Despite phosphorus’ essential role as a plant nutrient, current phosphate fertilisers are inefficient. Here, Dr Jean-Claude Yvin describes the importance of this mineral, his development of a new fertiliser and promising cross-continent findings that could significantly enhance agricultural efforts.

Sustainable phosphorus management

Agricultural Science Research Centre in France (CRIAS) – on humic aids and seaweed extracts respectively – we have created a new phosphate fertiliser, TOP-PHOS.

Why have you chosen to use phosphorus to create TOP-PHOS?

Phosphorus is a key element in plant nutrition, but few phosphorus-based innovations are introduced to the market. An important plant macronutrient, phosphorus makes up around 0.2 per cent of a plant’s dry weight. It is a component of key molecules such as nucleic acids, phospholipids and adenosine triphosphate, and, consequently, plants cannot grow without a reliable supply of this nutrient. Inorganic phosphate (Pi) is involved in controlling key enzyme reactions and in the regulation of metabolic pathways.

What roles do other components play? How do they affect plant growth?

Sulphur has recently become more important as a limiting nutrient in crop production for several reasons. Required for the formation of amino acids, proteins and oils, it is also necessary for chlorophyll formation, helps activate certain enzymes and vitamins, and is a structural component of two of the 21 amino acids that form protein. A crop’s need for sulphur is closely linked to nitrogen; both are components of protein and are involved in chlorophyll formation. The two are connected by the nutrient’s role in the conversion of nitrate to amino acids.

Could you provide an insight into the process of fertiliser production?

The manufacture of soluble phosphate fertilisers is based on their composition, have varying solubility in soil solutions and are therefore assimilated by plants differently. They include single superphosphate (SSP) and triple superphosphate (TSP). SSP is a mixture of monocalcium phosphate and gypsum (available phosphorus pentoxide 16-22 per cent), while triple superphosphate is composed mainly of monocalcium phosphate (available phosphorus pentoxide almost 46 per cent).

What are the differing impacts of using phosphorus fertiliser on the environment?

Phosphorus lost from agricultural soils can increase the fertility status of natural waters (eutrophication), which can accelerate the growth of algae and other aquatic plants.

Moreover, could you explain the differences between existing phosphorus fertilisers and TOP-PHOS?

The main differences between single superphosphates fertilisers and TOP-PHOS are efficiency within plants found in any types of soils. This is mainly traduced in terms of yield and quality.

In which countries have you conducted field experiments for the development of TOP-PHOS?

We have conducted many field experiments in Brazil, France, Belgium, Germany, Switzerland and Romania. Our involvement in a university experimentation network has resulted in an 8 per cent increase in soya yields. Recent research on wheat and rapeseed, conducted last year with Agroscope Changins-Wädenswil (ACW), demonstrated an improved uptake of phosphorus versus SSP.
Researchers from the Roullier Group in France have developed a revolutionary phosphate fertiliser that increases soil microbial activity, phosphorus uptake and crop yield, representing significant progress from existing compounds.

PHOSPHORUS IS ESSENTIAL for plant growth and development; those deficient in the nutrient are stunted in growth and have a characteristic purple colour. Because this also impedes root growth, underdevelopment is exacerbated as it inhibits uptake of other nutrients. Vital for optimal crop yields, phosphorus is also closely linked to the fertiliser development industry. The most commonly used phosphorus fertiliser currently is single superphosphate (SSP).

SSP, however, is agronomically inefficient. When water-soluble phosphorus is added by SSP, it reacts with compounds in soil and is rapidly immobilised, making the majority of the nutrient unavailable to plants. Furthermore, the eventual leaching of phosphate causes eutrophication in receiving water, leading to undesirable algae growth and underwater weeds. This, in turn, results in damaging oxygen shortages. As phosphorus management is vitally important for farming and the environment, modifying SSP to achieve lower phosphorus fixation rates and higher agronomical efficiency is a key objective in agricultural management.

Working to develop such an alternative is Dr Jean-Claude Yvin, Head of the Research and Innovation department at the Roullier Group, a commercial agriculture company based in France. By modifying the chemical process underlying SSP production, Roullier has developed TOP-PHOS – a novel phosphorus fertiliser. Field experiments in South America and Europe have shown promising results, and it seems TOP-PHOS could soon be the new gold standard.

TOP-PHOS: an ecological fertiliser
Research has shown that organic complexed superphosphates (CSPs) have a positive effect on microbial biomass and the microbial activity of soil.

CSP addition to calcareous soil was shown to increase microbial biomass and the activities of important enzymes found in bacteria. It appears humic acid (HA) contains compounds that act as ‘trigger molecules’ to stimulate soil microbiological and biochemical activities.

These findings are hugely important and are the basis of TOP-PHOS’ creation. Soil microbes are the most important functional component of soil, with key roles in energy flow and nutrient reaction. Moreover, microbial biomass is a crucial source of nutrients for the entire land ecosystem.

TOP-PHOS can increase the efficiency of plant growth in all types of soil, increasing both yield and quality of crops. TOP-PHOS: an essential nutrient

- It is a component of DNA, and ATP – the plant’s energy source
- Essential for many biochemical reactions, including photosynthesis
- Plays a key role in defending against biotic and abiotic stresses
- Involved in the formation of oils, sugars and starches
- Accelerates growth

PHOSPHORUS ABSORPTION
Plants absorb most of their phosphorus as inorganic phosphate (Pi), regardless of the original source. The uptake of this nutrient represents a challenge, but one they have adapted to, as Yvin explains: “Phosphate concentration in soil is low, but plant requirements are high. Plants thus have specialised transporters at the root/soil interface to extract Pi from solutions of micromolar concentrations, as well as mechanisms for transporting Pi between intracellular compartments where concentrations may be 1,000-fold higher”.

Although only small amounts are taken up at this stage, phosphorus uptake is critical during the first five to six weeks of growth, linked to both development and yield potential. “Cool air and soil slow plant development and root growth in the spring. Because phosphorus moves slowly in the soil and roots often do not grow enough to reach soil reserves, the plant becomes deficient,” elucidates Yvin.

THE RIGHT pH
Soil characteristics have a significant bearing on a plant’s ability to extract water and nutrients. “Soil can be neutral, acidic or alkaline, which affects the availability of nutrients and the activity of soil microorganisms,” Yvin comments. Soil pH has implications for the efficiency of almost every nutrient, phosphorus included. Indeed, availability of phosphorus is directly related to the pH and type of soil; optimum pH is 6.5 and such a precise requirement represents a real challenge to agriculture.

TOP-PHOS is the Roullier Group’s new technico-agronomic solution to this problem.
This fertiliser increases the available phosphorus in all types of soil. It also boosts hydrolytic and microbial activity in soil, enhances root quality and the uptake of phosphorus by the plant. Much more agronomically efficient than existing products, it improves the health of the plant, encouraging dry biomass production and the availability of other crucial nutrients including nitrogen and sulphur.

A NEW CLASS OF SUPERPHOSPHATE

TOP-PHOS’ development began in earnest following Yvin’s 2012 publication in the *Journal of Agricultural and Food Chemistry*, describing a new type of superphosphate – organic complexed superphosphate, or CSP – the underlying component of TOP-PHOS.

CSP was created by introducing chelating agents in the form of humic acid (HA) – a core organic component of soil – into the chemical reaction of SSP production. Reacting mineral acid and rock phosphate in the presence of HA yields monocalcium-phosphate-humic complexes (MPHC). The hypothesis was that the presence of MPHCs would inhibit phosphate fixation in soil, thereby increasing its availability for plant uptake and improving fertiliser efficiency.

After a series of structural studies, Yvin investigated the agronomical efficiency of the compound compared to SSP, using wheat plants grown in both alkaline and acidic soils. The findings aligned with his hypothesis about MPHCs, and revealed that CSP products were much more efficient in providing available phosphate, resulting in better phosphorus uptake and enhanced plant growth.

INCREASING BOTH YIELD AND QUALITY

This new class of fertiliser represents a more available and sustainable phosphorus source. Multiple experiments have proven its ability to decrease phosphate fixation in soils as well as its effectiveness against conventional fertilisers.

Following testing in controlled conditions, Yvin and his team took TOP-PHOS to the field. Experiments in multiple sites in Brazil showed that their new fertiliser increased yield by an average of 12 per cent. Concerns that the technology may not work in Europe due to the different soil types have been allayed by recent field experiments in a range of countries, including France, Belgium and Germany.

Making impressive progress, the TOP-PHOS technology is already patented and recent studies in collaboration with Agroscopic – the Swiss Federal government agriculture, food and environmental research organisation – have conclusively shown that the fertiliser can increase the efficiency of plant growth compared to SSP in all types of soil, increasing both yield and quality of crops. “These results will soon be published in an agricultural journal and presented at the 2014 European Phosphorus symposium in Montpellier,” Yvin concludes.