of plant P nutrition and found no relationship between growth responses and any soil or environmental parameters, despite most trials being responsive to P addition"*
>
> (Reported in Richardson & Simpson, 2011)

- Adding inoculants has not ***consistently*** shown benefit in dynamic, competitive soil systems which have an existing microbial community.
  - They can't compete with the native microbial community's homeground advantage
- While microbes may solubilise/release P for their own dietary needs, subsequent benefits to plants may only occur following turnover of the microbial biomass.

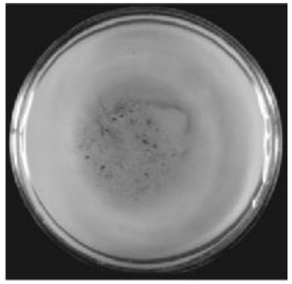
Q #3. What *else* can we do to change it?

- Existing microbial populations have flourished in that soil because of their *fit* with the soil chemical and physical properties.
- Microbial activity and community composition is also driven by interaction with various plant- and microbially-derived signal molecules and other regulatory compounds.
  - It's not all about P!
- Microbes may also be limited in their P-related functions due to lack of nutrients/pathogens/seasonal conditions/….. **Most limiting factor**….

So now what do we do?

If you build it, they will come

- The ability of microbes to release P is dependent upon:
  - Soil pH
  - Soil temperature
  - Soil moisture
  - Salinity
  - Source of insoluble P (inorganic acidic/alkali, organic forms)
  - Energy source (Maintaining organic C levels)
  - Balancing nutrients (Maintaining N content under high stubble loadings etc)



- Work on the big things which may be ‘most-limiting’ in the soil system first
  - Acid soils
  - Sodic/dispersive soils
  - Dominance of weeds/development of a productive pasture with vigorous roots

The microbes will thank you!

So how does the love story end?

- Not speed dating!
  - Plant-available P is only *slowly available* in highly acidic or alkaline soils
- Full service date - Dinner AND flowers needed!
  - Focus energy into managing the ***macro*** inputs at the farm scale, ensure good groundcover, balance nutrient requirements, apply lime or gypsum if required
  - The **micro** scale residents will flourish and work for you
- Balanced diet of wine and chocolate
  - Productive agricultural systems need P inputs (fertilisers or organic materials) to replace P removed by product (wool, meat, hay, grain)
- It’s not all about you!
  - Many microbes may contribute to increasing the pool of plant-available P.
  - These same microbes may also fulfil other roles in the soil system

Thank you

For more information:

Dr Cassandra Schefe
Schefe Consulting

cassandra.schefe@gmail.com

0419 238 798