1. THE INFLUENCE OF SOIL ACIDITY ON PLANT NUTRIENT UPTAKE

van Zyl,K: Omnia Fertilizer

The uptake of nutrients from the soil or applied fertilizer is a process largely determined by the soil's chemical, physical and microbial activity. The most important requirement for nutrient uptake is, however, the availability of sufficient levels of the specific nutrient in a plant-available form. Water is, of course, just as important, as it serves as the carrier for the dissolved nutrients.

To explain the processes that take place during nutrient uptake, one would first need to look at the plant and then the soil. Uptake of nutrients through the plant are mainly driven by three uptake processes, namely mass flow (water uptake); diffusion (concentration gradient for example in the fertilizer band with high concentration vs low concentration in the plant root); and root interception (roots growing towards the fertilizer band).

The physical uptake of nutrients takes place through ion exchange to balance the charges (positive and negative). For instance, uptake of calcium (Ca^{2+}) by plant roots will lead to the release of two hydrogen (H^+) ions. Cation uptake (positively charged ions Ca^{2+}, Mg^{2+}, K^+, Na^+, NH_4^+, Mn^{2+}, Cu^{2+}, Fe^{2+} and Zn^{2+}) is also associated with the release of hydrogen ions. On the other hand, anion uptake (negatively charged ions No_3^-, So_4^{2}, MoO_4^{2-} , $H_2Po_4^-$ and Cl^-) is associated with the release of hydroxide ions by plant roots. Cation uptake is therefore an acidifying process, while anion uptake increases pH. The nett effect is usually slightly acidifying.

Chemical processes in the soil are mainly controlled by the clay content and types of clay. With higher clay content, more negative charges are available and therefore more cations can be adsorbed. Figure 1 illustrates the cation composition on the clay complex (soil components) at varying soil pH levels. The number of charges is also determined by the pH of the soil and is better known as pH-dependent charges.

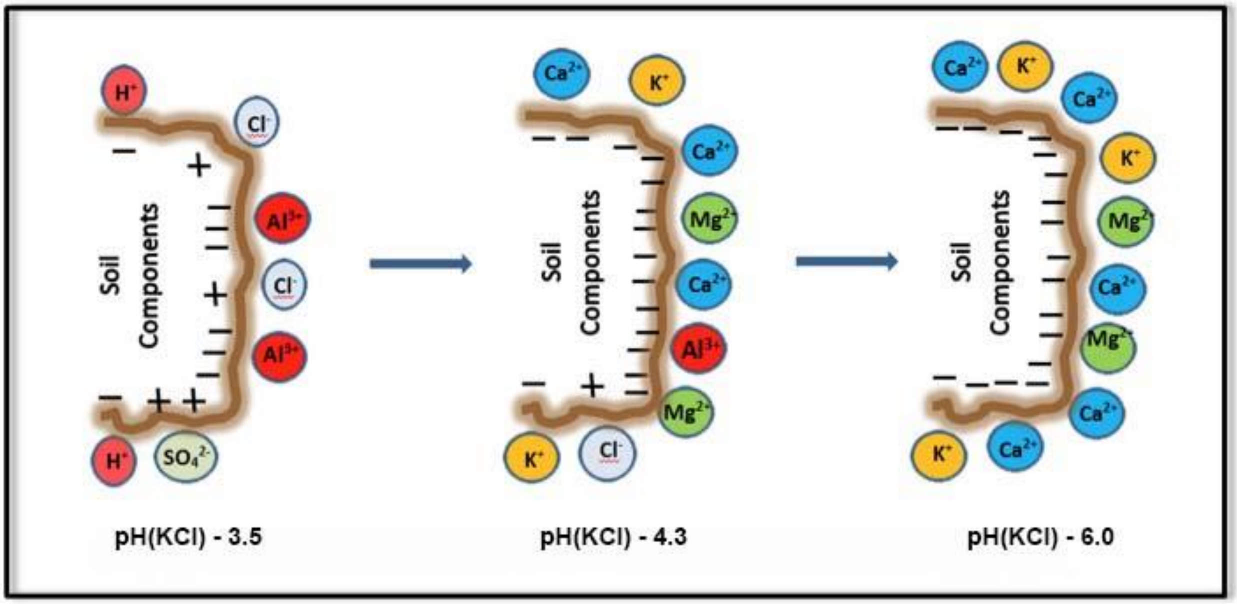
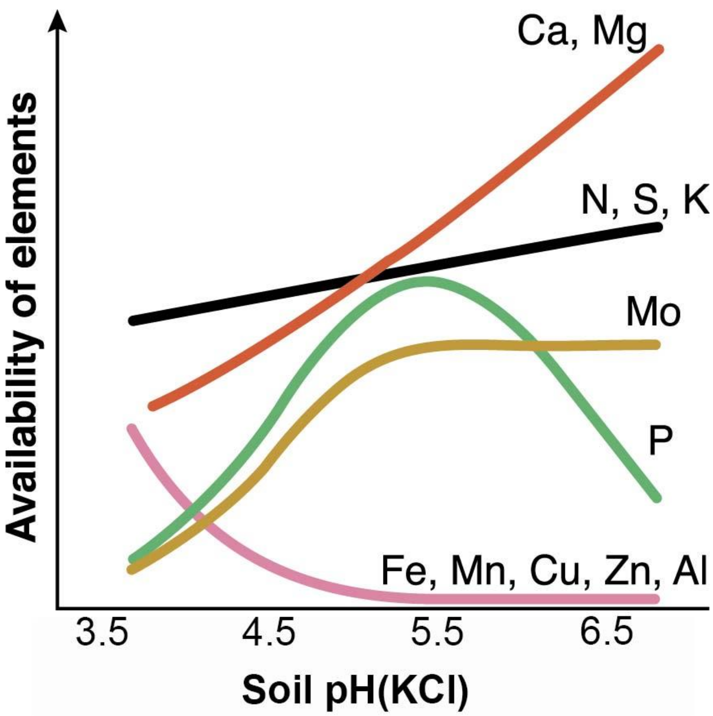


Figure 1. Illustration of cation composition on the clay complex at different soil pH levels.

(Sonan, LS, Kissel, DE and Saha, U, 2014)

Therefore, a higher soil pH leads to more negative charges to which essential nutrient cations such as calcium, magnesium and potassium can be adsorbed and exchanged in order to be taken up by plant roots. As the pH increases, the number of hydrogen ions will decrease, and the solubility of aluminium will also be reduced. Aluminium is toxic to plant roots and should preferably not be available for uptake. At pH(KCl) levels higher than 4.5, aluminium should no longer be available and harmful to plants. The availability of phosphate and molybdenum also increases with a rise in pH levels. Phosphate especially can also be negatively affected by too high soil pH levels, as illustrated in Graph 1 (*this graph is only for illustrative purposes and is not to scale*).



Graph 1. The effect of pH(KCl) on the availability of nutritional elements.

(Gazey, C and Azam, G, 2018)

Soil acidity also has an important effect on the microbial life in the soil, which leads to the question: what do fungi and bacteria have to do with nutrient uptake?

Many of the fungi and bacteria have symbiotic relationships with the roots of most plant species. Think for instance about the symbiotic relationship between soybean roots and *Rhizobium* bacteria. An illustration of the effect pH has on the microbial composition of soil is shown in Figure 2. Several specialised bacteria, fungi and mycorrhiza show beneficial effects on nutrient uptake, provided that the soil pH is optimal.

A less favorable soil acidity (low pH) can lead to the accumulation of root pathogens and a decrease in beneficial bacteria and mycorrhiza. Acidic soil can also influence the mineralization rate of organic matter, and drastically reduce and limit the supply of natural nitrogen, sulphur and potassium from soils (from organic matter).

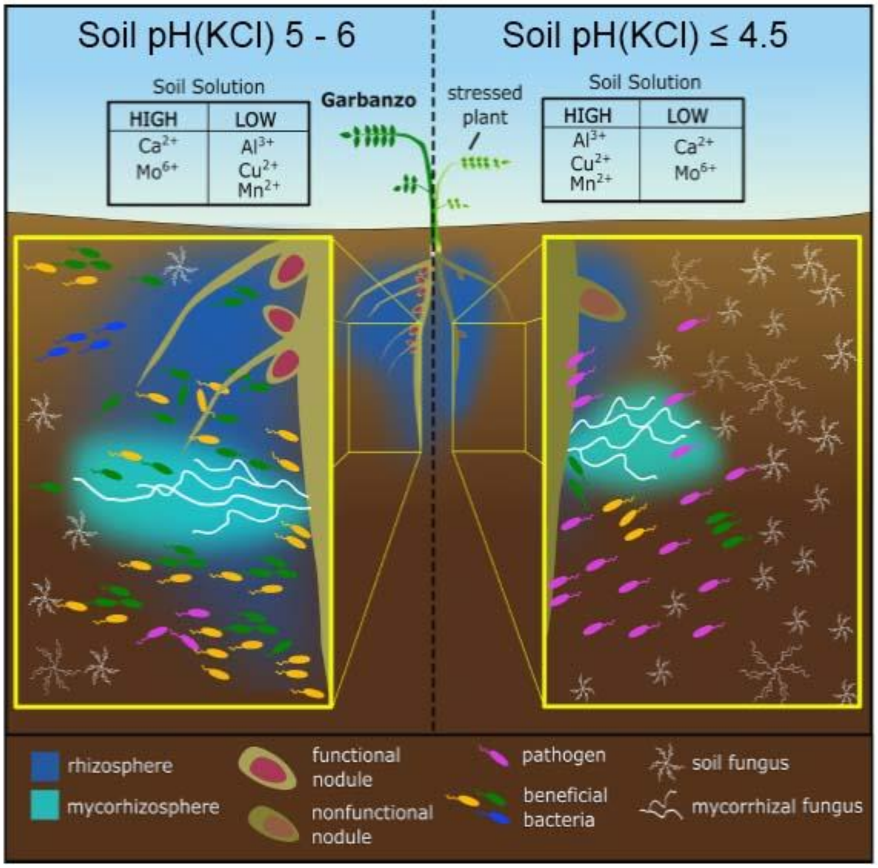
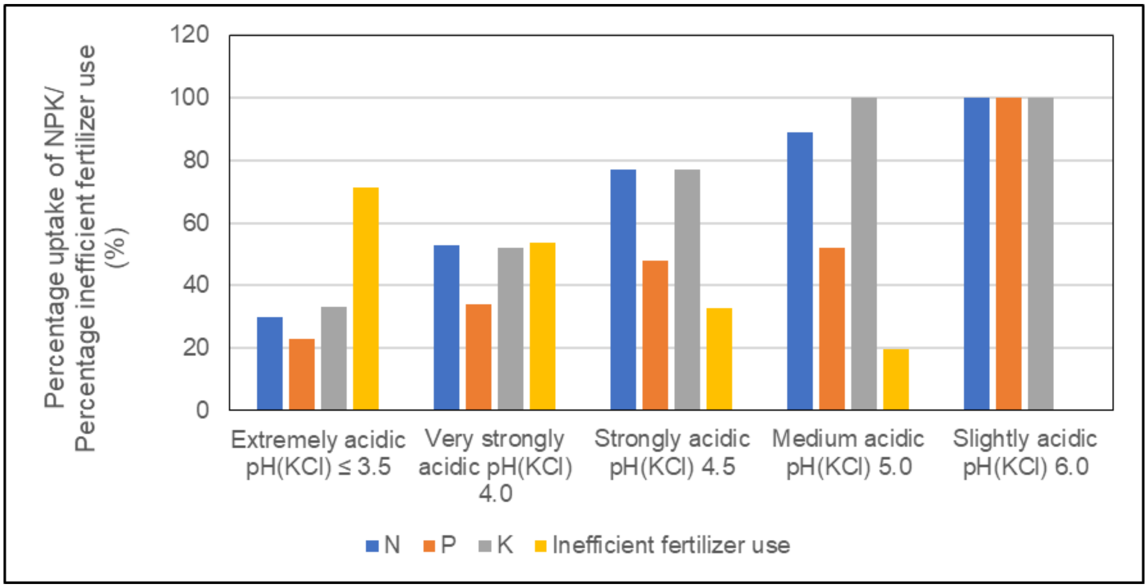


Figure 2. Illustrating the effect of soil pH on the microbiological composition in soil (Sullivan, TS and Lewis, RW, 2017)

The availability of nutrients for uptake by plant roots is therefore affected by a range of complex interactions between the soil, soil solution (soil water) and micro-organisms. Regular soil analyses should be conducted to ensure that soil acidity does not result in yield losses.

Soil acidity does not only lead to yield losses, but it also results in poor utilization of fertilizer and built-up soil fertility. Graph 2 gives an indication of the utilization of nitrogen (N), phosphate (P) and potassium (K), as well as the percentage fertilizer inefficiency at different soil pH levels.



Graph 2. Percentage utilization of NPK and inefficient fertilizer use at different pH levels. (Snyders, C)

It is clear from Graph 2 that nutrients are not used very effectively in acid soils. At a pH(KCl) of 4, as much as 54% of nutrients are not taken up efficiently. Only 53% of nitrogen is taken up, compared to 34% of phosphate and only 52% of potassium. In comparison, nutrients are taken up very effectively at a pH(KCl) of 5.5 or higher.

Furthermore, soil acidity can lead to induced deficiencies, even though enough nutrients are present in the soil. Plant roots are not able to absorb nutrients because of the soil acidity. Photo 1 shows critical phosphate deficiency symptoms on the leaves of a young maize plant. Photo 2 shows phosphate and magnesium deficiencies. After a thorough investigation, it was found that the soil was very acidic with very low levels of calcium, magnesium and potassium. The phosphorus supply was sufficient, but this could not be used by the plant due to the acidic conditions. Table 1 shows the soil analysis results.

Photo 1. Visible phosphate deficiency symptoms on a young maize plant in Viljoenskroon. (van Zyl, K, 2020)

Photo 2. Phosphate and magnesium deficiencies in Viljoenskroon.
(van Zyl, K)

Table 1. Soil analysis results relevant to Photo 1 and Photo 2.

pH(KCl)	%AS*	P(mg/kg)	Ca(mg/kg)	Mg(mg/kg)	K(mg/kg)
3.9	40.1	46	58	16	51

*%AS-% acid saturation (P-Bray 1 ; Cation – Ammonium accetate).

If high amounts of fertilizer are band placed in acidic subsoil before planting, the utilization of this fertilizer, especially the phosphate, will be very poor. Efficient nutrient uptake resulting in a maximum return on investment is only possible where soil acidity is managed optimally. For this, regular soil sampling and a correct liming programme is essential.

References:

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