How glow in the dark urine led to the discovery of Phosphate, The Bringer of Light

Phosphate, (P) is one of the three macronutrients required for plant growth, (the other two being Nitrogen, (N) and Potassium, (K)). A German, Hennig Brandt, first discovered phosphate in 1669. In an alchemistic career, which was to drain the wealth of two wives, Hennig discovered not gold, but, upon boiling his own urine, white phosphate.

White phosphate, which is an inorganic component of dissolved urine, glows in the dark. This is because when exposed to oxygen the white phosphate slowly burns, giving off the glow. However, as neither heat nor flames were apparent this was not realised at the time. The name phosphorus comes from the Greek word, phosphoros meaning light bearing or bringer of light.

Where does it come from?

The Phosphate we now use in fertiliser is almost entirely from Rock Phosphate. An inorganic element that is mined. How it got there is not so certain. It appears to be a sedimentary deposit created under special conditions in which no other sediment is present. Some suggest that it has been absorbed by ocean plants that then die. As they decompose so the phosphate accumulates.

Despite many theories there is, at this point, no certainty about its origin. There are also some igneous rock that are rich in phosphate, (often called hard rock phosphate), although sedimentary sources are far more plentiful.

Guano - now a depleted source of phosphate

Today, America, China and Morocco are the major producers of rock phosphate, each making up about a quarter of the world supply. In the past another source of phosphate was Guano. Guano is the excrement and urine of bats, seabirds and seals. In some places, notably Peru and some pacific islands, the reserves of Guano were huge.

It was mined for its phosphates and ammonia. Nauru, a small island in the Pacific, was for a time one of the richest countries in the world per capita, due to exporting Guano. After 80% of its surface had been strip-mined this source of phosphate has now been exhausted, as it has in other parts of the world.

How does it work?

Phosphate is important to plant growth because it allows the transfer of energy within plants cells, thus adequate levels of P are required to stimulate growth and create the changes that bring about maturity.

There is often a lot of P in a soil,varying from 500kg/ha to 2500kg/ha, (depending on the soil type, soil textureand depth). However only a fraction of this P is available to the plant. The Pneeds to be in the soil solution as soluble orthophosphate to be available tothe plant*. Often the available P is as low as 10g/ha. Cereal crops needbetween 12-16kg of P per ha while root crops require between 17-25kg per ha.The reserves of P in a soil are in basically in two forms; Mineral P and Organic P. Mineral P, as the name suggests is the insoluble and strongly absorbed P that exists in most soils. It is not available to plants although, through chemical transformation within the soil small amounts do become soluble and available. It's a bit like a reservoir of water with a dripping tap. The amount of the drip is dependant on soil type, ph, soil texture and soil organic matter.

How do phosphates become available to plants?

The Organic P is the return of organic crop residues, compost and farm yard manures. It is dependant on the microbial activity in the soil. This living activity converts (mineralise) the phosphates from the residues and makes them available to the plant.

Both the chemical and the microbial activity replenish the P in the soil solution as it is used by the plant. It is the interaction of soil organisms and soil organic matter that creates 80-90% of all soil processes. Organic matter is the main food source for soil organisms, breaking down the complex organic materials to obtain energy. Many micro-organisms (bacteria and fungi) are therefore able to mineralise organic P. Some of these organisms also excrete organic acids which are able to realise P from the Mineral reserve.

This process happens in a range of soil types although it is heavily dependant on soil organic matter levels and activity. It appears to be most efficient when soil Ph is between 6-7; near neutral.

It is important to note that soil testing does not indicate the level of organic P or the likely production of P available to the plants from this source. The routine soil test for P measure the labile P in mineral form together with the soil solution P. Therefore the organic half of the soil P cycle is invisible when routine soil test are considered alone.

Phosphate movement in the soil

Phosphate moves very slowly through soils. Unlike Nitrogen, phosphates are attached to other elements. Nitrogen will leach out of a soil after heavy rain, whereas phosphate will leave with the soil, eg when soil erosion occurs. Because of this the root length and distribution in the soil is important. The more roots spread through the soil the more P it will be able to come into contact with. Hence maintaining good soil structure and reducing possible compaction of the soil is of critical importance. Again the higher levels of organic matter present the more likely the soil will have a good structure.

Earthworms and phosphate

As well as the microorganism, the fungi and bacteria, the common earthworm also plays its part in the cycling of organic P. T J Barrett in his book, Harnessing The Earthworm, carried out an experiment. He found that a box of soil containing earthworms, increased available phosphate by 10% compared with a box of soil with no earthworms. An analysis of worm cases demonstrated that it contained five times the amount of Nitrogen, seven times the amount of P and eleven times the amount of

Potassium compared with the parent soil. Indirectly this is also dependant on soil organic matter. Just like the micro-organisms the earth worm depend on organic matter for food. Numbers of worms in a soil will depend on the level of organic matter available for them.

Plants and phosphate

A plants roots are much more than just a drinking straw for the plant. The area immediately around a root (about 1mm around the root), is called the rhizosphere. Within the rhizosphere the plant can have a direct influence through root secretion. Sloughed off plant cells, proteins and sugars realised by the root increase bacterial activity. Protozoa and nematodes graze on such bacteria and are in abundance within the rhizosphere.

Differences in plant species, rooting patterns and the way that some plants manipulate the rhizosphere mean that some plants are better able to access P than others. Experiments carried out by the Institute of Organic Training and Advice (IOTA), showed that buckwheat liberated P much more effectively than other crops, moving it from the mineral to the organic reserve.

It would therefore be much more available to following crops. Work carried out in Israel suggests that chicory may also have this property. Green manures are largely selected for their nitrogen fixing abilities or their organic matter. It may also be worth considering them for their ability to liberate mineral P.

Phosphate and the future

It is likely that there are huge deposits of rock phosphate still under the oceans of the world, particularly around the continental shelf. At present these are too expensive to extract. However, as the deposits on land are not estimated to exceed the next 35-50 years, it is possible that these reserves will have to be mined at some stage.

Phosphate is one of the limiting macronutrients upon which our present agricultural systems are reliant. It is a mined resource with ever increasing demands placed upon it. Just like Nitrogen it will only increase in cost over the coming years. As with Nitrogen Phosphate pollutes watercourses, causing euthophication. 26% of phosphate in rivers has been estimated to be of agricultural origin, entering the watercourses as soil erosion.

The decline in soil organic matter

Few soils are deficient in actual phosphate. Most contain sufficient reserves to support plant growth, if they were made available. However, to make them available we have to reverse the decline in organic matter. We have to start looking at the health of the soil rather than looking at the health of the crop.

It is estimated that each year in the UK 172000 tons of phosphate and 123000 tons of potassium are flushed into our river and sea. We then import 700000tons of North African rock phosphate and potash. With proper rotations and proper management of the soil this could be reduced dramatically.

In looking for short-term rewards we have managed to become dependant on the ever-increasing cost of the inputs necessary to sustain ourselves. At the same time we have reduced the capacity of our soils by regarding them as a medium rather than as a living organism upon which we depend.

About the author

Stephen Merritt is a partner in The Welsh Poultry Centre and an accredited advisor and board member of The Institute of Organic Training and Advice and has spent over 30 years working in sustainable agriculture in developing countries, England and Wales. In the last 8 years Steve has specialised in free range and organic poultry production and now offers on farm advice, information and training to this sector. He is the author of the e-book *A Producer Guide - Organic and Free Range Table Birds* (available on the website). A regular contributor to The Soil Association's *Organic Farming News*, he also frequently gives presentations on various aspects of outdoor poultry production