Final Project Summary

Project title	Cost-effective phosphorus management on UK arable farms		
Project number	RD-2160004	**Final Project Report**	570
Start date	August 2013	**End date**	December 2018
AHDB C&O funding	£249,600	**Total cost**	£283,600

What was the challenge / demand for the work?

The philosophy of phosphorus (P) management on UK arable farms has changed little through the past half-century. Although total fertiliser P inputs on UK farms have halved since the 1980s, their use is costly and unsustainable. Perpetual inputs of fresh inorganic fertiliser result in an accumulating store of soil P, increased transfers and concentration of P from arable onto livestock farms, and continuing pollution of fresh and marine water-bodies, with P in land runoff and soil erosion.

This work sought to evolve a less costly, more productive and more sustainable P philosophy, and to identify practical changes in on-farm P management that arable farmers could employ to their advantage.

Note: This work addressed P management on arable farms, which largely rely on inorganic P fertilisers. It did not address use of organic P resources or P management on livestock farms.

How did the AHDB address this?

Starting in April 2009, AHDB invested in three research reviews and three research projects:

Review 74, 2011: Response of cereals to soil and fertiliser phosphorus
Review 83, 2015: Routes to improving the efficiency of phosphorus use in arable crop production
Review 92; 2018: Offtake values for phosphate and potash in crop materials
Report 529, 2014: Identification of critical soil phosphate levels for cereal and oilseed rape crops
Report 451 / 569, 2016: Improving the sustainability of phosphorus use in arable farming – 'Targeted P'
Report 570, 2017 and 2019: Cost-effective phosphorus management on UK arable farms

What outputs has this research delivered?

The overall conclusion from this decade of collaborative research is that arable farmers' strategies for P management could become more economic, productive and sustainable, by adopting the maxim: 'feed the crop, not the soil', and by optimising the management of each element of their farming system – crop, soil, fertilisers and manures, and water – as follows:

Crop P:

1. Crop analysis could be recognised as a useful way of diagnosing crop P sufficiency, augmenting routine soil P testing alone. The critical level for P in cereal grain was found to be 0.32% DM. When compared to grain P values observed recently across the UK, this suggests that about a quarter of cereal crops could be P deficient. Other arable crops are likely to be affected similarly.

2. Thus, we propose that harvested materials from all crops (grain or non-grain) should be analysed routinely for P and, because they inherently come from the same analysis (at little or no extra cost), most other nutrients. This will help to diagnose adequacy of P supplies, as well as building intelligence about adequacy of other nutrients, and it will improve on-farm estimates of nutrient removals, including P_2O_5, by any crop.
3. If crop P analyses are not available, the assumed estimate of P_2O_5 offtake per tonne grain (at 15% moisture) should be reduced to 6.5, down from 7.8 kg/t. Hence, inputs of fertiliser or manure needed to maintain soil P levels will be less than has been assumed. Current assumptions of 14 kg/t P_2O_5 offtake in rapeseed should not be changed.

Soil P:

4. Farms should attach levels of uncertainty to their assessments of available soil P, and take precautions to maximise their confidence in soil P assessments by:
   (i) recognising that results are likely to be high or variable after recent applications, so avoiding soil sampling within six months of applying fertilisers or organic manures
   (ii) double-checking soil P results against results of analyses determined concurrently from adjacent locations, as well as previously at the same location
   (iii) checking against P concentrations determined on recent crops (as proposed above)
   (iv) repeating analyses of samples giving anomalous results
   (v) recognising whether recent land P balances have been positive, neutral or negative, and, therefore, whether they support (or otherwise) the observed changes, and
   (vi) seeking guidance on the likely P sorption (or P fixation) capacity of the soil
5. About 80% of UK arable land has a soil P Index of 2 or more; there is scope to let many soil P levels decrease to Index 3 or Index 2, depending on crops being grown. They could even decrease to Index 1, as long as:
   (i) only autumn-sown combinable crops are due to be grown,
   (ii) conditions for crop establishment and rooting are usually good, and
   (iii) fertiliser P is applied annually

   Thus, with careful monitoring, investments in soil P can be reduced on much arable land, even land that is not regularly receiving significant P inputs as livestock manures or other bio-resources.
6. Net amounts of P_2O_5 (added or removed) that will change available soil P levels of land by one mg / litre normally range from 10–30 kg/ha, about half of what RB209 suggests. A clear farm-factor applies, which includes additional effects to those of soil-type. This means farm are best to determine for themselves normal rates of soil P change for their land, as part of their soil P management planning.

Fertiliser P:

7. Recovery of P from commonly used fertilisers (e.g. triple superphosphate, TSP) by the crops to which they are applied is extremely poor (range 0–8%; average 4%). While the $\geq$90% of unrecovered P adds to soil P reserves, these are used inefficiently by subsequent crops. They also

contribute to P pollution of water bodies, so there is much scope, and cause, to gauge and improve fertiliser P recoveries, hence, to identify and favour P nutrition techniques (sources, formulations, rates, timings and methods of application) with proven improved efficiencies and recycling levels.

8. This raises significant challenges for the industry. If in future P fertilisers are seen less as a commodity and more like agro-chemicals and crop varieties, they will need more detailed product-specific performance data, and their distribution, pricing and trade will need to change. AHDB and other crop levy bodies will also need to gauge the need to provide independent testing and intelligence.
9. The inefficiency of triple-superphosphate (TSP) applications is such that they must usually be justified on the basis of rotation-long effects on crop yields through boosting available soil P status; even at P Index 1 or less, immediate crop responses to fresh TSP applications tend to be only just profitable.
10. Fertiliser placement by combine-drilling may be worthwhile for spring-established crops but, for autumn-sown crops at P Index 1 or more, advantages of placement are unclear, either in terms of crop recovery of fresh P applications or yield responses to them.
11. Many fertiliser and crop nutrition companies are working to improve P efficiency by marketing new products with claims of improved efficiencies and/or better recycling.
12. Water solubility is not a reliable indicator of P fertiliser efficiency; less soluble slow release products (e.g. struvite) can show equal or better efficiency. As well as new soil-applied products, seed-dressings and foliar applications can deliver P to crops successfully, but need field testing.
13. On-farm tramline comparisons of different P applications can detect yield effects of 2–4%. Farms with controlled traffic cultivation systems can generally make the most precise tests. Detectable differences are most likely to occur where grain P has been less than 0.32%, or soil P has been at Index 1 or less.
14. We have developed independent testing sites with large, replicated and randomised plots contrasting in available soil P (Index 1 v. Index 2). These can be used to validate any party's claims of improved fertiliser products or other techniques claimed to increase crop P recovery.

Water:

15. Challenging target concentrations have been set for P to help alleviate widespread eutrophication in UK water bodies under the Water Framework Directive.
16. Dissolved P in surface runoff and drain-flow from arable land relates directly to levels of available P in soils. Reducing available soil P from 25 mg/l (Index 2+) to 10 mg/l (Index 1-) could help substantially in achieving environmental targets.
17. However, reducing soil P levels will be incompatible with enhancing crop yield levels until (i) P fertilisers with markedly improved efficiencies are identified, and (ii) greater confidence in crop P sufficiency has been achieved, say by using analysis of P in harvested crop biomass (e.g. grain) to augment soil P analysis.

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General:

18. Immobilisation of applied P into less available forms in the soil matrix dictates that any impacts of new P management strategies will be slow to appear, and land managers must be persistent; overall success of long-term P management strategies must depend on assiduous record keeping.
19. Scope is identified for a new farmer-centric 'Phosphorus Efficiency Network', which would help to build growers' confidence in new P management strategies. Such a network could show how to make these strategies more crop-centric and farm-specific, by providing more detailed P management guidance (e.g. in RB209 and a new 'Farm Phosphorus Management Guide'), by coordinating on-farm monitoring and testing, and by independently validating new products and practices that claim to maximise crop uptake of P. Such a network could drive progress in efficiency of farm P use into the future.

Who will benefit from this project and why?
Farms will benefit from cost savings and farmers, and their advisors, from improved confidence in their P management decisions. As a result of this research, environmental gains from better-targeted P use will benefit farmers, the water industry and the public.

If the challenge has not been specifically met, state why and how this could be overcome
N/A

Lead partner	ADAS
Scientific partners	Bangor University; Lancaster University, NIAB
Industry partners	Frontier Agriculture; SOYL
Government sponsor	NA