Chapter 14

Interpretation of Soil Testing Results

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The amounts of nutrients extracted by the soil test methods described in this publication have been found to correlate with the availability of a nutrient to a crop. The strength of this correlation is the basis for selecting a particular soil test extractant for a given combination of soil, crop, and growing conditions. For an extractant to be useful, the extractable amount must be closely related to crop response. Extractants are developed from an understanding of the chemistry of the soils in the region where the test will be used and from a knowledge of the crop response to nutrients in the region. For example, the extractants commonly used for phosphorus (P) in the Northeast are designed to extract a fraction of the iron and aluminum phosphates which are assumed to be related to the P supplying ability of the acidic soils in the region. The exact amount of a nutrient that is extracted is a function of the makeup of the particular extractant as it interacts with soils of varying properties. Consequently different extractants remove different quantities of nutrients from the soil. While not necessarily equal to the actual "available amount", the quantity extracted by a successful soil test will be correlated to nutrient availability as reflected in crop response.

To interpret a soil test we must know the relationship between the amount of a nutrient extracted by a given soil test and the expected crop response for each crop. The process of determining the degree of limitation to crop growth or the probability of getting a growth response to an applied nutrient at a given soil test level is known as soil test calibration and must be determined experimentally in the field. (Dahnke and Olsen, 1990). A common procedure for calibrating a soil test is to grow the crop on soils representative of those where the test will be used that cover the range of soil test extractable nutrients likely to be encountered. This must be done for each crop with which the soil test will be used. From the results of these experiments, either the yield or the relative yield can be plotted against the amount of extractable nutrient as illustrated in Figure 12-1. Relative yield is the yield with optimum amounts of all nutrients except the nutrient of interest divided by the maximum yield with optimum amounts of all nutrients. A relative yield of less than 1.0 indicates that the crop responded to the nutrient in the experiment. Relative yield usually results in a better correlation than absolute yield because the influence of some of the uncontrollable factors influencing plant growth (e.g. weather) is eliminated (Bartholomew, 1972).

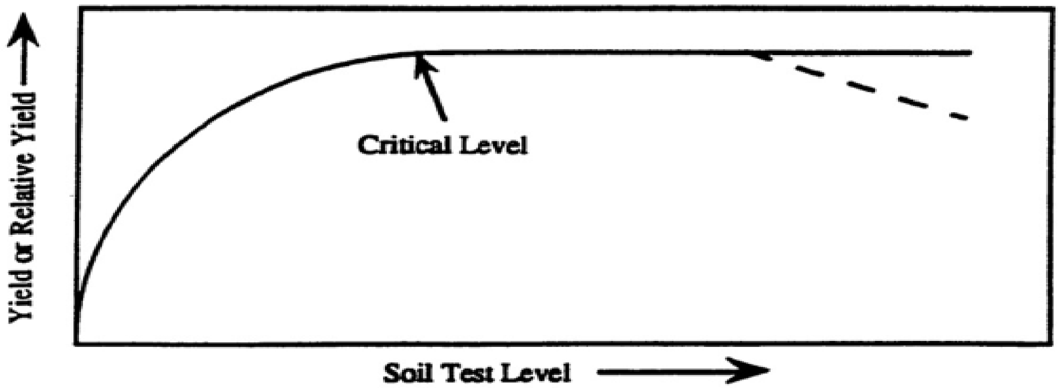

Figure 14-1. Conceptual relationship between soil test levels and yield or relative yield of a crop.

Even though the exact relationship between soil test level and yield or relative yield will vary considerably, the general shape of this relationship is relatively consistent (Figure 12-1). At low levels of extractable nutrients the yield is limited by lack of the nutrient. As the soil test level increases, yield increases until a point is reached where the nutrient being tested is no longer limiting yield and thus the curve levels out. Above this level there is no longer a relationship between the extractable amount of the nutrient and yield. At very high soil test levels the yield may actually decline as indicated by the dashed line in Figure 12-1. The point where the curve initially levels off is usually called the critical level. This is the soil test level that produces the best separation between soils that give a yield response for a given crop from those that do not (Black, 1993).

An example response curve relating the crop response to soil test P from research in New York is shown in Figure 12-2 (Greweling and Peech, 1960). The critical level is most often determined by a simple graphical method developed by Cate and Nelson (1965). This method is also illustrated in Figure 12-2. In this method, the calibration data is plotted as relative yield vs. soil test level. The data is then separated into four quadrants with the goal of minimizing the number of experimental points in the upper left and lower right quadrants. The data points in the upper left and lower right quadrants represent deviations from expected behavior. Points lying in the upper left quadrant represent situations where the soil test level is below the critical level and thus a response would be expected but no response is observed. Points lying in the lower right quadrant represent situations where the soil test level is above the critical level and thus no response would be expected but a response is observed. Partitioning the data into responsive and non-responsive populations and determining a critical level can be done graphically or Cate and Nelson (1971) also provide an analytical method for doing this.

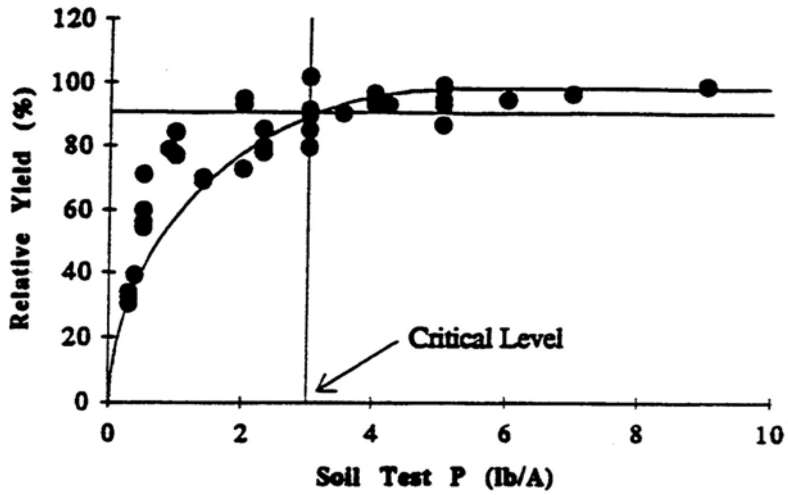

Figure 14-2. Relative yield vs soil test phosphorus showing response curve and Cate-Nelson graphical separation of the data into responsive and non-responsive populations. (Adapted from data of Greweling and Peech, 1960).

The soil test response curve is often used to further divide soil test levels into several categories such as below optimum, optimum, and above optimum as shown in Figure 12-3. The first step in developing these categories is to determine appropriate definitions for thedifferent categories. In the Northeast an attempt has been made by NEC-67 to standardize the definitions of the categories used to interpret a soil test. Proposed definitions for interpreting soil tests for crop response are given in Table 12-1a.

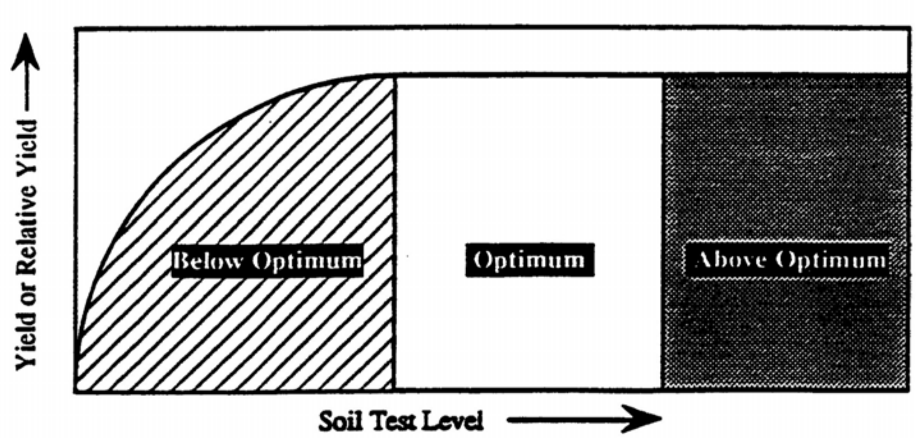

Figure 14-3. Response curve used to divide soil test levels into below optimum, optimum, and above optimum categories.

Table 14-1. Definitions of soil test categories proposed for the northeast region.
a. Crop Response

Category Name (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
Optimum, (Sufficient Adequate)	The nutrient is considered adequate and will probably not limit crop growth. There is a low probability of a economic crop yield response to additions of the nutrient.	If soils are tested annually no nutrient additions are needed for the current crop. For other than annual soil testing, recommendations are generally for maintenance applications to maintain the soil in the optimum range. Starter fertilizer is recommended as appropriate
Above Optimum (High, Very High, Excessive)	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 the 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.

b. Environmental Impact.

Potential negative environmental impact	There is the possibility that soils testing above this level may result in environmental degradation. This soil test level is independent of the crop response categories in part (a) of this table and may be above or even below the optimum level based on crop response. This level may vary depending on other site specific characteristics.	If other site factors minimize environmental impact, nutrient additions may be recommended under crop response guidelines. If other site factors indicate a potential environmental impact, no nutrient additions including starter fertilizer are recommended. Remedial action to protect the environment may be required.

Using these definitions, the break in soil test levels between the below optimum and optimum categories is fairly clear. This is the critical level discussed before. In the below optimum category recommendations are commonly made to optimize crop response and usually result in some buildup of nutrients in the soil. The break between optimum and above optimum is less clear. This distinction is more a matter of degree ie. low probability of response vs. very low probability of response. Some labs define the break between optimum and above optimum as the point where the recommendation is zero. For annual soil testing no nutrient applications are needed on an optimum testing soil. However, because many farmers do not test annually, a maintenance application of nutrients is often recommended on optimum testing soils even though the probability of a response to those nutrients is low. The rationale for this recommendation is that it will maintain the soil in the optimum range until the soil is tested again. Once the soil test level is in the above optimum category no maintenance application of nutrients is recommended. A soil testing in the very high category should be a warning that there may be a negative impact on the crop.

The definition for the environmental impact category in Table 12-1b, is fairly clear in itself, but very controversial and difficult to define in a practical way. First we need to ask, do routine soil test extractants, designed to assess plant availability of a nutrient, measure the forms of the nutrient most important to eutrophication or other negative environmental impacts (Sims, 1993)? If the soil test is appropriate, what should be the basis for interpreting the results for environmental purposes? Some people would simply extend the levels used for interpretation for crop response and say a soil test that is above the level where a crop response is expected is in excess of crop needs and therefore is potentially polluting. However, it cannot be assumed that there is a direct relationship between the soil test calibration for crop response to nutrients and nutrient pollution potential. The critical soil test level for pollution may be above or even below the critical level for crop response. If soil tests are to be properly interpreted for predicting the probability of nutrient pollution, calibrations that specifically relate the soil test to some measure of environmental response, such as P in runoff, will be necessary. Unfortunately, even though this is currently a very active research area, in most cases, a consensus has not been reached on interpreting nutrient soil tests for environmental purposes (Sharpley, 1995). Most soil scientists agree that it is not likely that there will be a simple critical soil test level for nutrient pollution. It is more likely that an integrated approach that includes many other site-specific factors will be necessary for interpreting soil tests for environmental pollution potential. An example is the "Phosphorus Index", a tool for assessing the potential for phosphorus pollution that has been described by Lemunyon and Gilbert (1993). The "Phosphorus Index" is a procedure for identifying soils, landforms, and management practices that could have unfavorable impacts on water bodies because of phosphorus movement. In this approach the soil test level is only one of several factors that are included in the assessment.

Some specific environmental tests and interpretations have been established for heavy metals (USEPA, 1986). These interpretations are used in managing certain waste applications to soil (USEPA, 1994).

The preceding description of the calibration and interpretation process is greatly simplified to illustrate the concepts. In the real world there are several issues that must be addressed to understand the full implications of interpreting a soil test result. It is clear that there is a relationship between soil nutrient levels and crop production as described above, but there are many other factors that also influence crop growth. These other factors may affect the crop independently or they may interact with the soil nutrient levels to influence the crop. For example, crop response to soil nutrient levels may be minimal even on a below optimum testing soil if crop production is limited by moisture stress. At the same time the crop response to moisture level may vary depending on the nutrient levels in the soil. Weather is probably the biggest factor that will affect the relationship between the soil test level and crop response. Other factors include soil physical parameters such as compaction, pest injury, weed competition, crop cultivar, and many cultural practices such as tillage system. A thorough understanding of crop response to nutrients and the effects of these other factors on this response is necessary to completely interpret a soil test result. The combined effects of these many factors are evidenced by the large amount of variability in the data in Figure 12-2. The data do not fall on a nice curve as illustrated in Figure 12-1. This is why the definitions in table 1 are given in terms of probabilities of response.

For soil test interpretations to be valid, they must be based on calibrations conducted under conditions similar to those where the test is used and must be calibrated for the specific crop to be grown. Therefore, local calibrations are desired. The appropriateness of the calibration database should be a major factor in selecting a soil testing lab. There are soil testing laboratories in other areas of the country that do an excellent job analyzing the soil and that have extensive calibrations for their area, but these labs may be totally inappropriate for use in the Northeast because their calibrations are for different soils and environmental conditions. Unfortunately, comprehensive local calibrations are not usually available for all nutrients, all crops and all conditions. When local data is not available to make an interpretation, good judgement and a thorough understanding of agronomy is required to properly use other data and experience to make an interpretation. This data and experience should be from similar soils, climate, and cultural systems.

The interpretation provided by a soil testing lab should not be considered the absolute interpretation but rather as a starting point for interpreting the soil test in the context of the other factors. Because of the large amount of variation in response, the interpretation provided by a soil testing lab is based on the average probability of expected response to the nutrient over a wide range of conditions. This simple interpretation provided by the lab is usually expanded on by producers or their agronomic advisors to come up with the best final interpretation and recommendation for the specific site and situation.

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