Site-Specific Management Guidelines

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SSMG-38
(12/02)

Collecting Representative Soil Samples for Nitrogen and Phosphorus Fertilizer Recommendations

Summary

Soil fertilizer recommendations in modern crop production rely on laboratory analysis of representative soil samples. Regardless of where the samples were collected (grid points, management zones, or whole fields) the accuracy and precision of the fertilizer recommendation can be improved by considering the factors that influence nutrient variability in the design of the sampling protocol. As each producer's crop production enterprise varies, it is recommended that producers select approaches that are suited for their operation. The objectives of this guide are to discuss how management influences nutrient variability and to provide insight into how to design soil sampling protocols that provide good fertilizer recommendations.

Introduction

A discussion on how to identify management zones or grid sample a field is beyond the scope of this guide and is available in Buchholz (1993), Franzen (1999), Ferguson and Hergert (2000), Jacobsen (1999), and Franzen and Cihacek (1998). The four topics discussed in this guideline paper are:

- Precision and accuracy of soil sampling;
- Management influences nutrient variability;
- Locating fertilizer band; and
- General soil sampling recommendations for fields.

Precision and Accuracy of Soil Sampling

The beginning point for soil fertilizer management is to obtain a reasonably accurate measurement of the various soil nutrient concentrations in the field. This can only be done when a representative soil sample is obtained. If the soil sample is not representative, then fertilizer recommendations resulting from these samples may be inaccurate. Two terms used to describe confidence in a fertilizer recommendation are precision and accuracy (Vaughan, 1999). Accuracy is the ability to get the correct result, while precision is the ability to get the same recommendation each time you sample. For example, let's say that a field was soil sampled three times. If the phosphorus (P) recommendations from these samples were 25, 75, and 100 lb P_2O_5/A, then this sampling strategy has poor precision. Conversely, if the P recommendations from these samples were 50, 55, and 60 lb P_2O_5/A, then we would have more confidence in our sampling strategy. Poor precision can be caused by not collecting representative soil samples. It is possible to have good precision and poor accuracy if the sampling approach is biased.

Precision (D) can be estimated using the equation (Stein, 1945; Skopp et al, 1995):

$$D^2 = (t_p^2)\,(s^2) / n \qquad \text{[Equation 1]}$$

where n is the number of soil cores collected, t_p is the Student t value associated with a specific probability level, and s^2 is the variance. When using this equation, the units or dimension used for s and D must be the same. The variance (s^2) is a measure of variation and can be calculated using a computer spreadsheet. The t value can be obtained from a statistical table in most statistical books. A further discussion of this equation is beyond the scope of this paper and is available in Skopp et al. (1995). *Equation 1 shows that increasing the number of samples (n) in the composite sample improves the precision (reduces D).*

It is important to point out that if a representative sample is collected, then the soil test result represents the field average. When fertilizing to the average, the portion of the field with a nutrient concentration less than the average is under-fertilized and the portion of the field with nutrient concentrations greater than the average is over-fertilized. To minimize the size of areas that are over- and under-fertilized, fields can be split into subfields, ranging in size from 10 to 20 acres, or management zones (Chang, 2002). A discussion on how to identify management zones is available in Doerge (1999), Franzen and Kitchen (1999), and Fleming et al. (1999).

The Site-Specific Management Guidelines series is published by the Potash & Phosphate Institute (PPI) • Coordinated by South Dakota State University (SDSU) • Sponsored by Foundation for Agronomic Research (FAR) through Initiative for Future Agriculture and Food Systems (IFAFS) program agreement No. 00-52103-9679 and other USDA-Cooperative State Research, Education, and Extension Service (CSREES) grants • Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the USDA. • For more information, call (605) 692-6280. www.ppi-far.org/ssmg

Management Influences Fertilizer Recommendation Precision and Accuracy

Inorganic nitrogen (N) distribution between the crop rows is influenced by how the N was applied, tillage system, and time. Clay et al. (1997) showed that one year after anhydrous ammonia was band-applied to the center of the interrow area of ridge and no-tillage systems, inorganic-N spatial distribution looked like a Christmas tree, with the highest inorganic N concentrations located directly below the old fertilizer band (**Figure 1**). This variation tends to decrease with time and tillage. In a system such as this, over-sampling N bands results in biased under-estimation of the N fertilizer. Conversely, under-sampling N band results in biased over-estimation of N fertilizer. The "best" soil sampling strategy in these fields was to composite 15 to 30 cores collected from a zone located halfway between the row and the fertilizer band (located in the center of the row).

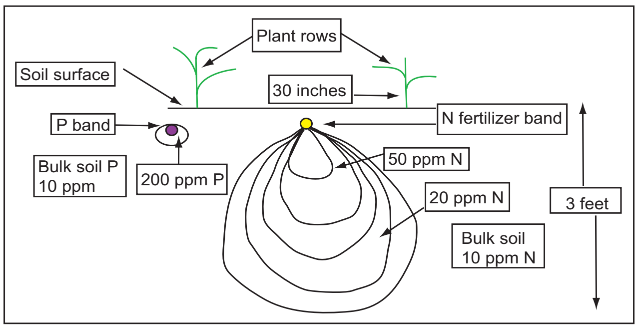

Figure 1. A hypothetical diagram shows the influence of N and P fertilizer bands on nutrient variability. The P band was placed 2 in. below and to the side of the seed and the N band was located in the center of the interrow area. This diagram was based on the findings of Stecker et al. (2000) and Clay et al. (1997).

Lory and Scharf (2000) had a different solution to the same problem. They recommended that the area between the center of the row and the row should be split into three equally sized zones, 5 in. wide. One sample should be collected from each zone. This sampling procedure should be repeated at approximately 10 different areas in a field, resulting in 30 cores being combined into a single sample.

A third option offered by Blackmer et al. (1991) reported that soil sampling bias for N fertilizer recommendations can be minimized by collecting soil samples in sets of eight cores that have various assigned positions relative to the past crop row. The first sample is collected in the row. After moving to another random location, the next core is collected one-eighth the distance between the row and the next row, and after moving to a different random location, the next core is collected one-fourth between any two rows. This process is continued until the eighth core is collected seven-eighths the distance between any two crop rows.

Similar research was conducted in no-tillage fields in Colorado and Kansas where P was band applied (Kitchen et al., 1990). This study found that if P band locations are known, based on stalk or straw from plant rows, then only one sample out of 20 should be collected from the band. In Missouri, Stecker et al. (2001) reported that residual P concentrations in band-affected soil were 5 to 30 times greater than unaffected soil and that high levels remained within 3 in. of the band. Both of these studies showed that over-sampling the band increased the difference between the true soil P level and the measured value, which resulted in under-estimating the P requirement. Based on Kitchen et al. (1990), an equation for calculating the relative number of soil cores that should be collected from on- to off-band locations in wheat-fallow and wheat-sorghum rotations was developed, as follows:

$$S = 8\,(\text{row spacing})/12 \qquad \text{[Equation 2]}$$

where s was the ratio between the number of off-band to on-band samples. This equation suggests that for 30-in. row spacing, 20 samples should be collected off-band for every sample collected from the band ($S = 8 \times 30/12 = 20$).

Old farmsteads may also influence the accuracy and precision of the fertilizer recommendation. In many situations soil samples collected from old farmsteads have higher P levels than the rest of the field (**Figure 2**). Elevated P levels may result from previous manure applications or areas formerly used for animal confinement. Including samples from these areas in the whole field composite sample may increase soil test result and the number of samples required to achieve a given level of precision (**Table 1**). Based on these results, we recommend that whole field composite samples exclude areas where old homesteads or feedlots were located. Although the sampling strategies discussed above are distinctly different, they share the common goal of reducing sample bias, and are based on the observation that previous N and P management influences our ability to collect unbiased soil samples.

Locating Fertilizer Bands

Locating the old N and P band is the first step in developing a sampling approach that accounts for management variability. When fertilizer bands are placed directly

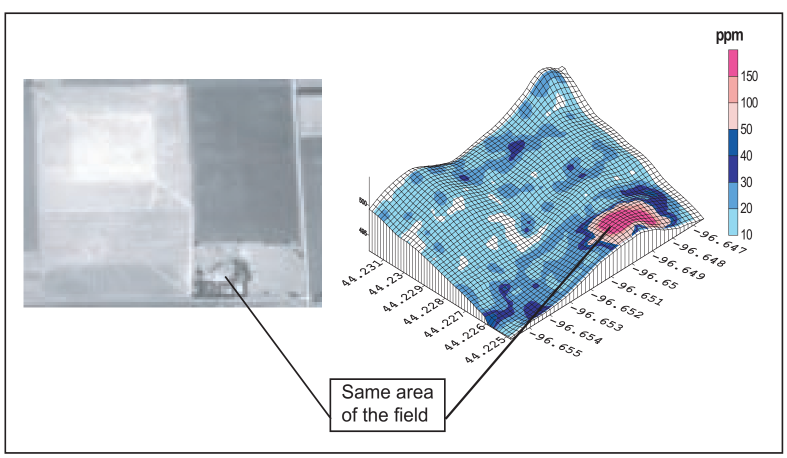

Figure 2. Soil P map superimposed on an elevation map and a 1956 black and white aerial photograph of the field (Kleinjan, 2002).

Table 1. The influence of sampling the old farmstead separately from the rest of the field on the average soil P concentration and soil sampling requirement (n). (Taken from Kleinjan, 2002).

	Sampling the whole field		Sampling the farmstead separately	
Field	Field average, ppm[1] P	Sampling requirement, n (±3 ppm)	Field average, ppm P	Sampling requirement, n (±3 ppm)
1	23.5	310	16.9	44
2	31.9	1,648	16.2	36
3	21.1	258	16.0	15
4	42.0	900	19.9	143
5	7.4	9	6.1	1
6	7.0	7	6.6	4
7	10.1	66	6.5	2
8	40.2	409	27.0	89
9	9.9	36	7.4	7
10	13.3	26	11.6	16
11	21.4	99	17.8	90
12	16.5	121	12.1	71

[1] ppm = parts per million

under the row or in the middle between the rows, the old rows can be used as markers for the fertilizer bands.

When the band was not placed under the row or exactly between the rows, locating residual bands can be challenging. For example, if the P band is placed 2 in. to the right and below the seed, then locating the bands requires that the planter direction of travel be known (**Figure 3**). If the planter is going in one direction, then the band will be on one side of the plant; if the planter is going in the opposite direction, then the band will be on the other side. In this situation, guess rows can contain either none or two bands. These problems can be solved by: 1) not collecting soil samples from guess row, and 2) collecting a single core from either side of the same crop row.

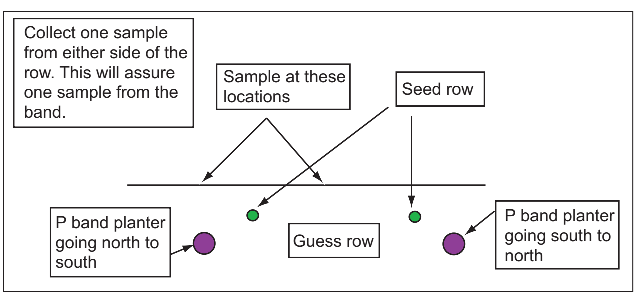

Figure 3. The relative location of a P fertilizer band placed 2 inches below and to the side of the seed.

Except in certain situations, it is easy to find N bands if the NH_3 fertilizer bands are applied directly down the center of the interrow. One exception was revealed by a telephone survey of South Dakota fertilizer applicators. Many NH_3 applicators have an odd number of shanks. When these applicators are used in tandem with a planter, i.e. eight-row planter followed by a seven-row fertilizer applicator, the guess rows may not be fertilized (**Figure 4**). This method of planting and fertilizing is used to minimize double fertilizing guess rows and to avoid running the fertilizer shank down a planted row.

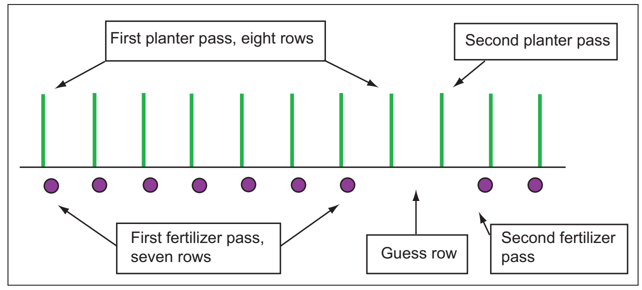

Figure 4. The relationship between the relative location of an N fertilizer applied by an applicator with seven shanks and an eight-row planter.

Summary of Sampling Strategies

1. The sampling strategy should consider how fertilizer was applied and the tillage system. A single, one-size fits all sampling protocol will not work for all situations.

2. Crop producers should develop a figure similar to that shown in **Figure 1** to identify the location of N and P fertilizer bands.

3. Sample areas where animals were confined separately from the rest of the field. Evidence of old homesteads and animal confinement can be seen in USDA-NRCS aerial photographs collected during the 1950s and 1960s. Many of these photographs are available from your local USDA-NRCS office or found in county soil survey manuals.

4. When possible, avoid sampling guess rows, as they may contain either zero or two fertilizer bands.

5. In tilled fields where N and P fertilizers were broadcast, a good sampling strategy is to randomly collect between 15 to 30 individual soil cores from each sampling zone.

6. In a reduced tillage system where nutrients are band applied, keep records on how, when, and where N and P fertilizers were applied. Use the following protocol for soil sampling when possible. For 30-in. row spacing, collect only one core from the old residual P band for every 20 outside the P band. If P was banded 2 in. below and to the side of the seed, then collect one sample on each side of the row (2 in. from the row). This will assure that only one sample is collected from the band. If N was banded halfway between the crop rows, then the remaining cores should be collected halfway between the center of the interrow and the crop row. If P was banded below the seed, then collect one sample from the row and the remaining cores halfway between the center of the interrow and the crop row.

7. If the N and P band locations are unknown, then collecting a representative soil sample is difficult. The best way to address this problem is to find out as much as possible about the past fertilizer and manure practices. Our experience is that in no-till systems, N bands influence inorganic N levels for several years, while P bands influence P levels for 4 to 6 years. If residual bands are present, you are more

apt to under-estimate crop fertilizer needs if the field is undersampled. A sampling strategy, such as that proposed by Blackmer et al. (1991), can be used if relatively little is known about a site. The Blackmer et al. (1991) approach, as described earlier, is a mix of random (for landscape –scale variation) and targeted sampling (for short scale variation from banding).

8. Soil from all cores should be crushed and thoroughly mixed before a subsample is removed for analysis.

9. The accuracy of the fertilizer recommendation is improved by increasing the number of individual cores included in a composite sample. A composite sample should contain at least 15 individual cores. More is better. Composite samples containing only 5 or 6 individual cores can result in misleading fertilizer recommendations.

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Support for this guideline paper was provided by the North Central Soybean Research Board, United Soybean Board, South Dakota Soybean Research and Promotion Council, USDA-CSREES-Fund for Rural America, USDA-CSREES-NRI, and National Aeronautics and Space Administration (NASA).

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Ref. #02086 / Item # 10-1038 / 12-02