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Moving Past the Routine: Precision Management for Alfalfa and Hay Crops

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Soil testing is made up of four distinct activities, collecting the soil sample, analyzing the sample, interpreting the results, and providing fertilizer recommendations that account for the fertilizer source, timing of application, rate of application, and placement of the fertilizer. Traditionally, collecting a soil sample was viewed as the limiting step because a recommendation is only as good as the sample that it is based on. With traditional soil sampling, we attempt to represent the field's average nutrient status. Typically, you would want one sample for every 10 – 20 acres. A sample should be collected to the depth prescribed by the lab (4" for untilled fields). If areas within a field are very different due to previous management or natural features, such as topography or soil texture, split the field up and collect samples from each distinct area. Each sample sent to the lab should be a composite of 12 or more soil cores.

Soil sampling for precision agriculture tries to separate fields into smaller management units to match nutrients to site-specific needs within a field. There are two main methods used when collecting soil samples for precision management, grid sampling and directed or zone sampling. Grid point sampling, a method of grid sampling, entails laying a grid over a field in geographic information system (GIS) software with 1 – 2.5-acre cells and collecting one soil sample from the center of each square. Another grid sampling method, grid cell, uses the same grid approach but instead of collecting a sample from a small point at the center of the grid the user zig zags across the grid cell and creates a composite sample from points across the entire cell. Grid point sampling is the most common and requires the user to perform interpolation. Interpolation is a statistical approach to fill in estimated values between the points where samples were collected. Grid sampling is thought to be best at identifying variability within a field due to previous management. Grid sampling is probably the most common precision ag soil sampling technique. It can be rapidly performed by someone with little knowledge of the field. However, grid sampling is probably not the best option. One of the major limitations of grid sampling is the use of interpolation with data that is too coarse. Spatial correlation describes how points close to each other tend to share similar characteristics. For interpolation to work the separation distance between sample points must have a correlation value > 0.3. Studies, such as one performed by Lauzon et al. (2005), have repeatedly shown that most soils require separation distances of less than 100 feet between sample points for interpolation to work. This would mean collecting samples on ¼ acre grids or less!!! This is clearly not feasible considering the time and expense of such dense soil sampling. For this reason, grid soil sampling as performed today is probably the wrong way to go. You can use your existing grid data to look at the distribution of nutrients in the field, by examining the range, mean, median, and standard deviation of soil test results. Grid-based soil samples should not be interpolated and used to create variable-rate prescriptions. Generally, research indicates that the average soil test value is closer to the true value of areas that weren't sampled than the value that would be predicted by interpolation. Zone management would probably be a better way to go. Directed or zone sampling is thought to be best for representing natural variability. With this approach, a user must use knowledge of the field and multiple data layers along with complex statistical approaches to divide a field up based on variability described by the data layers. Data such as yield history, soil texture, and topography can be used to delineate zones which are then sampled individually. While zone sampling can provide useful insights into spatial variation in nutrient and lime needs, it is more labor-intensive and requires high-quality data.

Once soil samples are collected they are sent to a lab for chemical analysis. You need to make sure that the method your lab uses matches the recommendation system you are using. The University of Kentucky Soil Testing Lab and our recommendations use Mehlich 3 extract for phosphorus and potassium. A soil test does not report the plant-available nutrient content or the total nutrient content. Rather, soil test results provide an index of nutrient availability based on established correlation and calibration data that is locally specific.

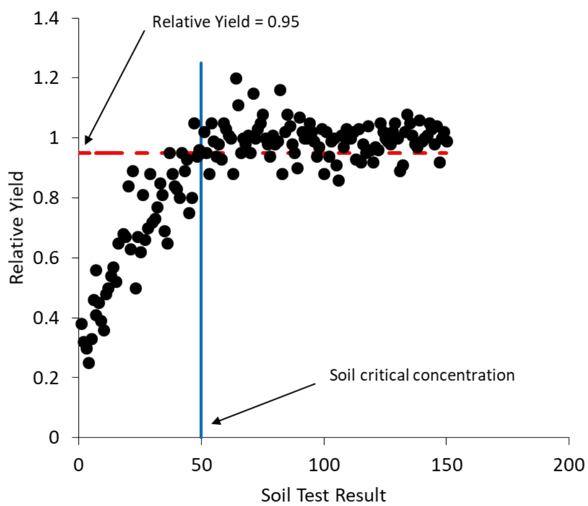

Figure 1. Hypothetical correlation data set. Relative yield is determined by dividing the unfertilized yield by fertilized yield. The critical soil test value is the point above which we no longer expect response to fertilizer.

Correlation and calibration data sets are used to interpret results in order to provide fertilizer recommendations. Correlation seeks to find the critical soil test concentration above which yield response to added nutrient is not expected. A simple correlation experiment can be conducted by having plots at multiple locations with a range of soil test values. These plots only need to have a check plot (no nutrient applied) and plot with sufficient fertilizer applied. Figure 1 shows an example of a hypothetical soil test correlation data. In this figure relative yield is equal to the yield of the unfertilized plot divided by the yield of the fertilized plot. In this example, a relative yield of 0.95 occurs on average at a soil test critical level of 50. It is important to note that correlation data is rarely this clean. Even within one field, there can be a range of soil test values where relative yields approach 1.

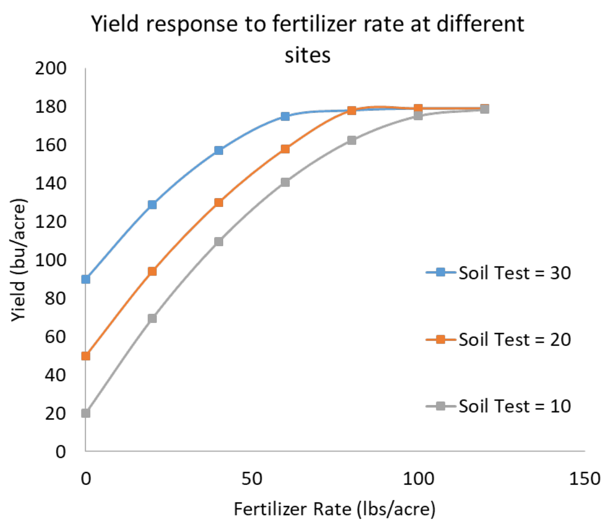

Figure 2. Hypothetical calibration data set. In this example a range of fertilizer rates are applied to three fields with different soil test values. The lower the soil test value the more fertilizer that is required to maximize yield.

Calibration is the approach used to determine the appropriate fertilizer rate to maximize yields on soils testing below the critical level. To conduct calibration studies researchers select multiple fields across the range of soil test levels below the critical value and set up plots with multiple fertilizer rates. Figure 2 shows an example of a correlation study conducted in three different fields.

After calibration and correlation studies have been conducted we can make fertilizer recommendations that appropriate for local conditions. There are different philosophies used to construct these recommendations. The sufficiency approach would make recommendations close to the rates determined to be optimum in the calibration studies. A build-up and maintenance approach would recommend very high fertilizer rates at low soil test ranges to try and rapidly build soil test and then decrease to a maintenance rate above the critical level. A true build and maintain approach would never go to zero, instead, it would always recommend enough fertilizer to keep the soil test value where it is.

Due to spatial variability and uncertainty in determining exact sufficiency rates and the large economic penalty associated with the build and maintain recommendations very few sources strictly adhere to either of these approaches. Instead, most sources of fertilizer recommendations use a hybrid approach. For example, the University of Kentucky makes recommendations well above the crop sufficiency requirement at low soil values and then recommendations decrease closer to sufficiency rates as soil test increases and the probability of fertilizer response decreases. Then our recommendations go to a low fertilizer rate at the critical level in order to keep soil tests from dropping below the critical level. Finally, our recommendations drop to zero above the critical soil test level.

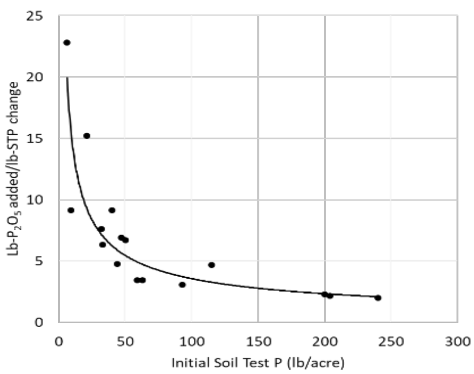

Figure 3. This data from Thom and Dollarhide (2002) demonstrates that at very low soil test phosphorus levels large amounts of phosphorus fertilizer would be required to move soil concentrations a relative small increment. As soil phosphorus increases the amount fertilizer required to increase soil phosphorus decreases.

It is important to point out the concept of soil buffer capacity. Build and maintain ignores this concept. Figure 3 is adapted from Thom and Dollarhide (2002) shows that it can take significant amounts of fertilizer P to raise soil test when soil P concentrations are very low. For this reason, it can be a foolish waste of money to try and build soils that are very low. Likewise, due to buffer capacity soils with higher soil test levels can supply adequate nutrients for many years, making maintenance recommendations in these ranges wasteful as well. Buffer capacity can be thought of as an iceberg. Only the tip of the iceberg shows above the waterline. If you take this tip off the iceberg it will float up to expose more ice above the waterline. A soil has a large amount of P that doesn't show up in soil test results. When crops remove a small amount of P the soil reserve, or buffer capacity, can easily replenish these nutrients when soil test levels are high and can even replenish some of these nutrients in lower soil test ranges.

In summary, traditional soil testing relies on collecting a sample that adequately represents the area being sampled. The same is true for site-specific management in precision agriculture. It is important to realize that soil test recommendations require local correlation and calibration data. Most of this work was done at universities many years ago. Differences in fertilizer rate recommendations are typically due to variations in fertilizer philosophy. Some recommendations lean more towards build and maintain, while others are closer to sufficiency rates.

Lauzon, J.D., I.P. O'Halloran, D.J. Fallow, A.P. von Bertoldi, and D. Aspinall. 2005. Spatial Variability of Soil Test Phosphorus, Potassium, and pH of Ontario Soils. Agron. J. 97(2): 524–532. doi: 10.2134/agronj2005.0524.

Thom, W.O., and J.E. Dollarhide. 2002. Phosphorus Soil Test Change Following the Addition of Phosphorus Fertilizer to 16 Kentucky Soils. Univ. Ky. Coop. Ext. Serv. Agron. Notes 34(2): 5.