Soil Test Correlation and Calibration: What Does that Exactly Mean?

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Common questions...

• What does the soil nutrient level mean?

- Is that considered high or low?
- When is high, too high?
- How do I convert soil test levels from parts per million (ppm) to pounds per acre (lb/acre)?
- When can I start cutting back on fertilizer?
- Do I still need to apply starter fertilizer?
- I have high soil pH. Is that a problem?



Today's outline

- 1. What does a soil test actually measure?
- 2. What is soil test correlation and calibration?
 - What is the difference between a correlated soil test method and an "uncorrelated" soil test method?
 - Field research data from numerous trials must be collected
- 3. Interpreting a soil test level and making a recommendation





Thought you'd never see this again?

Havlin et al. 2013. Soil fertility and fertilizers: An introduction to nutrient management. 8th ed. Pearson Education, Inc.



Why do we soil test?

- Monitor soil nutrient status for...
 - Crop production
 - Animal waste management (manure)
 - Environmental monitoring
- Determine the available soil nutrient pool
- Optimize crop inputs to prevent over- and under-fertilization across field(s)
- Reduce environmental loss risks



A soil test method does...

- 1. To provide an index of soil nutrient availability
 - Extract a portion of the soil nutrient in the plant available nutrient "pool" (i.e., solution, exchange sites, organic, mineral)
 - Does not measure the *actual* amount available for most soil nutrients, not always a "functional" pool

Correlation and Calibration

- 2. To predict the probability of crop response to fertilizer application
- 3. To provide a basis for making fertilizer recommendations



A quick laboratory tour...









Soil analysis: the basic procedure

- Start with known amount of soil
- Add extracting solution for desired nutrient (mimics plant availability)
- Mix or shake (5 min to 2 hour)
- Filter the solution
- Measure the extractable
 nutrient concentration





Soil test methods must be standardized and approved

- Consistent methods produce consistent results
- Soil test methods supported with university research
- Practical for commercial labs





Different soil nutrients use different soil test methods

Soil nutrient or property	Extraction method	Determination instrument
nitrate-nitrogen	0.2 M potassium chloride	Cd reduction, colorimetric
phosphorus	Bray-1 or Olsen solution	colorimetric
potassium, calcium, magnesium, sodium	1.0 M ammonium acetate	AAS or ICP
sulfate-sulfur	0.2 M potassium chloride	turbidimetric
chloride	0.25 M potassium sulfate	potentiometric titration with silver nitrate
boron, copper, iron, manganese, zinc	DTPA-sorbitol solution	AAS or ICP
рН	1:1 soil:water	pH electrode
soluble salts (EC)	1:1 soil:water	EC electrode
organic matter	360 °C furnace	weight loss on ignition
carbonate (CCE)	15% hydrochloric acid	pressure calcimeter



AGVISE uses NCERA-13 approved soil testing methods

Laboratory proficiency certification

QC/QA blind and doubleblind samples sent quarterly to laboratories

- Agricultural Laboratory Proficiency (ALP) program
- North American Proficiency Testing (NAPT) program
- Performance Assessment Program (PAP)







Analyzing phosphorus

- Measure a defined amount of soil using NCR-13 approved soil scoop
- Add Olsen
 bicarbonate extracting solution





Analyzing phosphorus

- Shake soil and extracting solution for 20 minutes
- Pour solution through filter paper





Analyzing phosphorus

- Analyze phosphorus concentration with PFIA flow-injection analyzer
- Coloring agent (molybdate blue) reacts with phosphorus and color absorption is measured





Why are P & K reported in ppm?

- Soil immobile nutrients are reported in parts per million.
- Soil test method measures a portion of the plantavailable soil nutrient pool – not the *actual* amount.
 - Historically, the soil testing industry did report all soil nutrients on reports in lb/acre, which caused confusion and lead to erroneous fertilizer rate calculations.
 - Reported in parts per million since 1990s, reducing confusion.
- Each soil test method and nutrient is correlated to crop response with field research in the region. Classified as an index of predicting crop response to fertilization: low, medium, or high.
- A low soil test level means there is a high probability of crop response to fertilization.



Let's invent a new soil test method

- The soil test method is _____.
- Your soil test level is 28 ppm...
- What did we actually measure?
- What does that number mean?
 - Is that high or low?
 - What is the nutrient?
 - What is the crop?
 - What is the crop yield potential?



Soil test interpretation

Soil test category	Soil nutrient sufficiency	Soil test level
Very high	100%	???
High	90-100%	???
Medium	70-90%	???
Low	50-70%	???
Very low	<50%	???

<u>Soil test correlation and calibration</u> = replicated field trials are conducted across a range of soils, in different crops, for different nutrients to assign soil test categories and appropriate fertilizer rates.

<u>Soil test critical level</u> = point at which no crop response to additional fertilizer is expected.



Soil test correlation and calibration studies are required





Soil test correlation and calibration Find the soil test level and fertilizer rate



Soil test: Very low low medium/optimum high very high

Optimum fertilizer rate determined with multiple replicated field trials across a range of soil test levels



Different fertilizer rates required for different soil test levels and crops



Soil test: Very lowlow medium/optimum highvery highOlsen P (ppm)0-312-1520-40



Interpreting a soil test report

cutoff for high category = soil test critical level Olsen P = 15 ppm





nutrient guideline: 1) crop choice, 2) yield goal, 3) placement

Interpreting a soil test report

A well-calibrated soil test method should predict soil nutrient availability and appropriate fertilizer guideline.

Nutrient In	The Soil	Interpretation	1s	t Cro	o Choice	2n	d Cro	p Choice
		VLow Low Med High		Wheat	-Spring		Wheat	-Spring
0-6"	52 lb/acre	*****		YIELD	GOAL		YIELD	GOAL
				70	BU		70	BU
			SUG	GESTED	GUIDELINES	SUG	GESTED	GUIDELINES
Nitrate	me	dium rating		Broa	dcast		Ba	ind
	IIIC		LB/A	CRE	APPLICATION	LB/A	CRE	APPLICATION
Olsen Phosphorus	11 ppm	*****	N	107		N	107	
Potassium	321 ppm	*****	P ₂ O ₅	65	Broadcast	P ₂ O ₅	34	Band *
0-6''	7 lb/acre	***	K2O	10	Band (Starter)*	K2O	10	Band (Starter)*
0-6"	120 +lb/acre	*****	CI	26	Broadcast	CI	26	Broadcast
Sulfur			S	0		S	0	
Boron	2.0 ppm	*****	В	0		В	0	
Zinc	0.62 ppm	*****	Zn	0		Zn	0	



higher soil test level, lower fertilizer rate guideline

Some soil test correlations are clean



Soil test K had strong correlations with corn plant K concentrations at growth stages V5 and VT



Some soil test correlations are messy (i.e., uncorrelated, no relationship)





Flaten, D., A. Mangin, T. Fraser, J. Seward, and J. Heard. 2018. Estimating the nitrogen supplying power of Manitoba soils. In: Lee, J.T., chair, 19th AGVISE Soil Fertility Seminar - Canada, Portage la Prairie, MB. 14 Mar. 2018. AGVISE Laboratories, Northwood, ND.

Sometimes, there are exceptions

- Measuring soil properties
 - Soil pH (unitless scale)
 - Soil salinity (electrical conductivity, EC)
 - Soil texture (%sand, %silt, %clay)
 - Soil water holding capacity (%)
- Measuring total quantities
 - Soil organic matter
 - Total organic carbon
 - Calcium carbonate equivalent (CCE)



Takeaways on soil test correlation and calibration

- Soil test methods measure a nutrient pool that is related to crop uptake and yield
- A good soil test method offers:
 - 1) an index of plant availability
 - 2) a prediction of crop response to fertilizer
 - 3) a basis for fertilizer recommendations
- A well-calibrated soil test method <u>AND</u> interpretation is unearthed with numerous field research trials (i.e., a lot of data and statistics)





Them is the nuts and bolts. What do you do?



Sprengel-Liebig's Law of the Minimum (First Commandment of Soil Fertility)

Crop growth and yield is proportional to the amount of the <u>most limiting nutrient</u>, whichever nutrient it may be.

Supplying the limiting nutrient will increase crop yield until some other nutrient (or factor) becomes the new "minimum."



If you see hoof prints, look for horses, not zebras.



Phosphorus (P), 0-6 inch topsoil

Bray P1 or Olsen P method

Bray P1 is the older method, developed on acidic soils in eastern Corn Belt. Fails on calcareous soils, delivers false low STP result. No Bray P1 correlation work on high pH soils.

Olsen P was developed later, designed to work across low and high pHs.

Soil test category	Soil test P (ppm)		
	Bray P1 Olsen F		
	pH<7.3	рН 5.5-8.5	
Very Low	<5	<3	
Low	6-10	4-7	
Medium	11-15	8-11	
High	16-20	12-15	
Very High	>20	>15	



Bray P1 vs. Olsen P

The problem

In high pH soils, calcium carbonate neutralizes the acidic Bray P1 extractant, resulting in false low STP data.



Failed Bray P1

The fix

Use Olsen P across a range of soil pHs, especially in the same field if grid or zone soil sampling.



Soil samples with soil test phosphorus below 15 ppm (Olsen P) in 2022



Data not shown where n< 100 AGVISE Laboratories, Inc.



Soil pH controls soil phosphorus availability



Soil test extraction mimics the relative availability and unavailability of soil nutrient pools.

Potassium (K), 0-6 inch topsoil

Ammonium acetate K method

Soil test K critical level varies based on soil texture and clay mineralogy. Historically, 150 or 160 ppm STK across all soils – still works for low K requirement crops.

Soil test category	Soil test K (ppm)		
	Coarse-textured	Medium- & fine-textured	
Very low	<30	<50	
Low	31-60	51-100	
Medium	61-90	101-150	
High	91-120	151-200	
Very high	>120	>200	



Soil samples with soil test potassium below 150 ppm in 2022



Data not shown where n< 100 AGVISE Laboratories, Inc.



Soil samples with soil test potassium below 200 ppm in 2022





Nitrogen is a little different

- Nitrogen is transient in the environment
 - Nitrate-N is mobile in soil, moves readily with water
 - Vulnerable to environmental loss
- Apply nitrogen fertilizer on an annual basis to meet crop N requirement
- Fall soil nitrate testing is a recommended practice in "drier" regions (95th Meridian westward)
 - Measure residual nitrogen supply left after crop (carryover), credited to next year's nitrogen



Residual nitrate following wheat

Trend from 1986 to 2022





Residual nitrate following corn

Trend from 1995 to 2022





Residual nitrate following sugarbeet

Trend from 1986 to 2022





What goes into the nitrogen fertilizer guideline?

Topsoil and subsoil nitrate-N (0-24 inch)

- Soil nitrate level (0-24 inch)
- Crop requirement (yield x N factor)
- Previous crop N credit (legumes)



Crop nitrogen needs are different

Crop	Soil + fertilizer N requirement		
	lb N/bushel		
Canola	3.0-3.5		
Corn	1.0-1.2		
Spring wheat	2.5-3.0		
Soybean	0		



Previous crop nitrogen credits reduce fertilizer N requirement

Previous crop	AGVISE I Ib N/a	University N credit Ib N/acre	
	Long-season crop e.g., corn, sunflower	Short-season crop e.g., wheat	All crops
Alfalfa	50	25	50
Dry bean	30	15	40
Faba bean	30	15	40
Field pea	30	15	40
Lentil, chickpea	20	10	40
Soybean	30	15	40



Why do we collect 0-24 inch soil samples for nitrogen?

- Strongest relationship with nitrogen uptake
- Frigid, semi-arid environment
 - Frozen soil does not leach nitrate or allow N mineralization
 - Limited water to leach nitrate below root zone between fall and spring

Sampling depth (inch)	Plant N uptake explained by soil nitrate-N (r ²)
0-6	32%
0-12	64%
0-24	84%
0-36	82%
0-48	78%



Plant roots reach deeper than most people think

Plant roots can access subsoil nitrate-nitrogen as long as there is water

Standard 0-2 ft soil sampling depth





Lundstrom, D.R., and E.C. Stegman. 1988. Irrigation scheduling by the checkbook method. NDSU Ext. Circ. AE-792 (revised). North Dakota State Univ., Fargo, ND.



If you want to learn more about humankind's long struggle with soil erosion...

Thank you for your kind attention! Are there any questions?

Remember: Your soil test is only as good as the soil sample.

