



Why Do We Still Sprinkle Salts on the Soil: Phosphorus?

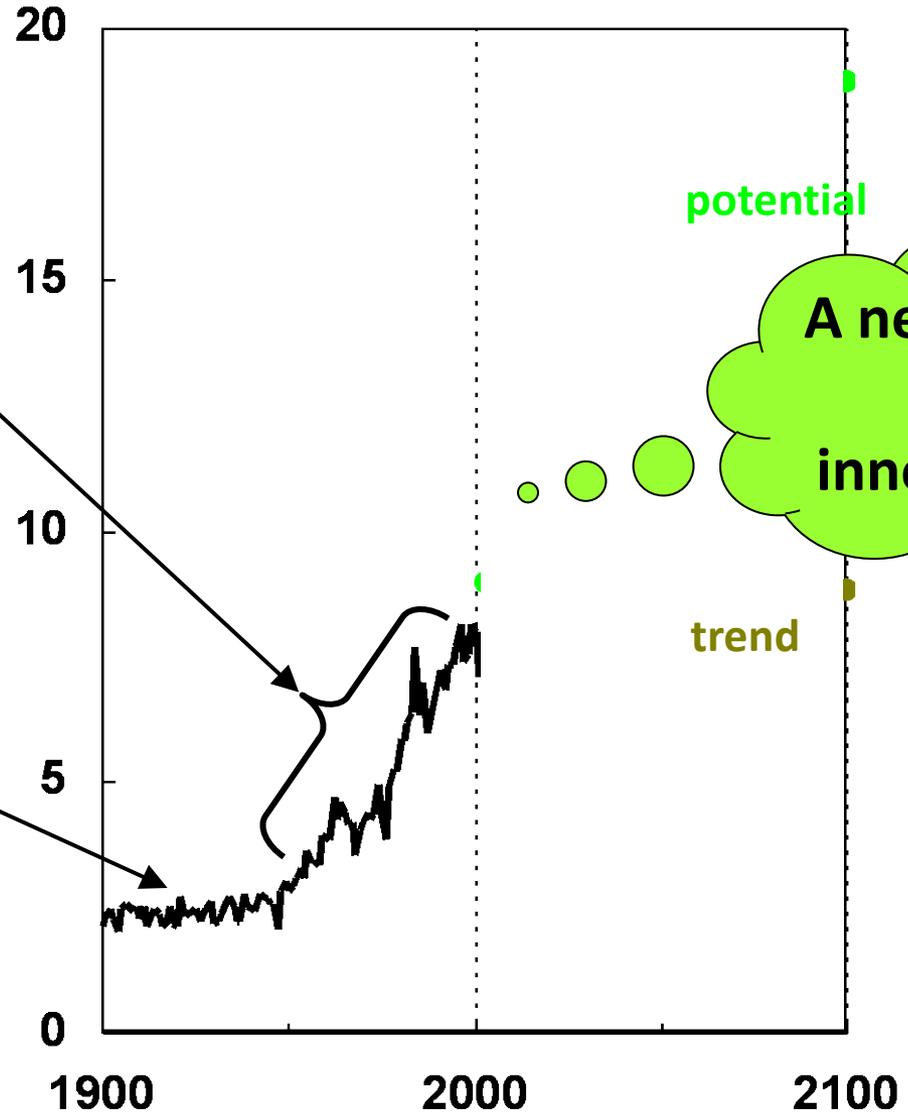
Paul Withers, Roger-Sylvester-Bradley,
Tony Edwards and Davey Jones



UK Wheat Yields - t/ha

price support
grants for land drainage,
liming, hedge removal
gov't support for research
& technology
hormone herbicides
myxomatosis
N P K fertilisers
fungicides
plant breeding

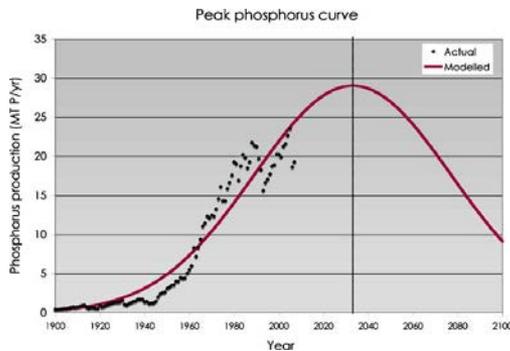
low prices
low gov't support
mechanisation



Why do we need to change?



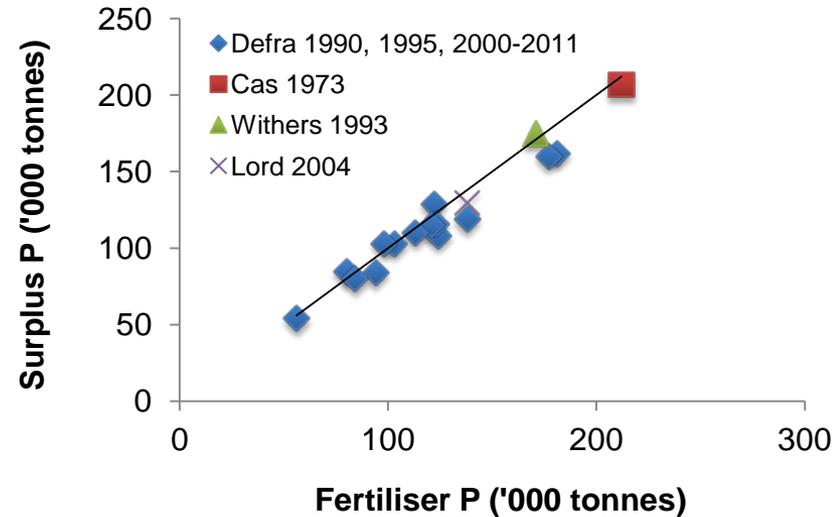
- Rising energy costs of fertiliser manufacture



- Depletion of natural resources



- Environmental pollution and threats to human health

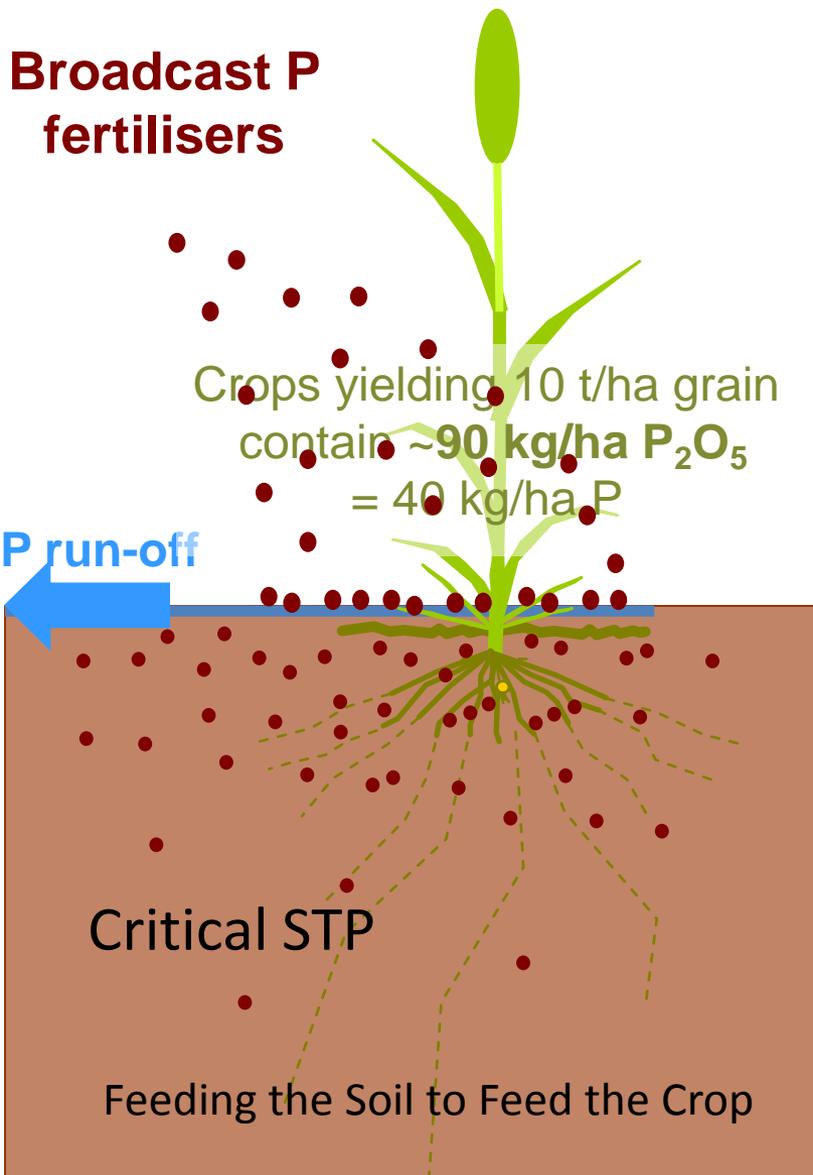


There is too much P (or too little)

How can we reduce reliance on fertiliser P imports?

Can the efficiency of fertiliser P use be substantially improved?

Whats Wrong with the Current System?



Crop roots utilise only a small proportion of the soil volume leading to poor nutrient capture

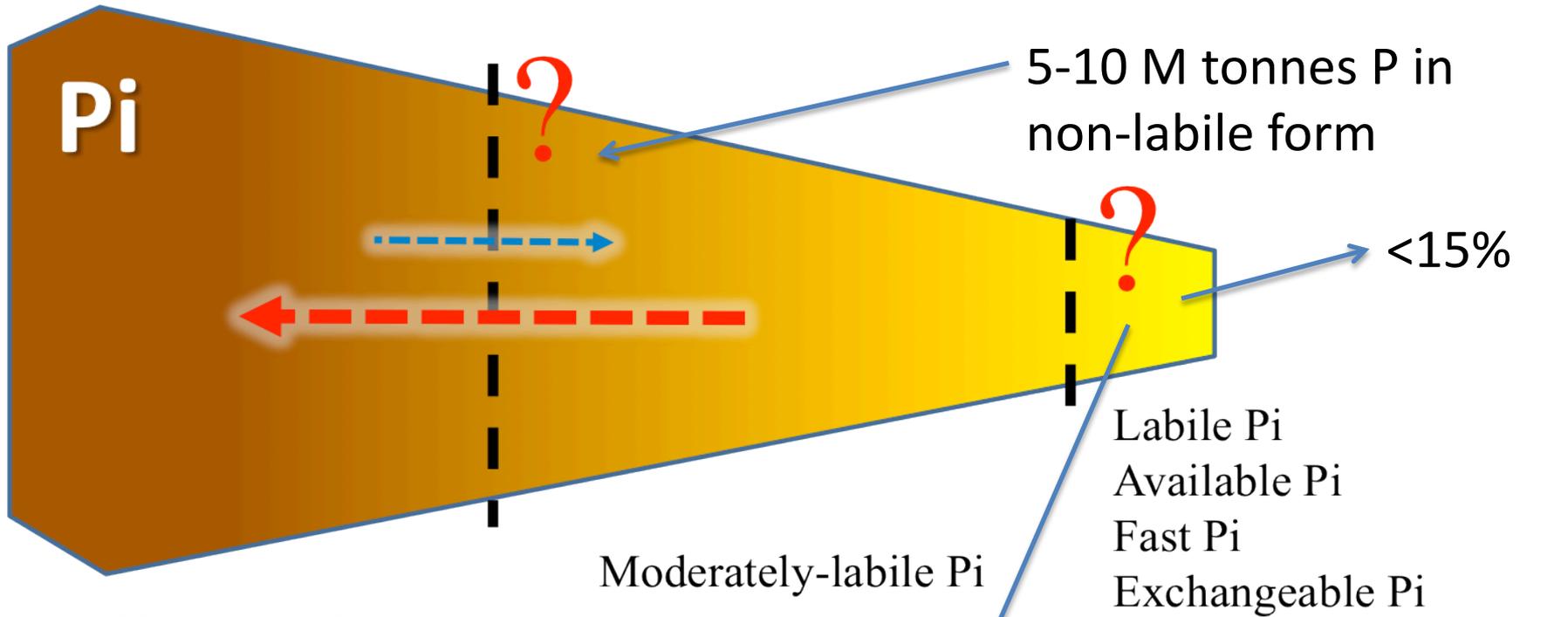
A large proportion of applied P is immobilised in soils by inorganic and organic processes

Critical soil test P levels vary widely from site to site leading to insurance-based applications

Soil sampling/analysis is crude, has high uncertainties leading to potential misinterpretation

Contributions from organic P and subsoil P are largely ignored

Soil Inorganic P



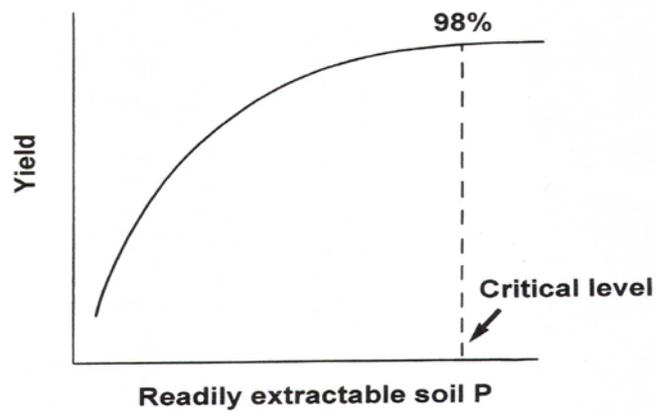
Non-labile Pi
Recalcitrant Pi
High-energy Pi
Slow Pi
Occluded Pi

5-10 M tonnes P in non-labile form

<15%

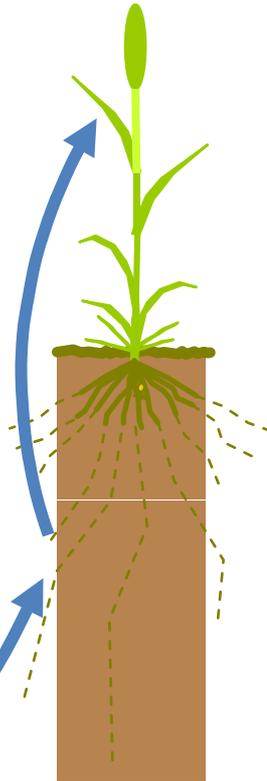
Labile Pi
Available Pi
Fast Pi
Exchangeable Pi

Moderately-labile Pi



Can we farm on low STP soils?

Innovation in Crop Nutrition



- Reduce crop P demand
- Utilise total soil P reserves
- Improve fertiliser efficiency



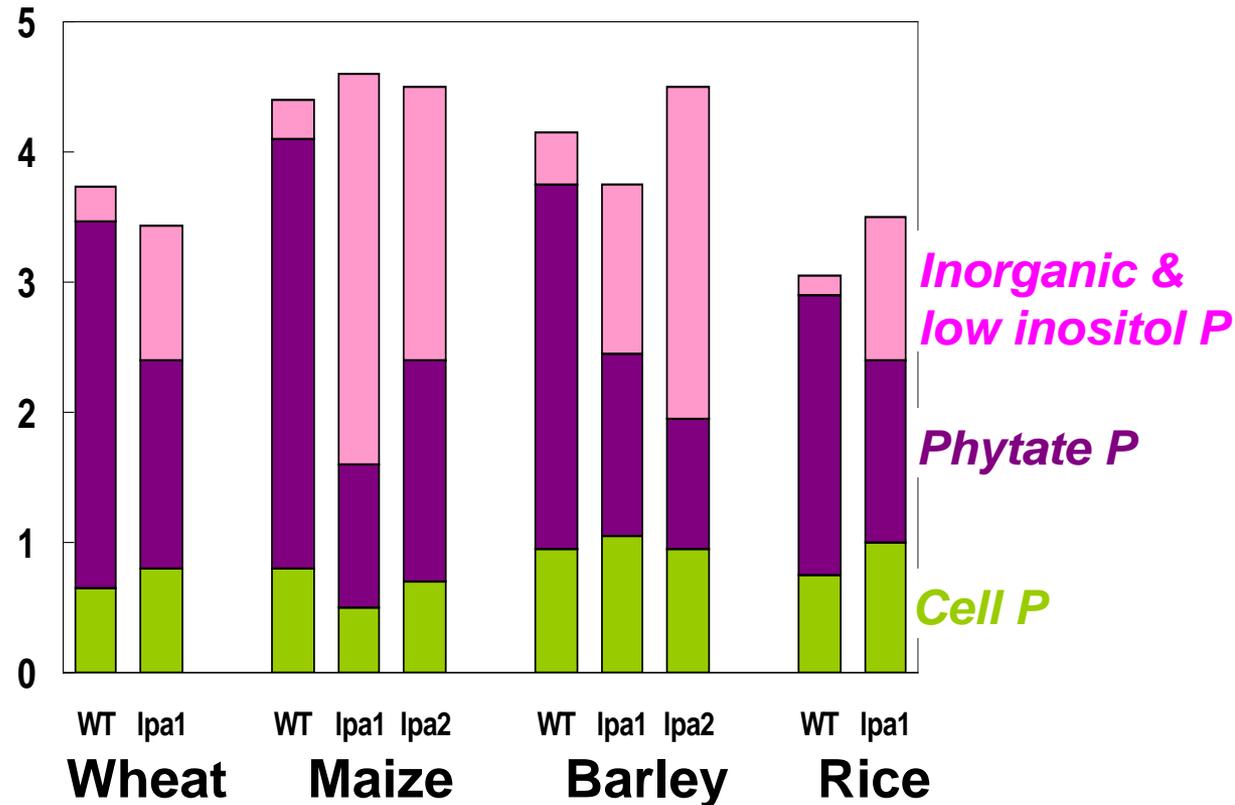
Lowering Crop P Demand

Photosynthetic demand for P maybe only 7-8 kg P/ha

BUT crop uptake is 20-50 kg P/ha

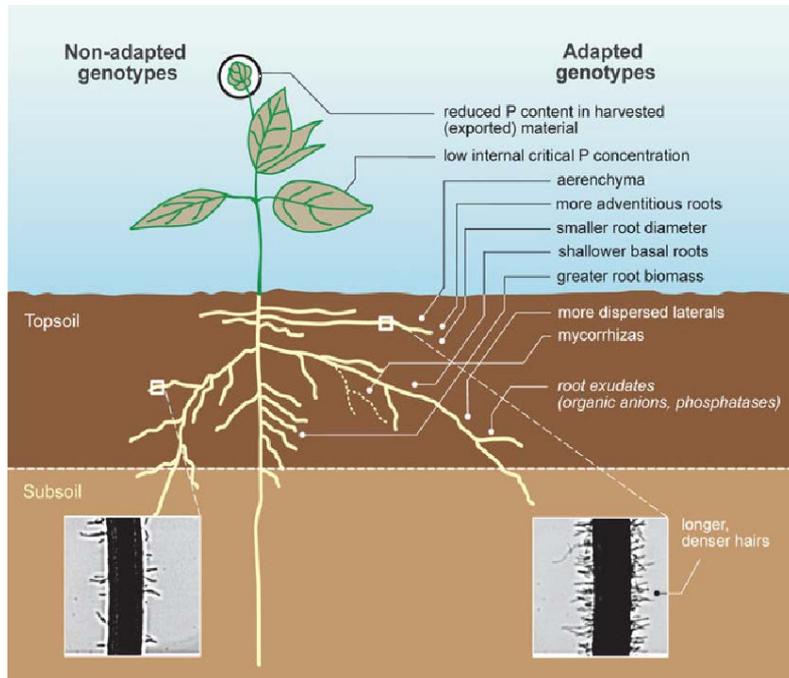
BECAUSE majority of P taken up is stored P either in the canopy or the seed

Grain P (mg/g DM)



After Guttieri et al. 2004; & Raboy 2002 *J Nutrition* 132-S, 503-505.

Mechanisms of Soil P Acquisition

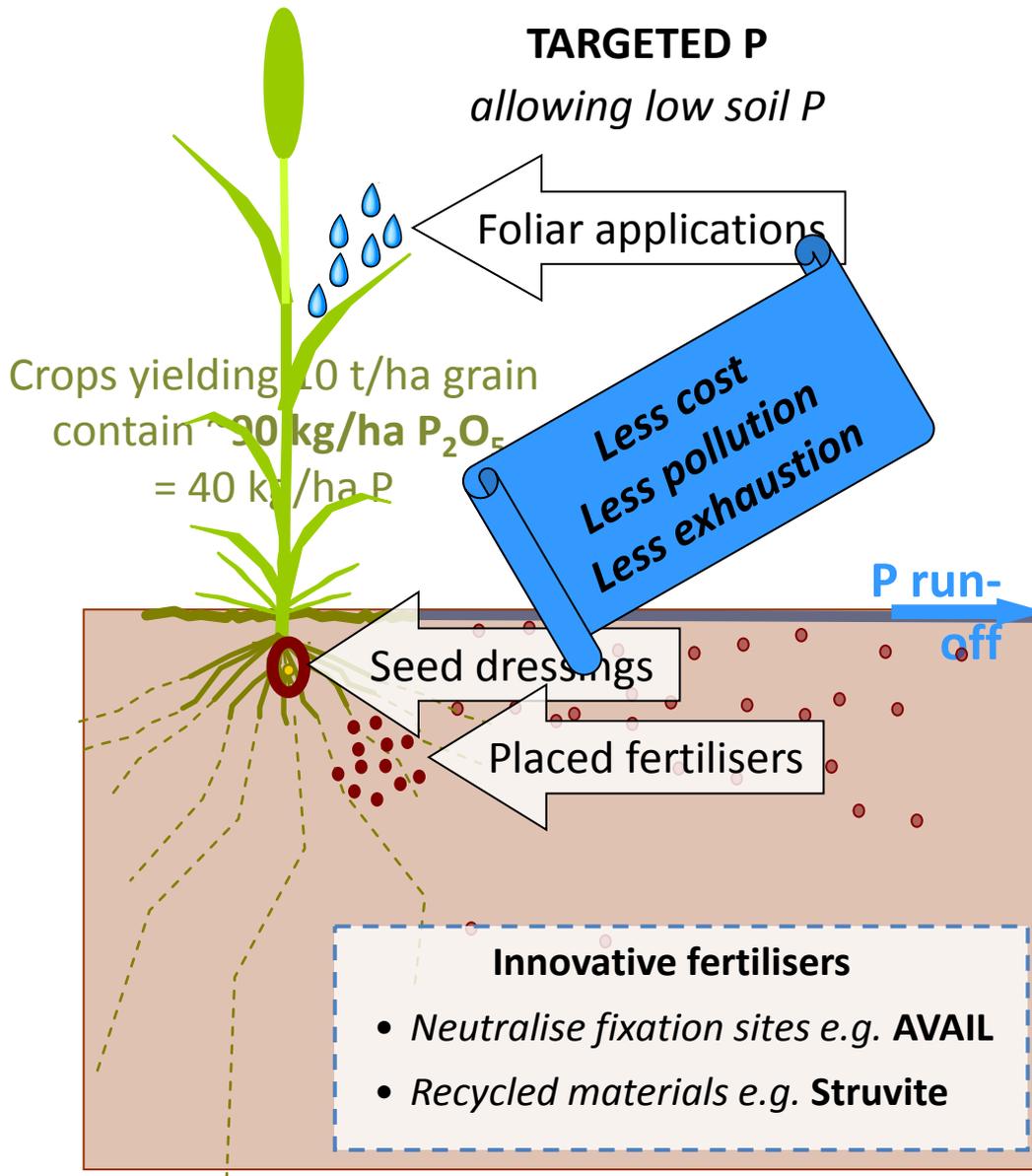


Lynch, 2007

- Root distribution morphology (lateral roots, root hairs)
- Symbiotic relationships (Mycorrhizal)
- Exudation of organic acid anions (carboxylates)
- Release of protons (H^+)
- Release of ectoenzymes (phytase and phosphatases)

Crop specific adaptations to reduced P supply

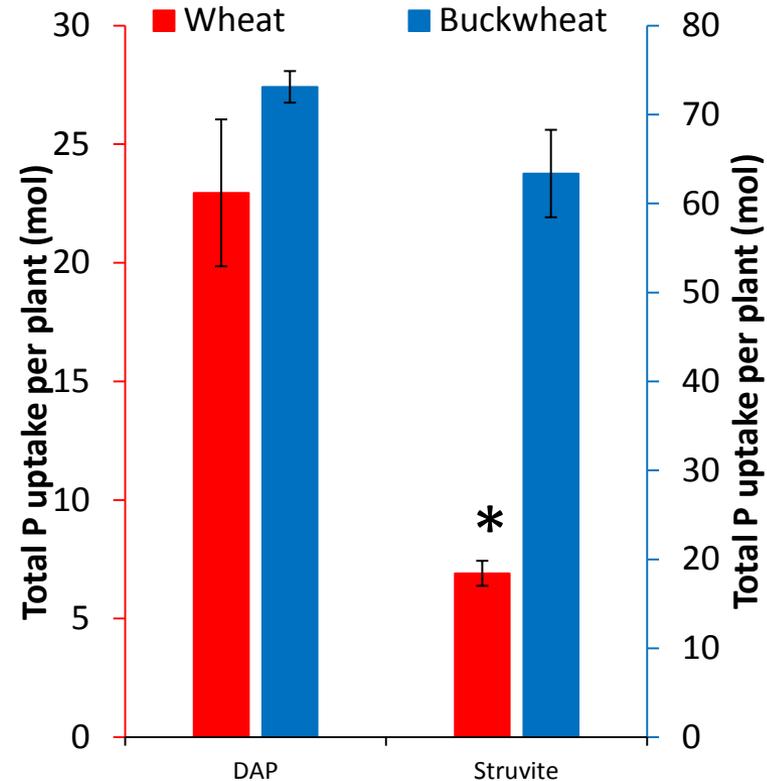
Improving Fertiliser Efficiency



- Provide a more even supply of fertiliser P
- Reduce fixation of applied P
- By-pass the soil altogether

Mechanisms of Soil P Acquisition

- Buckwheat exudes large amounts of organic acids when compared to wheat
- Buckwheat outperforms wheat in “mining” struvite Pi



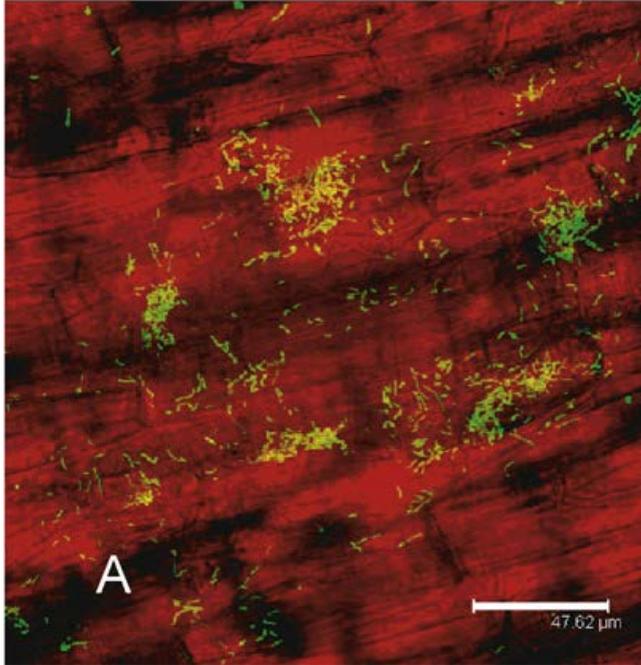
Struvite solubility is enhanced by organic acids

Microbial Enhancement

maize

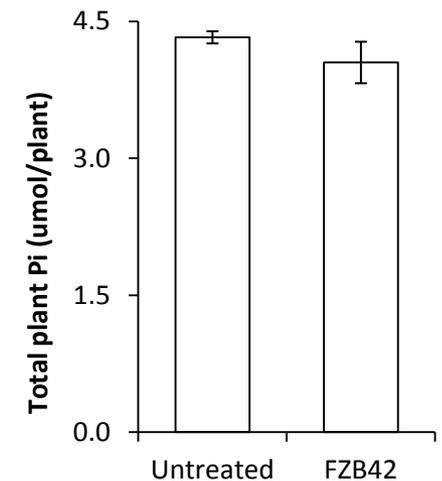
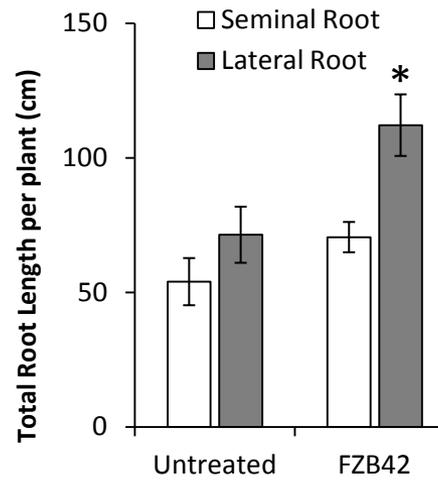
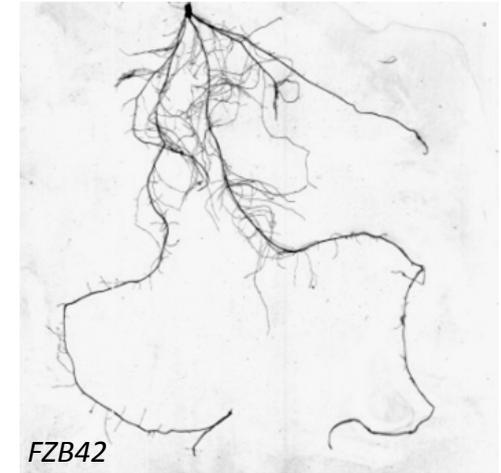
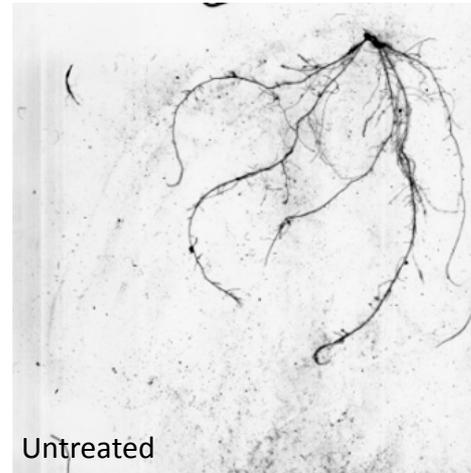
Biomex - *Bacillus amyloliquefaciens* strain FZB4

Low P soil



(Fan et al., 2011)

- Colonises root surfaces
- Secretes phytase and auxin

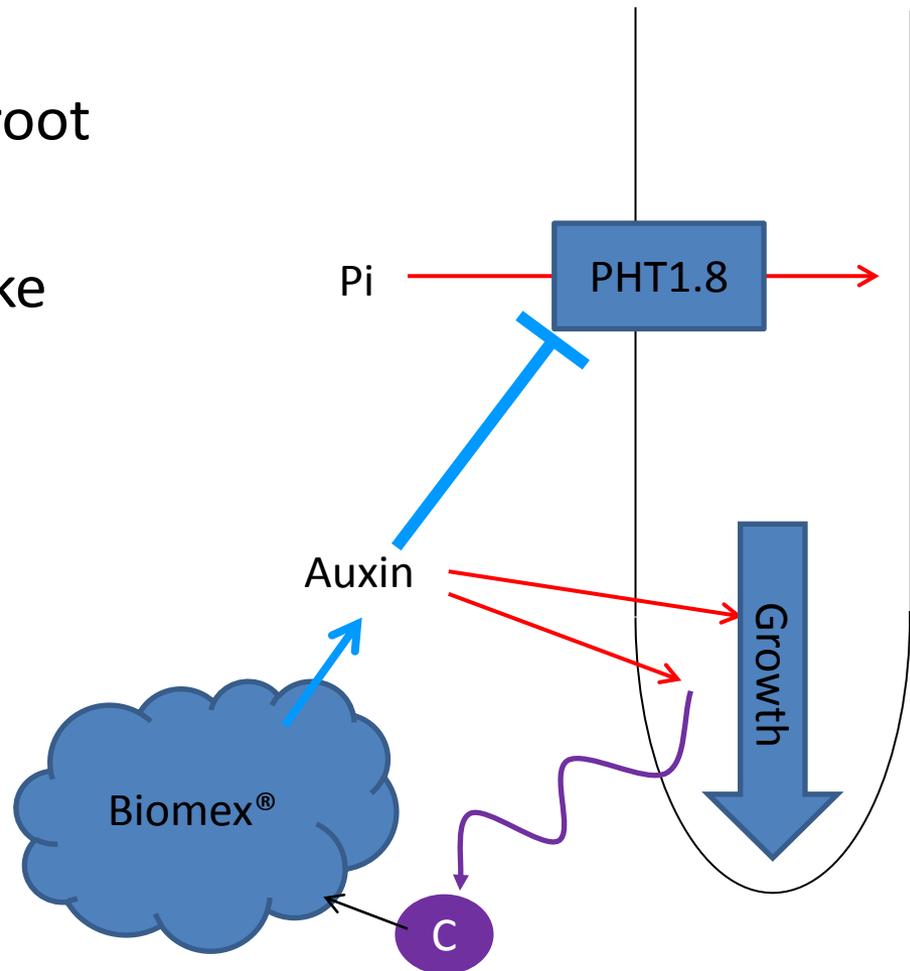


Biomex increases root growth but not P uptake

Talboys et al – in prep

Microbial Enhancement

- Biomex[®] secretes auxin
- Auxin drives increased root growth
- Auxin represses Pi uptake in low P index soils by reducing *PHT1.8* expression
- Auxin induces organic C efflux from the root



Concluding Perspectives

- There are compelling resource, economic and environmental reasons to reduce our reliance on mined (fertiliser) P and increasing its efficiency of use
- Improving P use efficiency compliments other aspects of sustainable P use including recovery/recycling and reducing wastage/losses
- Current reliance on soil P storage is inefficient and there is scope to improve P use efficiency by:
 - Reducing crop P demand
 - Exploiting total soil P reserves
 - Targeting more efficient fertilisers

Future Challenges

Plant breeding

How far can crop breeding take us in producing plants that have lower nutrient requirements and that can mobilise soil nutrient reserves more effectively?

System management

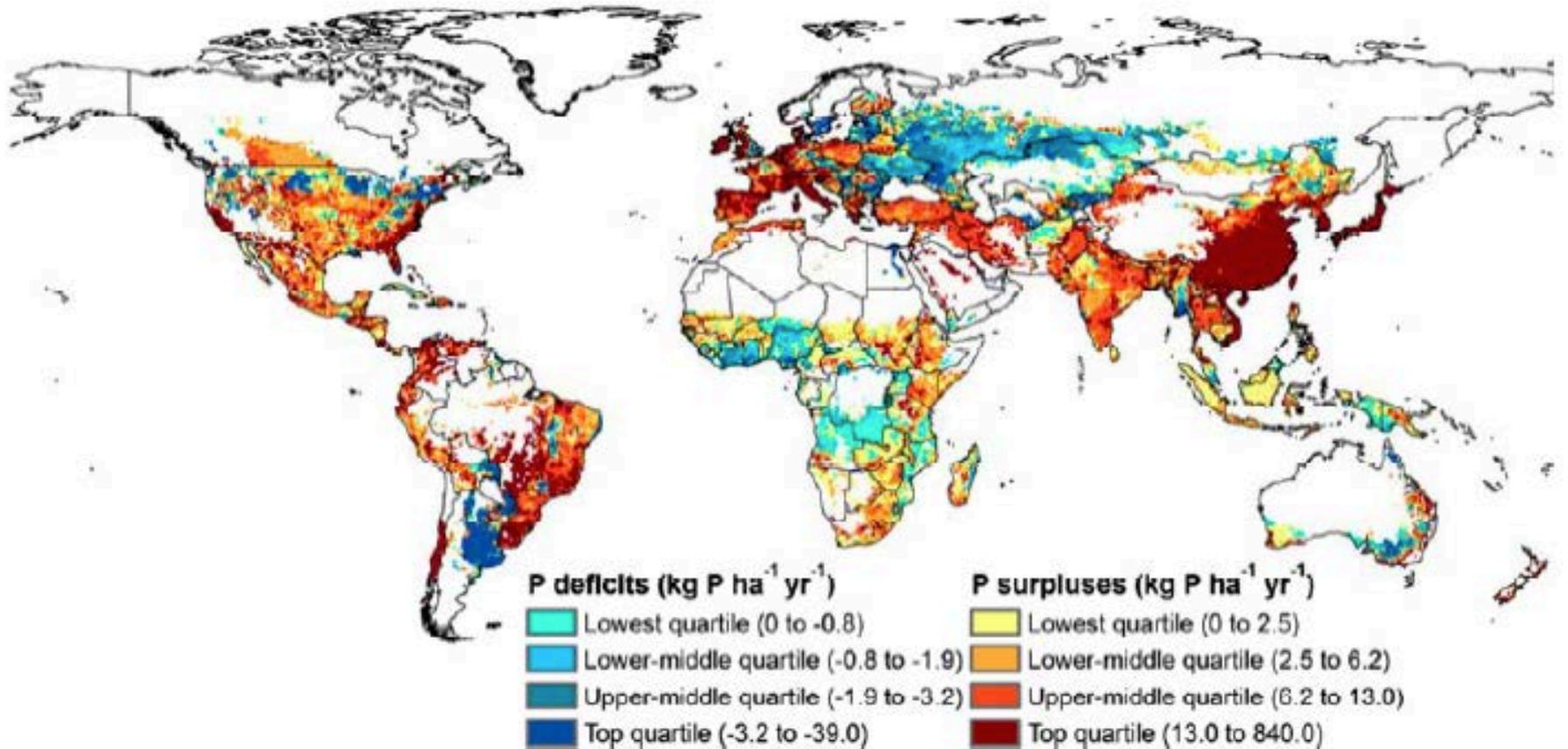
How far can fertiliser innovation and crop agronomy take us in improving the efficiency of P use?

Biotic manipulation

How far can manipulation of microbial communities take us in utilising our natural capital more efficiently?

Is feeding the soil rather than the plant a luxury we can no longer afford? Can we farm on low P soils?

Impoverished Soils



Low P availability is still a major limitation to food production in many parts of the world – (MacDonald et al. 2011).

LINK Project 09136

Improving the sustainability of phosphorus use in arable farming

