Science Societies

Soil testing: How precise is my lab data?

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As a group, the agricultural and environmental laboratories doing soil analysis are capable of reasonable precision. Some methods have good precision, and others are relatively less precise. Photo courtesy of BYU photography.

Technologically advanced management of plants growing in soils can be greatly benefited by properly performed soil, water, and plant tissue analysis. But how accurate and precise does this data need to be? And, how well are our laboratories performing for each of the various tests that are performed? This article provides an assessment of soil analysis.

This article was prepared as a contribution of the Western Region Nutrient Management Coordinating Committee (WERA-103).

In a previous article on plant tissue testing that we wrote for this magazine, we stated that “Data is the air needed by the lungs of our decision making. Bad data is like bad air—toxic to the organisms breathing it” (**https://doi.org/10.1002/crso.20113**). This is true for soil testing as well with great importance for measuring soil fertility accurately and precisely.

Precise Data

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Producing good data requires three critical steps, namely:

- Proper sampling
- Accurate and precise analysis
- Correct interpretation

For most of us, we can more easily control the first and last steps, but we often feel less control with regard to the analysis portion as we are typically depending on others to do the analysis. However, we can employ actions that allow us better control. This was outlined in a previous article in this magazine regarding the importance of having defensible recommendations, including laboratory credentials (**https://doi.org/10.1002/crso.20048**). In addition to these actions, we can also understand the precision of data in general. We have open access to the collective data provided by the lab community. Herein, we provide an assessment of soil analysis.

North American Proficiency Testing Program Database

The **Soil Science Society of America** (SSSA) has the vast expertise of its more than 6,000 member scientists. The North American Proficiency Testing (NAPT) Program (**www.naptprogram.org/**) is operated as an activity of SSSA and governed by an oversight committee comprised of some of these experts as representatives of regional soil and plant analysis workgroups, scientific organizations, state/provincial departments of agriculture, and private and public laboratories. The NAPT program furnishes agricultural and environmental laboratories with quality control and quality assurance tools through quarterly blind and double-blind statistical evaluation of soil, plant, and water samples. These tools assist laboratories in generating accurate and precise analyses as well as leveraging their participation in assuring clientele and other consumers that their data meets high standards.

This valuable program, with the collective wisdom and expertise found in the credibility of SSSA, not only provides resources to laboratories, but also to consumers of the data that is generated. The aggregated soil data (as well as water, plant, and environmental data) generated by these laboratories are openly available at **www.naptprogram.org/content/laboratory-results**. The data are gathered from five unique samples submitted to participant laboratories each quarter for them to test and then submit data on for any or all of the nearly 100 NAPT-accepted analytical methods. A subset of this data from 2019–2021 from this library of soil data was used for this evaluation.

How Are the Laboratories Performing?

A measure of precision for each method was made by dividing the median absolute deviation (MAD) by the median for each of the 27 program standards (soil samples submitted to labs for analysis) evaluated over these many years for each analyte. These precision scores had values of average = 8%, median = 7%, standard deviation = 5%, minimum = 1%, and maximum = 34%. (Note that, surprisingly, these values are all lower than the similar plant tissue analysis data of average = 11%, median = 8%, standard deviation = 10%, minimum = 4%, and maximum = 43%.) The median precision score data, combined across methods, is shown in Figure 1. These values give a sense

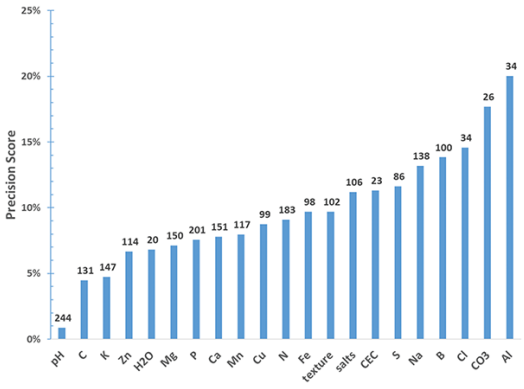


Figure 1, *Comparison of relative soil analysis precision across laboratories for physical and chemical soil properties (averaged across methods). The additive number of laboratories submitting data for all methods (multiple methods are available for most of the analytes) is shown over each bar.*

of the precision of the data generated collectively across labs. There is much data to parse in this analysis, which will be the subject of a future, in-depth article. However, there are some important preliminary points to glean for those using soil data in their management.

The soil pH (including standard pH and buffer pH) was clearly the most precise method with a median of 0.9% (all pH methods were similarly precise with a range of 0.6–1.4%). The various measures of carbon (C), including organic matter and total C, were ranked next in greatest precision (range = 4–6%). When combined, the primary macronutrients—nitrogen (N), phosphorus (P), and potassium (K)—were relatively precise with an average precision score of 7% (range 4–20%, with nitrate-N by saturated paste notably less precise than all others). The secondary macronutrients were variable with calcium (Ca) and magnesium (Mg) less than 10% but with sulfur (S) at 12%. The micronutrients were considerably more variable with zinc (Zn), manganese (Mn), and copper (Cu) all below a threshold of 10% but iron (Fe, 10%), boron (B, 14%), and chloride (Cl, 15%) above the 10% threshold we would prefer to see. The miscellaneous tests of texture (10%), salts (11%), cation exchange capacity (CEC, 11%), sodium (Na, 13%), carbonates (CO_3, 18%), and aluminum (Al, 20%) were among the most imprecise methods.

Bottom Line

What do we learn from this database evaluation from across the majority of agricultural laboratories in North America (and some from other continents as well)?

- On average, the data precision is about plus or minus 7% (plants were 10%) when we examine it across laboratories with significantly better values for pH and relatively better values for the macronutrients vs. the micronutrients.

- Collectively, we gain confidence in the capabilities of the agricultural and environmental laboratories participating in the NAPT program. They are capable of excellent precision. For example, the precision for pH methods is very good, which suggests that their collective abilities are outstanding.
- However, some methods have inherent random, indeterminate errors that impact their precision. For example, the analysis for aluminum (Al) is relatively imprecise. This is partially due to known instrument background "noise" that causes fluctuations in the readings. It is also because soil has relatively high concentrations of this element and, thus, it is relatively variable across soils and has greater potential for method contamination.

These data do not give us a measure of any one laboratory but rather an overview of the laboratory community. Within a laboratory, the precision (and accuracy) can be much tighter than what is shown here. Clients of laboratories can work together for quality assurance as it is a reasonable expectation as part of the quality assurance/quality control relationship.

What This Means

A message came to us from a concerned agronomist who had sent in soil samples to three different laboratories in an effort to evaluate them. He stated that he was concerned about the variability. For example, on phosphorus, he got results of 40, 43, and 25 ppm (parts per million). The first two values are within 10% of one another, which is reasonable and relatively precise if we compare it to what is realistic according to the soils database we have examined here. And, frankly, the interpretation of 40 vs. 43 ppm would be roughly the same, and thus, this is not a concern. The value of 25 ppm would possibly be a concern, but we discovered that a different extractant was used by this laboratory, and thus, he was not comparing "apples to apples."

Various extractants will give varying values and need to be interpreted on their own scales. Similar to temperature, if you say it is 30 degrees, the only way to interpret that is to know which scale was used to measure it. A temperature of 20 °F is cold, but 20 °C is warm. We have combined across methods here, but we have converted to relative values in order to do so.

The bottom line is that this evaluation of our laboratories shows that they are collectively capable of excellent analysis, especially for the routine tests commonly done and utilized for managing crops.

Summary

You cannot manage well what you do not measure. But how precise is the “measuring spoon” we are using for that management? A regular “teaspoon” is not necessarily calibrated for accuracy and precision, whereas one that we buy in a set of measuring spoons theoretically has a volume that is accurate and precise. In soil analysis, we need to have an understanding of what is realistic with regard to the precision provided by laboratories and not attempt to interpret the results to a finer scale than what is actually achieved.

As a group, the agricultural and environmental laboratories doing soil analysis are capable of reasonable precision. Some methods, such as pH and carbon (C), have good precision, and others, such as boron and chloride, are relatively less precise due to random, indeterminate errors inherent in the methodology. On average, laboratory data precision is about plus or minus 7%. In general, the macronutrients have more analytical precision than the micronutrients. Soil analysis is a proven, valuable tool to assist in the management of plants and soils. But, its interpretation needs to be done with an eye towards actual, measured precision with interlaboratory methods.

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