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Soil pH and Plant Nutrients

Farmers frequently ask, "What effect does pH have on availability of nutrients in the soil?" There is no simple answer to this question, since the effects of pH are complex and vary with different nutrients. However, some broad generalizations are useful to keep in mind when making nutrient management decisions.

Soil pH

The first order of business is a quick review of pH and the associated terminology. Soil pH or soil reaction is an indication of the acidity or alkalinity of soil and is measured in pH units. The pH scale goes from 0 to 14 with pH 7 as the neutral point. As the amount of hydrogen ions in the soil increases, the soil pH decreases, thus becoming more acidic. From pH 7 to 0, the soil is increasingly more acidic, and from pH 7 to 14, the soil is increasingly more alkaline or basic.

Using a strict chemical definition, pH is the negative log of hydrogen (H^+) activity in an aqueous solution. The point to remember from the chemical definition is that pH values are reported on a negative log scale. So, a 1 unit change in the pH value signifies a 10-fold change in the actual activity of H^+, and the activity increases as the pH value decreases.

To put this into perspective, a soil pH of 6 has 10 times more hydrogen ions than a soil with a pH of 7, and a soil with a pH of 5 has 100 times more hydrogen ions than a soil with a pH of 7. Activity increases as the pH value decreases.

Agronomists generally use soil pH as measured in a 2:1 water-to-soil mixture as an index of a soil's acidity or alkalinity. In a soil test report, pH is often reported with descriptive modifier as shown in Table 1.

Table 1. Soil pH and Interpretation

5.0	5.5	6.0	6.5	7.0	7.5	8.0
Strongly Acid	Medium Acid	Slightly Acid	Neutral	Neutral	Mildly Alkaline	Moderately Alkaline
			Best Range for Most Crops			

Nitrogen

One of the key soil nutrients is nitrogen (N). Plants can take up N in the ammonium (NH_4^+) or nitrate ($N0_3^-$) form. At pH's near neutral (pH 7), the microbial conversion of NH_4^+ to nitrate (nitrification) is rapid, and crops generally take up nitrate. In acid soils (pH < 6), nitrification is slow, and plants with the ability to take up NH_4^+ may have an advantage.

Soil pH also plays an important role in volatization losses. Ammonium in the soil solution exists in equilibrium with ammonia gas (NH_3). The equilibrium is strongly pH dependent. The difference between NH_3 and NH_4^+ is a H^+. For example, if NH_4^+ were applied to a soil at pH 7, the equilibrium condition would be 99% NH_4^+ and 1% NH_3. At pH 8, approximately 10% would exist as NH_3.

This means that a fertilizer like urea (46-0-0) is generally subject to higher losses at higher pH. But it does not mean that losses at pH 7 will be 1% or less. The equilibrium is dynamic. As soon as a molecule of NH_3 escapes the soil, a molecule of NH_4^+ converts to NH_3 to maintain the equilibrium.

There are other factors such as soil moisture, temperature, texture and cation exchange capacity that can affect volatilization. So pH is not the whole story.

The important point to remember is that under conditions of low soil moisture or poor incorporation, volatilization loss can be considerable even at pH values as low as 5.5.

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Soil pH is also an important factor in the N nutrition of legumes. The survival and activity of *Rhizobium*, the bacteria responsible for N fixation in association with legumes, declines as soil acidity increases. This is the particular concern when attempting to grow alfalfa on soils with pH below 6.

Phosphorus

The form and availability of soil phosphorus (P) is also highly pH dependent. Plants take up soluble P from the soil solution, but this pool tends to be extremely low, often less than 1 lb/ac.

The limited solubility of P relates to its tendancy to form a wide range of stable minerals in soil. Under alkaline soil conditions, P fertilizers such as mono-ammonium phosphate (11-55-0) generally form more stable (less soluble) minerals through reactions with calcium (Ca).

Contrary to popular belief, the P in these Ca-P minerals will still contribute to crop P requirements. As plants remove P from the soil solution, the more soluble of the Ca-P minerals dissolve, and solution P levels are replenished. Greenhouse and field research has shown that over 90 per cent of the fertilizer P tied up this year in Ca-P minerals will still be available to crops in subsequent years.

The fate of added P in acidic soils is somewhat different as precipitation reactions occur with aluminum (A1) and iron (Fe). The tie-up of P in A1-P and Fe-P minerals under acidic conditions tends to be more permanent than in Ca-P minerals.

Potassium

The fixation of potassium (K) and entrapment at specific sites between clay layers tends to be lower under acid conditions. This situation is thought to be due to the presence of soluble aluminum that occupies the binding sites.

One would think that raising the pH through liming would increase fixation and reduce K availability; however, this is not the case, at least in the short term. Liming increases K availability, likely through the displacement of exchangeable K by Ca.

Sulfur

Sulfate ($S0_4^{2-}$) sulfur, the plant available form of S, is little affected by soil pH.

Micronutrients

The availability of the micronutrients manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), and boron (B) tend to decrease as soil pH increases. The exact mechanisms responsible for reducing availability differ for each nutrient, but can include formation of low solubility compounds, greater retention by soil colloids (clays and organic matter) and conversion of soluble forms to ions that plants cannot absorb.

Molybdenum (Mo) behaves counter to the trend described above. Plant availability is lower under acid conditions.

Conclusion

So, soil pH does play a role in nutrient availability. Should you be concerned on your farm? Be more aware than concerned. Keep the pH factor in mind when planning nutrient management programs. Also, keep historical records of soil pH in your fields. Soils tend to acidify over time, particularly when large applications of NH_4^+ based fertilizers are used or there is a high proportion of legumes in the rotation.

Recent years have shown the pH decline occurring more rapidly in continuously cropped, direct-seeded land. On the other hand, seepage of alkaline salts can raise the pH above the optimum range. So, a soil with an optimum pH today may be too acid or alkaline a decade from now, depending on producer land management.

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