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

Potential trend

A new phase of innovation?

- price support
- grants for land drainage, liming, hedge removal
- govt’s support for research & technology
- hormone herbicides
- myxomatosis
- N P K fertilisers
- fungicides
- plant breeding

Low prices
Low govt’s 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?
Broadcast P fertilisers

Crops yielding 10 t/ha grain contain ~90 kg/ha $\text{P}_2\text{O}_5 = 40$ kg/ha P

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

5-10 M tonnes P in non-labile form

<15%

Labile Pi
Available Pi
Fast Pi
Exchangeable Pi

Can we farm on low STP soils?

Gratiboni 2012

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

Moderately-labile Pi

Yield

Critical level

Readily extractable soil P

98%
Innovation in Crop Nutrition

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

Mechanisms of Soil P Acquisition

- 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)

Lynch, 2007

Crop specific adaptations to reduced P supply
Crops yielding 10 t/ha grain contain ~90 kg/ha P₂O₅ = 40 kg/ha P

TARGETED P allowing low soil P

Foliar applications

Less cost
Less pollution
Less exhaustion

Seed dressings
Placed fertilisers

Innovative fertilisers

• Neutralise fixation sites e.g. AVAIL
• Recycled materials e.g. Struvite

• Provide a more even supply of fertiliser P

• Reduce fixation of applied P

• By-pass the soil altogether
• 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

Talboys et al. in prep
Biomex - *Bacillus amyloliquefaciens* strain FZB4

- Colonises root surfaces
- Secretes phytase and auxin

(Fan et al., 2011)

Biomex increases root growth but not P uptake

Talboys et al – in prep
- 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?
Low P availability is still a major limitation to food production in many parts of the world – (MacDonald et al. 2011).
Improving the sustainability of phosphorus use in arable farming