Soil Testing Philosophy, or
"How we make Fertilizer Recommendations"

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Soil testing is the principle science-based means of making nutrient recommendations for crop production that we have available in agriculture. The number of farmers that soil test each year is currently fairly low, especially when you consider the cost of fertilizer nutrients applied (Table 1). Sample numbers appear to be increasing each time the Potash & Phosphate Institute (PPI) conducts a soil testing summary, likely a reflection of the samples collected as part of nutrient management planning programs. This is verified by the ever increasing number of samples collected that have very high soil test phosphorus (P) levels.

Table 1. Estimates of farmers that soil tested in the fall of 2000 and spring of 2001 in Alberta, Saskatchewan and Manitoba. PPI estimates from soil test summary.

	Alberta	Sask	Manitoba
Fields sampled (based on total samples in summary)	37,437	24,627	14,999
Fields seeded (2001 census data – acres seeded/160)	150,242	237,467	72,816
Fields sampled as a % of fields seeded	25%	10%	21%

The soil testing process is made up of four steps:
1) field soil sampling,
2) sample extraction and chemical analysis in the lab,
3) correlation and calibration of results, and
4) fertilizer recommendation philosophy.
The first three steps in this process will be addressed briefly in this presentation, with the emphasis on the process of making fertilizer recommendations.

Soil sampling holds the greatest potential for introducing errors into the soil testing process. Problems with sample depth, handling in the field, storage containers and shipping conditions can impact on the results obtained. These problems are further compounded by the natural spatial variability of all nutrients in a field. Most labs have suggested sampling procedures for soil samples, guidelines which should be carefully followed. An additional challenge with sampling is related to "who took the sample", and is it relative to the "average" production areas of the field? In many cases the farmer needs to be out when the samples are collected to ensure that the sample truck avoids problem areas in the field, and sticks to those average production areas. Most agronomy companies can now send a truck with GPS, so this process is only required once to setup the benchmark sampling sites in each field.

Extraction and chemical analysis is generally a well monitored and regulated process in soil testing labs. Most North American labs participate in proficiency testing programs, evaluating their methods and equipment with standardized samples circulated by program coordinators. Any errors or deviation from the standard values are addressed promptly.

Almost all soil testing labs have some data on file that is used to correlate soil sample results with, and provide some sort of calibration with the data set. However, remember that a lab based in the southern USA, or Ontario, will likely use data from that region, often not relevant to western Canadian farms. In the absence of field data some labs use crop removal data to calibrate soil test results and fertilizer recommendations. This avoids the need to have a data base for every area samples come from, but does not allow for regional specific growing conditions which may influence your results. This is especially true in those areas where leaching during the growing season results in the loss of mobile nutrients like nitrate and sulphate, and as a result they are not considered when evaluating a fall sample.

Fertilizer Recommendation Philosophy

There are three main methods used to make fertilizer recommendations. These are the sufficiency approach, build and maintenance and the base cation saturation ratio (BCSR).

1. Sufficiency

Field research evaluating crop response to soil nutrient content has identified a soil test level at which crop response is no longer expected from nutrient addition. Below this soil test level the field trial results indicate that some response by the crop is expected from nutrient addition. There are probabilities of responses occurring, again based on the results in the field trial database. This method of assessing crop response is used with all nutrients, and is based on a <u>crop response to the nutrient</u>. This designation is important given that there are other methods of making recommendations that are based on soil responses. The sufficiency strategy fertilizes only when there is a good chance that a profitable yield response can be obtained. As a result the soil test levels are usually always maintained in the responsive range.

There are a few questions a farmer or crop advisor may want to ask when using the sufficiency approach for fertilizer recommendations.

- The first is related to the extraction methods used by a lab – are the chemicals used to extract the nutrient from the soil sample appropriate for your area?
- Secondly, where was the data collected that is being used to determine the need for fertilizer addition, and is it appropriate for your part of the world?
- Finally, what method of fertilizer application does the lab base its recommendations on? This is important for nutrients like P and K, with broadcast application rates being significantly higher than band or seed placed rates.

Answers to these questions may quickly identify some of the differences you are observing in the sample recommendations from different labs.

2. Build and Maintenance

The build and maintenance approach to nutrient application is based on applying nutrients in excess of crop removal as a means of increasing the soil test level to the non-responsive range. This approach removes any potential of a nutrient deficiency as a yield limiting factor. Once at this soil test level, nutrients are applied based on estimated crop removal so that the soil nutrient level is maintained. This method of fertilizer application is only suitable for less mobile nutrients like P and K, given the potential for losses of nutrients like N and S (leaching and denitrification). This method of nutrient application is based on a <u>soil response to the nutrient</u>, and is not commonly practiced in Western Canada.

The build and maintenance strategy is to apply extra P and K, more than the growing crop removes, to build the soil test level to a point that is not yield limiting. Typically this method of fertilization has been practiced on lands that are owned or in long-term lease, ensuring that the benefit of adding the nutrient can be captured by the renter. Often the additions are made so that the soil building occurs over several years, avoiding a one-time high application rate. While the amount of fertilizer nutrient required to build soil P and K varies by soil type and conditions, the ranges are 6-14 lb P_2O_5/A to increase soil P by 1 lb P/A, and 4-8 lbs K_2O/A to increase soil K by 1 lb K/A. Heavier textured (clay) soils require more nutrient addition to change soil test levels than do light textured (sandy) soils. Remember, this nutrient addition to change soil test levels is in excess of that required to grow the crop in a given year. Manure application based on N requirements of the crop often result in an increase in soil test P and K, reflecting the large supply of these nutrients in excess of what the crop required. As a result, it was often recommended that manure be applied to those areas of a field that would benefit most from extra P and K, such as eroded hilltops.

3. Basic Cation Saturation Ratio (BCSR)

The BCSR method of fertilizer recommendation promotes the concept that maximum yield is only achieved by creating an ideal ratio of calcium (Ca), magnesium (Mg) and potassium (K). It is used principally for fertilizer recommendations of these three nutrients, and does not apply to nitrogen, phosphorus, sulphur and micronutrients. The original research by Bear in 1945 with BCSR proposed that there was an "ideal" percent saturation of cations that was 65% Ca, 10% Mg, 5% K and hydrogen at 20%. Future work with the ratio concept found that there was some flexibility in the percentage of each cation. Unfortunately, while the concept was found to work reasonably well on highly weathered soils with a low to moderate cation exchange capacity, low pH, and requiring major adjustment in fertility, it completely neglects the total amount of nutrient in the soil. As a result, under conditions of high K and Ca nutrient content, BCSR would recommend K application when the supply of K is more than adequate (>500 lb/A in top 6 inches). Evaluation of soil test and crop response data from western Canada by Western Co-operative Fertilizers Limited has shown that there is no relationship between the K saturation and crop response on the prairies, mainly due to high sufficiency of K. Use of the BCSR method generally results in over-recommendation of nutrients like K and needs to be checked with the actual soil test level of the nutrient like K.

Other Recommendation Methods

Two additional recommendation methods that are available are the crop removal based method and the Plant Root Simulator (PRS) probes. Crop removal is simply based on applying nutrients to meet a particular yield goal, using nutrient removal estimates published by organizations such as PPI (www.ppi-ppic.org [features link]) and Canadian Fertilizer Institute (www.cfi.ca [publications]). The crop removal estimates are often used when a soil test is not available. One of the disadvantages of the crop removal method is that it does not take into account the nutrients available from the soil. For example, you may have a projected crop removal of 30 lb P2O5/A from a crop, but if you have high P testing soils you would not need to apply this full amount – you can rely on the soil supply to meet the crop requirements. In some cases crop removal can be used successfully with a good understanding of the history for a particular field response.

The Plant Root Simulator (PRS) probes provide an assessment of nutrient supply rates from the soil to the probe based on a timed burial in moist soil. Using a computer program this information is entered along with some moisture, environmental and soil factors, leading to recommendations for the crop grown based on the yield potential established. Estimates of inputs such as precipitation can be adjusted to determine their impact on nutrients required. The computer forecasting model makes recommendations based on soil nutrient supply and predicted crop responses, based on the yield goal entered into the program. The PRS service is delivered by approved field agronomists.

So, why do we get different recommendations?

For those people who have split a soil sample and sent it to a number of different soil testing labs they are often surprised with the differing recommendations they get back. However, when you consider that these fertilizer recommendations are based on completely different recommendation philosophies used in each lab, one should not be surprised. Western Co-operative Fertilizers Limited did just that, splitting a soil sample and sending it to 6 labs for analysis. The fertilizer recommendations (N – P_2O_5 – K_2O – S), target yield, actual yield and net return ($/A) they received are shown in Table 2. While the range of nutrient rates applied varies considerably, the difference in yield obtained only varied by 5 bu/A between the lowest and highest yielding treatment. However, the difference in net return to fertilizer (total crop value less fertilizer cost) was just over $24/A. The final entry in the table is the virtual soil test (VST), a method of estimating crop nutrient requirements using past years soil test reports.

Table 2. Fertilizer applied, target yield, actual yield and net return for spring wheat grown at Irricana, AB. (Western Co-operative Fertilizers Limited)

Fertilizer Recommendation	**Target yield**	**Actual yield**	**Net return**
	bu/A	*bu/A*	*$/A*
1. 55 – 20 – 0 – 0	43	51.7	216.11
2. 60 – 20 – 19 – 5	32	52.9	216.52
3. 60 – 23 – 0 – 4	40	53.4	217.64
4. 65 – 20 – 0 – 0	33	54.4	224.70
5. 110 – 20 – 10 – 14 + 3 Cu	55	55.7	210.77
6. 129 – 24 – 25 – 0 + 1 Cu + 1 B	55	55.9	214.00
VST: 78 – 22 – 15 – 7 (Virtual soil test)	45	56.7	235.33

The results show that the bulk of the crop response was met with 60-70 lb N/A, with no response to the K and S or micronutrients applied. Labs number 5 and 6 are located in a much higher production area than the Irricana, AB test site, and this is reflected in the N recommendations. The target yield was almost identical to the actual yield for these two labs, however, they projected a much higher rate of N required to achieve this yield. They do not account for residual N coming from the soil, as in their environment any N or S left in the soil after the previous crop is either lost by leaching or denitrification. Phosphorus rates are very similar for all labs, even though a number of different extraction methods were used. This result supports those collected by the Potash & Phosphate Institute in their soil test surveys across North America. Labs numbers 1 to 4 are from the prairie region and make recommendations based on field trial data from areas like this Irricana site. Samples sent outside the region for analysis cost the grower about $24/A more than was required to grow the crop.

Recommendations from Production Models

Many labs make fertilizer recommendations based on some production model they have developed over the years. These models account for a number of the 'less quantifiable' factors that influence nutrient response, such as mineralizable N estimates, fertilizer-use efficiency, and value of soil residual nutrients. The soil test results become only a part of these production models that make the final recommendation. Soil mineralizable N has become an issue of great interest in recent years, largely because of the lack of crop response that growers observe when N fertilizer is applied. Past research in Saskatchewan has shown that it is fairly easy to predict the soil mineralizable N supply on Brown and Dark Brown soils, but next to impossible on many of the Black soils. This is because of a larger organic matter pool supplying mineral N. As a result, if you farm in the Black soil zone you are more likely to be less satisfied with the fertilizer N recommendations made. Ultimately, the strength and weaknesses of these production models resides with their ability to accurately predict these factors involved in the nutrient supply process.

Summary

Our review of differences in fertilizer recommendation philosophy clarified one thing: there are several options available for soil analysis, and all of them are appropriate for a certain set of environmental (location) conditions. However, many of these recommendations may not be appropriate for your farm or clients based on the region, data considered and philosophy used by the soil testing lab in making the fertilizer recommendation. Carefully considering where you have soils analyzed will help to build a soil analysis data base which is applicable for your farm and region. This begins by asking the right questions when considering a soil testing lab to handle your samples.