Plant Nutrition V – Soil Tests

I'm sure you've heard the mantra, "Don't Guess, Soil Test". And one of the first questions that a horticulture agent will ask you when you send them pictures of a "less than healthy" plant or lawn is, "Have you done a soil test?"

Throughout this series of articles, soil tests have been brought up over and over. Since they seem to be a subject of every soil/plant article and are apparently valued by horticulture agents, then we should look more closely at the subject of "Soil Tests".

Many gardeners have taken soil samples for soil tests and diligently sent them off for analysis. They get the results, look them over and, based on the number of phone calls we get, ask, "What does it all mean?" Many of you use the LSU AgCenter Soil Testing & Plant Analysis Lab (STPAL) to perform your soil tests. Therefore, we will use their report to explore what we can learn from soil analysis.

Routine Soil Test

Soil pH

At the STPAL, soil pH is measured in 1:1 suspension of soil in deionized water and Louisiana interpretations are based on that method. Other laboratories may use different ratios or even different background liquids, which will result in different pH values. Figure 1 shows the relationship between soil pH and plant nutrient availability for most plants, which is in the slightly acidic range. However, there are plants that prefer a more acid and others that prefer a more alkaline pH. Plants can take up their nutrients only in specific chemical forms. Because soil pH affects chemical composition of soils, it has great influence on whether the soil nutrients are available to plants.

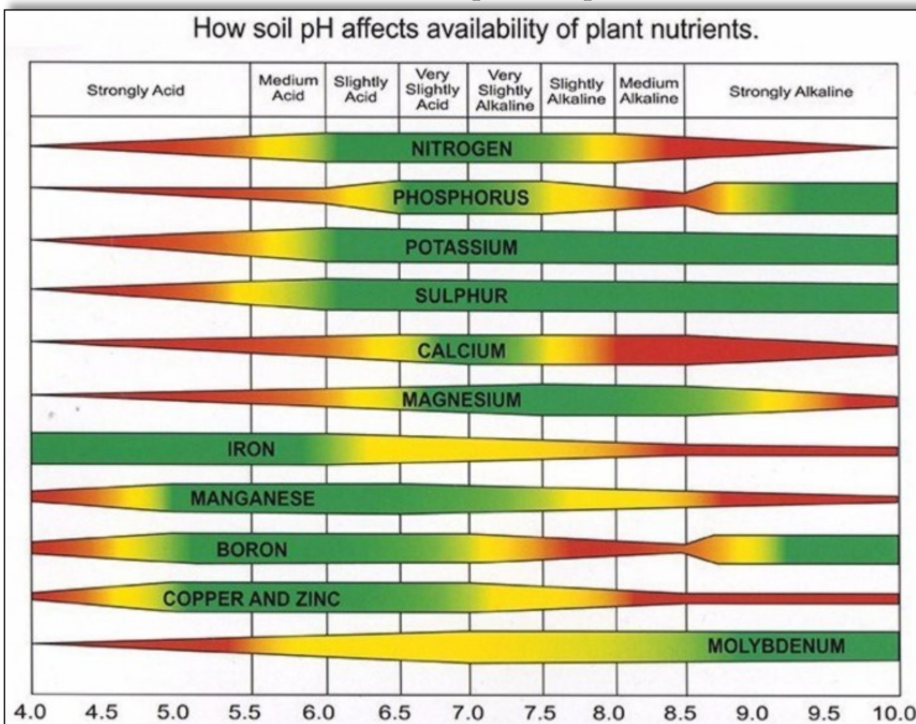

Figure 1: Effect of soil pH on soil nutrient availability. The wider the band, the more the nutrient is available.

Soil test pH results will range from very low – low – optimum – high – very high. Each plant species has a pH range that is considered optimum for its peak performance. Figure 2 shows the effect of soil pH on plant performance which can be evaluated by different metrics such as the plant's appearance or yield.

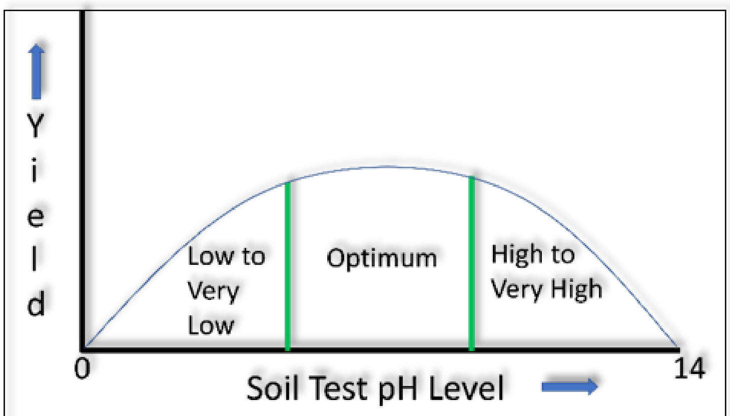

Figure 2: Effect of soil pH on plant production.

When you submit a soil sample for testing, you indicate what you plan to grow, and the soil pH interpretation is based on the requirements of the plants that you plan to grow and on the measurement method. While the optimum pH is the most desirable, in most cases, the shoulders near the optimum curve will suffice. In cases where the pH is far outside the optimum range, the soil test results will make recommendations for raising or lowering the soil pH (see GNO Gardening 11/21 and 12/21 for articles on how to adjust soil pH).

Phosphorus, Potassium, Calcium, Magnesium, Sodium, Sulfur, Copper, Zinc

At the STPAL, availability of these plant macro- and micronutrients is evaluated by extraction with Mehlich 3 reagent and the Louisiana interpretations are based on that method. Other laboratories may employ different reagents. For each of these nutrients reported on your soil test results, there will be an interpretation ranging from very low – low – optimum – high – very high. Figure 3 shows the expected plant yield results for given nutrient levels in the soil.

What the interpretation range means is, when the soil test is very low to medium, addition of this nutrient fertilizer is expected to give a yield/performance increase. When the soil test result is optimum to very high, addition of this nutrient fertilizer will give no yield/performance increase. When fertilizer addition is recommended for soils testing high, the addition is to maintain soil fertility at the desirable level. In general:

Rating	Meaning
Very Low	Less than 50 % of the crop yield potential or esthetic value is expected without the addition of that nutrient.
Low	Somewhere between 50–75 % of the crop yield potential or esthetic value is expected without the addition of that nutrient.
Medium	From 75- to perhaps 95 % of the crop yield or esthetic value is expected without the addition of the nutrient.
High	A yield increase to the added nutrient or an increase in esthetic value is not expected. The soil can supply the entire crop nutrient requirement for both the vegetative and reproductive stages of development.
Very High	A yield increase or increase in esthetic value from adding that nutrient is not expected. The soil can supply much more than the entire crop requirement, and still contain a reserve of that nutrient for the next crop.

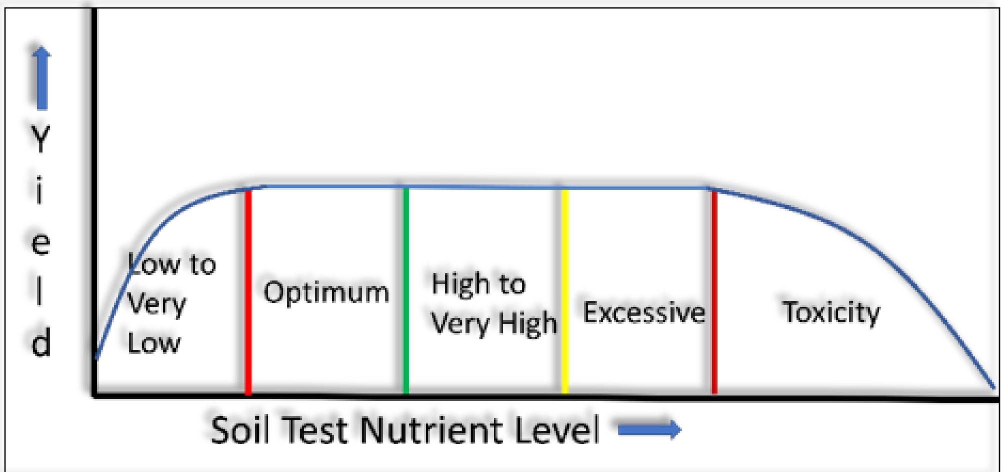

Figure 3: Plant yield based on soil nutrient levels.

What about "Excessive" levels of these nutrients?

Excessive phosphorus, particularly in combination with a high soil pH (above 6.5), can induce micronutrient deficiencies of zinc and iron. Excessive phosphorus levels may also have negative environmental impacts to nearby water sources.

When it comes to potassium, plants are able to tolerate relatively large extractable concentrations. However, excessive potassium can induce deficiencies of other nutrients such as nitrogen, calcium and magnesium.

Excessive calcium is unlikely to cause toxicity in and of itself, but just like potassium, it can reduce the uptake of other nutrients (mostly cations) with corresponding consequences.

Magnesium toxicity is rare.

Sodium is not a plant nutrient for most plants because it does not meet the strict definition of "essentiality." However, it is required by some plants such as corn and it plays a role in soil health. High levels of sodium indicate salinity or sodicity problems such as poor soil structure. Excess sodium can also reduce the uptake of other nutrients by plants.

For practical purposes, sulfur toxicity should be considered unlikely as sulfate, the main form of sulfur in soil, can be leached after major rain events. Excess soil sulfur can prevent the uptake of other nutrients though - nitrogen for example.

Excessive copper can inhibit iron uptake by plants and can also stunt growth. Excess soil copper can inhibit seed germination. If you find excessive levels of copper in your soil, ensure your soil has enough phosphorus and zinc, that the pH is not too low (too acidic) and add plenty of organic matter such as compost on a regular basis.

Zinc toxicity is most common when plants are grown in acidic soil and in the presence of excessive soil magnesium. In tests, concentrations above 150 ppm Zn corresponded to severe stunting.

You may have noticed that nitrogen levels in the soil are not part of the routine soil test even though it is the most prominent nutrient among those obtained by plants from soil. Soil nitrogen levels fluctuate because it is susceptible to loss. In addition to the desired loss by crop removal, it can be lost by leaching, denitrification, or volatilization. Denitrification is the microbial process of reducing nitrate ion to nitrite ion and then to gaseous forms of nitrogen. If you take a soil sample in the morning and a second sample in the evening after a day of heavy rain, the levels of phosphorus and potassium will be similar in both samples. However, nitrogen levels may vary greatly because the heavy rain will leach a large amount of the available nitrogen out of the root zone. Soil mineral nitrogen in form of ammonium ion is susceptible to loss in soil with pH above 7.5 due to volatilization in form of ammonia gas.

Recommendations

Along with the results of your routine test, there will also be recommendations based on the results of your test and the crop you indicated that you plan to grow. If the pH is too high or too low, there will be a recommendation of the amount of lime or sulfur you need to add to correct the pH. The recommended amount should be added to the soil all in one application and thoroughly mixed into the top 4-6" of soil.

If there is insufficient phosphorus available, there will be a recommendation of the amount of triple super phosphate ($Ca(H_2PO_4)_2 \cdot H_2O$) also known as 0-45-0 to add to the soil. Triple super phosphate is the most common and readily available agricultural source of phosphorus. All of the recommended amount should be added to the soil at the beginning of the growing season. Except for sandy soils, phosphorus is not susceptible to leaching losses and will remain in the root zone for a duration of a growing season. However, it is not recommended to fertilize with phosphate in excess of one growing season as the unused excess gradually precipitates in the form of insoluble salts.

If there is insufficient potassium available, there will be a recommendation of the amount of muriate of potash (KCl:NaCl = 95:5 or higher) also known as 0-0-60 to add to the soil. This is the most common source of agricultural potassium. Potassium is very stable in most soils with the exception of very sandy soil and will remain in the root zone for a duration of a growing season. Therefore, the entire recommended amount of muriate of potash can be added all at once at the beginning of the growing season.

The nitrogen recommendation is for the amount of nitrogen your crop will need for optimal performance for that growing season. Due to soil nitrogen instability, the recommended amount of nitrogen SHOULD NOT all be added to the soil at one time. The recommended amount should be divided up based on soil texture and plant growth stage into two or more applications spread throughout the season. You should check the specific recommendations for the crop you are growing to see when these applications should be made.

Another difference with the nitrogen recommendation is that the recommendation says, "Nitrogen source (Choose One)". The recommendation gives you three options as a source for nitrogen: ammonium sulfate ($(NH_4)_2SO_4$), urea ($CO(NH_2)_2$), or ammonium nitrate (NH_4NO_3). You choose which you want to use as your nitrogen source usually based on availability and cost. Do NOT add recommended amounts of all three. Finally, soil fertilization cannot be approached selectively, and equal attention must be paid to all recommended nutrients as improved plant performance due to increasing availability of one nutrient may increase the demand for other nutrient(s).

Additional Soil Tests

In addition to the Routine Soil test, additional soil tests can be performed for additional fees. The following are some of the additional tests that can be requested.

Soil Organic Matter (SOM)

Soil organic matter is composed of materials containing organic form of carbon. These materials include plant and animal remains (including bacteria and fungi) in various stages of decomposition, root and microbial exudates and humus. Increasing levels of SOM improve the physical, chemical, and biological functions of the soil (see GNO Gardening, "Organic Matters", October 2018).

Most garden and landscape plants perform best when the SOM level is at least 2% (the goal for vegetable and flower beds should be 5%-7%). Soils in Louisiana have an average SOM of 1.4%. See GNO Gardening, October 2018 for ways to increase SOM.

Aluminum

Aluminum is the third most abundant element (after oxygen and silicon) in the earth's crust, representing approximately 8.1% of its content by weight. Plants and soil organisms are not usually exposed to problematic concentrations of aluminum in the soil as it is mainly found in the form of a mineral (aluminosilicates and aluminum oxides). Concentrations of soluble aluminum increase in acid soils and this soluble aluminum is toxic for plant growth with the main effect of aluminum toxicity being inhibition of root growth.

High levels of aluminum are toxic to some plants and are associated with acidic soil. Plants will become stunted if they absorb too much aluminum. They may also show symptoms of phosphorus deficiency, calcium deficiency, magnesium deficiency or sulfur deficiency. If the pH of soil is greater than 5.5 aluminum is not as available to plants so is less likely to cause toxicity.

Boron

Boron is an essential plant micronutrient. It is used by plants during cell division and is required for development of tissue near the tips of shoots and roots. It is also required for the growth of the pollen tube during flower pollination and thus fruit and seed production. Boron is thought to increase nectar production by flowers, so it is important for attracting pollinating insects. It is also required for good cell structure and as a result, the tissue of boron deficient plants often breaks down prematurely resulting in brown flecks, necrotic spots, cracking and corky areas in fruit and tubers. Excess boron inhibits seed germination. Boron deficiency is seldom a problem in our soils.

Soluble Salts

Water soluble salts are a natural component in soils. At the STPAL, the content of water-soluble salts is estimated by measuring Electric Conductivity (EC) of the 1:2 suspension of soil in deionized water. The content is then reported as the amount of Total Dissolved Salts (TDS). The most common soluble salts in soils are composed of the cations, calcium (Ca^{2+}), magnesium (Mg^{2+}), and sodium (Na^+), and the anions chloride (Cl^-), sulfate (SO_4^{2-}), and bicarbonate (HCO_3^-). Smaller quantities of potassium (K^+), ammonium (NH_4^+), nitrate (NO_3^-), and carbonate (CO_3^{2-}) are also found in most soils.

Many of these ions are plant nutrients and at optimum levels do not harm plants. However, excess soluble salts can damage roots and lead to problems with water uptake. High soluble salt content in irrigation water can also lead to leaf burn. Wilting, yellowing, and marginal and tip burn of leaves, (scorching), are all symptoms of excess soluble salts. Plant species vary markedly in their tolerance to soluble salts. Therefore, the values must be interpreted in relation to a specific plant species.

Manganese, Iron, Copper, Zinc

Manganese is a plant micronutrient. It fulfills a number of roles and is important in photosynthesis, synthesis of chlorophyll and nitrogen absorption as well as the synthesis of riboflavin, ascorbic acid and carotene. Manganese deficiency is most common on alkaline and poorly drained soils as well as those high in available iron. Manganese toxicity is more common on very acidic soil. It can be toxic in its own right, but excess manganese can also cause iron deficiency.

Iron is the fourth most abundant element found in soil where it is largely present in solid form with extremely low solubility in water, which limits its availability to plants. Iron, in small amounts, is essential for healthy plant growth and is classed as a micronutrient. It is important for the development and function of chlorophyll and a range of enzymes and proteins. It also plays a role in respiration, nitrogen fixation, energy transfer and metabolism. Iron deficiency is most likely to occur in plants when the soil is alkaline or when the level of phosphorus, zinc, manganese or molybdenum in the soil is high. Heavy metal contamination can also lead to iron deficiency.

Total Nitrogen

Total nitrogen analysis measures nitrogen in all organic and inorganic forms. Total nitrogen does not indicate plant-available nitrogen; hence, it is not included in routine soil testing. Total nitrogen analysis, while not recommended as part of a standard soil testing program, may be better than organic matter analysis for estimating soil nitrogen supplying capability.

Total Carbon

Total carbon in soils is the sum of both organic and inorganic carbon. Organic carbon is present in the soil organic matter fraction, whereas inorganic carbon is largely found in carbonate minerals.

Soil carbon can provide some plant nutrients through mineralization. However, its main functions are to aggregate soil particles (structure) to provide resilience to physical degradation and improve water infiltration and percolation, increases microbial activity, and protects soil from erosion.

Flood Test

Flood test provides results in the form of water-soluble major ions such as calcium, magnesium, sodium, chloride and sulfate, Electric Conductivity (EC), and Sodium Adsorption Ratio (SAR).

The SAR is the ratio of sodium (Na) to calcium (Ca) plus magnesium (Mg) in the soil solution. A high SAR can cause the deterioration of soil aggregates and often results in surface crusting and poor water infiltration, poor plant emergence and growth. Soils with a SAR greater than 10 to 15 and EC lower than 4 dS/m are classified as sodic and will likely require the addition of gypsum (hydrated form of calcium sulfate) or other amendments (such as elemental sulfur and/or organic matter) to aid in the displacement of sodium, reformation and stabilization of soil aggregates, and improvement of infiltration.

Chlorine is classed as a plant micronutrient meaning that it is essential for the proper growth of plants. Chlorine is important for plant photosynthesis as it is involved in the opening and closing of stomata. Chlorine toxicity can occur naturally when plants are grown in coastal soils and near chlorinated pools (though much of the damage associated with chlorinated pools is due to the vapors coming into contact with leaves rather than because the plant has too much chlorine uptake).

Summary

Though soil test results may sometimes seem like a lot of data with little meaning to the average gardener, the results can be very informative once you know why the tests were performed. A soil test, whether a routine analysis or a combination of multiple tests, provide a lot of information about the soil you are growing your valuable plants in. It lets you know what nutrients are in the soil, whether they are available for your plants to use, whether any common nutrients are present at toxic levels, and what you need to add or do to your soil to make it the most hospitable environment for your plants.

Hopefully, this article makes reading your soil test results more of a journey of enlightenment rather than an unintelligible maze of information.

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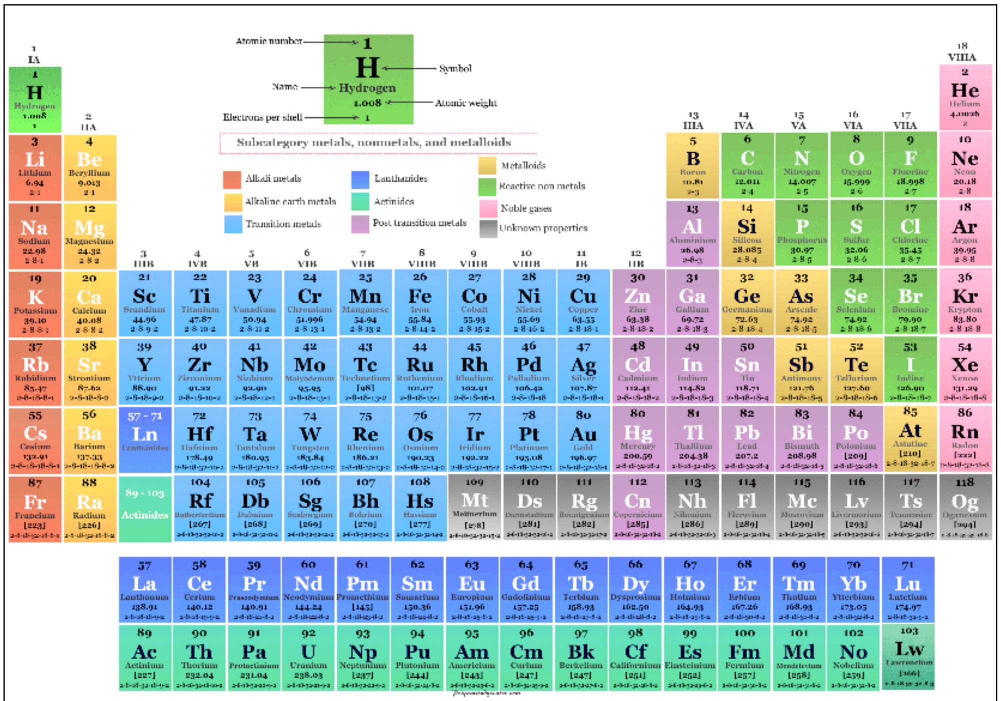

The periodic table of chemical elements, often called the periodic table, organizes all discovered chemical elements in rows (called periods) and columns (called groups) according to increasing atomic number.

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