

9 Soil Testing and Nutrient Recommendations

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For over 40 years, soil testing has been a recommended means of predicting the kind and amount of fertilizers needed. Yet, many farmers still do not use this relatively simple tool to increase fertilizer profitability. Producers still apply fertilizer where none is required or at higher rates than required to optimize yields. Others apply inadequate rates or use ineffective application methods. While soil test recommendations for nutrient requirements and optimum rates needed for maximum profit are not always totally correct, they are superior to no soil testing program at all.



Expectations for a soil test's ability to predict nutrient needs are often very high. When predictions seem to fail, some producers lack confidence in them and therefore, choose to forego using soil testing as a tool. Soil testing can detect soil nutrient levels prior to planting quite well; however, soil testing cannot predict future factors that may influence crop yields which sometimes greatly affect crop response to fertilizers. Soil testing is a practical and common-sense means of using reliable chemical analyses to assess nutrient levels in soils in order to make decisions to improve fertilizer use. Note that words such as "exact," "precise," or "accurate" are not in this definition. A principal word, however, is "assess" which means to evaluate, to estimate, or to set a fixed value. The key to soil testing and fertilizer recommendations is to correlate and calibrate a soil test's numerical value with field nutrient response. Without this information, soil testing and the resulting fertilizer recommendations have no meaning. The producer must understand the limitations and capabilities of soil tests in order to develop a fertilizer management strategy.

Soil Sampling

The producer must base fertilizer decisions on the probability of yield response to fertilizer. Soil tests indicate relative nutrient availability at the time of sampling. If a soil test is low, the probability is high that a yield response to fertilizer application will occur if the crop matures to produce a harvestable yield. While the probability for yield increase may be high, it does not guarantee crop response. Similarly, when the soil test is high, the probability of yield response to fertilizer application is low, but that does not guarantee no response.

The components of a successful soil testing/fertilizer recommendation system include laboratory analyses, good soil samples, correlation/calibration information, and interpretation.

The top eight inches of soil in an acre weigh over two million pounds. The soil sample from a field may weigh about two pounds. When a soil sample is analyzed in the laboratory, the sample weighs less than one ounce. Because the soil sample must accurately represent the field or area sampled, soil sampling is the weakest link in the chain of the developing fertilizer management program.

■ *The effect of soil variability on sampling*

Farmers and agronomists have always been aware that soils vary from farm to farm, from field to field, and even within a given field. It is easy to detect noticeable visual differences in soils such as color, slope, erosion, salinity or drainage. Detecting differences in soil chemical properties such as pH, phosphorus (P) or potassium (K) status is much more difficult.

Soil testing has historically focused on determining the *average soil test value* for a field or area. Soil sampling plans are designed to determine an adequate number of samples to provide a reliable estimate of the mean, the most efficient sampling plan, and some measure of spatial variability. The best sampling plans are ones which give the lowest sampling error at a given cost or the lowest cost at a given sampling error. While past research has shown that grid sampling almost always increases precision compared to random sampling, most farmers have sampled to determine field averages as a matter of cost and convenience.

Site specific management (SSM) and variable rate application (VRA) have changed the way we think about soil sampling compared to the way it's been done for the past 40 years. The difficulty with soil testing today is that quantifying a soil test parameter's variability requires soil sampling at an intensity which allows the variability to be mapped spatially with some degree of confidence. This is nothing new as agronomists 50 years ago concluded that field variation was much greater than laboratory variation, that each soil property has a unique variation in a specific field, and that the specific soil property having the greatest variation cannot be anticipated.

Fertilizer application over the past 40 years has increased field variation in soil nutrients and pH. Most current soil sampling guidelines call for sampling to the depth of tillage, normally six to eight inches. However, fertilizer application methods (band vs. broadcast, manure application, differential crop removal) and changing tillage practices have increased heterogeneity and complicated both sampling and interpretation processes. Additional research is needed to determine improved future sampling techniques to deal with nutrient and pH stratification.

The following statements summarize the requirements for proper soil sampling, depending on the producer's objectives:

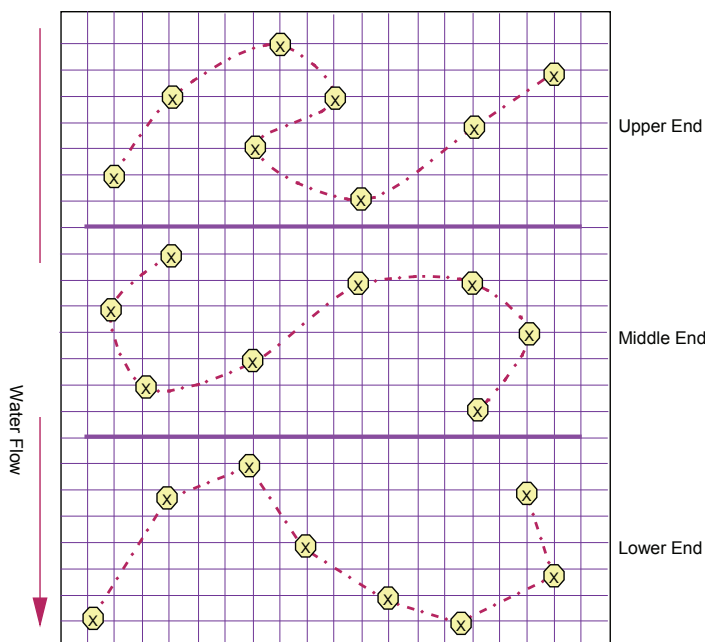
1. For conventional sampling (compositing cores), the person sampling should take several individual cores for compositing into a single sample for analysis, and take samples from all areas that he determines are different.
2. If the farmer is willing to invest more in soil testing, he should grid sample once on a two-acre basis to determine base maps of soil fertility, then sample at a reduced intensity every four to five years.

■ Sampling methods

Current guidelines recommend sampling areas no larger than 40 to 50 acres per sample with a minimum of 20 to 25 cores (Penas, et al., 1991). A simple random sampling pattern is favored by most agronomists (Figure 9-1). For minimum tillage, the producer should take samples at a shallower sampling depth of two to four inches in addition to a sampling depth of eight to ten inches to monitor surface pH and the buildup or stratification of immobile nutrients.

FIGURE 9-1

Dividing and sampling a 60-acre, furrow-irrigated field.



Sampling for Site Specific Management

Because of the intensity required for site specific management soil sampling, farmers must first look at sampling frequency. In the past many producers sampled fields yearly, often because it was offered as a service by local agrichemical dealers or by consultants. Annual sampling isn't really beneficial because most soil test values (immobile nutrients, pH) do not change rapidly. Instead, the original process was to collect a good sample, get the results and recommendations, follow the recommendation for four to five years, and then sample again (Table 9-1). In Nebraska, annual sampling is necessary only for residual nitrate determination.

TABLE 9-1

Relationship between changes in soil properties and frequency of sampling.

Soil Test Property	Frequency of Sampling
CEC/OM	15 years
pH	5 to 10 years
P, K, Zn	5 years
NO ₃ , SO ₄	1 year

Detailed sampling provides significantly more information about soil properties than field average sampling. Because most soil properties (physical or chemical) do not change rapidly, the producer should base soil sampling frequency on the expected change in the parameter measured, and he should base site-specific management sampling strategy on an anticipated change in properties.

Intensive sampling, whether it is a two-acre grid or direct sampling based on yield maps, remotely sensed images, or other spatial resources, provides much more information than a whole field average sample. The additional information can improve management and possibly reduce input costs by applying nutrients/amendments where they are really needed. This additional information comes with greatly increased sampling and analysis costs, however. The producer may initially sample intensively to establish base fertility maps of fields, then reduce sampling based on the initial map at one-third to one-fourth the initial intensity to develop a cost-effective site-specific soil testing plan. Sampling costs for these plans will still cost more than field average sampling, but this method will provide greatly improved information for making management decisions. For more information about spatial sampling techniques, refer to University of Nebraska Extension Circular EC00-154, *Soil Sampling for Precision Agriculture*.

■ *Drying the soil sample*

For best results, the person taking soil samples should air-dry them before they go to the laboratory for analysis. In drying soils, the sampler should not apply any heat, but should spread the soil out on clean paper and protect the soil from *any* contamination (such as fertilizer, dust).

Chemical Analysis

Today's soil test laboratory analyses are the result of many years of research and field verification. This process has developed chemical procedures that are reliable, reproducible and suitably accurate. Generally, a chemical procedure applied to a given soil should yield reported values within $\pm 10\%$, depending on the test. For example, a reported phosphorus value of 20 ppm may actually be between 17 and 23 ppm, a reported pH value of 6.5 is often between 6.35 and 6.65, and a zinc value reported as 3.0 ppm is somewhere between 2.5 and 3.5.

Not all essential plant nutrients are needed in a fertilizer management program as the soil or irrigation water may supply sufficient amounts. Copper, boron, sulfur, or chlorine analysis of all soils would not always provide information useful in deciding what fertilizer nutrients are needed. Therefore, it is reasonable not to test for all nutrients on all samples when a particular nutrient is well supplied by the soil or water. This can save on analytical costs.

No matter how good a chemical test, a soil test value is meaningless unless the producer can relate it to the nutrient status of the soil in order to apply a corrective soil amendment or fertilizer treatment. A single numerical value reported by a soil test (say 11 ppm for phosphorus) has no meaning unless information is gathered to evaluate (1) whether crops will attain maximum growth and/or yield at that assessed phosphorus level, (2) whether crop growth or yield will be greater when the nutrient phosphorus is added to the soil, and (3) the amount of phosphorus needed for the crop to attain better growth or yield in different soils at different test levels.

Correlation and Calibration

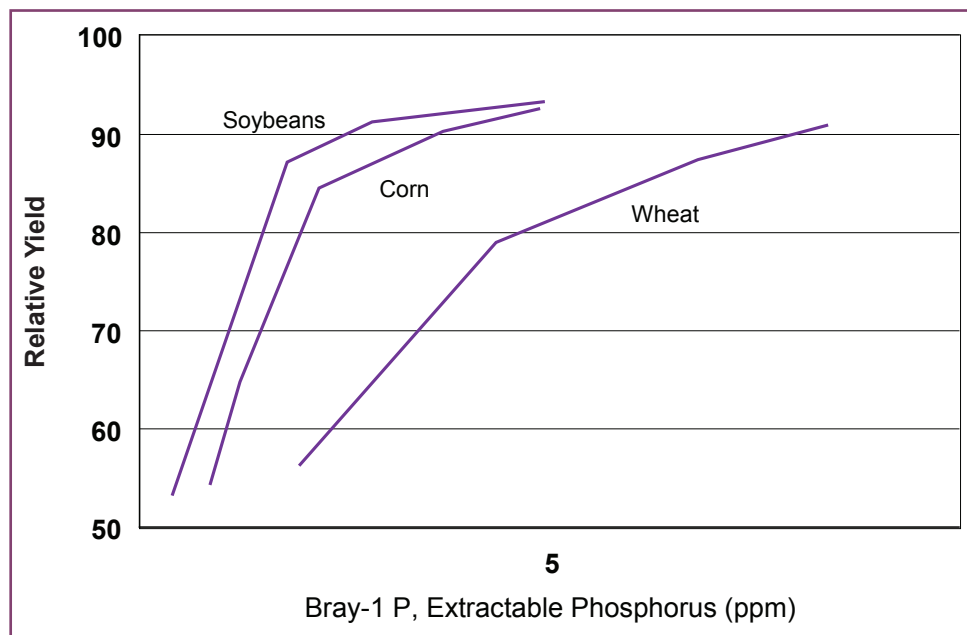
A combination of *correlation* and *calibration* research is necessary to gather information needed to answer these questions. Correlation is a relationship between the amount of nutrient extracted from soil by a laboratory test and nutrient uptake by plants in the greenhouse or field, and/or crop yield. If such a relationship cannot be established, the analytical procedure has little or no usefulness. Sometimes the relationship can be established for only one nutrient and one crop and on a particular group of soils. This is a limitation that the producer must know and recognize, and the soil test should only be used for those limited conditions.

A useful correlation has been established between the Bray-1 P test and percent of maximum yields for soybean, corn, and wheat grown under Nebraska soil and climate conditions. This correlation helps determine when soil test phosphorus is adequate for maximum yields—when no response from additional fertilizer is expected.

Different crops vary in their response to the amount of phosphorus in the soil (Figure 9-2.) Yields of both corn and soybean change rapidly with small differences in soil test phosphorus. Winter wheat requires higher levels of soil phosphorus to attain maximum yields. Because of crop differences, soil test correlation research must be conducted with a large number of crops.

FIGURE 9-2

Different crop responses from different soil Bray-1 P levels.



Calibration establishes the relationship between a given soil test value and the yield response from an addition of the fertilizer nutrient to the soil. Table 9-2 shows the response of alfalfa hay produced from several rates of applied phosphorus on a soil with a Bray-1 P value of 8 ppm. Additional field experiments were repeated where soil phosphorus levels ranged from 2 to 30 ppm. From the yield results, one can determine the amount of fertilizer phosphorus needed over a range of phosphorus test levels for many soils where alfalfa is grown.

TABLE 9-2

Alfalfa yield response to applied phosphorus on a soil with a low Bray-1 P value.

P₂O₅ Applied	Alfalfa Hay Yield
<i>pounds per acre</i>	<i>pounds per acre</i>
0	1600
20	2400
40	3000
60	3600
80	3800
100	3600

After field correlation-calibration experiments have been completed, the producer can place soil levels of phosphorus into categories related to their probability of yield response. These categories give quick insight to fertilizer decisions. Their general meaning is given in Table 9-3 in terms of the probability of a yield increase due to phosphorus fertilizer application.

TABLE 9-3

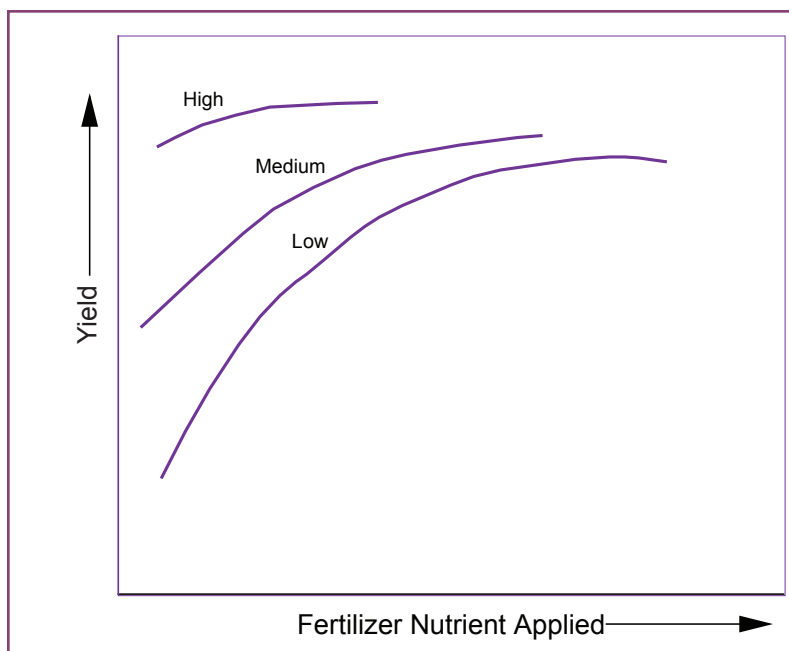
Probability of a yield increase due to phosphorus fertilizer application.

Assessed Soil P Level	Nutrient Index Level	Meaning of Index Level for Small Grains
0 to 5	Very low	Applying P to a crop will be beneficial over 95% of the time.
6 to 15	Low	Applying P to a crop will be beneficial between 75% and 95% of the time, depending on crop and growing conditions.
16 to 24	Medium	Applying P to a crop has about a 50-50 chance of being beneficial in growth or yield.
>25	High	Applying P to a crop will be beneficial less than 10% of the time.

— The increase in yield expected from different rates of a given nutrient will change as the soil test index changes (Figure 9-3).

FIGURE 9-3

Crop response to applied fertilizer phosphorus at different soil test phosphorus levels.



This explanation illustrates much of the basic science behind using correlation-calibration to develop fertilizer recommendations. The table method explains the process and works well if computers are not required. Additional research and statistical methods can be used to develop continuous response functions or algorithms for fertilizer recommendations. These equations lend themselves better to variable rate application and will be the next generation of fertilizer recommendations. Additionally with computer generated recommendations, the producer can combine additional factors such as soil pH, placement methods, and even selling price of the crop into multi-variate equations for predictions. These are not as easy to illustrate, but they perform the same function as looking up a value in a table. They allow the producer to specify more options than he was able to do in the past to improve fertilizer management and profitability.

Resources

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