Soil Test Laboratory Analysis and Fertilizer Recommendations

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Key Messages

- Soil test laboratories provide a critical step in management decisions of nutrients for optimum crop production, however the best analytical process cannot compensate for poor sample collection and handling.

- Laboratory methods, calibrations and recommendations must be based on local (Alberta or western Canada) research.

- Soil test methods will vary among laboratories and in their ability to measure crop available nutrients.

- Calibration of soil test methods and recommendations can be influenced by soil properties (soil pH, texture, seedbed moisture), agro-climatic zones and cropping systems.

- AFFIRM will provide access to 4R Nutrient Stewardship for a range of laboratory soil test methods.
A Good Nutrient Soil Test

- Needs extensive field and laboratory research.
- Needs to provide a measure of the nutrient proportional to what a plant utilizes for a wide range of soils.
- Able to identify responsive vs non-responsive soils based on soil test critical level and/or other related properties.
- Able to predict nutrient application rate for responsive soil.
- Able to identify excessive nutrient levels.
Limits of a Nutrient Soil Test

- One-time snap-shot of nutrient levels that must be able to take the entire crop growing season into account.
- Misconception – nutrient measure equals availability; Soil analysis is an index of nutrient levels in the soil.
- Requires continuous verification, evaluation and updates.
- Field research related to management changes crops, varieties, nutrient sources, rates, time of application, placement, tillage, etc.
- Laboratory improvements: procedures, detection limits, multiple nutrient extraction.
Soil Testing Recommendation Process

- Extraction and Chemical Analysis
  To extract “available” forms of nutrients. The values extracted this way have no absolute meaning, i.e., they are only indices and as such they must be calibrated against yield.

- Correlation and Interpretation
  The process whereby the “indices” derived from extraction and chemical analysis are calibrated against plant growth or nutrient uptake.

- Fertilizer Recommendation
  The process whereby the “calibrated indices” are applied to providing a fertilizer recommendation using crop response curves or production models.
Soil Test Calibration

- Nutrient soil test laboratory methods must be calibrated with crop yield response across many different soil types
- May use crop nutrient removal
- Often regionally specific
- Costly and time consuming
Soil Test Interpretation

Interpretation directly related to philosophy and subsequent recommendation.

Philosophies

- Sufficiency - Deficiency Correction:
  Deficient, Marginal, Adequate, Excessive, Toxic
- Replacement - Crop Removal:
  Uses target yield goals for nutrient requirements
- Build and Maintenance:
  Application of nutrients in excess of crop removal
- Base Cation Saturation Ratio (BCSR):
  Maximum yield is only achieved by creating an ideal ratio of soil calcium, magnesium and potassium.
Laboratory Soil Test Questions

- Soil test methods will vary among laboratories. What chemical extractant is used for the soil nutrient analysis? Is it appropriate for your area?

- Determination of fertilizer required for sufficiency? What is the source of the data gathered to assess how much fertilizer would be required?

- What method of supplying the fertilizers is used? Some labs consider the fertilizer is applied by broadcast application, others banding – are you broadcasting or banding?
Soil Testing Laboratory Objectives

- Maintain high analytical standards - Participate in the North American Proficiency Testing or equivalent program.
- Identify soil related problems (fertility, salinity, pH) that may be limiting yields.
- Analytical results to formulate a fertilizer recommendation.
- Timely sample turnaround.
- Agronomic and environmental limits.
The goal of the Analytical Laboratory QA/QC Program is to guarantee the generation of precise and accurate analytical data.

Includes: Standard operating procedures (SOPs), Training, Reliable and well-maintained equipment, Traceability, Annual QC results review, QC samples.

Soil Analytical Process Contains Errors:

- 80% due to the soil
- 20% due to the analytical equipment
Laboratory Analysis - Soils

- NO$_3$-N
- PO$_4$-P
- K
- SO$_4$-S
- pH
- Salinity (E.C.)
- Micronutrients (Cu, Zn, Mn, Fe, B, Cl)
- Organic Matter
- N Mineralization
- Soluble salts
- Cation Exchange Capacity
- Particle size (texture)
Soil Test Nitrate

Five Year Running Averages - Stubble

<table>
<thead>
<tr>
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<th>YEAR</th>
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<td>62</td>
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<td>88</td>
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<td>90</td>
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</table>

- BROWN & DARK BROWN
- THIN BLACK & BLACK
- IRRIGATED
- GRAY WOODED
- PEACE RIVER REGION

Soil NO₃-N lb/ac (0-6in)
Soil Test Nitrate

Five Year Running Averages - Fallow

- BROWN & DARK BROWN
- THIN BLACK & BLACK
- GRAY WOODED
- PEACE RIVER REGION

Soil NO₃-N lb/ac (0-6in)

YEAR

62 64 66 68 70 72 74 76 78 80 82 84 86 88 90
Soil Test Phosphorus

Five Year Running Averages - Stubble

Soil P lb/ac (0-6 in)

YEAR

62 64 66 68 70 72 74 76 78 80 82 84 86 88 90

BROWN & DARK BROWN
THIN BLACK & BLACK
IRRIGATED
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PEACE RIVER REGION

Alberta
Soil Test Phosphorus

Five Year Running Averages - Fallow

- BROWN & DARK BROWN
- THIN BLACK & BLACK
- GRAY WOODED
- PEACE RIVER REGION

Soil P lb/ac (0-6 in)

YEAR

62 64 66 68 70 72 74 76 78 80 82 84 86 88 90

Soil Test Phosphorus

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Soil Test Potassium

Five Year Running Averages - Stubble

Year

Soil K lb/ac (0-6 in)

BROWN & DARK BROWN
THIN BLACK & BLACK
IRRIGATED
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PEACE RIVER REGION
Soil Test Potassium

Five Year Running Averages - Fallow

Year

Soil K lb/ac (0-6 in)

BROWN & DARK BROWN
THIN BLACK & BLACK
GRAY WOODED
PEACE RIVER REGION

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Soil Test Sulfate

Five Year Running Averages - Stubble
Soil Test Sulfate

Five Year Running Averages - Fallow

Soil SO₄²⁻ S, lb/ac (0-6 in)

BROWN & DARK BROWN
THIN BLACK & BLACK
GRAY WOODED
PEACE RIVER REGION

Year

62 64 66 68 70 72 74 76 78 80 82 84 86 88 90

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Field trials - Variables:
- Crops, varieties, fertilizer products, time of application, fertilizer placement, tillage
- Regions - soil types, climate, soil moisture, irrigation
- Soil samples

Laboratory soil test methods - Chemistry:
- Chemical extraction solutions
  - Acids, bases, neutral salts
  - Anion and cation displacement

Correlation - How good is the relationship:
- Crop response - Fertilizer rate relationship
- Soil test - Crop response relationship
- Soil test - Fertilizer rate relationship
- Linear, Non-linear, Spline, etc
- As the soil test increases, the recommended fertilizer rate decreases
Soil test P calibration trials in Alberta
Calibration curve indicates which soil test levels tend to limit yields.

The results of this calibration data set from Alberta show a critical level (sufficiency) of 20 to 25 ppm (40 to 50 lb/ac) P.

This is the level of soil test P above which minimal response to applied P can be expected.

McKenzie et al., 1995
Phosphorus Soil Tests

Calibrated in Western Canada Field Studies
- Miller Axley
- Olsen (bicarbonate)
- Kelowna
- Modified Kelowna (Exova, ALS)

Not Calibrated in Western Canada Field Studies
- Bray I (weak), Bray II (strong)
- Mehlich-1, Mehlich-2, Mehlich-3
- Morgan
- Many others
IPNI Soil Test Summary

Potassium sample distribution: Alberta

- 2001: 28,858
- 2005: 39,091
- 2010: 33,181
- 2015: 56,726

Relative Frequency, %

Ammonium acetate equivalent soil test level, ppm

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IPNI Soil Test Summary

pH sample distribution: Alberta

2001; 28,855
2005; 35,960
2010; 38,530
2015; 59,958

Relative Frequency, %

1:1 soil:water equivalent soil test level

< 5.1  5.1-5.5  5.6-6.0  6.1-6.5  6.6-7.0  7.1-7.5  7.6-8.0  8.1-8.5  > 8.5

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Today's Laboratory Challenge

The challenge today in the selection of a soil extractant is to select ones that accommodates several factors:

- multielement in order to take full advantage of multielement analyzers, such as the ICP,
- suitable for a range of soil characteristics, such as pH, texture, organic matter content, etc.,
- have an established significant relationship between elemental level and crop response.
Nutrient Recommendations

Factors Influencing Recommendations

- Soil Nutrient Level
- Crop
- Agro-Climatic Zone
- Growing Season Precipitation
- Soil Texture
- Soil Moisture
- Soil Organic Matter
- Soil pH
- Soil Salinity
Nitrogen Fertilizer Recommendation

Soil Test N (lb/ac) 0-24 in
N Recommendation (lb/ac)

Recommendation Curves
- Crop, Soil Zone, Moisture

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Phosphate Fertilizer Recommendation

Recommendation Curves
- Crop, Soil Zone, Moisture

Soil Test P (lb/ac) 0-6 in

P$_{2}$O$_{5}$ Recommendation (lb/ac)
Potash Fertilizer Recommendation

K₂O Recommendation (lb/ac)

Soil Test K (lb/ac) 0-6 in

Recommendation Curves
- Crop, Soil Zone, Moisture

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Sulfur Fertilizer Recommendation

**Soil Test S (lb/ac) 0-24 in**

**S Recommendation (lb/ac)**

- Recommendation Curves
  - Crop, Soil Zone, Moisture

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# Micro Nutrients Interpretation

## Micro Nutrient Critical Levels (ppm)

<table>
<thead>
<tr>
<th></th>
<th>Boron 0-6&quot;</th>
<th>Copper 0-6&quot;</th>
<th>Iron 0-6&quot;</th>
<th>Manganese 0-6&quot;</th>
<th>Zinc 0-6&quot;</th>
<th>Chloride 0-24&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deficient</strong></td>
<td>&lt;0.35</td>
<td>&lt;0.2</td>
<td>&lt;2.0</td>
<td>&lt;1.0</td>
<td>&lt;0.5</td>
<td>&lt;15</td>
</tr>
<tr>
<td><strong>Marginal</strong></td>
<td>0.35-0.5</td>
<td>0.5-1.0</td>
<td>2.0-4.0</td>
<td>0.5-1.0</td>
<td>16-30</td>
<td></td>
</tr>
<tr>
<td><strong>Adequate</strong></td>
<td>0.5-3.5</td>
<td>&gt;1.0</td>
<td>&gt;4.0</td>
<td>&gt;1.0</td>
<td>&gt;1.0</td>
<td>&gt;30</td>
</tr>
<tr>
<td><strong>Excessive</strong></td>
<td>&gt;3.5</td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
Soil Organic Matter & Soil Nitrogen Mineralization

\[ y = 0.1814x^3 - 2.7679x^2 + 17.641x \quad R^2 = 0.82 \]
Moisture

- Spring plant available soil moisture (PAW)
- Growing season precipitation (GSP)
- Probabilities by soil zone
- Total Avail Moisture (TAM) = PAW + GSP
Precipitation Probabilities (May – July)
Estimating Plant Available Soil Moisture

Field Capacity

Available Water

Wilting Point

Unavailable Water

Per Cent Water

mm Water Per 30 cm of Soil

Texture

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## Estimating Plant Available Soil Moisture

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>PAW cm/m</th>
<th>Depth of Moist Soil (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dry</td>
</tr>
<tr>
<td>Very Coarse</td>
<td>FS, LS</td>
<td>7 – 8</td>
</tr>
<tr>
<td>Coarse</td>
<td>SL, FSL</td>
<td>10 – 14</td>
</tr>
<tr>
<td>Medium</td>
<td>L, SiL, CL</td>
<td>15 – 18</td>
</tr>
<tr>
<td>Fine &amp; Very Fine</td>
<td>SiCL, SiC, C</td>
<td>16 - 19</td>
</tr>
</tbody>
</table>
Crop Response to Nitrogen & Moisture

Crop Yield (bu/ac) vs. Soil & Fertilizer Nitrogen (lb/ac)

- Wet
- Medium
- Dry
Crop Response Curves

Increasing Yield

Increasing Limiting Factor

Increasing Fertility
Intermediate
Average
Increasing Fertility
Increasing Yield
Fertilizer Cost $
Optimum
Intermediate
Average
Irrigation Level
Irrigation
Growing Season Moisture

Increasing Yield

Fertilizer Cost $

Increasing Fertility

Growing Season Moisture

Wet

Medium

Dry
### Soil pH

<table>
<thead>
<tr>
<th>Soil pH</th>
<th>Relative Yield Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>0.0</td>
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<tr>
<td>4.0</td>
<td>0.2</td>
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<tr>
<td>5.0</td>
<td>0.4</td>
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<tr>
<td>6.0</td>
<td>0.6</td>
</tr>
<tr>
<td>7.0</td>
<td>0.8</td>
</tr>
<tr>
<td>8.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Legend:**
- Red: Alfalfa
- Yellow: Barley
- Green: Oats
- Cyan: Wheat
- Blue: Timothy

**Map:**
- pH 5.5-6: Dark Red
- pH 6-6.5: Red
- pH 6.5-7: Light Red
- pH 7-7.5: Pink
- pH 7.5-8: Light Pink
- pH 8-8.5: Blue

**Location:**
- Alberta
Soil pH

Increasing Yield

Fertilizer Cost $

Increasing Fertility

pH Level

Neutral +

Moderately Acidic

Very Acidic

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Soil Salinity

Salinity Level
- Non-Saline
- Moderately Saline
- Very Saline

Increasing Fertility

Fertilizer Cost $
s

Increasing Yield

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Zones reflect differences

- Soils
- Climate
  (pptn, temp, growing season)
- Crop management
- Yield potential
- Nutrient availability
- Nutrient requirements

Agro-Climatic Zones

Alberta Soil Group Areas
Alberta Farm Fertilizer Information and Recommendation Manager (AFFIRM)

- Fertilizer recommendations based soil test calibrations from Alberta research.
- Able to utilize soil test results from several different laboratories.
- Access to current nutrient management knowledge based on Alberta research.
- Nitrogen fertilizer-crop response model that incorporates soil test and fertilizer nitrogen with spring moisture conditions and growing season precipitation.
- Balanced nutrient economic analysis model.
- Nitrogen mineralization estimates to improve fertilizer nitrogen recommendations for crop production.
- Field and whole farm optimization for nutrient management.
AFFIRM Enhancements

- Update Laboratories and Soil Test Calibrations
- New fertilizer products research
  - Enhanced Efficiency Fertilizers
    ESN (coated urea) and other fertilizer products
- 4R Nutrient Stewardship
  - Product, Rate, Time, Placement
- Incorporate nutrients from manure sources
- Linkage to AB Climate Information Services and AB Soil Information Viewer
Your Responsibility

- Need to collect and handle the best representative sample.
- Use a reputable laboratory.
- Surface and subsurface samples.
- Provide field management information.
- Be aware of the soil test methods that the laboratory uses.
- Is the laboratory using research data, soil test calibrations and recommendations appropriate for your region?
- Does the laboratory have a QA/QC program?
- Be careful when switching laboratories.
- Unusual soil test results need to be checked. Reanalyze or resample?
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