



Fact sheet

Soil Fertility Test Interpretation *Phosphorus, Potassium, Magnesium, and Calcium*

Joseph R. Heckman, Ph.D., Extension Specialist in Soil Fertility

Introduction

A soil fertility test evaluates the nutrient-supplying power of a soil. The results of the test are used to predict if, or how much fertilizer is required for optimum plant growth.

The conceptualized relationship between soil nutrient level and plant response is shown in Figure 1. Rutgers Cooperative Extension classifies relative fertility levels into three main categories: *Below optimum*, *optimum* and *above optimum*. *Below optimum* is divided into subcategories: *very low*, *low*, and *medium*.

These soil fertility categories gauge the probability of a plant showing a beneficial response to the addition of a given nutrient (assuming that other factors such as temperature, moisture, disease, etc. are not limiting growth).

The soil test categories as described in Table 1 are the basis for how much phosphorus (P) and potassium (K) to apply to reach optimum growth levels. For limestone recommendations, these categories indicate the concentrations of calcium (Ca) and magnesium (Mg) most suitable for use as a liming material.

Recommendations Based on Soil Test Categories

Soil test categories along with crop nutrient requirements are the basis for nutrient recommendations. Rutgers Cooperative Extension publishes production recommendation guides for vegetable, tree fruit, field crops, nursery crops and turf. These recommendation guides provide tables that indicate for various soil test categories how much phosphorus and potassium to apply to produce each crop.

For example, when the soil test category for K is *below optimum—low* the recommendation guide will indicate how much K to apply. The amount of K recommended however, varies depending on the crop. Various

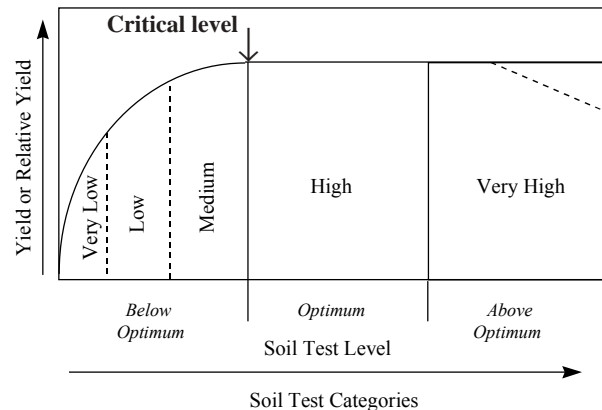


Figure 1. This conceptual soil test response curve is divided into categories that correspond with *below optimum*, *optimum* and *above optimum* soil test values. The critical level is the soil test level, below which a crop response to a nutrient application may be expected, and above which no crop response is expected. At very high soil test levels crop yield may decrease.

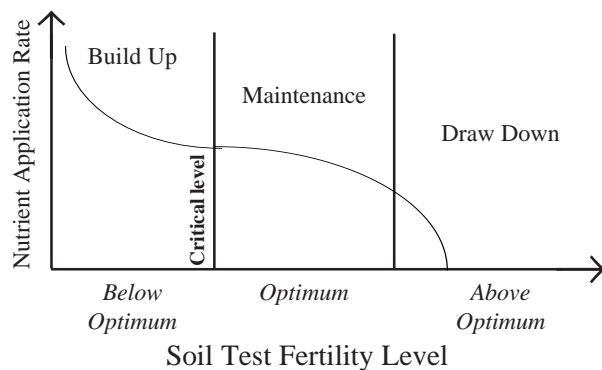


Figure 2. Nutrient application rates vary in relation to soil test category.

crops accumulate different amounts of nutrient. Generally, crops that produce large yields of harvestable material will remove large amounts of nutrients from the soil and will have a higher nutrient recommendation.

Table 1. Definitions of soil fertility test categories.¹

Category Names (Commonly used terms)	Category Definition	Recommendations
Below Optimum (Very Low, Low, Medium)	The nutrient is considered deficient and will probably limit crop yield. There is a high-to-moderate probability of an economic crop yield response to additions of the nutrient.	Recommendations are based on crop response. These recommendations will generally build the soil into the optimum range over time. Starter fertilizer is recommended as appropriate.
Optimum² (High)	The nutrient is considered adequate and will probably not limit crop growth. There is a low probability of economic crop yield response to additions of nutrient.	If soils are tested annually, no nutrient additions are needed for the current crop. For other than annual testing, recommendations are generally for maintenance applications to maintain the soil in the optimum range. Starter fertilizer is recommended as appropriate.
Above Optimum (Very High)	The nutrient is considered more than adequate and will not limit crop yield. There is a very low probability of an economic crop yield response to additions of the nutrient. At very high levels there is a possibility of a negative impact on the crop if nutrients are added.	No nutrient additions are recommended. Starter fertilizer may be recommended as appropriate. At very high levels, remedial action may be required.

¹Adapted from *Recommended Soil Testing Procedures For The Northeastern United States*, Northeastern Regional Publication No. 493.

²*Optimum* is the preferred terminology for this category.

When the soil fertility category is *below optimum*, the nutrient recommendation for a particular crop is designed to achieve its full crop yield potential and to build the soil fertility level into the *optimum* range over time. If the soil fertility level is already in the *optimum* range, the nutrient recommendation is designed to replace the amount of nutrient removed by the crop so as to maintain *optimum* soil fertility. No nutrient application is generally recommended when the soil test category is *above optimum*. This allows “draw-down” of the nutrient level to the *optimum* range. These concepts are illustrated in Figure 2 and summarized in Table 2.

Soil Test Method and Interpretation

A common misconception is that a soil fertility test is a direct measurement of the total plant-available nutrient content of a soil. Soil test values have historically been expressed in units of pounds per acre, but they have no meaning in terms of actual quantity of plant-available nutrients. It should be understood that a soil test only provides an index of soil nutrient availability that is correlated with plant response. This correlation is determined by soil test calibration research and is the foundation for soil test interpretation.

Many different types of soil test extraction methods are in use, but only a few are appropriate for our local soils. The Mehlich-1 and Mehlich-3 soil tests were

developed for soil types found in the Mid-Atlantic Region.

Soil test results and interpretations are specific for the soils of a region and for the particular soil test method employed. The soil test values for Mehlich-1 and Mehlich-3 categories (Table 2) were established based on soil fertility research conducted on soils of the Mid-Atlantic Region. The categories were developed from crop yields that were observed during nutrient response studies conducted over a range of soil test levels.

It is important to understand that soil test values (lbs/acre) extracted by a particular soil test should be interpreted as an index value and are not equivalent to actual pounds of available nutrient per acre. The Mehlich-3 soil test method extracts more P, K, Mg, and Ca from soil than the Mehlich-1 method. Once the results are translated into soil test categories, the soil test interpretations are the same for both methods. Thus, the place to focus attention when reviewing a soil test report is on the soil test category.

Nutrient Management: Phosphorus

Crops are very likely to respond to P fertilization when the soil test indicates that P is *below optimum—very low or low*. A soil testing *below optimum—medium* will sometimes respond to P fertilization and will sometimes not. Soils testing *optimum* or *above optimum* are unlikely to respond to P fertilizer, but P may be applied to maintain the fertility level in the *optimum* range. Crops are more

Table 2. Soil test categories for nutrients extracted by the Mehlich-3 and Mehlich-1 methods.

Soil Test Category	Phosphorus (P)	Potassium (K)	Magnesium (Mg)	Calcium (Ca) ¹	
Mehlich-3	Mehlich-3 Soil Test Value (lbs/acre) ^{2,3}				
	Below Optimum (very low)	0–24	0–40	0–45	0–615
	Below Optimum (low)	25–45	41–81	46–83	616–1007
	Below Optimum (medium)	46–71	82–145	84–143	1008–1400
	Optimum (high)	72–137	146–277	144–295	1401–1790
Above Optimum (very high)	138+	278+	296+	1791+	
Mehlich-1	Mehlich-1 Soil Test Value (lbs/acre) ²				
	Below Optimum (very low)	0–13	0–29	0–35	0–400
	Below Optimum (low)	14–27	30–70	26–70	401–800
	Below Optimum (medium)	28–45	71–134	71–125	801–1200
	Optimum (high)	46–89	135–267	125–265	1201–1600
Above Optimum (very high)	90+	268+	265+	1600+	

¹ Calcium values are for sandy loam soils. Multiply the calcium values in Table 2 by 0.625 to use for loamy sand soils, by 1.25 for loam soils, and by 1.5 for silt loam soils.

² Values are reported in elemental forms.

³ Soil tests based on Bray-1 extractable P and neutral, 1N ammonium acetate extractable, K, Ca, and Mg are very similar to the Mehlich-3 extractable amounts of these nutrients.

likely to respond to P fertilizer when growing conditions are favorable for high yields.

It is often recommended that a band of P fertilizer be placed near the seed as a starter fertilizer regardless of the P fertility level. Banded P is especially helpful at low soil test levels. Even at P soil test levels that are *above optimum*, a small amount of banded P may benefit crop establishment.

When the soil test level is *below optimum*, P should generally be applied as a combination of broadcast and banded methods. When the level is *above optimum*, only a small amount of P may be applied as a band.

Many soils test *above optimum* for P due to previous fertilizer and manure applications. When applied in excess of crop removal, P accumulates in the soil. Phosphorus is strongly adsorbed to soil particles and very little is subject to loss via leaching. When the soil test level is *above optimum*, growers can benefit economically by reducing P fertilizer rates accordingly.

Nutrient Management: Potassium

Crops are very likely to respond to K fertilizer when the soil test indicates that K is *below optimum—very low* or *low*. A soil testing *below optimum—medium* in K may or may not respond to K fertilizer. Crops are more responsive to K when growing under drought stress or when growing under favorable conditions. Soils testing *optimum* or *above optimum* are unlikely to respond to K fertilizer but K may be applied to maintain the fertility level in the *optimum* range.

In general, most of the K fertilizer should be broadcast. When the fertility level is *below optimum*, it may be advantageous to apply a portion of the total K application as a band. There is generally no benefit to applying banded K when soil fertility levels are *optimum* or *above optimum*.

Crops remove larger amounts of K than P from the soil during a growing season. In addition sandy soils have low reserves of K, and K is susceptible to leaching. Therefore, more frequent applications of K are needed to maintain K at an optimum fertility level.

Liming Practice: Calcium and Magnesium

Liming materials neutralize soil acidity and supply Ca and Mg. Selection of the appropriate liming material based on its Ca and Mg concentrations is a key to furnishing crops and soils with sufficient amounts of these nutrients. The goal of a liming program is to establish the desired soil pH and to maintain the soil fertility levels for Mg and Ca in the *optimum* range.

When the soil pH is low, the soil test levels of Ca and Mg may be *below optimum*. When the Mg soil test level is *below optimum*, it is important to choose a liming material that contains a significant concentration of Mg (such liming materials are commonly referred to as dolomitic type or dolomite.) If the soil Mg level is *below optimum—very low* or *low*, use a liming material that has a minimum concentration of 9% Mg. If the soil Mg level is *below optimum—medium*, use a liming material that has

3.6 to 9% Mg. If the soil Mg level is *optimum* or *above optimum*, use a liming material that has less than 3.6% Mg (such liming materials are commonly referred to as calcitic or calcite).

Occasionally soils test *below optimum* in Mg or Ca, but do not need lime for pH adjustment. For soils needing Mg, apply epsom salt (9.9% Mg) or sulfate of potash magnesia (21.8% Mg). If soil pH is satisfactory for the crop, but the soil test Mg level is *below optimum—very low*, apply 30 lbs Mg/acre from a Mg fertilizer. If Mg is *below optimum—low*, apply 15 lbs. Mg/acre.

If soil pH is satisfactory for the crop, but the Ca level is *below optimum—very low*, apply 350 lb Ca/acre (1500 lb/acre of gypsum). If the pH is satisfactory but Ca is *below optimum—low*, apply 175 lb Ca/acre (750 lb/acre of gypsum).

Sustainable Nutrient Management

A major objective of nutrient management is to bring the soil fertility level into the optimum range and to sustain that fertility level for the long term. Once the soil fertility has been built up to the *optimum* level the nutrient application rate should be only large enough to maintain the *optimum* level. This can be accomplished by applying nutrients at a rate that closely matches the rate of nutrient removal in the harvested crop. The rate may need to be slightly higher to account for other losses such as leaching.

Keeping records of soil test results enables growers to track changes over time and to adjust recommendations as needed to maintain soil fertility in the *optimum* range. Meaningful records require a consistent approach to soil testing in terms of sample collection, sampling depth, and laboratory submission. Soil test levels can vary somewhat from sample to sample and having records helps to spot unusual soil test values that should be rechecked.

Laboratories Using Mehlich-3 Extractant

Rutgers, The State University of New Jersey
 Pennsylvania State University
 University of New Hampshire
 North Carolina Department of Agriculture
 AgriAnalysis, Inc.
 A & L Eastern Agricultural Laboratory (By Request)
 Brookside Laboratory, Inc.
 Spectrum Analytic, Inc.

Laboratories Using Mehlich-1 Extractant

University of Delaware
 University of Maryland
 Virginia Polytechnical Institute and State University
 University of West Virginia

Although soil fertility levels naturally fluctuate from year to year due to crop rotation and manure application, the average trend over time should remain in the *optimum* range, as shown in Figure 3. If soil fertility levels are observed to fall *below optimum*, underfertilization is indicated. The nutrient recommendation should be adjusted so that the nutrient application rate is large enough to meet the needs of the current crop and also gradually rebuild the nutrient supply to the *optimum* level. If soil fertility levels are observed to climb well *above optimum*, overfertilization is indicated. There is no economic advantage to applying additional nutrients. Good crop yields can be obtained without adding the nutrient. Over a period of time, nutrient removal by crops should allow the soil fertility level to fall back into the *optimum* range.

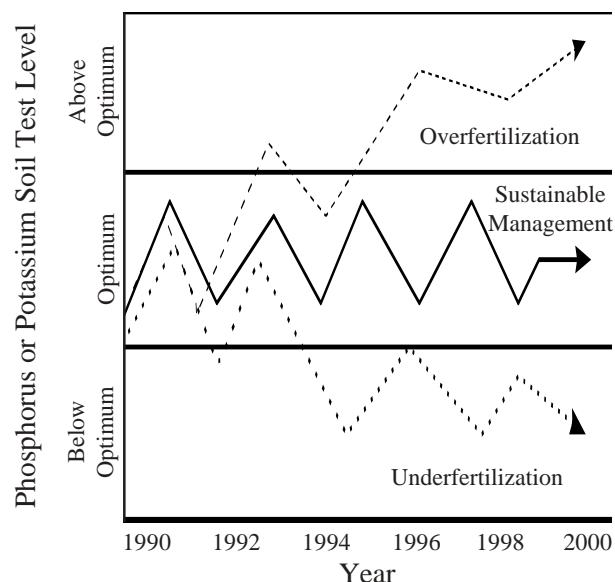


Figure 3. Changes in soil test levels over time under different nutrient management scenarios.

The Mehlich Soil Test Methods

Mehlich-1 and Mehlich-3 are the most widely used soil test methods in the Eastern United States. They were developed by Dr. A. Mehlich at the North Carolina Department of Agriculture. The Mehlich-1 soil test extracting solution (0.025N H₂SO₄+ 0.05N HCl) is no longer used at Rutgers but is still in use in some neighboring states. The Mehlich-2 soil test is similar to Mehlich-3 but is not widely used. In 1993, Rutgers Soils Laboratory began using Mehlich-3 soil test extracting solution (0.2 N CH₃COOH+ 0.25 N H₄NO₃+ 0.015 N NH₄F+ 0.013 N HNO₃+ 0.001M EDTA, adjusted to pH 2.5). The Mehlich-3 soil test improves laboratory efficiency by performing simultaneous extractions for P, K, Ca, Mg, Mn, Cu, B, and Zn.