

## Interpreting a Soil Test Report

Soil testing is a critical practice for producing healthy plants and crops, providing essential information on soil nutrient levels and their availability for plant growth.

The Soil, Water and Plant Testing Lab (SWPTL) provides soil testing packages that support effective soil management for agricultural and horticultural professionals and others seeking to diagnose and improve soil fertility. This guide explains how to interpret soil test reports and use the results to make informed fertilizer and soil amendment decisions that promote healthy plant growth and development.

Soil sampling procedures should be conducted properly to obtain quality soil test results. Each sample should represent the entire field or a specific sampling area. Samples must be taken at the proper depth, 6 or 8 inches (2 or 3 inches for turf and lawns) during the same time each year to identify trends over time. Ideally, soil sampling should be done annually in the spring to best estimate nutrient availability for the upcoming growing season. Sampling in the fall does not always capture the true amount of nitrogen (N) that will be available at planting in the spring because some N is released from organic matter (OM) during the winter months due to a process known as mineralization or decomposition. However, if the fall and winter are cold and dry little N mineralization and/or leaching occur.

Soil test results categorize nutrient levels as low, medium, optimum, or high. For certain nutrients, the SWPT Lab further refines these categories to very low, low, medium, optimum, high, and very high. The limit between the medium and high categories is defined as the *critical level*, which indicates when fertilizer applications are needed (below the critical level) or unnecessary (above the critical level) (Figure 1). These ranges apply only to the test methods specified in the report.

Soil test values are interpreted in relation to expected crop yields and production goals. Nutrient ranges are established around a critical level—the point at which 90–95% of maximum yield is achieved. These ranges are derived from fertilizer trials that evaluate crop responses to varying nutrient application rates. Values above the critical level are considered adequate, allowing for natural field variability and sampling error.

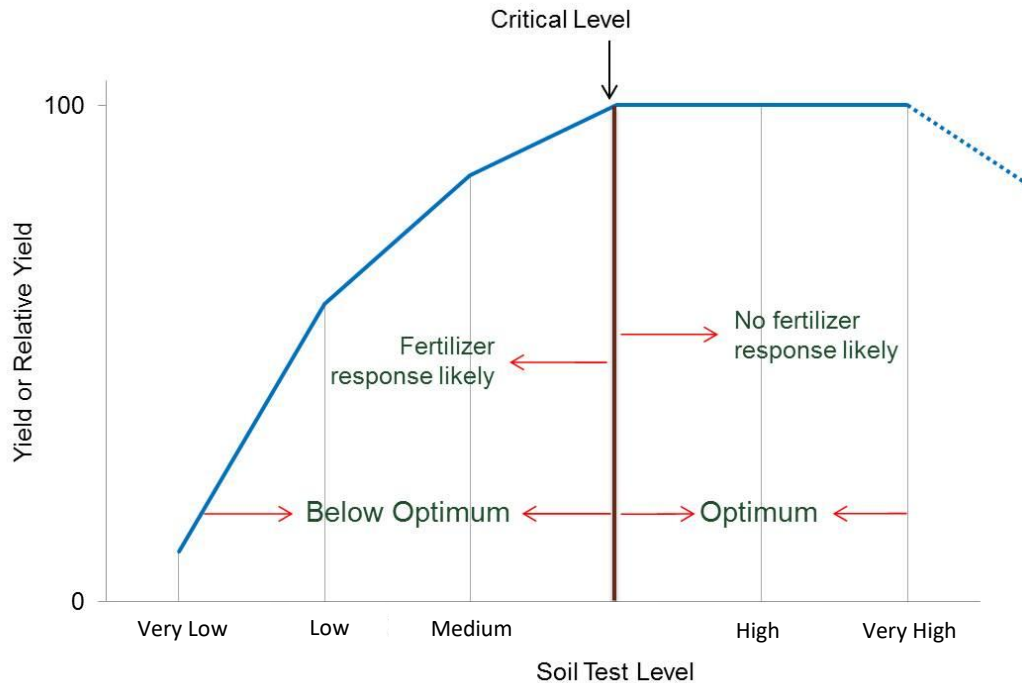


Figure 1. Soil test value vs. probability of crop yield response to nutrient addition. Crop yield increase due to nutrient addition is likely at low soil test values and unlikely at high soil test values

This guide describes each of the soil parameters measured and included in the different soil test packages offered by the SWPTL.

**Soil pH** indicates the acidity or alkalinity of a soil. Values below 7.0 are considered acidic, those above 7.0 are alkaline, and a pH of 7.0 is neutral. Soil pH typically ranges from 3 to 9. Most plants grow well within a pH range of 6.0 to 7.5, where nutrient availability is generally highest (Figure 2), although some species require conditions outside this range.

**Soil pH** influences numerous biological and chemical processes, including nutrient availability, the presence of toxic elements, microbial activity, soil-borne disease dynamics, pesticide behavior, and soil structure.

Lowering **soil pH** is challenging. Ammonia-based fertilizers may gradually acidify soil, and elemental sulfur (S) can also reduce pH. However, substantial sulfur inputs are required; for example, approximately 10,000 lb per acre (230 lb per 1,000 sq ft) are needed to reduce soil pH from 8.0 to 7.5 in soils containing 1.5% calcium carbonate ( $\text{CaCO}_3$ ).

**Soluble Salts or Electric Conductivity (EC)** is a measurement of dissolved inorganic solutes. The most common soluble salts in soils are the cations, calcium ( $\text{Ca}^{+2}$ ), magnesium ( $\text{Mg}^{+2}$ ), and sodium ( $\text{Na}^{+}$ ), and the anions chloride ( $\text{Cl}^{-}$ ), sulfate ( $\text{SO}_4^{-2}$ ), and bicarbonate ( $\text{HCO}_3^{-}$ ). Smaller quantities of potassium ( $\text{K}^{+}$ ), ammonium ( $\text{NH}_4^{+}$ ), nitrate ( $\text{NO}_3^{-}$ ), and carbonate ( $\text{CO}_3^{-2}$ ) are also found in most soils. Sources of soluble salts in soils include soil organic matter, commercial fertilizers, animal manures, municipal

sewage sludge, runoff from areas where salt or ice-melt products have been used and irrigation water that is high in dissolved salts.

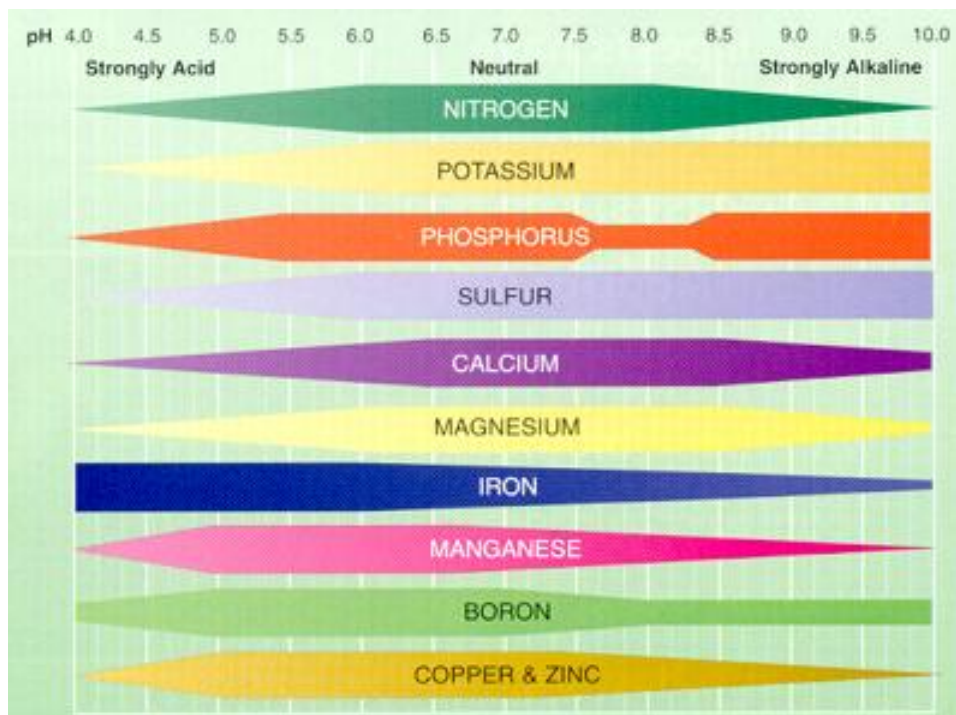


Figure 2. Soil pH effects on nutrient availability (Adapted from Truog, USDA Yearbook of Agriculture 1943-1947)

At low concentrations, soluble salts do not adversely affect plants. However, elevated levels can damage foliage, impair root function, and reduce water uptake. Symptoms of salt injury include wilting, yellowing, and marginal or tip leaf burn. Because plant tolerance to soluble salts varies widely among species, soil test values must be interpreted in the context of the specific plant being grown.

**Soil Organic Matter (SOM)** consists of carbon-based materials, including plant and animal residues, microbial biomass, and humus. SOM levels are influenced by factors such as soil texture, tillage practices, parent material, crop productivity, drainage, and overall management. It plays a critical role in enhancing soil water retention and nutrient-holding capacity. In Colorado, SOM levels are generally low, typically below 3%.

**Nitrogen (N)** is essential for plant growth and development. Plants take up nitrogen primarily as nitrate ( $\text{NO}_3^-$ ) and, to a lesser extent, ammonium ( $\text{NH}_4^+$ ). Soil test reports list only nitrate-N because ammonium-N levels are typically much lower. Nitrate-N is reported in parts per million (ppm) and represents the amount immediately available to plants, not the additional nitrogen that may become available through organic matter mineralization or losses that may occur through leaching or denitrification.

Nitrogen recommendations are based on **crop nutrient requirements and anticipated yield**, with the assumption that very small amounts of available N remain in the soil after a growing season. Nitrate, the mobile form of nitrogen, is primarily used to identify plant-available soil nitrogen.

Soil nitrogen content is calculated as:

$$\text{lb N/ac} = \text{ppm NO}_3\text{-N} \times 2 \times (\text{sample depth increment in/6 in})$$

The sample depth increment refers to the vertical distance represented by the sample. For example, a 0–8-inch sample has an 8-inch increment, and an 8–24-inch sample has a 16-inch increment.

**Phosphorous (P)** is involved in many vital plant growth processes, particularly energy storage and transfer. Soil test phosphorous an index of availability and is reported in parts per millions (ppm). The quantity of total P in the soil has little or no relation to the availability of P to plants as it is immobile in soil. The amount of phosphorus required to correct a deficiency depends on soil characteristics and the crop being grown. Availability decreases under cool, wet conditions, and additional phosphorus is not recommended when soil test values are high or excessive.

Table 1. Phosphorous (P) test (Olsen Bicarbonate) categories

| Soil P (ppm)<br>Olsen Bicarbonate | Relative Level |
|-----------------------------------|----------------|
| <3                                | Very Low       |
| 4-6                               | Low            |
| 7-10                              |                |
| 11-15                             | Medium         |
| 16-20                             | High           |
| >21                               | Very High      |

**Potassium (K)** is taken up by plants in large amounts compared to any other nutrient except nitrogen. Although total soil K content exceeds plant uptake during a growing season, in most cases only a small fraction of it is available to plants. Soils in Colorado have medium to high available K levels. It is recommended that soil be tested for K in the spring to provide the most accurate estimate of available K for crops that season. Potassium plays a key role in plant water regulation and contributes to important quality traits by supporting the synthesis and movement of photosynthates to reproductive and storage organs. In fruits and vegetables, adequate K improves size, color, and flavor.

Table 2. Potassium (K) test (Ammonium Acetate) categories

| Soil K (ppm)<br>Ammonium Acetate | Relative Level |
|----------------------------------|----------------|
| <60                              | Very Low       |
| 60-120                           | Low            |
| 121-160                          | Optimum        |
| 161-220                          | Medium         |
| 221-80                           | High           |
| >280                             | Very High      |

**Sulfur (S)** is a secondary macronutrient required in relatively large amounts for plant growth. Sulfur reactions in soil are very similar to N reactions. Like P and K, only a small fraction of the total soil S is readily available to plants.

Table 3. Sulfur (S) test (Calcium Phosphate) categories

| Soil S (ppm)<br>Calcium<br>Phosphate | Relative Level |
|--------------------------------------|----------------|
| <2                                   | Very Low       |
| 2-5                                  | Low            |
| 6-10                                 | Medium         |
| 11-15                                | High           |
| >15                                  | Very High      |

**Calcium** is closely related to soil pH. Calcium deficiencies are rare when soil pH is 6.2 to 7.2. The level for calcium will vary with soil type, but optimum ranges are normally in the 65% to 75% of cation saturation range. Calcium saturations above 85% may indicate a calcareous soil.

**Magnesium** is affected by the same factors affecting calcium levels in the soil. Adequate magnesium levels range from 30 to 70 ppm (60 to 140 lb/ac). The cation saturation for magnesium should be 10 to 15%. Magnesium saturations above 20% can adversely affect soil structure, water-infiltration, soil drainage and aeration.

**Sodium** is not a plant nutrient and therefore it is not necessary for plant growth. High levels of sodium are detrimental to soil structure and plant growth. Sodium levels are evaluated based on exchangeable sodium percentage (ESP). The ESP is the percentage of the cation exchange capacity (CEC) occupied by Na. ESP values above 10 percent are of concern. Excessive sodium levels can occur naturally or can result from irrigation with high-sodium water.

**Cation Exchange Capacity (CEC)** refers to the amount of positively charged ions (cations) a soil can hold. Nutrients are either positively charged or negatively charged when dissolved in water. Examples of positively charged ions (cations) include calcium ( $\text{Ca}^{++}$ ), magnesium ( $\text{Mg}^{++}$ ), potassium ( $\text{K}^+$ ), sodium ( $\text{Na}^+$ ), and ammonium ( $\text{NH}_4^+$ ). Soils have a slight negative charge due to the presence of clay particles and organic matter. Thus, the higher the clay content and organic matter content, the higher the CEC of the soil. Soils with a high CEC will tend to hold on to nutrients better than soils with a low CEC. The CEC of a soil can be increased by increasing the SOM content.

**Base Saturation** is defined as the percentage of the soil exchange sites (CEC) occupied by basic cations, such as potassium ( $\text{K}^+$ ), magnesium ( $\text{Mg}^{++}$ ), calcium ( $\text{Ca}^{++}$ ), and sodium ( $\text{Na}^+$ ). The base saturation percentages are calculated for each cation then added up to determine base saturation.

The percentage saturation for each of the base cations are commonly within the following ranges: calcium 40 to 80%; magnesium 10 to 40%; potassium 1 to 5%. Many consider an ideal base saturation range to be calcium 65 to 80%; magnesium 10 to 20%; potassium 2 to 7%; and sodium less than 1%.

**Micronutrients** or trace minerals are essential to plants but are required in very small amounts. **Zinc (Zn)**, **iron (Fe)**, **manganese (Mn)**, **copper (Cu)**, and **boron (B)** are reported. Micronutrient deficiencies occur in sandy, low organic matter soils. Deficiencies of **Zn** and **Fe** are commonly observed in Colorado due to high soil pH. Availability of most micronutrients is pH-dependent; availability decreases as pH increases [except for molybdenum (**Mo**)], which becomes more available as pH increases (Figure 2). Deficiencies rarely occur in soils with pH below 6.5. If a micronutrient deficiency is suspected, plant tissue testing may be a better diagnostic tool than soil testing.

A **Zn** soil test above 1.5 ppm using the DTPA extraction method is sufficient for most crops. Values of **Cu** above 0.6 ppm using the DTPA extraction method are sufficient. Copper deficiencies are extremely rare, regardless of soil test results. Adequate soil test **Mn** varies with plants, but soil test values between 1 and 5 ppm using the DTPA extraction method are usually sufficient. Manganese deficiencies occur only when soil pH is 8.0 or above. Low levels of **B** may limit plant growth, while high concentrations can be toxic. When applying B, apply it uniformly as a broadcast application and mix it thoroughly with the soil.

**Chloride (Cl)** testing is not a common practice, and little data exists for interpretation of test results. Wheat sometimes benefits from a Cl application. Little information exists on Cl soil test values and recommended rates in Colorado. Chloride is supplied with irrigation water and from organic sources such as manure and compost.

**Soil Texture** is dependent on how much sand, silt and clay is present. Soil texture will influence the physical and chemical properties of the soil. Soils with a light texture (sandy soils) and low CEC are more susceptible to leaching and should be managed by applying smaller quantities of nutrients more frequently.

### **Soil Salinity**

The terms salt and salinity are often used interchangeably, and sometimes incorrectly. Salt is simply an inorganic mineral that can dissolve in water. Many people associate salt with sodium chloride or common table salt. In reality, the salts that affect soils often are a combination of Na, Ca, K, Mg, Cl, NO<sub>3</sub>, SO<sub>4</sub>, bicarbonates (HCO<sub>3</sub>) and carbonates (CO<sub>3</sub>). These salts result from weather, in which small amounts of rocks and other deposits are dissolved over time. Fertilizers and organic amendments also add salts to the soil.

**Alkalinity** is associated with the **presence of sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>) or sodium bicarbonate (NaHCO<sub>3</sub>) in the soil**, either as a result of natural weathering of the soil particles or brought in by irrigation and/or flood water.

**Sodium Absorption Ratio (SAR)** is a measure of the amount of Na relative to Ca and Mg in the water extracted from a saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration. Soils that have values for SAR of 13 or more may have an increased dispersion of organic matter and clay particles, reduced saturated hydraulic conductivity and aeration, and a general degradation of soil structure.

### Fertilizer Recommendation

The nutrient recommendations provided in the soil test report refer to the actual amount of nutrient required, not the amount of fertilizer to apply. Determining the correct fertilizer rate requires knowing the fertilizer grade—the three numbers shown on the label—which indicate the percentages of total nitrogen (N), available phosphorus ( $P_2O_5$ ), and soluble potassium ( $K_2O$ ). A fertilizer labeled **5-10-15**

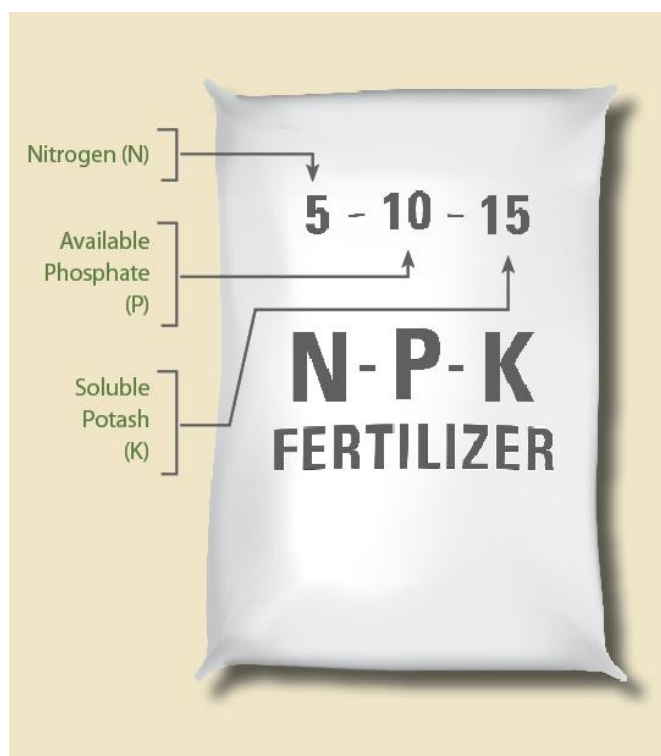


Figure 3. Fertilizer grade

contains **5% nitrogen (N)**, **10% available phosphorus ( $P_2O_5$ )**, and **15% soluble potassium ( $K_2O$ )**. When a fertilizer includes a significant amount of another nutrient beyond N, P, or K, it is listed as a fourth value—commonly seen with products containing sulfur (e.g., **21-0-0-24**).

Fertilizer application rates may require adjustment based on local climate and soil characteristics, which can vary widely across Colorado. For site-specific recommendations, consult your local CSU Extension agent or crop adviser.

An example of the fertilizer calculation based on a recommended nitrogen rate using a fertilizer blend is as follows:

**Soil Test Report Recommendation rate: 3 lb N/1000 sq. ft.**

**Using a fertilizer 46 - 0 - 0 (Urea)**

**Fertilizer fraction** 46% N (0.46 lb N/lb fertilizer); 0% P<sub>2</sub>O<sub>5</sub> (0.0 lb P<sub>2</sub>O<sub>5</sub>/lb fertilizer); and 0% K<sub>2</sub>O (0.0 lb K<sub>2</sub>O/lb fertilizer)

**Fertilizer needed = Fertilizer fraction = Fertilizer applied**

$$3 \text{ lb N}/1000 \text{ sq. ft.} = 0.46 \text{ lb N}/\text{lb fertilizer} = 6.5 \text{ lb fertilizer (Urea)}/1000 \text{ sq. Ft.}$$

Below is another example to calculate the amount of fertilizer for a specific phosphorus recommendation rate:

**Soil Test Report Recommendation rate 1 lb P<sub>2</sub>O<sub>5</sub>/1000 sq. ft.**

**Using a fertilizer blend 5 - 10 - 15**

**Fertilizer fraction** 5% N (0.05 lb N/lb fertilizer); 10% P<sub>2</sub>O<sub>5</sub> (0.1 lb P<sub>2</sub>O<sub>5</sub>/lb fertilizer); and 15% K<sub>2</sub>O (0.15 lb K<sub>2</sub>O/lb fertilizer)

**Fertilizer needed = Fertilizer fraction = Fertilizer applied**

$$1 \text{ lb P}_2\text{O}_5/100 \text{ sq. ft.} = 0.1 \text{ lb P}_2\text{O}_5/\text{lb fertilizer} = 10 \text{ lb fertilizer}/100 \text{ sq. Ft.}$$

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**January 3, 2024**

reminders