Soil Sampling and Crop Nutrient Requirements: Critical Tools for the Nutrient Management Toolkit

Len Kryzanowski

Crop Diversification Centre – North, Alberta Agriculture, Food and Rural Development, Edmonton, AB
Tel: (780) 422-1252
Email: len.kryzanowski@gov.ab.ca

Take Home Messages:

1. Nutrient management is a balance between production/economics and environment.
2. Soil testing provides a means of checking the soil nutrient account and monitoring excessive nutrient accumulations. Benchmark or topographic landscape sampling will provide the best soil sampling results for temporal and spatial variability.
3. Crop nutrient requirements are functions of the crop, yield potential, soil nutrient levels, soil pH, soil salinity, moisture conditions and agro-climatic zones.
4. Nutrient use efficiencies are affected by the nutrient source, time of application, methods of application and the specific nutrient biological and chemical interactions with the soil.

Introduction

The challenge of crop nutrient management is to balance production and economic optimization with environmental impacts. Successful crop production is dependent upon effective nutrient management that includes identifying nutrient deficiencies and excesses. Soil sampling and soil testing provides an opportunity to check the "soil nutrient account" and is critical for developing a nutrient management plan. Knowing the nutrient requirements and nutrient removal by a crop is important for achieving a balance of nutrient inputs and crop removal outputs. Reliable nutrient recommendations are dependent upon accurate soil tests and crop nutrient calibrations based on extensive field research.

Soil Sampling and Testing: when, where and how

Field sampling and soil testing has become an important tool for assessing soil fertility and arriving at proper fertilizer recommendations. It's also a valuable management aid for studying soil changes resulting from cropping practices and for diagnosing specific cropping problems. Soil testing provides an index for the nutrient availability in soil and is a critical step in nutrient management planning. Soil sampling technique, timing of sampling and type of analysis need to be considered for accurate results. The biggest problem in the effective use of soil testing is proper and representative sampling. Proper soil sampling will provide accurate soil test results and reliable nutrient recommendations.

When should I sample?

Cultivated fields for spring seeding should be sampled after October 1. These fields can also be sampled in the spring but time may be limited then. Fields for fall-seeded crops should be sampled one month before seeding. Forage fields for seed, pasture, or hay may be sampled after September 1. Problem soil areas may be sampled anytime. Frozen and waterlogged soils should not be sampled because of the difficulty in obtaining a representative sample.

Where Should I Sample?

Soil variability is a major concern when deciding how to collect a representative soil sample. Soil samples submitted for analysis should be representative of the field or portion of a field. Therefore, by sampling from an area of the field where yield is typically average, soil test results should come back with an average representation of the field. Identifying areas that are representative can be difficult without a first hand knowledge of the field. If the person taking the soil samples does not take the time or have the knowledge required to take a sample in the appropriate location, the results can come back somewhat sporadic.

Random soil sampling is the traditional approach that works for uniform fields with little variation. **Managed random sampling** technique samples from areas identified as average production areas. This is different from random sampling, which provides an average of all cores taken throughout your field. Managed random sampling is recommended if you cannot identify a dominant production area on your field.

Benchmark sampling is recommended for fields with more variability (hills, pot holes etc). Benchmark sampling reduces the inherent variability of a field by reducing the area sampled. A small area (generally about ¼ of an acre) representing the majority of the field is sampled the same number of times as in random sampling. This is the reference area from which fertilizer recommendations are made. The benchmark site should be marked with a global positioning system (GPS) or other means so that one can return there for subsequent years sampling. Sampling from the same area will reduce sampling variability to create a better picture of year-to-year changes. More than one benchmark is recommended if you cannot identify a dominant production area on your field.

In the first year, analyzing a few separate benchmark areas will reduce the risk of getting a sample not representative of the field. Although there are higher costs of laboratory analysis, it will help determine what area to use as a benchmark for future soil sampling. When picking a benchmark area, use observable features such as soil color and landscape to identify where different soil types occur. Select a site that has characteristics similar to most of the field or the dominant soil type. Often the best time to identify different soil characteristics is through crop development. At the beginning of the growing season differences in crop establishment and vigor can be seen making a representative location easier to pick out. Other ways of selecting potential benchmark sites include the use productivity, yield, aerial and/or topographic maps. The benchmark process can be further extended by establishing a couple of benchmark areas in different areas that allow customization of fertilizer rates. By identifying a primary benchmark area and a secondary benchmark area and perhaps even a tertiary benchmark area, a fine-tuned fertility management strategy can be achieved even without variable rate technology.

Topographic soil sampling is an extension of benchmark sampling, where a producer selects the separate soil sampling sites based on topography. A set of soil samples is taken from each uniquely different topographic area within a field.

Grid soil sampling is a very intensive sampling program where a field is sampled in an organized grid pattern. Soil sample frequency may range from taking one sample in 0.5 acre units of the field to one sample for each 5.0 acre units of the field. The smaller the soil-sampling unit the greater the accuracy of the sample. The advantage of this method is that a field map that can be prepared for each nutrient and be used for variable rate fertilization and precision farming. The cost of taking the soil samples and the soil analysis is very high and therefore is not economical for many producers.

Dividing a field into management zones allows for an understanding of different conditions within a field. This is particularly effective in rolling and hummocky landscapes. For example, a large depression may be a very productive area, but a separate soil test may indicate it can be optimized with a higher rate of nitrogen than the benchmark is indicating. While most producers do not have variable rate capabilities, rates can often be easily increased through other adjustments.

Each field (with the same crop and management history) must be sampled separately. Size up each field and observe variations in yield and crop growth, texture, color, slope, degree of erosion, drainage, and past treatment. Sizable areas of fields where growth is significantly different from the rest of the field should be sampled separately. Avoid unusual areas such as dead or back furrows, old straw, hay or manure piles, waterways, saline spots, eroded knolls and old fencerows. Select 15 to 20 sampling sites representative of the portion of the field to be tested.

How Should I Sample?

A variety of **sampling tools** are available to collect soil samples. They range from a spade to hydraulic powered coring equipment. Representative soil samples can best be obtained by using a core-sampling tool. The use of a proper sampling tool is essential for sampling to depths below 15 cm. Take soil core from 0-15 cm at each of the 15 to 20 sampling sites. For improved nitrogen and sulfur evaluation or where problem soils are encountered, separate samples should be taken from the 0-15 cm, 15-30 cm, and 30-60 cm depths at the same 15 to 20 sites.

Place cores in clean pails or bags then mix cores taken from same depths, crushing lumps in the process. Keep samples taken from individual depths separate from one another. Soil samplers may be available on request from fertilizer dealers, private labs or crop advisors. Many fertilizer dealers offer a soil sampling services.

Sample Preparation

Preparing samples for laboratory analysis is just as important as collecting the soil sample. Remove half a kilogram, and air dry to stop nitrate build-up. To air dry, spread a thin layer of soil on a clean piece of paper, plastic sheets or clean shallow containers (plastic, aluminum, etc) in a clean room at room temperature. Do not dry with artificial heat. Some laboratories accept moist samples, but these must be delivered to the laboratory the same day as when they are collected. Samples can also be stored in a refrigerator for a couple of days or frozen if sample delivery is delayed. Provide complete information for each soil sample on the sheet supplied.

Where unusual problems exist, these should be noted in detail. Keep a completed field plan of the area represented by each sample for your own records.

Laboratory Analysis

Consult with your laboratory regarding laboratory analyses of agricultural soils. Research in Alberta indicates that the typical soil analyses package for surface (0-15 or 0-30 cm) agricultural soils should include soil tests for nitrate-nitrogen, available phosphorus, available potassium, and extractable sulfur, plus soil pH and salinity (electrical conductivity). If possible, the nitrate and sulfur analysis should be completed for subsurface soil samples (15-30 and 30-60 cm). Additional analyses for micronutrients (Boron, Chlorine, Copper, Iron, Manganese or Zinc), or organic matter for the surface soil samples may be requested. Some laboratories may provide additional analyses as part of their routine analysis package that they may use to improve interpretations and recommendations.

Considerations for soils with a history of manure application

Fields that have historically received manure present a challenge for soil sampling and soil testing. Collecting a representative soil sample may be difficult and unlike fertilizers where the nutrients are readily available during the current year, manure nutrient availability to crops is extended over several years because of the organic nature of manure. Nutrients from organic sources may not show up in a chemical soil test, so typical nutrient calibrations may result in over application of nutrients. Soil test labs need to know the nutrient application history of a field to take into account manure nutrient sources for nutrient recommendations. A gross accounting procedure of manure nutrient and fertilizer inputs versus nutrient removal along with soil testing helps to monitor the nutrient balance for fields that receive manure.

Crop Nutrient Requirements

Crop nutrient requirements for optimum crop growth are dependent upon adequate supplies of crop nutrients. The total nutrient removal by a crop depends on the yield – higher yields will mean greater amounts of nutrients removed by the crop. Healthy, high-yielding crops can vary considerably in the nutrient concentration in the grain, straw, and forage. Nutrients not actually removed from the land are returned to the soil in organic residues. Crop removal should be adjusted in proportion to the actual yield. Crop removal calculators such as the Crop Nutrient Tool of the NRCS USDA (http://npk.nrcs.usda.gov/) provide an estimation of the nutrients removed with a specific crop yield. However, crop nutrient requirements are not as simple as replacing the nutrients removed by a crop. Nutrient removal should be an important consideration in overall soil fertility management, but nutrient management based solely on nutrient removal could lead to nutrient deficiencies or result in overuse of some nutrients. The behaviour of each nutrient, nutrient sources, soil nutrient levels, nutrient use efficiency, soil properties, and crops to be grown must also be considered.

Nutrient Use Efficiency

Nutrient use efficiency (NUE) refers to the proportion of applied nutrients that are taken up by the crop. In an ideal world, 100% of the nutrients applied would be used by the crop, but in the real world, much smaller proportions are typical. The NUE is dependent upon the nutrient source, time of application, methods of application and the specific nutrient biological and chemical interactions with the soil. Higher NUEs improves crop productivity, enhances economic returns and minimizes environmental impacts.

Nutrients for Crop Production

Nitrogen

Crop removal indicates a minimum amount needed. Immobilization, leaching and denitrification of fertilizer nitrogen may result in as much as 50% fertilizer nitrogen lost. Substantial amounts of nitrogen are supplied from organic matter in the soil as a result of mineralization. Soil microorganisms can also tie up soil nitrogen as fresh organic residues decay. Legumes obtain all of their nitrogen requirements through fixation of atmospheric nitrogen by *Rhizobia* bacteria in nodules on the roots. Although legumes such as peas, beans and alfalfa remove large quantities of nitrogen, significant amounts of nitrogen are returned to the soil in the crop residue.

Phosphorus

Removal by the crop is not a good indicator of fertilizer phosphorus needs. Well-fertilized soils have an abundant reserve of soil phosphorus, which is available to crops. Since phosphorus does not leach, it can build up to very high levels in well-fertilized or manured fields. In young, growing plants, phosphorus is most abundant in the actively growing tissue. By the time plants have attained about 25 per cent of their total dry weight, they may have accumulated as much as 75 per cent of their total phosphorus requirements. Therefore, most crops require significant quantities of P during the early stages of growth. Phosphorus requirements for optimum yields vary with different crops.

Potassium

Potassium deficiency in Alberta is less common than nitrogen, phosphorus or sulphur deficiency for several reasons. First, the parent geologic material on which the soils developed generally contained considerable potassium-bearing minerals. Secondly, the soils are young and have undergone minimal weathering and leaching. Thirdly, crop removal has been relatively small where cereals have been the dominant crop, especially where straw was left on the field, or manure returned to it. There are an estimated 3 million acres of potassium deficient soils in Alberta. Of this total, about 2.5 million are moderately deficient and 0.5 million very deficient. Potassium deficient soils tend to be light to medium textured, alkaline, carbonated and imperfectly to poorly-drained in their natural state. Organic soils are also frequently deficient in potassium. Most crop-available potassium is exchangeable potassium. Mineralization of potassium from primary soil minerals and organic residues occurs. Potassium deficiencies are limited to highly weathered soils in the grey and dark grey soils of Alberta. Most of the rest of the province has adequate amounts of soil potassium. The majority of the potassium taken up by a crop will accumulate in the stems and leaves, and only a small portion in seeds. As a result, crop residues represent a significant amount of potassium returned for subsequent crops.

Sulfur

Sulfur is an essential plant nutrient for all crop production. This situation is especially true for canola, which has a higher requirement for S than other annual crops such as wheat Soil organic matter is the primary source of plant available SO_4-S. Soils that are sandy, low in organic matter and found in upper to mid-slope positions are especially prone to S deficiency since the small amount of SO_4-S released from organic matter is susceptible to leaching loss. Soils most prone to S deficiency are the Grey Wooded, Thin Black and Black soils because they were formed in areas of relatively high rainfall (>leaching) and have greater yield potential (high S demand). Brown and Dark Brown soils are usually not considered S deficient because they often have gypsum ($CaSO_4$) laden subsoils. However, within all soil zones, various combinations of high rainfall, high yield potential, low organic matter, topography and coarse texture will predispose fields to S deficiency.

Calcium and Magnesium

Calcium and Magnesium levels in Alberta soils are generally considered to be adequate for crop production. However, solonetzic soils will have an imbalance of calcium to sodium which results in poor soil structure with permeable soil layers. Use of calcium as gypsum or lime will improve crop growth and soil tilth.

Boron

Boron deficiencies have been suspected in canola and alfalfa grown on sandy-textured Grey Wooded soils. However, research specifically documenting the response to added boron is limited. Brown and Dark Brown irrigated soils in southern Alberta will frequently test deficient for boron. However, cereal crops do not respond to additions of boron. Boron is one nutrient for which there is a fine line between deficiency and toxicity. Canola, pea and bean yields have declined by 10 to 20 per cent due to boron toxicity after a 2 lb/ac application of boron.

Copper, Iron, Manganese, Molybdenum, and Zinc

The availability of these micronutrients has little to do with crop removal. They are needed in extremely small quantities and often, as the case with iron, the soil contains thousands of times more than the crop needs for maximum production. Soil properties such as pH and organic matter govern micronutrient availability to plants.

Copper deficient soils tend to be either sandy or light loam soils with relatively high levels of organic matter (6-10%). High levels of soil phosphorus or heavy applications of manure are often associated with a copper deficiency on these soils. Wheat, barley and oats are the most sensitive to a copper deficiency. Park spring wheat and Condor barley are the varieties that are the most sensitive to copper deficiency and show the most obvious disease symptoms. Rye and canola are relatively tolerant to a copper deficiency. Research has shown that cereal crops grown on organic soils (greater than 30% organic matter to a depth of 30 cm) often respond to copper fertilization. More recently, copper deficiency has been identified in wheat, barley and oats grown on mineral soils in the Black and Grey-Black soil zones of Alberta.

Iron deficiencies have not been observed in field crops in Alberta. However, iron deficiency symptoms such as leaf yellowing are common among various trees, shrubs and ornamentals on high pH soils because lime reduces the availability of iron.

Manganese deficiencies are most common on organic soils and high pH mineral soils. Deficiency symptoms are commonly observed following cool wet conditions in spring. Oats are more susceptible to a manganese deficiency than other cereal crops. Organic soils with a high pH are the most likely to respond to manganese fertilizer.

Molybdenum deficiencies have not been diagnosed in field crops in Alberta. However, isolated deficiencies have been observed in vegetable crops such as cauliflower.

Zinc deficiencies tend to occur on calcareous, high pH soils that have been machine leveled, are sandy in texture or have relatively high soil phosphorus levels. Deficiencies are most common in spring when conditions are cool and wet. In southern Alberta, irrigated field beans have responded to applications of zinc. Zinc deficiencies have been suspected in some irrigated cornfields in southern Alberta, but research trials have not confirmed this. A response to applied zinc may occur on badly eroded soils or soils that have had large amounts of added phosphate fertilizer.

Soil acidity and salinity

Soil acidity and salinity has a significant impact on yield potential and crop nutrient requirements. The adverse effects of acidic soil pH (pH < 6.0) on crop growth and the different adaptability of crops to soil pH will influence crop yield and nutrient uptake. Excessive soluble salt concentrations or salinity affects crop growth and production by increasing the osmotic potential of the soil solution. As the salinity increases, the growth rate and final yield of most crops progressively decrease and the nutrient requirements will also decrease.

Moisture conditions

Moisture conditions have a major influence on crop growth, nutrient uptake and subsequent recommendations for nutrient management. Irrigated fields or fields within high precipitation zones produce higher crop yields and require higher nutrient levels. Spring soil moisture conditions will also influence yield potential and nutrient requirements

Conclusion

Proper nutrition is essential for satisfactory crop growth and production and use of soil tests can help to determine the status of plant available nutrients to develop fertilizer recommendations to achieve optimum crop production. The profit potential for farmers depends on producing enough crop per acre to keep production costs below the selling price. Efficient application of the correct types and amounts of fertilizers and manure for the supply of the nutrients is an important part of achieving profitable yields and minimizing environmental impacts.

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