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Nutrient Management Module No. 1

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CEU

Soil Sampling and Laboratory Selection

by Clain Jones and Jeff Jacobsen

Introduction

This module is the first in a series of Extension materials designed to provide pertinent information on a variety of nutrient management, water management, and water quality issues to Extension agents, Certified Crop Advisers (CCAs), consultants, and producers. We have included 10 questions at the back of this module that will make the learning "active" as well as offer the potential for credits for CCAs in the nutrient management competency area of "Soil test reports and fertilizer recommendations." In addition, we have included a resource section of other Extension materials, books, web sites, and professionals in the field.

Objectives

Soil testing and laboratory selection are critical components of all nutrient management operations. With increasing fertilizer costs, and low commodity prices, it is very important to apply the correct amount of fertilizer and/or soil amendments to optimize economic return. The objectives of this module are to:

1) describe soil sampling and handling procedures,
2) explain the different philosophies in soil testing programs, and
3) provide criteria for selecting analytical laboratories that will provide accurate results.

Nutrient Management
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Background

Soil sampling and testing provide an inventory of nutrients in the soil. Soil testing for nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) is done to help professionals determine crop nutrient needs and monitor previous management practices. The other macronutrients (calcium and magnesium) and micronutrients (boron, chlorine, copper, iron, manganese, molybdenum, nickel and zinc) are sometimes analyzed to diagnose nutrient deficiencies. **In addition, soil sampling and testing prior to animal manure application may be required in the near future.**

Soil samples are generally submitted to independent analytical laboratories for analysis of plant available nutrients. This is a difficult, and sometimes inconsistent, portion of the process because different laboratories may use different analytical procedures to estimate available nutrients. Therefore, the laboratory selected should be familiar with the area sampled in order to use the appropriate analytical procedure for the tests requested. Fertilizer recommendations are subsequently provided by the laboratory or calculated by the end user of the soil test data. Recommendations may vary greatly for the same soil, in part due to different interpretation philosophies.

Table 1. Variability in soil tests of 40 individual soil cores from an 80-acre field.

	Soil Test Value	
Analysis	**Range**	**Average**
Nitrate-Nitrogen	1-34 lb/acre	11 lb/acre
Phosphorus	3-14 ppm	5 ppm
Potassium	74-385 ppm	153 ppm

Soil Testing

The goal of soil sampling is to characterize the nutrient status of a field as accurately and inexpensively as possible. Details on sampling plans, locations, depths, tools, timing, and sample handling follow.

Sampling Plan

The goal of the sampling plan is to determine where and when to collect soil samples that are representative of the field to be fertilized. If soil is submitted from only a few locations that do not represent the entire area to be fertilized, the fertilizer added may be too much or too little for the majority of the acreage, causing decreased yields, reduced crop quality, or wasted fertilizer. Table 1 demonstrates an actual example of the variability of nutrient concentrations within a field, and shows why taking a few samples could greatly misrepresent the nutrient status of a field.

Sampling depth and timing of sampling are critical components of a well-designed sampling plan. The sampling plan may be constructed in the sampler's head, but it may be more objective to sketch out the plan ahead of time. In addition, the actual sampling areas need to be recorded, or flagged, to help the producer determine where to fertilize.

Sampling Locations

A good starting point is to obtain the soil survey map and topographic map for the area to be sampled. Each soil series has different characteristics, and will likely have different amounts of available nutrients. In addition, the soil maps are based on aerial photographs that can prove useful in determining your relative location when out in the field. To minimize laboratory costs, soil samples are generally collected from several locations within a field and composited (mixed) in a clean bucket prior to submitting to an analytical laboratory.

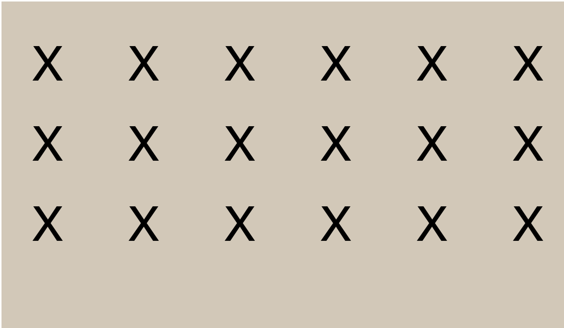

Figure 1. Systematic soil sampling.

If more information is desired about the variability within a field, then more samples should be collected and samples should not be composited. The experience and knowledge of the land owner or producer should be utilized extensively to select a method of soil sampling. The standard sampling method is to collect soils systematically at fixed intervals as shown in Figure 1.

Distance between sampling locations can be greater on homogenous fields than on variable fields. Separate soil samples should be collected from areas or fields that have had different crop history, yield, and fertilizer treatments, or that vary substantially in slope, texture, depth, or soil color.

Another soil sampling method is to sample each soil series in the field and area-weight the results based on the extent of each soil series in the field. To determine the worth of soil series sampling, an economic study of continuous corn compared 100 yard sampling grids to sampling by soil series on a 160 ac field (Clay et al., 2000). The study found the grid sampling to be more accurate and produce higher yields, but the soil series sampling resulted in greater profits, primarily due to smaller analytical costs (six-fold fewer samples) and smaller fertilizer costs.

Another study conducted in North Dakota compared grid sampling at 220 ft, 330 ft, and 5 acre grids to 'area-based' topography sampling and 'point-based' topography sampling (Franzen et al., 1998). 'Area-based' means that composites were created from 6 samples collected 110 yd apart in the center of each topographic unit (hilltops, slopes, depressions, ...), whereas 'point-based' means one sample was collected from the center of each topographic unit. The study found that point based topographic sampling was generally worse at estimating nitrate-N and P concentrations than both 220 ft and 330 ft grids, but was better than 5 acre grids on a 40 acre field. Area-based topographic sampling was better than all grid sampling at estimating nitrate-N concentrations, but worse than both 220 ft and 330 ft grids for estimating P concentrations. Actual soil test results will depend on the uniformity of the field, and the economic worth of each sampling strategy will be dependent on the crop(s) grown, analytical costs, and fertilizer costs.

Sampling Time

Soil sampling should be done to allow adequate lead-time for sample analysis, data interpretation, fertilizer recommendation, and application, though should be performed as close to seeding as practical. Due to time restrictions or soil conditions, it may be more practical to sample in the late fall or winter for spring planted crops. Fall sampling results are likely quite similar to spring sampling results if the fall is dry and the winter is cold, restricting microbial activity. Organic matter, pH, and soluble salts are likely to be similar between fall and spring, regardless of weather conditions.

Sampling Tools

Hand probes, hand augers, spades, shovels or vehicle-mounted hydraulic

Q&A #1

How do I decide the number of soil samples to collect?

This is dependent on the size of the field, the variability within the field, the fertilizer application equipment, how feasible it is to change application rates within a field, and how much time and money you have allocated for sampling. For example, if a producer has 100 acres on a uniform looking field, all within the same soil series, 1 composite sample from 20 soil samples is recommended to characterize that field. However, if the field has different depths of A horizon, has visual differences in color or other characteristics, then 20 soil samples may not be adequate. In addition, if the producer has equipment capable of variable rate application, then more samples will allow for more precise application of fertilizer. In a practical sense, the number of cores collected will be largely dependent on the time required to sample and the available sampling budget.

probe and auger are common tools to sample soil (Figures 2 and 3). If the soil is being composited, shovels and spades should be avoided because it is difficult to obtain the same amount or volume of soil from each location, hence possibly biasing results. Hand augers are useful especially when sampling at different depths. Tools should be cleaned between fields and stored away from fertilizers to prevent contamination.

Sampling Depth

The sampling depth should correspond with crop rooting depth. For example, if the bulk of a plant's roots are located within the top six inches of soil, then the relatively immobile nutrients (such as P and K) need only be sampled in the top six inches. Sampling depth for the more mobile nutrients (nitrate, sulfate, and chloride) should be to the depth that roots can extract water. This depth varies with crop, cropping system, and soil depth. For example, winter wheat grown in an alternate crop-fallow cropping system will use water to approximately seven feet. However, in an annual cropping system, winter wheat may only use soil water to two or three feet because of the lack of soil water at deeper depths.

Fig. 2 Hand probe.

Fig. 3 Truck-mounted probe.

Figure 4. Subsampling depth intervals.

Therefore, the sample depth for the mobile nutrients is a compromise of usually three feet, although with a hand probe, it may only be practical to sample to 18 inches depending on soil texture and moisture.

Sampling and Handling Methods

Crop residue should be removed from the sampling locations. Special areas, such as salty areas, eroded knolls, wet spots, and those without plant growth, should be sampled separately or avoided. Samples should be collected with one of the above tools and divided into depth increments such as 0-6, 6-12, and 12-24 inches (Figure 4). Each depth increment should be **mixed thoroughly** in a large plastic container, subsampled, and placed into a plastic-lined soil sampling bag or glass jar.

Laboratories will either supply sampling bags or can direct you to suppliers. Samples should either be kept cool near 40 degrees F, dried at no more than 120 degrees F, or frozen and dried later to prevent nutrient transformations caused by microorganisms. Oven drying above 120 degrees F is not recommended because the excess heat can change the availability of nutrients making some tests invalid. For example, P can precipitate into relatively unavailable minerals. If drying or cooling equipment is unavailable, samples should be shipped or taken to a laboratory as soon as possible. During any preservation technique, care should be taken to avoid contamination from dust or foreign particles.

Reduced tillage or no-till fields require different sampling techniques due to unique distribution patterns of pH, phosphorus, and potassium. Cores should be collected between the rows if fertilizer was banded in recent years. Collect samples at equal spacing (e.g. 9 inches) between the ridge or row. This decreases the chance of sampling directly in a fertilizer band.

Sampling for Precision Farming

A number of relatively new techniques have been developed using technologies that have only recently become available. Global positioning systems (GPS) can be used to record locations of sampling points to ensure the same points are sampled in the future. GPS systems mounted on farm machinery that is fitted with electrical conductivity (EC) or nitrate probes help some producers determine where and how much fertilizer to apply. Precision farming is discussed in more detail in a later module.

Choosing a Laboratory

Selecting a laboratory that can supply fast and accurate results can be time-consuming; however, the time spent in choosing a good laboratory can quickly pay for itself in the form of accurate fertilizer recommendations, desired crop responses, and better economic returns. A high degree of variability has been observed in fertilizer recommendations between laboratories. Specifically, some studies have shown that when the same soils were sent to different laboratories requesting a fertilizer recommendation for a specific crop and yield goal, significantly different recommendations have been provided (Davis et al., 1999; Follett and Westfall, 1986; Olson et al., 1982).

Much of the variation in fertilizer recommendations is attributed to philosophical differences (Figure 5). For example, the sufficiency approach only uses fertilizer when there are insufficient amounts of nutrients in the soil. With the sufficiency approach, 'critical' values are used to determine whether a field should be fertilized. Specifically, the critical value is the nutrient test result above which only minimal yield responses are observed when fertilizer is added. A maintenance approach replaces nutrients removed in the crop without substantially changing the soil test level, whereas a build approach increases the soil test level over time.

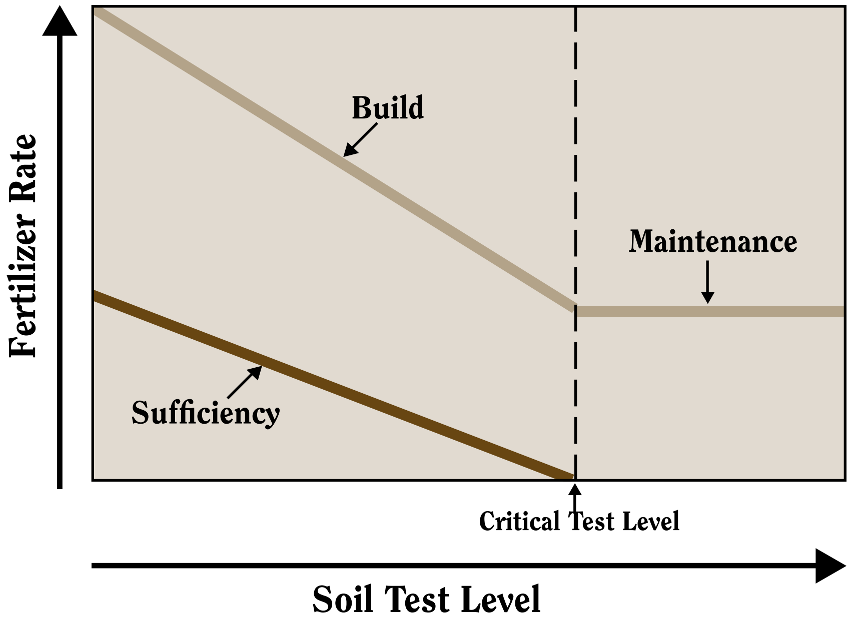

Figure 5. Fertilizer recommendation philosophies.

The build approach is generally only practiced at low soil test levels, and maintenance is generally only done at higher soil test levels. Table 2 demonstrates example fertilizer

Table 2. Example difference in fertilizer recommendations for both a sufficiency and a build/maintenance approach.

P Soil Test (ppm)	Fertilizer Recommendation (lb P_2O_5 / acre)	
	Sufficiency	Build/Maintenance
5	40	70
20	0	30

recommendations for both a sufficiency and a build/maintenance approach (critical test level for P is approximately 16-18 ppm). The resulting economic differences between different philosophies and different laboratories can be large. For example, in a multi-year study of fertilizer recommendations from six different laboratories, fertilizer costs were found to range from $57/ac to $102/ac in the first two years, yet there were no significant differences in yields between the six fertilized fields (Follett et al., 1984). Another similar study found the difference between greatest and least economic return on six cornfields ranged from $45/ac to $180/ac (Davis et al., 1999), demonstrating the importance of accurate fertilizer recommendations. Growers can assist laboratories in making accurate recommendations by selecting realistic yield goals.

Researchers have also found substantial differences in soil analytical results that may also affect fertilizer recommendations. In a study of ten laboratories used by Northern Great Plains consultants and producers, nitrate-nitrogen (NO_3-N) concentrations for the same soil ranged up to a factor of 30 between the lowest and highest result (Jacobsen et al., 2002). Fortunately, this did not have a large effect on fertilizer recommendations because the nitrate levels were small compared to crop uptake for this sample. The soil (Brocko series) with the highest levels of nitrate showed a smaller range of results (9.7-14.5 ppm), yet this difference would still alter fertilizer recommendations by approximately 10 lb N/ac.

Phosphorus test results varied from 7 ppm to 42 ppm, and averaged 28 ppm in one of the four soils tested in this study. Phosphorus fertilizer would likely be recommended for a soil with a 7 ppm test result, yet would likely be wasted on this soil if the actual value was similar to the average soil test P value of 28 ppm (well above the critical level). Some of the differences in results may be due to different analytical methods being selected. For example, laboratories either use Bray, Olsen or Mehlich P tests, all of which use different extractants. However, some laboratories do not report which test they use. It is critical that the user of soil analytical results be aware of the actual analytical procedure since different tests may produce different results.

Q&A #2

How do I choose a good soil analytical laboratory?

A list of laboratories and contacts for laboratories in the Northern Great Plains is included in the appendix. Methods used by these labs are described in EB 150 (ordering information also in appendix). Start by choosing two or three based on your experience and others' recommendations. Then, ask some questions: 1) Do they participate in the North American Proficiency Testing Program (NAPTP) 2) What other QA/QC protocols (quality assurance/quality control) do they use? 3) Will they send you results from both their NAPTP and relevant QA/QC results? 4) What kind of technical support do they provide? If they don't know the answers to the above questions, or aren't willing to send on results, that may be a red flag for you. If you can obtain results from more than one laboratory, compare the results between laboratories to see which look more accurate (see "Assessing Laboratory Accuracy").

Assessing Laboratory Accuracy

Any quality assurance/quality control (QA/QC) data supplied by a laboratory should have both a 'true' value and a measured value for each analysis (pH, nitrate, phosphorus, etc.). The true values reported are typically the average results from many reputable laboratories, producing a 'mean' value. The North American Proficiency Testing Program reports the 'median' value, which is the concentration that has the same number of labs reporting higher values as lower values, and is often close to the average, or mean. By subtracting the difference between true and measured concentration and dividing this difference by the true value, you can obtain a relative estimate of 'error'. You can compare the errors reported by laboratories that you are considering using, and choose a laboratory that has a low error (high accuracy) for the test(s) that you are most interested in (e.g. nitrate, phosphorus). Laboratories should also have high 'precision', which is a measure of how consistent the results are for the same sample. Some laboratories may report the 'standard deviation', which is a measure of how precise the results are (low standard deviation implies high precision). Contact one of the fertility specialists listed at the end of this module if you need help choosing a laboratory.

Summary

Accurate and economical fertilizer recommendations are only as good as the sampling and analytical techniques used to determine these recommendations. A well-designed and implemented soil sampling plan will consider topography, soil type, timing, depth, and preparation/storage. Laboratories range greatly in their accuracy and precision; therefore, laboratories should be selected by comparing quality assurance/quality control data among laboratories. Future educational modules will address cycling, testing, and fertilizer recommendations for specific nutrients, such as N, P, and K.

References

Clay, D.E., J. Chang, C.G. Carlson, D. Malo, S.A. Clay, and M. Ellsbury. 2000. Precision farming protocols. Part 2. Comparison of sampling approaches for precision phosphorus management. Comm. Soil Sci. Plant Anal. 31: 2969-2985.

Davis, J.G., D.B. Bosley, R. Buhler, A.W. Cooley, T. Macklin, R.F. Meyer, F. Sobolik; and K.V. Iversen. 1999. Comparison of soil testing laboratories. In Proceedings of the Western Nutrient Management Conference-Volume 3, Salt Lake City, UT, March 4-5, 1999; Potash and Phosphate Institute: Brookings, SD, 1999.

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J.S. Jacobsen, S.H. Lorbeer, B.E. Schaff, and C.A. Jones. 2002. Variation in soil fertility test results from selected Northern Great Plains laboratories. Comm. Soil Sci. Plant Anal. In press.

Olson, R.A., K.D. Frank, P.H. Grabouski, and G.W. Rehm. 1982. Economic and agronomic impacts of varied philosophies of soil testing. Agron. J. 74: 492-499.

Resources

Books

Soil Testing: Prospects for Improving Nutrient Recommendations. J.L. Havlin and J.S. Jacobsen, 1994. Soil Science Society of America Special Publication No. 40. 216 p. $30

Western Fertilizer Handbook. 9th Edition. 2001. Soil Improvement Committee. California Fertilizer Association. Interstate Publishers. 351 p. (http://agbook.com/westernfertilizerhb.asp) $35 including shipping.

Plant Nutrition Manual. J. Benton Jones, Jr. 1998. CRC Press, Boca Raton Florida. 149 p. Approximately $50.

2005. Soil Fertility and Fertilizers: An Introduction to Nutrient Management. Havlin, J.L., S.L. Tisdale, J..C. Beaton and W.L. Nelson. 7th edition. Pearson Prentice Hall. Upper Saddle River, New Jersey. 515 p. approx. $100.

Extension Materials

Soil, Plant, and Water Analytical Laboratories for Montana Agriculture (EB 150), single copy is free.

Data Interpretation and Fertilizer Sources (MT8704AG), single copy is free.

Fertilizer Guidelines for Montana Crops (EB161), single copy is free.

Online at: http://www.montana.edu/wwwpb/pubs/eb161.html

Diagnosis of Nutrient Deficiencies in Alfalfa and Wheat (EB 43), $7

Digging for Top Crop Profits (VIDEO 7), $14.95

Obtain any of the above Extension materials (add $1 for shipping) from:
MSU Extension Publications
P.O. Box 172040
Bozeman, MT 59717-2040

See Web Resources for online ordering information.

Personnel

Engel, Rick. Associate Professor. Montana State University, Bozeman. (406) 994-5295. engel@montana.edu

Jackson, Grant. Associate Professor. Western Triangle Agricultural Research Center, Conrad. (406) 278-7707. gjackson@montana.edu

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Westcott, Mal. Professor. Western Agricultural Research Center, Corvallis. Phone: (406) 961-3025. westcott@montana.edu

Web Resources

www.montana.edu/publications
Montana State University Publications ordering information on Extension materials including information on Data Interpretation and Fertilizer Sources (MT8704AG) and Fertilizer Guidelines for Montana Crops (EB161).

http://agnotes.org
MSU weekly Agronomy Notes by Dr. Jim Bauder on range of issues, including fertilizer management. Currently there are 23 notes on Fertilizer Management, and over 300 Agronomy Notes total answering questions from producers, agents, and consultants.

http://landresources.montana.edu/FertilizerFacts/
Fertilizer Facts summarizing fertilizer findings and recommendations based on field research conducted in Montana by Montana State University personnel.

www.nwag.com/interpre.htm
A very complete 57 page 'book' on interpreting soil tests intended for use by the layperson. Note that consultant is from Washington State, so some of the fertilizer recommendations may be too high for the semi-arid Northern Rockies. Source: Northwest Agricultural Consultants, Washington.

Soil, Plant and Water Analytical Laboratories for Montana Agriculture

Agvise Laboratories
P.O. Box 510, HWY 15
103 Waldron Hall
Northwood, ND 58267-0510
701-587-6010

Astro-Chem Lab, Inc.
P.O. Box 972
Fargo, ND 58105-5575
Williston, ND 58802-0972
701-572-7355

B&C Ag Consultants
315 South 26th Street
P.O. Box 1184
Billings, MT 59107
406-259-5779
800-764-1622

Energy Laboratories, Inc.
PO. Box 30916
Billings, MT 59107
406-252-6325
800-735-4489

Maxim Technologies, Inc.
600 South 25th Street
P.O. Box 30615
Billings, MT 59107
406-248-9161

MDS-Harris Laboratories
621 Rose Street
P.O. Box 80837
Lincoln, NE 68501
402-476-2811

Midwest Laboratories, Inc.
13611 B Street
Omaha, NE 68144
402-334-7770

MVTL Laboratories, Inc.
710 South 14th Street
P.O. Box 1104
Grand Forks, ND 58201
800-272-7645

MVTL Laboratories, Inc.
1411 South 12th Street
Bismarck, ND 58504
800-279-6885

Sathe Analytical Laboratory, Inc.
P.O. Box 1527
Williston, ND 58801
701-572-3632

Soil Testing Laboratory
North Dakota State University
103 Waldron Hall
P.O. Box 5575
Fargo, ND 58105-5575
701-231-8942

Soiltest Farm Consultants, Inc.
2925 Wapato Drive
Moses Lake, WA 98837
509-765-1622
800-764-1622

Stukenholtz Laboratory, Inc.
P.O. Box 353
Addison Avenue East
Twin Falls, ID 83303
208-734-3050
800-759-3050

University of Idaho
Analytical Sciences Laboratory
Holm Research Center
Moscow, ID 83844-2201
208-885-7081

Western Testing Laboratory, Inc.
1920 9th Avenue North
P.O. Box 3165
Great Falls, MT 59403
406-761-1724
888-862-1724

Note: There are likely other laboratories in the Northern Great Plains that can meet your analytical needs. These were the laboratories that were known about at the time of this publication.

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