Grid Sampling
Grid Sampling for Phosphorus, Potassium and pH — Is It Worth It?

Have you considered grid sampling? Do you know the benefits? Before expending resources on a process that is time consuming and costly, it makes sense to know what you want to achieve. Most growers use soil testing to determine fertilizer needs. Nearly all growers agree on the benefits of having adequate fertility to increase crop profitability. But there are questions concerning how to determine what is adequate.

There are many components to assessing fertility. Some of the components include how and when to sample, lab analysis, accuracy of recommendations, fertilizer placement, and hybrid or variety. Many of these questions have been addressed with research from Iowa State University and other sources.

Grid sampling has created considerable debate around the country over the last decade. It seems obvious there is a need to determine the best fertilizer rate for each part of a field because fields are variable. However, little evidence is available to growers to support this theory. Farmers facing the actual cost of grid sampling and variable rate applications would like assurance that their investment is profitable. Increased interest in grid sampling has been driven by discussions about possible requirements for nutrient management planning.

In response to questions about the value of grid sampling, the Iowa Soybean Promotion Board commissioned the Iowa Soybean Association to analyze available data and summarize the results to benefit Iowa growers.

Most Common Grower Questions

The data from field trials in four different regions of Iowa (near Fort Dodge, Council Bluffs, Waterloo, and Burlington) were used to address three primary questions:

1. How much do soil-test values vary within fields?

2. Can I accurately map the variation within a field and justify the cost?

3. Can I use soil map units to predict differences in soil-test values within a field?

The answers are based on information from 38 Iowa fields that were sampled on one-acre grids. More than 2,500 samples were collected and analyzed. In addition, intensive sampling in transects was done to evaluate variability among samples collected as close as five feet apart. Each sample collected to represent the grid point for each acre consisted of a composite from eight cores (1-in. diameter). These cores were collected along a 40-ft. transect parallel with the corn rows but staggered various distances between rows after planting.
Question 1: How much do soil-test values vary within fields?

All fields should have some variability, but the amount and importance of the variability should be expected to vary greatly among fields. The amount of variability does not necessarily indicate the importance of variability because variability at high test values does not influence management decisions. Below are three tables summarizing the variability of the samples collected in this study.

Table 1a. Distributions of soil-test values for P

<table>
<thead>
<tr>
<th>P Level</th>
<th>Bray P Standards*</th>
<th>Olsen P Standards **</th>
<th>Percentage of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low</td>
<td>0-8</td>
<td>0-5</td>
<td>4</td>
</tr>
<tr>
<td>Low</td>
<td>9-15</td>
<td>6-10</td>
<td>14</td>
</tr>
<tr>
<td>Optimal</td>
<td>16-20</td>
<td>11-14</td>
<td>13</td>
</tr>
<tr>
<td>High</td>
<td>21-30</td>
<td>15-20</td>
<td>24</td>
</tr>
<tr>
<td>Very High</td>
<td>30+</td>
<td>21+</td>
<td>45</td>
</tr>
</tbody>
</table>

* The numerical values included in each category are from the Iowa State University website.
** The Olsen P test is used only when soil samples are found to have a pH value of 7.4 or greater.

Total: 100

Table 1a shows that about 17 percent of samples collected were “low” or “very low”; 36 of 38 fields tested had samples below the optimal category and in the very high category. This distribution of test values provides some evidence that fields are variable and there is potential benefit to spatial management.

Table 1b. Distributions of soil-test values for K

<table>
<thead>
<tr>
<th>K Level</th>
<th>Ammonium Acetate and Mehlich-3 Extractable K**</th>
<th>Percentage of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low</td>
<td>0-90</td>
<td>2</td>
</tr>
<tr>
<td>Low</td>
<td>91-130</td>
<td>7</td>
</tr>
<tr>
<td>Optimal</td>
<td>131-170</td>
<td>15</td>
</tr>
<tr>
<td>High</td>
<td>171-200</td>
<td>17</td>
</tr>
<tr>
<td>Very High</td>
<td>201+</td>
<td>59</td>
</tr>
</tbody>
</table>

* The numerical values included in each category are from the Iowa State University website.

Total: 100

Soil-test K values shown in Table 1b indicate substantial variability, but relatively few deficient areas were detected. The potential benefit of spatial management, therefore, was less for K than for P.

Table 1c. Distributions of soil-test values for pH

<table>
<thead>
<tr>
<th>pH Level</th>
<th>pH Level</th>
<th>Percentage of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acidic</td>
<td>&lt; 6.0</td>
<td>35</td>
</tr>
<tr>
<td>Slightly Acidic to Slightly Alkaline</td>
<td>6.0 - 7.2</td>
<td>50</td>
</tr>
<tr>
<td>Alkaline, Calcareous</td>
<td>&gt; 7.2</td>
<td>15</td>
</tr>
</tbody>
</table>

Total: 100

Soil pH values are shown in Table 1c. If it is assumed that lime would be applied only for soils having pH values less than 6.0, there was a higher percentage of the samples indicated need for corrective treatment than was observed with either P or K. These findings indicate higher potential benefits from variable rate application of lime than of P or K.
**Question 2:**

*Can we accurately map the variability within a field?*

Several approaches were utilized to answer this question.

The first approach was to assess the errors that occur in commonly used interpolation methods. Interpolation methods are often used to estimate soil-test values between sampling points after fields are grid sampled. Figure 2a illustrates a one-acre grid-sampling pattern for a field. To assess errors caused by interpolation, half of the samples were deleted as shown in Figure 2b. Values obtained by interpolation were compared to the measured values replaced by question marks in Figure 2b. It should be noted that this is the worst-case scenario for a two-acre grid because each “?” is located at the furthest point from the actual interpolated data. It also should be noted, however, that most fields are grid sampled in patterns greater than two acres and that the wider patterns would have greater errors.

**Figure 2a.** Grid sampled on a 1-acre grid (208 ft x 208 ft)

**Figure 2b.** Grid sampled on a 2-acre grid

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**Figure 4a.** Errors of interpolation for soil-test P values observed across all 38 fields.

Disagreements between measured and extrapolated soil-test values were considered to be errors of interpolation. Figure 4a shows the errors of interpolation for soil-test P values observed across all 38 fields. Data presented show that 50% of the errors of interpolation were > 8 ppm, which is twice the width of the “optimal” soil-test category. About 21% of the errors were greater than 16 ppm. The pattern shown in this figure is similar to patterns observed in most individual fields. These observations indicate that interpolation results in large errors and suggest that soil-test values vary greatly even when samples are collected relatively close together.

**Figure 4b.** Errors of interpolation for soil-test K values observed across all 38 fields.

Figure 4b shows the errors of interpolation for soil-test K values observed across all 38 fields. Data presented show that 50% of the errors of interpolation were > 30 ppm, which is almost the width of the “optimum” soil-test category (40 ppm). About 13% of the errors were greater than 80 ppm which is the range between this “very low” and “high” soil-test categories.

**Figure 4c.** Errors of interpolation for soil pH values observed across all 38 fields.

Figure 4c shows the error of interpolation for soil pH values observed across all 38 fields. Data presented show that 50% of the errors of interpolation were > 0.25 pH units. About 7% of the errors were greater than 1 pH unit. The pattern shown in this figure is similar to patterns observed in most individual fields.
Interpolation errors of this magnitude are a surprise to many growers, and they commonly ask why the errors are so large. There are a number of possible explanations. One is error associated with obtaining a representative sample. Collecting more cores would reduce this error, but increase cost of sampling. The importance of this problem could be estimated by collecting multiple samples at each site, which was not done in this study and is not normally done by producers.

A second possible explanation is errors in laboratory analysis. The importance of this error can be estimated by sending replicate samples to multiple laboratories, which was not done in this study and not normally done by producers.

A third possible explanation is the way the points were estimated by interpolating. There are many different methods of interpolating. Because samples were collected on one-acre grids in this study, we could evaluate alternative methods by using the approach illustrated in Figures 2a and 2b. All commonly used methods were evaluated in this study, and all methods had similar errors.

A fourth possible explanation is that sampling points on a two-acre grid are too far apart to be used for meaningful interpolation. The nature of this problem is illustrated in Figure 5, which emphasizes that it is not reasonable to estimate soil-test values in Iowa by sampling in California and Maine.
Each of these four possible reasons could produce errors and, even in our study, it was difficult to assess the relative importance of each factor. However, the data in the Figures 4 a, b, and c show the overall importance of the errors. Farmers have no way to assess the importance of these errors when their own fields are grid sampled.

Additional information concerning the importance of interpolation errors was provided in the studies where samples were collected in transects as illustrated in Figure 6. The transect consisted of 20 samples collected at 20-ft. intervals along a line parallel with the corn rows. Each transect also included an area of more intensive sampling, 12 additional samples were collected at 5-ft. intervals between the 20-ft. intervals. The total length of each transect (400 ft) corresponds with the distance between samples for a 3.7 acre grid.

Figure 7a shows soil-test P values collected at 20-ft. intervals along transects in three fields. In one field, the soil-test values showed a tendency to decrease as distance increased along the transect. In the other two fields, soil test values tended to erratically fluctuate between soil-test categories.

Figure 7b shows soil-test P values collected at 5-ft. intervals including and between points shown in Figure 7a. Erratic fluctuation was observed in all three fields. In one field, the fluctuations were not important because all the soil-test values were in the “very high” range. Soil-test values in the other two fields fluctuated between three or four soil-test categories within a span of 80 ft. These three fields are generally representative of the variability observed in the 13 fields intensively sampled.
Figure 8a shows soil-test K values collected at 20-ft. intervals along transects in three fields. In each field erratic fluctuations in soil-test values were more important than consistent spatial trends.

Figure 8b shows soil-test K values collected at 5-ft. intervals including and between points shown in Figure 8a. Erratic fluctuation was unimportant in one field because all points were in the “very high” category. In both of the other fields, soil-test values fluctuated between three soil-test categories within a span of 80 ft. These three fields are generally representative of the variability observed in the 13 fields intensively sampled.

Figures 9a and 9b show soil-test pH values collected at 20-ft. intervals along transects in three fields. In two of the fields, soil pH values erratically fluctuated by more than 0.5 pH units within the 5-ft. intervals.

Observations in Figures 7, 8, and 9 clearly indicate that soil-test values found at a given point usually do not offer reasonable predictions for nearby points. This suggests that one or two samples may not offer reasonable assessments of P, K, and pH values for a soil type or soil map unit. These errors, therefore, explain why soil-test values are usually not consistent within a soil type or soil map unit. The data illustrate that interpolating between points in normal grid sampling often may produce errors that are similar to those found when interpolating between Maine and California.
**Question 3:**
Can we use soil map units to predict the differences in soil-test values within a field?

Soil survey maps are often used to divide fields into areas that are relatively similar with respect to many factors (organic matter, texture, drainage, etc.) that influence crop yields and soil test values. It is obvious that variability in soil-test values can often be reduced when samples are collected within soil map units, but more information is needed to assess the benefits of this approach in production agriculture. This approach would have little value, for example, if most of the variability in soil-test values were due to non-uniform applications of fertilizer in the past.

A simple way to illustrate the inherent variability within soil types is to examine a map constructed like Figure 10, which shows interpolated soil-test values and those from actual grid sampling points. Figures 11-13 illustrate the amounts of variability within and among soil map units within a region. All one-acre grid points for each field were grouped by soil type and compared. Figures 11-13 show the results of all the individual one-acre sample values for each soil type. The value for each soil type was averaged and is shown by the red line. The next three pages focus on P, K, and pH as related to soil map units in Iowa.

**Figure 10.** Spatial variability in soil-test P observed in a field near Waterloo
The circles represent points of sampling (one-acre grid), the numbers besides the circles indicate soil test values, the lines indicate boundaries between soil map units. The colors outside of the circles represent the spatial pattern of soil P categories as calculated using an interpolation method (KDW).
Soil-test P values found in various soil map units commonly found in various parts of Iowa

The figures below show data pooled from 38 different fields, but data from individual fields show the same trends.

**Figure 11a.** Soil-test P values for different soil map units near Burlington

**Figure 11b.** Soil-test P values for different soil map units near Waterloo

**Figure 11c.** Soil-test P values for different soil map units near Fort Dodge

**Figure 11d.** Soil-test P values for different soil map units near Council Bluffs
Soil-test K values found in various soil map units commonly found in various parts of Iowa

The figures below show data pooled from 38 different fields, but data from individual fields show the same trend.

**Figure 12a.** Soil-test K values for different soil map units near Burlington

**Figure 12b.** Soil-test K values for different soil map units near Waterloo

**Figure 12c.** Soil-test K values for different soil map units near Fort Dodge

**Figure 12d.** Soil-test K values for different soil map units near Council Bluffs
Soil pH values found in various soil map units commonly found in various parts of Iowa

The figures below show data pooled from 38 different fields, but data from individual fields show the same trend.

**Figure 13a.** Soil pH values for different soil map units near Burlington

**Figure 13b.** Soil pH values for different soil map units near Waterloo

**Figure 13c.** Soil pH values for different soil map units near Fort Dodge

**Figure 13d.** Soil pH values for different soil map units near Council Bluffs
Key points to consider

Spatial variability in soil-test values is a serious problem in fields used for crop production. Producers must have a good understanding of this problem to make informed decisions relating to application of P, K, and lime. Following are six points to consider.

First, large variability is often observed when samples are collected relatively close together, variability is often substantially greater than the range of the test values included within the “optimal” soil-test category. This variability means that (1) any soil-test value contains considerable uncertainty due to exact sampling point and (2) interpolations between test points are often very inaccurate and misleading.

Second, soil-test values often are not any more consistent within a soil map unit than between soil map units. This means that soil testing by soil map unit often does not help explain variability in test values within a field. It seems that previous additions of P, K, or lime often mask differences associated with soil types. Differences in soil pH do exist, but the scale of existing maps often does not identify soil-type boundaries accurately enough to predict soil pH levels. It is always mentioned, and should be emphasized again and again, that knowing the past field boundaries or locations of barnyards when sampling is extremely important.

Third, an extremely wide range of soil-test levels is often observed within small areas of a single field. Extreme variability in soil-test values can introduce bias when individual cores are collected to form a composite sample. Several cores that have relatively low values can be outweighed by a single core having an extremely high test value. Growth of most of the plants within the area, however, would be limited by the low-testing soil rather than the soil-test value measured on the composite sample.

Fourth, it is not possible for most growers to distinguish accurate soil test values from sample errors.

Fifth, there are no easy solutions to dealing with the problem of spatial variability in test values within fields.

Sixth, use of inaccurate maps to guide variable-rate applications of fertilizer and lime should be expected to increase variability in soil-test values within fields.

Suggestions and Opinion

Grid sampling is clearly an effective way to learn about spatial variability in soil-test values within fields, but it is important to understand the limitations and shortcomings of this approach. It is also important to recognize that grid sampling does not obligate you to apply fertilizer at variable rates or continue to grid sample in future years.

If you decide to grid sample and can see patterns that are believable, it makes sense to manage them separately. Such patterns could be blocks that were previously a livestock area or previous field boundaries. Additional areas with recognizable patterns could include areas that have additional influences such as found in the calcareous soils in central Iowa. Once a field is grid sampled, monitoring the buildup or decline in carefully selected places over time seems to make sense.

Please send your thoughts or experiences on this topic to Tracy Blackmer at tblackmer@iasoybeans.com.