

Identification of critical soil phosphate (P) levels for cereal and oilseed rape crops on a range of soil types

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What was the challenge/demand for the work?

Over the five-year period from 2008 to 2012, overall use of phosphate fertiliser (P_2O_5) on winter wheat, spring barley and oilseed rape averaged 25, 33 and 26 kg P_2O_5 /ha, respectively, a substantial decline from comparable data for the period 1983–1987 when applications to winter wheat, spring barley and oilseed rape were 55, 42 and 61 kg P_2O_5 /ha, respectively. Overall, phosphate use on wheat, barley and oilseed rape in 2009 was the lowest ever recorded by the British Survey of Fertiliser Practice (an average of 22 kg/ha). This decrease is largely the result of a decline in the proportion of crops being treated rather than a reduction in the amount of phosphate applied to fields receiving phosphate, which from 2008 to 2012 averaged 59, 49 and 58 kg/ha for winter wheat, spring barley and oilseed rape, respectively. For arable cropping as a whole, the phosphorus (P) balance (P applied minus P removed in crops) for P applied only as fertiliser (i.e. excluding P applied in manures and compost) has been negative since 1995, never the less recent surveys of soil samples tested indicate that some soils are still well supplied with P, whereas others have too little.

Current advice for arable and forage crops in the Fertiliser Manual RB209 (Defra, 2010) is to maintain soils at a target P Index of 2, or 16–25 mg/litre Olsen P. This is considered the level of plant-available soil P needed to achieve optimum yields of most arable crops, including cereals and oilseeds, grown in rotation in most years. Soils at P Index 0 are considered to be P deficient and yields are likely to be increased by adding phosphate fertiliser. Soils at P Index 1 are borderline deficient and yields will often be increased by applying sufficient new phosphate fertiliser.

The current target P Index for arable and forage crop rotations indicated in RB209 is based on the results of field experiments made over many years but only on a limited range of soil types. Many of the earlier experiments were reviewed in HGCA Research Review 16, while HGCA Research Review 74 presented results from recent and current experiments. Both reviews indicate the range of Olsen P levels (the critical level) at which crop yield reaches 98% of the maximum yield, (for advisory purposes, Olsen P associated with maximum yield is never used because yield increases so slowly as it nears the maximum that the associated Olsen P is unrealistically high). For a given Olsen P value, the crop availability of P per unit volume of soil should be the same regardless of the crop and soil type (except perhaps on acid soils or for permanent grassland). However, critical

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P values can vary between soils and years, depending on weather, and soil factors such as soil structure, moisture content, bulk density, porosity and stone content. Critical P values will also depend on the crop grown, on root growth or architecture and the daily rate of P uptake needed for maximum yield. In general recommendations, like those in RB209, it is not possible to allow for all these interacting variables, although it might be possible, given sufficient data, to be more specific for certain soil types.

Where soils are maintained at below the critical P level, yield potential will be reduced and there is a risk of lower profitability and nitrogen (N) fertiliser use efficiency. Previous research has indicated that even a large amount of fresh P fertiliser added to a P-deficient soil will not usually give yields equal to those on a P-sufficient soil in the short-term. This is because of the difficulty of mixing freshly added fertiliser uniformly throughout the soil, and the phosphate ion, H_2PO_4^- , which is added in water-soluble P fertilisers and taken up by roots, moves only about 0.13mm per day so little P moves to the root by diffusion, and the root has to grow to the freshly-added P, which is poorly distributed throughout the soil. Equally, where soils are maintained above the critical level, there will be little or no yield benefit to justify the cost of the fertiliser, and there is a potential environmental cost if soil that is high in plant-available P is eroded into water courses. Rising phosphate fertiliser prices and concerns about scarcity of supply have led some growers to question whether or not current recommendations are appropriate for all soil types, arable rotations and crop conditions. In particular, many have asked if arable soils can be maintained at a P Index less than 2 (i.e. below 16–25 mg/litre) without risk of yield loss.

How did the project address this?

This project first reviewed existing data on critical soil P levels for cereals and oilseed rape and identified soil types and crop situations where data are lacking so that new field trials could be made on these soil types, to determine the influence of soil and crop factors on critical soil P levels and on crop responses to P fertiliser at different soil P levels.

Six new field sites with low Olsen P (15 mg/l or less, Index 0 or 1) were chosen on soils ranging from deep clays to loams and shallow soils over limestone or chalk. The experiment, with 18 large plots, was established at each site in autumn 2009 and was then continued in exactly the same place for four successive cropping years (2009/10, 2010/11, 2011/12 and 2012/13). A range of combinable crops (mainly winter wheat, oilseed rape and spring barley) were grown following the host farmer's normal rotation. In the first autumn, a range of Olsen P levels was established on the plots at each site by applying the amount of triple superphosphate (TSP) fertiliser required to achieve the desired Olsen P on each plot. The target range of Olsen P levels, once the Olsen P levels had equilibrated, was from Index 0 or low Index 1 (10 mg/l or less) to Index 3 (26–45 mg/l). No further fertiliser P was applied to any plot in the first two cropping years. Each year, the measured grain or seed yield on each plot was related to the Olsen P on that plot. For the third and fourth years, each large plot was split into three sub plots, two of which continued to receive no P

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fertiliser. The third sub plot received fresh P fertiliser prior to cultivation and sowing in autumn 2011 and again in autumn 2012 to test crop response to fresh P at each level of soil P.

What outputs has the project delivered?

Results over four cropping years from the six sites on contrasting soils generally support current advice, namely to maintain soil at P Index 2 for combinable crops. In a few cases the critical P values exceeded 25 mg/kg (P Index of 3) but it would not be justified economically to raise Olsen P to this level. Crop response to Olsen P varied between sites and crops or years but this variability was not obviously related to soil conditions or other crop or site factors. However, the extremes of weather experienced during the project mean that further cropping years are required to give more robust advice on the level at which Olsen P should be maintained for different sites. On soil at P Index 0 even a large amount of fresh P fertiliser did not raise wheat yields to the level achieved at Index 2. However, at Index 1 a large amount of P did increase yield to that achieved at Index 2. This perhaps offers the potential to manage P fertiliser application for optimum yield at soil P Index 1, but the annual amount and method of applying the P needs to be thoroughly tested.

There were differences between sites in the apparent availability of the P applied as fertiliser, although the average was similar to that observed previously (availability is the proportion of the applied P that remains as Olsen P once equilibrium has been established). The proportion of the P applied in autumn 2009 that remained as Olsen P was greatest on the heavy clay soil at Peldon and at Caythorpe (sandy loam) and was similar but smaller at Weston, Great Carlton, Cholsey, and Cirencester but at this latter site availability was not maintained, perhaps because it had a high level of extractable calcium. On this, and similar calcareous soils, it may be appropriate to use an organic source of P, but the likely effectiveness of this would require further investigation.

Who will benefit from this project and why?

The outputs from the project will be used to update P recommendations for cereals and oilseeds like those provided in the Fertiliser Manual (RB209). The results will also benefit advisors and growers enabling them to make more informed decisions regarding P fertiliser applications. Data from the Professional Agricultural Analysis Group (PAAG, 2012), shows that 23% of UK arable soil samples tested in 2011/12 were at P Index 0 or 1. Assuming that only 40% of these received fresh P fertiliser, based on British Survey of Fertiliser Practice data (Defra, 2013), over the UK wheat area of about 1.9M hectares, this could equate to a loss of as much as 300,000 tonnes of grain, worth up to £45M each year, in fields maintained at Index 0 or 1. Even if all wheat fields at Index 0 or 1 received fresh P fertiliser, this would still equate to 60,000 tonnes of lost grain worth up to £9M.

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If the challenge has not been specifically met, state why and how this could be overcome
<p>There were differences between sites and crops or years in the response of grain and seed yield to Olsen P, which could not obviously be related to soil conditions or other crop or site factors. However, the extremes of weather experienced during the period of the project mean that further cropping years are required to enable a more robust interpretation. To achieve this and provide more information on year to year variation, three of the sites will continue for three more years and grain or seed yield related to Olsen P in each year resulting in a total of 9 crop harvests on completion in 2016.</p>

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