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## What Happens to Superphosphate P in the Soil?

Superphosphate (Super) is still the dominant phosphorus (P) fertiliser used in NZ. Despite this, Super users often have little idea of what happens to the P supplied in this fertiliser when it is added to the soil.

### Background

It is important to appreciate that P exists in the soil in both inorganic and organic forms, most of which are insoluble. As a result, the concentration of P in soil solution at any given time is generally quite low. This can lead to problems with the level of plant available P in the soil, which of course is the chief reason P fertiliser is applied.

Though P is relatively immobile in the soil, some P still reaches water courses from leaching and erosion, where it can cause environmental pollution, even at very low concentrations. Ongoing excessive P fertiliser applications worsen this problem. Fertiliser P should be applied until there is an adequate availability of P in soil solution so that plant growth is not restricted. Applying P fertiliser to achieve soil target levels higher than optimal levels does not cause plants to grow more but may hasten environmental degradation.

Though the P mechanisms operating in the soil are complex, seeking to understand them is beneficial and may help a user to save some fertiliser dollars by not applying unnecessary P fertiliser. Reducing unnecessary P fertiliser use will also benefit the environment and help enhance our “clean green” image.

The P in Super is in a water soluble inorganic form known as mono-calcium phosphate. When Super is applied this leads to an initial flush of this soluble P in the soil solution which usually declines very rapidly, especially in soils of high P retention capacity and low P status. What happens to this P? Depending on prevailing soil conditions, it is subject to one or more competing processes: formation of iron, aluminium and manganese phosphate compounds, formation of di-calcium phosphate, absorption onto and into soil particles, and uptake by plants and soil microbes. Let's examine each of these a little more closely.

### 1. Formation of Metal Phosphates

After Super has been applied and while it is being assimilated into the soil, dissolution-precipitation processes are active. These involve both the formation of and subsequent dissolving of phosphate precipitates. The fertiliser granules on the soil surface attract moisture to them, resulting in chemical reactions which convert the soluble P within the granules into phosphoric acid and a less soluble form of P, di-calcium phosphate. If the prevailing soil conditions are acidic, and good levels of iron, aluminium, or manganese are present, the P from the granules can be transformed into low solubility phosphates of these metals. On the other hand, if the overall soil pH is neutral or alkaline,

and adequate levels of calcium are present, di-calcium phosphate can be further converted to an insoluble tri-calcium phosphate, a compound similar to naturally occurring rock phosphate. The latter scenario is believed to be more important to the overall concentration of P in soil solution and thus also to plant P nutrition. Maintaining an overall soil pH 6-6.5 lessens the likelihood of P precipitation and enhances P solubility.

During the assimilation process, an acid laden solution of low pH (1.5) moves out into the soil. This is hostile to soil biology and, as a result, any biological life in the vicinity of the disintegrating Super granule is wiped out. The impact of a fertiliser on soil biology is often ignored when fertiliser is applied, yet soil biology is critical to the plant uptake of nutrients from the soil. How long these adverse acid conditions continue varies depending on other soil factors but eventually the pH returns to levels close to that which existed before the fertiliser was applied.

The application of ammonium phosphate fertilisers also lowers pH during assimilation but not as severely as Super does. Dicalcium phosphate and RPR fertilisers do not lower pH when being assimilated and are thus “friendly” to the organisms living within the soil. The latter fertilisers also release P more slowly and at a rate which more closely complements plant P requirements. Plants are unable to uptake all of the initial soil solution flush of P from Super.

Although Super lowers pH around the granules during the assimilation phase, this situation is not permanent. In terms of overall soil pH, Super only slightly increases overall soil acidity.

## **2. Absorption on Soil Particles**

Sorption-desorption processes play a significant role in removing soluble inorganic P from soil solution. Sorption occurs when P is removed from the soil solution and becomes attached or fixed to the surface of soil particles. The impact of sorption varies depending on the nature and extent of the particle and aggregate surfaces within the soil, but it is generally worse in ash derived soils and other soils with a large content of amorphous or poorly structured material. Such soils have a large available surface area to which P can become fixed. Once the initial dissolution-precipitation reactions outlined above have run their course, sorption-desorption processes become the main controller of soil solution P concentration. In time, and again depending on other prevailing soil factors, the P absorbed on these soil surfaces either slowly penetrates deeper into the fabric of the soil material or becomes buried beneath iron and aluminium oxide coatings which form on the surface of soil particles. When this occurs the P is said to be “occluded”.

It is sometimes assumed that P fixation processes are always in the direction of loss of P from soil solution. This is not correct. P is also released back into soil solution from soil surfaces by the reverse process, desorption. However, the P that has penetrated within soil particles or become occluded is only released very slowly, and then not until surface absorbed P reserves have been depleted. Release of penetrated P generally occurs too slowly to maintain soil solution P concentrations at a high enough level for good plant growth.

## **3. Organic Immobilisation**

Plants remove P from soil solution through their roots. In time, much of this P is returned to the soil in plant litter, roots etc and in animal dung. Because dung is often deposited at stock camps or in races etc, dung transfer can result in losses of P from the system, or at best uneven re-distribution of P. Obviously, some P is also lost in products/commodities that are removed from the farm.

P is constantly being cycled through soil organic matter. It is constantly being incorporated into the plant and then subsequently released and made available again and so on.

Soil microbes, soil animals and other soil biological life also remove P from soil solution. The life cycle of the microbes is usually quite short and hence, after they die, the P is released again, generally with a much faster turn around than occurs with plant P. Microbial P is returned to soil solution in both organic and inorganic soluble P forms. Just like the P immobilised in plants, so also the P in soil organisms is recycled either through other soil organisms, or back into plants or else it is subjected to the other processes described earlier.

Soil biological life plays a key role in the mineralization of P from both organic and non organic sources. In many pastoral situations, organic material can often comprise 50 – 80% of the total P in the soil. Not all of this P is plant available or even becomes plant available P in the short term. However, the microbial biomass P is usually re-cycled quite rapidly when soil conditions favour these organisms. For instance, in a typical soil with say 1000kg/ha of total P within the plant rooting zone and a microbial biomass comprising say 3% of the total soil P, P re-cycled from this source could supply roughly 15-24kg of P/yr or the equivalent of an annual application of 250kg/ha of Super!

In a manner similar to the way soil solution P is subject to sorption-desorption processes on the surface of soil particles, it can also become absorbed onto the surface of organic matter particles within the soil. If conditions are favourable, significant amounts of P can be immobilised in this way, especially as soils become more acid. The chemistry of organic P is complex and not very well understood. Never the less, it is clear that under the influence of soil microbial life, and in particular rhizosphere fungi, a portion of this organic P is returned to soil solution.

As a general rule, there is often more organic P in soil solution than inorganic P. When it is considered that the Olsen P test only assesses the inorganic plant available P fraction of the soil, then it becomes clear that the Olsen P test may under-estimate plant available P i.e. there may be much more P available than is commonly realised. Because of the size and complexity of organic soil molecules, it is difficult to assess how much of this soluble organic P is taken up by plant roots but clearly, organic P does contribute to plant P nutrition.

### **Discussion**

It is often easier, but economically more costly, to keep on applying more Superphosphate fertiliser year after year than to seek to understand what actually happens to the P that is applied to the soil. Although the soil P mechanisms are complex, never the less, even a cursory appreciation of the processes involved indicate that these operate in both directions: some remove P from soil solution, while at the same time others are acting to return P to soil solution. Plant P availability is the culmination of all these dynamic processes.

Where plant available P is less than optimum, fertiliser P should generally be applied, depending on stocking rate, intensity of farm operation etc. Where levels are adequate, fertiliser P applications are not an ingrained annual necessity. In fact, many NZ soils have experienced decades of fertiliser P applications and now contain high levels of P. They don't require more P fertiliser additions unless plant available levels reduce below optimum.

An alternative to Super application is to apply lime, which can decrease the fertiliser P requirement and increase the cycling of P. This is especially the case, if the lime is finely ground and evenly applied. Applications of fine lime stimulate soil biology leading to improved P mineralization, P uptake, better soil physical properties and ultimately better plant growth. However, if plant available P levels and soil biological and physical properties are already good, then all a grower may need to do is to “do nothing.”

What's the bottom line with soil P? Try to develop a better understanding of how P functions in your soil. This will give you, the fertiliser user, more confidence about the fertiliser decisions you need to make. If tests show that P applications are not currently necessary, this will bring an immediate cost saving i.e. there is no need to add fertiliser P if levels are already optimal. If the target is optimal and sustainable levels soil P levels as compared to unnecessarily high levels, then the environmental impact will also be positive. Bear in mind that there are several other granular P fertilisers in the market place today as well as other fertiliser technologies i.e. fine particle fertilisers. In many situations, some of these alternatives might yield production results and cost-benefit returns which exceed those obtained with Superphosphate fertiliser. Until you check out these other options, you'll never know what benefits they may give you.