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Understanding Phosphate

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I have recently seen two statements that imply that using water-soluble phosphate fertilisers increases the risk of loss of phosphate to surface water, with its adverse environmental implications, and that the majority of the phosphate applied to soil becomes fixed in the soil and is unavailable to plants.

Neither statement is true as shown by the results from long-term experiments at Rothamsted and elsewhere. Most fertiliser-derived phosphorus that is transferred to surface water is attached to soil particles, and is therefore related to soil erosion, and not to the form in which the phosphate was applied.

Phosphate fixation

English is a rich and varied language but suffers in one sense from the fact that we have a number of words that apparently mean the same thing but their meaning can be varied by the user to suit their requirements and purpose. One such word is "fixation" when describing the reaction of phosphates when applied to soil, and it is being used to imply that "fixed"phosphate is not available to plants, as noted above. Often too, the expression"fixed" is changed to "locked-up", which is even more unhelpful and misleading.

More than a century ago, many chemists showed that nearly all the water-soluble phosphate applied to soil was retained in soil and not lost in drainage water. This is still a very essential feature of phosphorus/soil chemistry. These early researchers used the word "fixed"; it might have been helpful to have used the word "retained", and importantly, they made no comment on the availability of this phosphate to crops. The implication that fixed phosphate was unavailable for crops appears to have been widely used to persuade farmers that it was essential to apply water-soluble phosphate fertiliser for every crop, and not to buy alternative types of inorganic phosphate fertilisers.

Phosphate in Soils

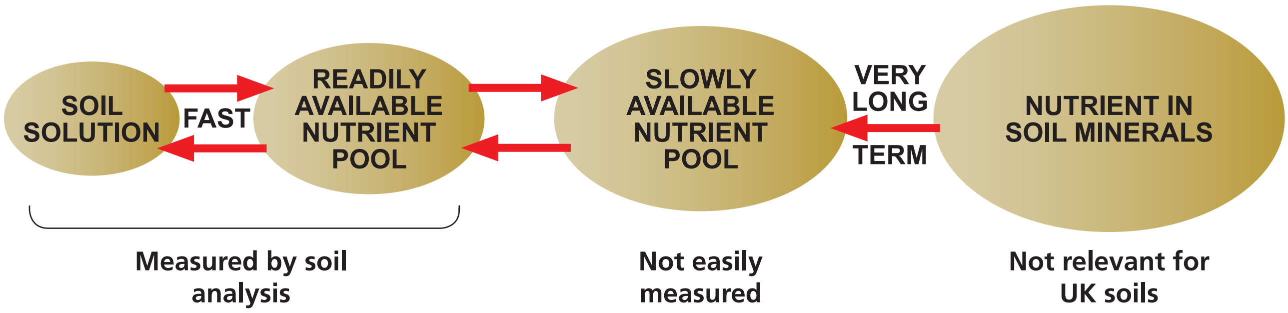
Two statements often made are that:

1) in many cases only 10-15% of applied water-soluble phosphate fertiliser is taken up by the crop to which it was applied, and the rest remains fixed in the soil where it is not available for uptake by plant roots, and

2) the other 90-85% of the phosphorus in the crop has come from soil supplies.

But where has this soil supply, which is clearly crop available as it has been taken up by plant roots, come from if applied phosphate fertiliser is fixed, or 'locked-up', in forms unavailable to crops?

Most UK soils contain little plant-available "native" phosphate, so the soil phosphorus taken up by crops must come from reserves accumulated from past phosphate applications, so clearly these reserves have not been fixed irreversibly in the soil as shown by the results from an experiment at Rothamsted. Some of the phosphorus applied as single superphosphate, which is water-soluble, to soils between 1856 and 1901 has been retained in the soil and is still being slowly released and taken up by crop roots.



Phosphate 'Pools'

A way of visualising the behaviour of soil phosphorus is to think of it existing in four pools of different availability to crops and with reversible transfer of phosphorus between the pools.

The phosphorus that is immediately available for uptake by plant roots is that in the soil solution (pool 1) and the amount is very small. There is more phosphorus in pool 2, and this phosphorus is readily transferred to pool 1 as the amount of phosphorus there is depleted when taken up by roots. The phosphorus in pools 3 and 4 has low immediate availability and very low availability, respectively. (By analogy to money and its availability, there is cash in the pocket (pool 1), cash in the current account (pool 2), cash in bonds, stocks and shares and least available in the short term, money in land and bricks and mortar (pools 3 and 4 respectively)).

When a phosphate fertiliser, even a water-soluble one. is added to soil only a very small amount stays in the soil solution (pool 1) and the rest transfers to the other pools at varying rates depending on the type of fertiliser and on soil properties. Because there is rapid transfer of phosphorus between pools 1 and 2 the amount of phosphorus in these two pools is often a good indicator of the immediate plant-availability of the phosphate in the soil. Thus, it is this amount that is determined by soil analysis using various reagents that have been shown to correlate well with crop response to soil and applied P. In England, Wales and Northern Ireland, Olsen's method is widely used. The phosphorus that transfers to pools 3 and 4 is slowly available but is not fixed irreversibly in soil, as shown by the results of the experiment mentioned above.

Target Indices

The general advice today to optimise the efficient use of phosphate in most arable crop production is to raise soils to P Index 2, the critical level, and then maintain them at this level by replacing the phosphorus removed in harvested crops.

Experiments show that for many soils in England, Wales and Northern Ireland the quickest way to raise a soil to P Index 2 is to apply appropriate amounts of water-soluble phosphate fertilizer. Often less soluble phosphate fertilizer, but still NACS soluble, can be used to maintain a soil at P Index 2, but it is essential to sample each field every three or four years to ensure that the phosphate fertilizer or phosphate source, such as an organic manure or other inorganic material being used, is maintaining the appropriate level of plant-available phosphorus. Choosing which source to use will depend on its ability to maintain the required critical level of Olsen P for the crops grown, and the cost and availability of the phosphate to achieve this aim.

A recent report published by the United Nations on the efficiency of soil and fertilizer phosphorus use concluded among other facts that:

1. There is strong evidence that P added to soils in fertilisers and manures is sorbed reversibly and that it is not irreversibly fixed in soil. This even applies to very acid soils in Brazil and Peru.

2. There is a strong relationship between the amount of P in the most readily-extractable P pool in soils and the P that has the greatest availability for plant uptake. "Critical" values for the most readily-available pool have been established for a number of crops grown in different farming systems on a range of soil types.

Where do we go from here?

The article above highlights the behaviour of phosphate in soils, but understanding how to manage phosphate for a rotation relies on taking both the soil and the crops into account. Phosphate management should be looked at across a rotation, rather than in isolation as different crops have both differing demands for phosphate, but also differing abilities to access soil reserves. As Johnny writes, soils are not locking up the reserves of phosphate so that they are inaccessible to all future crops grown, but retaining them for later release. The form that they are retained will vary depending on the soil type and the other nutrients within the soil. Calcareous soils are more likely to retain the phosphate as calcium phosphate, whereas acidic soils with higher proportions of iron or aluminium are likely to retain phosphate in these forms. The form which predominates in soils will have implications for crops trying to access this phosphate, and different crops are able to tap into these resources with differing efficiency. White lupins for example are much more capable of accessing iron or aluminium forms of phosphate than wheat or in particular oilseed rape.

Oilseed rape may not be particularly adept at accessing aluminium or iron phosphate, but it does have a greater ability to tap into the reserves of calcium phosphate in soils. This is likely to be due to the acidifying ability of the root exudates close to root tips.

Therefore, as has been identified, an understanding of the phosphate demands of the crops grown across the rotation, combined with regular soil testing should be the starting point for phosphate management.