Interpreting Soil Sample Results

Soil analysis is a great tool to assess what soil amendments are needed for optimum plant function and yield potential. Soil test results list the soil test concentration for specific parameters along with an interpretation value (low, optimum, and high) and a recommendation. This Spotlight will help explain the meaning of each soil test parameter, what the optimum values are for each parameter, and general recommendations based on the soil test values.

Soil Sampling and Lab Testing

To obtain quality soil test results, the soil samples must be taken properly. Each sample must be representative of the entire field or specified sampling unit. The samples must also be taken at the proper depth during the same time frame every year. Sample depth can vary by test but is usually within 6-12 inches. Once proper depth is chosen be consistent as this will influence the soil test result. For more detail on soil sampling refer to *Agronomic Spotlight - Soil Testing*.

Lab Results

Soil lab results list the test, the result, and may list an interpretation or recommendation. When reviewing lab results, it important to know what extraction method was used. In addition, using the same lab for annual analysis will help ensure uniformity of year to year comparisons. Labs may report the results in parts per million (ppm) or lbs/acre. To convert ppm to lbs/acre multiple ppm by 2 (lbs/acre = ppm x 2). To convert lbs/acre to ppm divide lbs/acre by 2 (ppm = lbs/acre ÷ 2).

Soil Parameters

Macronutrients are needed in large amounts by plants and are the most common fertilizers applied to the soil. Nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), and magnesium (Mg) are all macronutrients. The label on a bag of fertilizer lists the most commonly applied macronutrients in this order; N-P-K. Micronutrients are needed in trace amounts for plant function. The micronutrients are: copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), boron (B), chloride (Cl), nickel (Ni), and molybdenum (Mo). Other soil characteristics that play a role in nutrient availability may also be analyzed and reported. These may include organic matter (OM), soil pH, soluble salts (salinity), and cation exchange capacity (CEC). More detailed definitions of each soil parameter follow.

Nitrogen (N)

An adequate supply of nitrogen is associated with high photosynthetic activity as well as the vigorous growth and dark green color of plant vegetation. There are two forms of plant available N: nitrate (NO_3^-) and ammonium (NH_4^+). Nitrate is measured most often in soil tests. Soil test results report NO_3^- N in lb N/ acre. Nitrate can be leached through the soil and lost to denitrification during periods of soil saturation. Nitrate is also produced by microbial decomposition of organic matter. Consequently, nitrate levels reflect what is immediately available and not what will be available in the future. The Late Spring Nitrate Test also known as the Preside-dress Nitrate Test (PSNT), may be used in-season, when corn plants are 6-12 inches tall, to determine how much N should be applied as a side-dress application. The test is useful to find out if significant amounts of nitrate have leached after excessive rain early in the season. Table 1 lists the critical nitrate levels for side-dress N applications to corn, recommended by Iowa State. Since nitrate soil test thresholds are regional, consult the nitrate soil test thresholds specific to your geography.

Phosphorus (P)

Phosphate compounds store energy created from photosynthesis and carbohydrate metabolism that will be used for plant growth and reproductive processes. Phosphorus is not as naturally abundant in soils compared to N and K. Phosphorus is relatively immobile in the soil because its negative charge binds to positively charged particles, such as calcium. This makes it unavailable to plants and limits movement through the soil profile. Because the amount of calcium and other cations influence soil pH, the amount of plant available P in the soil solution is also related to soil pH. The form of plant available P changes in alkaline soils; therefore, at a pH of 7.2 or higher plant uptake of P is slower. Because of this pH sensitivity, there are three P extraction methods used for lab tests. The extraction methods are: Bray P (acidic soils), Mehlich-3 P (acidic soils), and Olsen P (neutral to alkaline soils). The extracted P is then measured using a colorimetric method, or if specifically noted by an inductively coupled plasma (ICP) in the case of some Mehlich-3 ICP results. Test results may vary based on the extraction method or test used for measuring P therefore; it is important to know which extraction method and test were used, and how the results were reported, when interpreting the results. Phosphorus recommendations for corn and soybean production based on soil test results from each of the three soil extraction methods can be found in Table 2.

Table 1. Late spring nitrate test recommendations for corn. The critical nitrate soil test level represents the value when a response from additional N will not be seen.

Crop Rotation and Conditions	Critical Nitrate Level (ppm)
Corn after corn or soybeans	25 ppm
Corn after corn or soybeans and rainfall 20% above normal after April 1st	20-22 ppm
Corn on manured soils grown after alfalfa	10-25 ppm

Source: [1]Iowa State University, 2011

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Potassium (K)

Potassium plays a role in many functions in the plant including: activating enzymes, drawing water into the roots, producing phosphate molecules and CO2, providing energy for the translocation of sugars, and taking up and assimilating N. Potassium is present in large quantities in most soils, although it is not always available. Some forms of K can be adsorbed to clay particles which are tightly fixed in feldspar or mica. Conversely, K^+ ions bonded to negative clay minerals can easily be "knocked off" or exchanged. Potassium can also become available from manure applications or decomposition of plant residue. In addition, plants take up K^+ by luxury consumption, which means more can be consumed than is needed for plant function. The K cycle is always changing and soil test K concentrations will fluctuate seasonally due to differing environmental conditions. Due to the seasonality of K availability, choosing the proper time to test can be difficult. Comparing soil tests over time is the best method of evaluating nutrient management decisions. Soil testing in the fall or spring are acceptable for determining K soil concentrations. However, sampling should occur at the same time each year for comparisons over time. Soil test K recommendations for corn and soybean production can be found in Table 3.

Table 2. Phosphorus (P_2O_5) recommendations for corn and soybean production when utilizing various extraction methods.

Bray P and Mehlich-3 P Soil Test Values PPM			Corn	Soybean
PPM			P_2O_5 to	P_2O_5 to
	Low Sub-soil P	High Sub-soil P	Apply	Apply
Very Low	0-8	0-5	100	80
Low	9-15	6-10	75	60
Optimum	16-20	11-15	55	40
High	21-30	16-20	0	0
Very High	31+	21+	0	0
Olsen P Soil Test Values PPM			**Corn**	**Soybean**
PPM			P_2O_5 to	P_2O_5 to
	Low Sub-soil P	High Sub-soil P	Apply	Apply
Very Low	0-5	0-3	100	80
Low	6-10	4-7	75	60
Optimum	11-14	8-11	55	40
High	15-20	12-15	0	0
Very High	21+	16+	0	0
Melich-3 ICP Test Values PPM			**Corn**	**Soybean**
PPM			P_2O_5 to	P_2O_5 to
	Low Sub-soil P	High Sub-soil P	Apply	Apply
Very Low	0-15	0-10	100	80
Low	16-25	11-20	75	60
Optimum	26-35	21-30	55	40
High	36-45	31-40	0	0
Very High	46+	41+	0	0

Source: [2] Iowa State University, 2011

- Corn recommendations are based on 150 bu/acre yield target and soybean recommendations are based on 50 bu/acre, if yield target is higher or lower, P_2O_5 application rates may need to be adjusted.
- Sub-soil P is determined based on yield history, soil series, and deeper soil sampling and testing at a 30-42 inch depth.
- Sub-soil Bray P1 values are considered low at 8 ppm or less and high at 9 ppm, or more.
- Application amounts were calculated based on nutrient removal throughout the season via tissue sampling and analysis.
- If soil test values are above optimum levels (high or very high), no additional P_2O_5 needs to be applied.

Sulfur (S)

Sulfur has many important functions in plant growth and metabolism. Deficiency symptoms resemble those of N: stunting, chlorosis, thin stems, and spindly plants. Sulfur deficiency is found in young tissue where as N deficiency can be found in both young or old plant parts. Only a small fraction of the total soil S is readily available to plants and that form is sulfate (SO_4^{2-}). Sulfur can be mobile or immobile in soil depending on microbial activity and the quantity of carbon (C), N, and P. Sulfate may leach but quantities can also be retained in soils by adsorption to iron and aluminum oxides or clays in the soil profile. S-deficient soils have soluble SO_4^{2-} concentrations less than 5 to 10 ppm[5].

Calcium (Ca) and Magnesium (Mg)

Calcium enhances NO_3-N uptake and also regulates the uptake of cations, such as K^+ and sodium (Na^+). Calcium saturation results in a high pH or alkaline soil. In addition, high concentrations in the soil typically result in low concentrations of undesirable cations, such as aluminum (Al^{3+}) in acidic soils and sodium (Na+) in saline soils. Conversely, a low calcium content in the soil can result in a low pH or acidic soil.

Magnesium (Mg) is a major part of the chlorophyll molecule and without it photosynthesis can not take place. Mg is also imperative in many other physiological and biochemical functions within the plant and is a structural component of the ribosomes. Magnesium and Ca have some behavioral similarities in soil. Both Mg and Ca ions can easily be exchanged or taken off of negative soil colloids. One difference is that Mg can only become fixed to certain clays. Mg deficiencies are not widespread but can occur. Concentrations of Mg^{2+} in the soil are commonly 5-50 ppm in temperate soils but can be much higher[5].

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Table 3. Potassium (K_2O) recommendations for corn and soybean production when utilizing the Ammonium Acetate and Mehlich-3 Extractable K extraction method.

Ammonium Acetate and Mehlich-3 Extractable K Soil Test Values PPM			Corn K_2O to Apply (ppm)		Soybean K_2O to Apply (ppm)	
	Low Sub-soil K	High Sub-soil K	Fine	Sandy	Fine	Sandy
Very Low	0-90	0-70	130	110	120	100
Low	91-130	71-110	90	70	90	85
Optimum	131-170	111-150	45	45	75	75
High	171-200	151-180	0	0	0	0
Very High	201+	181+	0	0	0	0

Source: [2] Iowa State University, 2011

- Corn recommendations are based on 150 bu/acre yield target and soybean recommendations are based on 50 bu/acre, if yield target is higher or lower, K_2O application rates may need to be adjusted.
- Higher concentrations of sub-soil K require less surface soil K for optimum crop production.
- Sub-soil K is determined based on field history, soil series, and deeper soil sampling and testing at a 12-24 inch depth.
- Sub-soil K ammonium acetate test values are considered low at 50 ppm or less and high at 51 ppm or more.
- Application amounts were calculated based on nutrient removal throughout the season via tissue sampling and analysis.
- If soil test values are above optimum levels (high or very high) no additional K_2O needs to be applied.

Micronutrients

The micronutrients needed in trace amounts for plant function are: copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), boron (B), chloride (Cl), nickel (Ni) and molybdenum (Mo). Although many of the micronutrients are reported on soil test reports their levels do not currently affect fertilizer recommendations, with the exception of zinc. Soil test zinc recommendations for corn are shown in Table 4. Plant tissue and soil analyses should be used together to assess the need for application of the other micronutrients.

Organic Matter (OM)

Organic matter (OM) affects many soil biological, chemical, and physical properties that influence nutrient availability. OM content is related to productivity and soil tilth. Some roles of organic matter in the soil include: storage for nutrients, energy for microbial activity, increasing water holding capacity, and providing a buffer against changes in pH and salinity. On many soils, suitable physical properties occur at relatively low levels of organic matter ranging from 2 to 4%; however, increasing soil organic matter can generally increase productivity[3]. When OM levels are higher than 2% more N will be mineralized. A general guideline is to reduce fertilizer recommendations by 20 lb/acre for soils with >3% OM and increase N recommendations for soils with <1% OM[4]. Consult your regional guidelines for a more precise influence of OM on nutrient availability.

Table 4. Zinc (Zn) recommendations for corn production utilizing the DTPA Extractable Zn extraction method.

	Zn Soil Test PPM	Zn application broadcast	Zn application band
Low	0-0.04	10	2
Marginal	0.5-0.8	5	1
Adequate	0.9+	0	0

Source: [2] Iowa State University, 2011

Soil pH

Soil pH is an indicator of the level of acidity or alkalinity of the soil, ranging from 0 – 14. A reading of 7 is neutral, values lower are acidic and values higher are alkaline. Crops typically grow best when pH is between 6 (slightly acidic) and 7.5 (slightly alkaline). Results of soil pH are reported on a logarithmic scale; therefore, caution in interpretation should be made. For example, a soil with a pH of 6 is 10 times more acidic than a soil with a pH of 7, and a soil with a pH of 5 is 100 times more acidic than a pH of 7. Nutrient availability may be hindered if soil pH is not within the optimum range and can result in crop deficiencies.

Soluble Salts

High soluble salt content (or salinity) can cause water stress and nutrient imbalances in plants, as well as affect nutrient uptake. Seedlings are more sensitive to higher than normal soluble salts in soil compared to older plants. High soluble salt levels above 4 mmhos/cm (or 'dS/m') can potentially damage plants[4]. Salinity levels in soil can change rapidly due to leaching; therefore, sampling should take place periodically within the growing season.

Cation Exchange Capacity (CEC)

CEC is not always part of soil analysis. If it is included on a lab result, a CEC above 10 milliequivalents per 100 grams (10 meq/100g) is considered adequate[4]. CEC can also be reported as cmols/kg, and may be interchangeable between units reported. A high CEC is sought because it indicates a high capacity for the soil to hold cations (positively charged particles), such as, K^+, NH_4^+, Cu^{2+}, Fe^{2+}, and Mn^{2+}.

Region Specific Information

The soil parameter descriptions and optimum values provided within this Spotlight can help assess your soil fertility program and reach optimum yield potential. Due to variability in soil, lab analysis, and reporting, guidelines specific to your region may exist. A local agronomist or extension specialist can provide information specific to your area.

Sources: [1]J. E. Sawyer, et al. July 15, 2003. Interpretation of Soil Test Results. Iowa State University Extension. Publication No. PM1310; [2]J. E. Sawyer, et al. April 2011. A general guide for crop nutrient and limestone recommendations in Iowa. Iowa State University Extension. Publication No. PM1688; [3]J. Lickacz and D. Penny. May 30, 2001. Soil Organic Matter. Government of Alberta. Agriculture and Rural Development; [4] C.P. Dinkins, et al. July 2007. Interpretation of Soil Test Results for Agriculture. Montana State University Extension. MontGuide. Publication no. MT200702AG; [5] S.L. Tisdale, et al. 1993. Soil Fertility and Fertilizers Fifth Edition. MacMillan Publishing Company; Additional references used in creating this publication: L. Espenoza, et al. 2007. Understanding the numbers on your soil test result. University of Arkansas. Division of Agriculture. Cooperative Extension Service. Publication no. FSA2118.