IPNI
Plant Nutrition TODAY
Better Crops, Better Environment...through Science

From Scientific Staff of the
International Plant Nutrition Institute (IPNI)
3500 Parkway Lane, Suite 550
Norcross, Georgia 30092-2806 USA
Phone: 770-447-0335 Fax: 770-448-0439
E-mail: info@ipni.net Website: www.ipni.net

Fall 2010, No. 2

SOIL pH AND THE AVAILABILITY OF PLANT NUTRIENTS

Soil pH is a characteristic that describes the relative acidity or alkalinity of the soil. Technically, pH is defined as the negative (-) log or base 10 value of the concentration of hydrogen ions (H^+). Pure water will be close to a neutral pH, that is 10 to the minus 7 concentration of H^+ ions (10^{-7} [H^+]). This concentration is expressed as 7. Any value above 7 means the H^+ ion concentration is lower than at a neutral pH and the solution is alkaline and there are more hydroxyl (OH^-) ions present than H^+ ions. Any value below 7 means the H^+ ion concentration is greater than at neutral pH and the solution is acidic. Soils are considered acidic below a pH of 5, and very acidic below a pH of 4. Conversely, soils are considered alkaline above a pH of 7.5 and very alkaline above a pH of 8. Typically, soil pH values are measured when 10 g of air-dried soil is mixed with 20 ml of double-distilled water or 20 ml of 0.01 M $CaCl_2$ solution, and the pH is measured using an appropriate electrode connected to a pH meter. This soil analysis is a regular part of most if not all soil test protocols.

The availability of some plant nutrients is greatly affected by soil pH. The "ideal" soil pH is close to neutral, and neutral soils are considered to fall within a range from a slightly acidic pH of 6.5 to slightly alkaline pH of 7.5. It has been determined that most plant nutrients are optimally available to plants within this 6.5 to 7.5 pH range, plus this range of pH is generally very compatible to plant root growth. Nitrogen, K, and S are major plant nutrients that appear to be less affected directly by soil pH than many others, but still are to some extent. Phosphorus, however, is directly affected. At alkaline pH values, greater than pH 7.5 for example, the HPO_4^{2-} phosphate ions tend to react quickly with calcium (Ca) and magnesium (Mg) to form less soluble compounds. At acidic pH values, the $H_2PO_4^-$ phosphate ions react with aluminum (Al) and iron (Fe) to again form less soluble compounds. Most of the other nutrients (micronutrients especially) tend to be less available when soil pH is above 7.5, and in fact are optimally available at a slightly acidic pH, e.g. 6.5 to 6.8. The exception is molybdenum (Mo), which appears to be less available under acidic pH and more available at moderately alkaline pH values.

In some situations, materials are added to the soil to adjust the pH. On a field scale, this is most commonly done for acidic soils to raise the pH from an acidic level of 4.5 to 5.5 up to 6.5 or approaching neutrality. This is done by applying and incorporating a liming material, often finely ground calcitic ($CaCO_3$) limestone, or dolomitic [$CaMg(CO_3)_2$] limestone, that is spread using specialized lime spreaders, or spin-spreaders adapted with vibrating systems to prevent bridging of the material in the hoppers of the spreaders. It is possible to lower the pH of a soil using a liquid acid solution, or finely ground elemental S that oxidizes to sulfuric acid through the action of soil inhabiting S-oxidizing bacteria. However, this is rarely done on a field-scale basis because of the high cost. It is more commonly done in horticulture production applications where individual plant containers or limited areas (e.g. <10 to 20 acres) are managed to lower the pH for acidic soil adapted plants such as some flowers, trees, and/or small fruits (i.e. blueberry and cranberry). It is important to note that most on-going crop production, especially where NH_4^+ based, or NH_4^+ releasing N fertilizers (e.g. anhydrous ammonia, ammonium sulfate, and urea) are applied, will gradually lower the soil pH, as the H^+ ions are released from the NH_4^+ ions when they are converted over to nitrate (NO_3^-) by soil microbes.

Whether or not you try to adjust pH, it is important to understand other methods to increase the availability and use of added nutrients. This can be done in a number of ways for the nutrients mentioned above that are adversely affected by extremes in soil pH, acidic or alkaline. For example, P-containing fertilizer can be applied in or close to the seed-row at planting to facilitate early season uptake of phosphate ions by crop roots before allowing it to react with soil cations dominating under acidic (e.g. Al^{3+} or Fe^{3+}) or alkaline (e.g. Ca^{2+} or Mg^{2+}) soil pH conditions. Under alkaline soil pH values, the phosphate fertilizer can be applied in bands with fertilizer which generates NH_4^+ as noted above. That will allow slight acidification of the soil adjacent to the fertilizer band. Another method is to manufacture compound nutrient fertilizer granules that contain the N, P, and even elemental S-containing fertilizers, for application to alkaline soils so the soil adjacent to the granule will also be acidified slightly and allow enhanced P uptake when the crop roots intercept the granules. Yet another example is the foliar application of soluble Fe fertilizer compounds to Fe-deficient crops grown in high pH soils where the Fe^{3+} ions of the Fe fertilizer react so fast with soil that the nutrient is tied up and unavailable to plants. This is why soil applied Fe fertilizers often do not successfully correct Fe deficiencies. By avoiding the soil and applying the Fe to the leaves, the small amount of plant-required Fe is successfully introduced into the crop.

Next time you have soil samples taken on your fields, take time to note what the pH values are in your results. It is useful to compare these values to previous soil test pH values and determine if there is a trend of soil pH change. By monitoring the pH values regularly (every 2 to 3 years) in a field, you may consider action to raise the pH of the soil from acidic to near neutral pH values by liming. Increased nutrient availability and improved crop growth can be achieved when adding liming material to an excessively acidic soil. This can be especially important for crops requiring neutral pH, such as legume forages or pulses, as the *Rhizobia* species bacteria do not nodulate and fix N effectively under pH values less than 5.5.

—TLJ—

For more information, contact Dr. Thomas L. Jensen, Northern Great Plains Director, IPNI, 102-411 Downey Road, Saskatoon, SK S7N 4L8. Phone: (306) 652-3535. E-mail: tjensen@ipni.net.

Abbreviations: N = nitrogen; NH_4^+ = ammonium; P = phosphorus; K = potassium; S = sulfur.

Note: ***Plant Nutrition TODAY*** articles are available online at the IPNI website: www.ipni.net/pnt