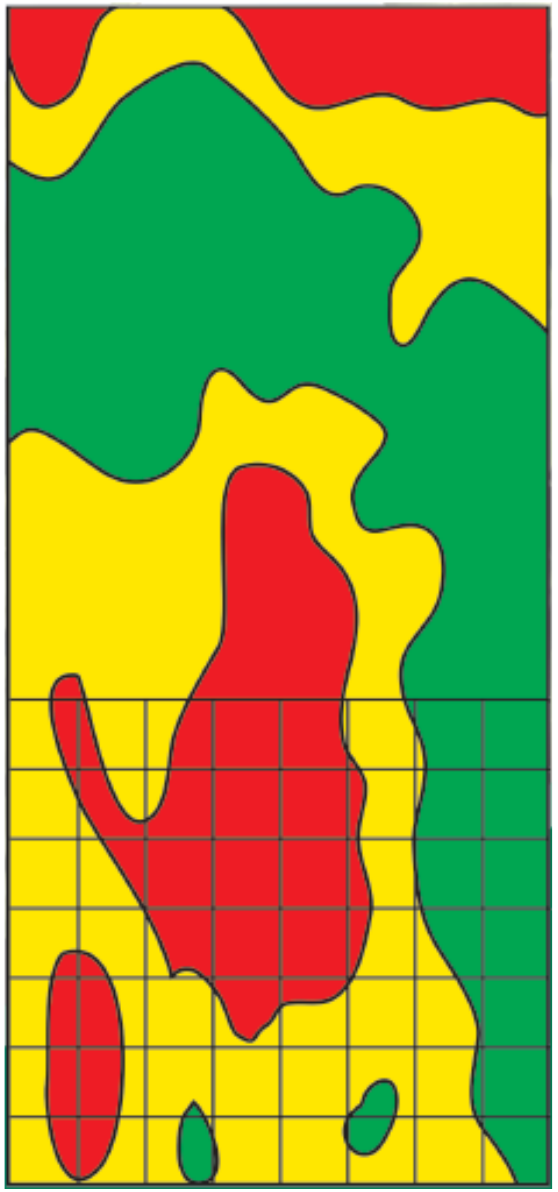
Soil Test Correlation and Calibration: What Does that Exactly Mean?



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@jsbreker

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?

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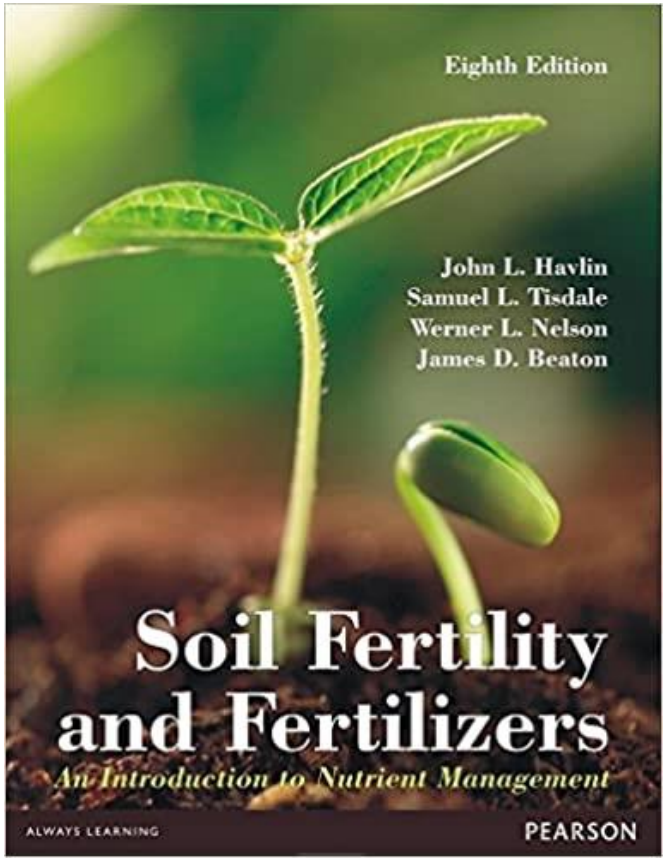
Today's outline

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.

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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…

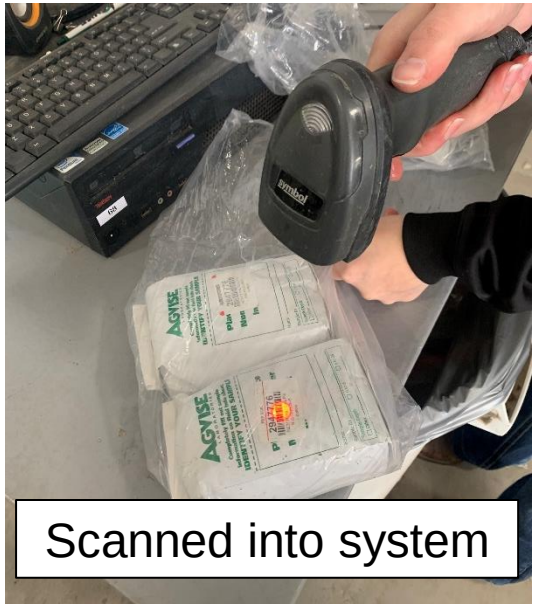
1. To provide an index of soil nutrient availability
   - Extract a portion of the soil nutrient in the plant available nutrient "pool" (i.e., solution, exchange sites, organic, mineral)
   - Does not measure the *actual* amount available for most soil nutrients, not always a "functional" pool

<u>Correlation and Calibration</u>

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

A quick laboratory tour…

Samples received



Scanned into system

Removed from bags to dry overnight

Ground the next morning

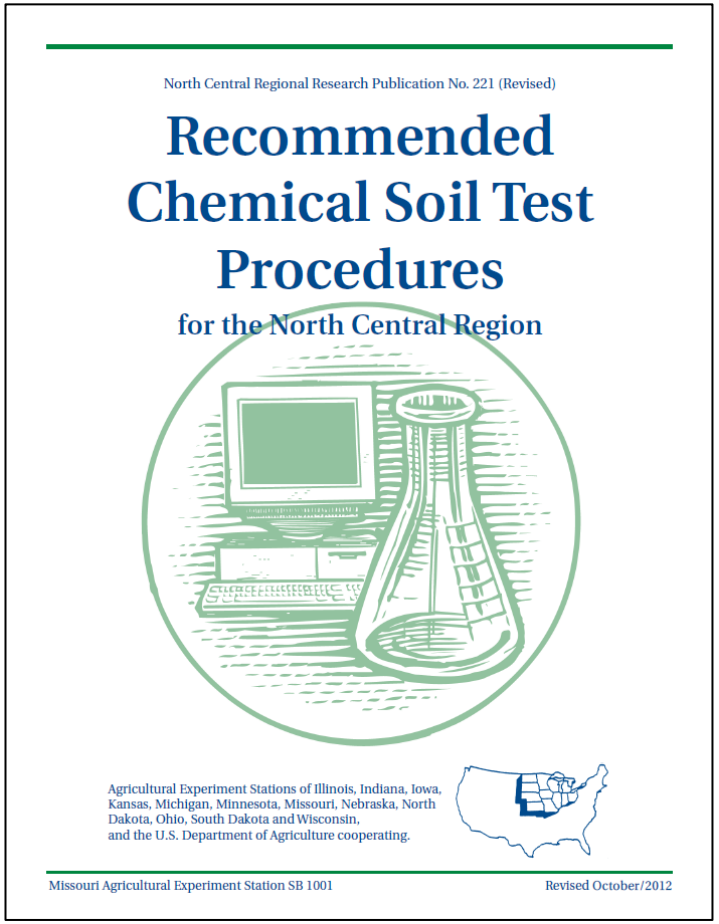
Ready to run through lab

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
pH	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

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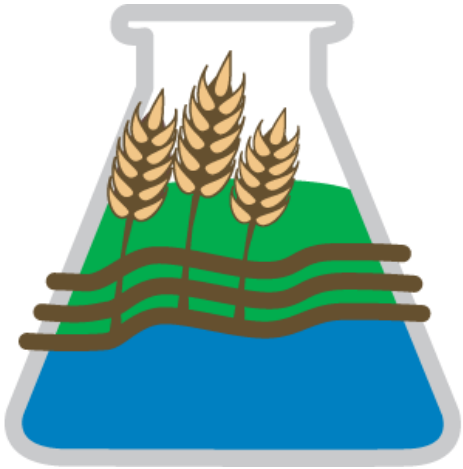
AGVISE uses NCERA-13 approved soil testing methods

Laboratory proficiency certification

QC/QA blind and double-blind samples sent quarterly to laboratories

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

NAPT Program
North American Proficiency Testing



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Analyzing phosphorus

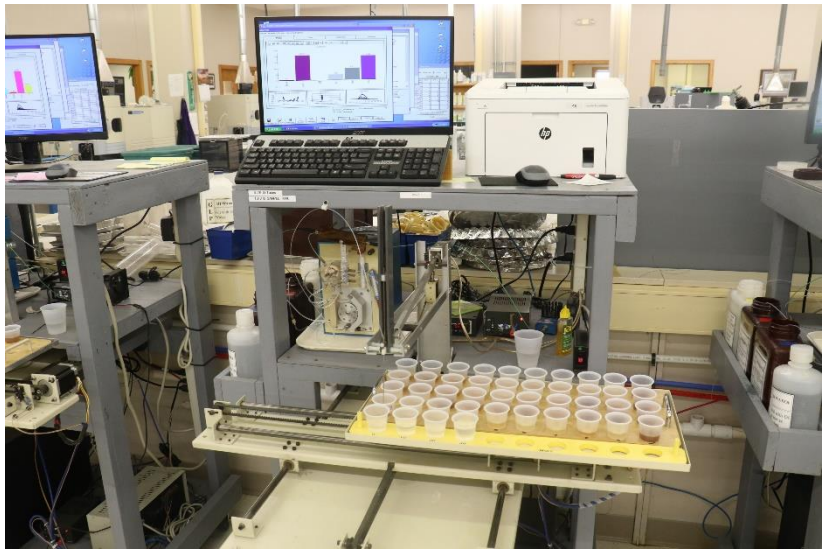
- Measure a defined amount of soil using NCR-13 approved soil scoop
- Add Olsen bicarbonate extracting solution

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 plant-available 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.

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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%	???

Soil test correlation and calibration = 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.

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

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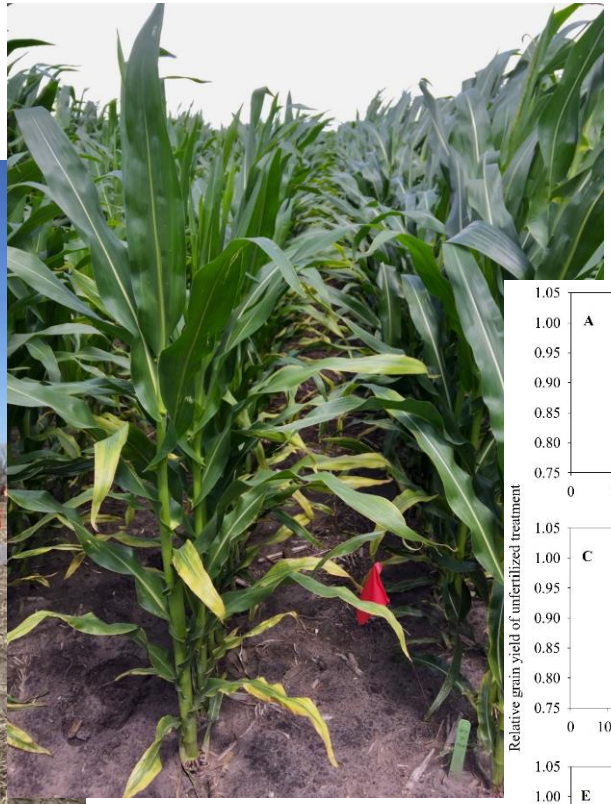
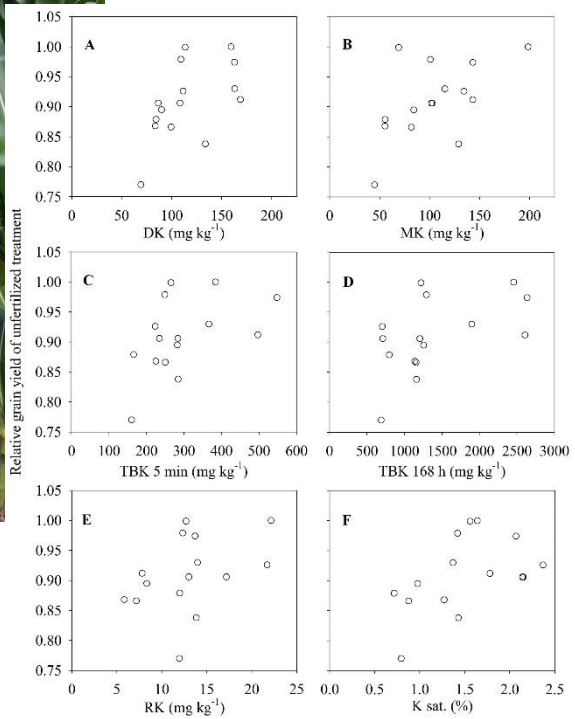
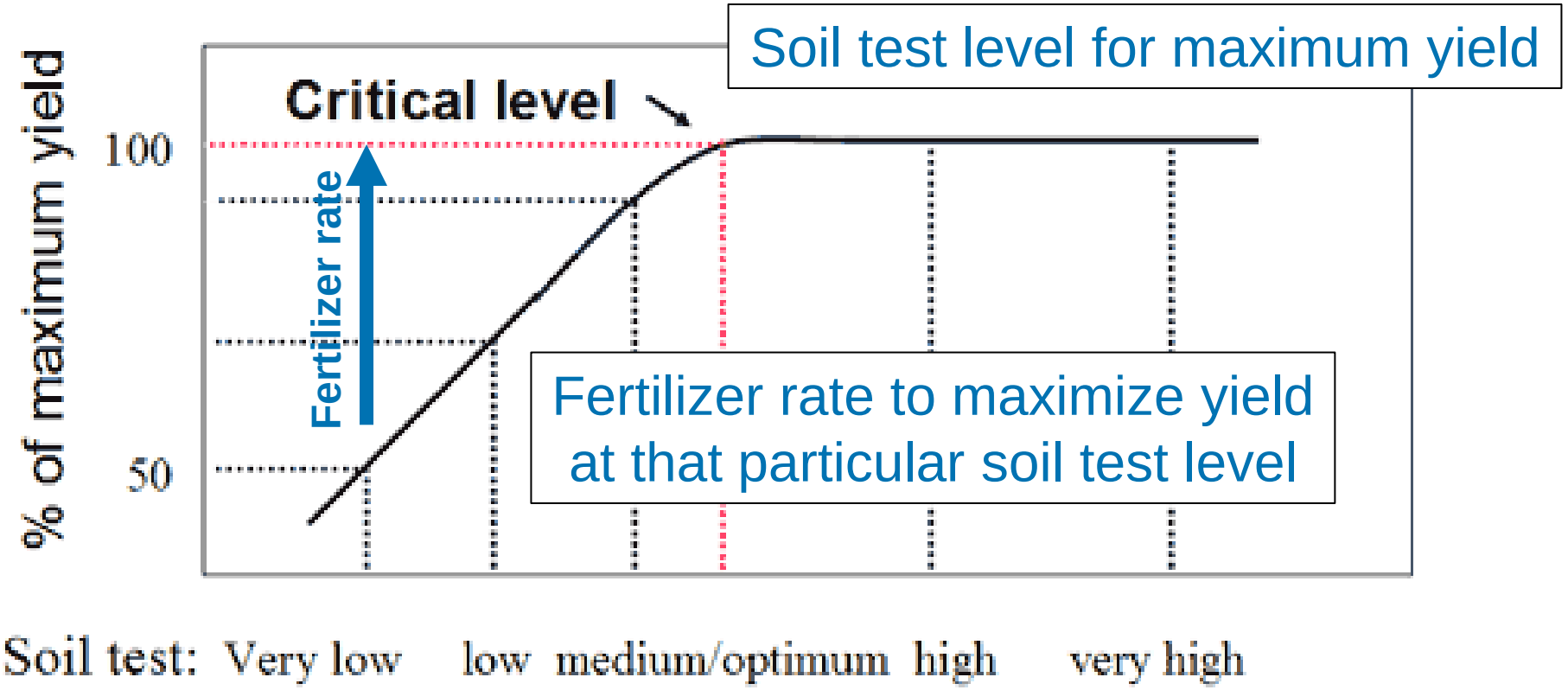
Soil test correlation and calibration studies are required





Breker, J.S. 2017. Recalibration of soil potassium test for corn in North Dakota. M.S. thesis. North Dakota State Univ., Fargo, ND.

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



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

Image from https://courses.cit.cornell.edu/css412/mod3/ext_m3_pg3.htm

Different fertilizer rates required for different soil test levels and crops

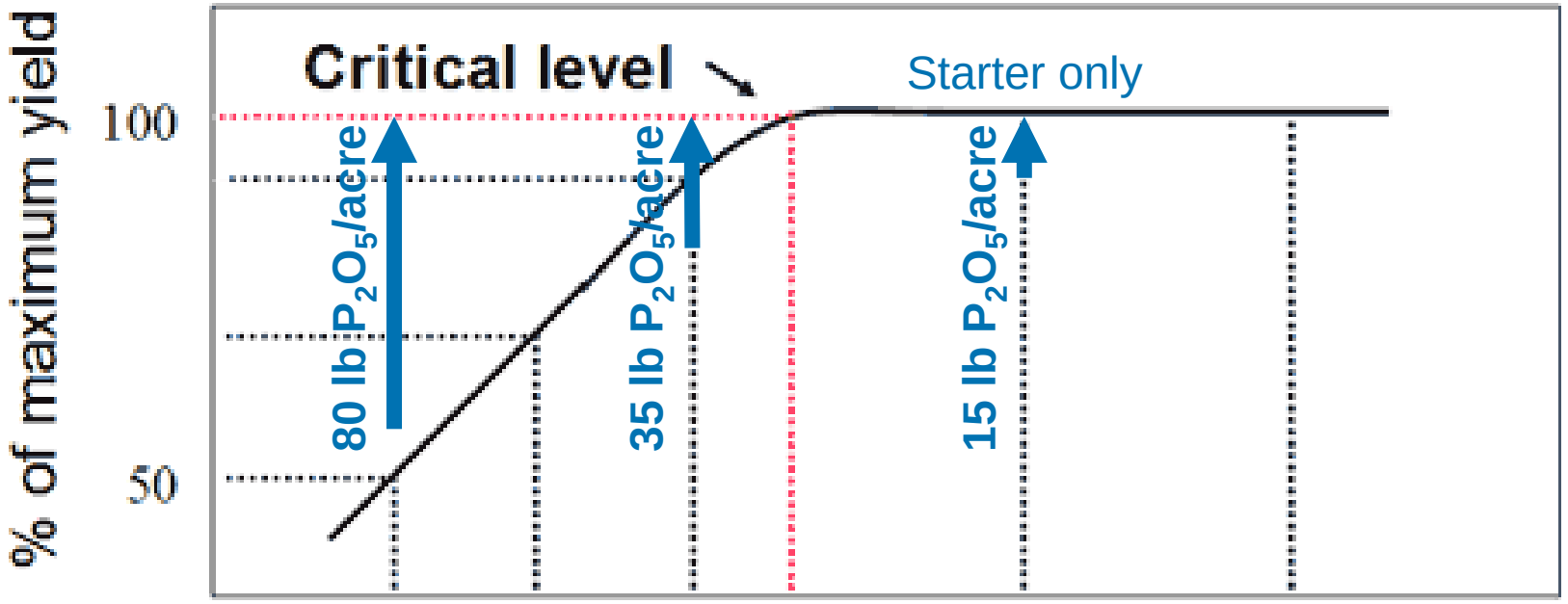
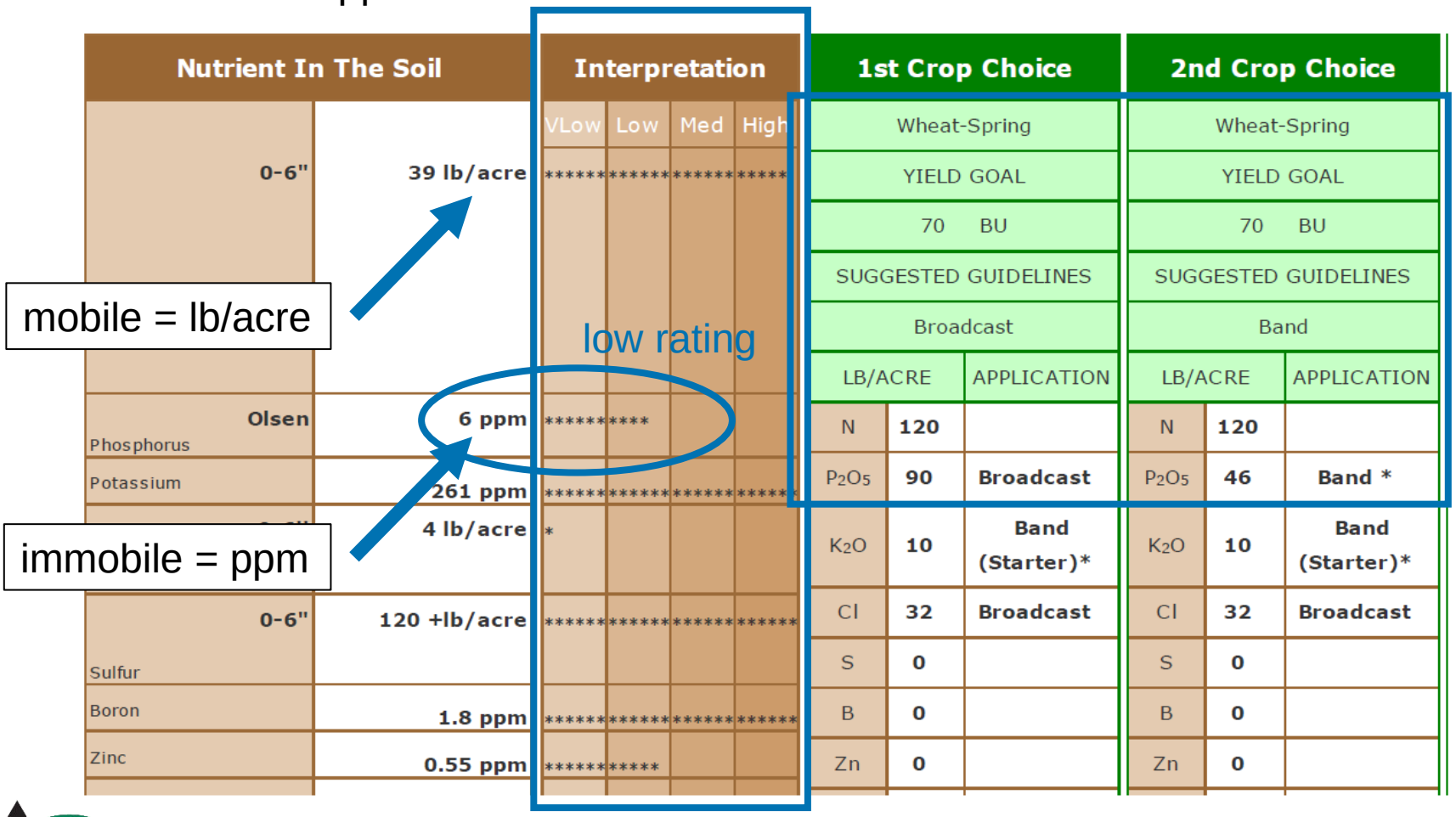


Image from https://courses.cit.cornell.edu/css412/mod3/ext_m3_pg3.htm

Interpreting a soil test report

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



Nutrient In The Soil		Interpretation				1st Crop Choice			2nd Crop Choice		
		VLow	Low	Med	High	Wheat-Spring			Wheat-Spring		
0-6"	39 lb/acre	**********	**********	**********	**********	YIELD GOAL			YIELD GOAL		
						70 BU			70 BU		
						SUGGESTED GUIDELINES			SUGGESTED GUIDELINES		
						Broadcast			Band		
						LB/ACRE		APPLICATION	LB/ACRE		APPLICATION
Olsen Phosphorus	6 ppm	**********				N	120		N	120	
Potassium	261 ppm	**********	**********	**********	**********	P_2O_5	90	Broadcast	P_2O_5	46	Band *
	4 lb/acre	*				K_2O	10	Band (Starter)*	K_2O	10	Band (Starter)*
0-6"	120 +lb/acre	**********	**********	**********	**********	Cl	32	Broadcast	Cl	32	Broadcast
Sulfur						S	0		S	0	
Boron	1.8 ppm	**********	**********	**********	**********	B	0		B	0	
Zinc	0.55 ppm	**********	**********			Zn	0		Zn	0	

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.

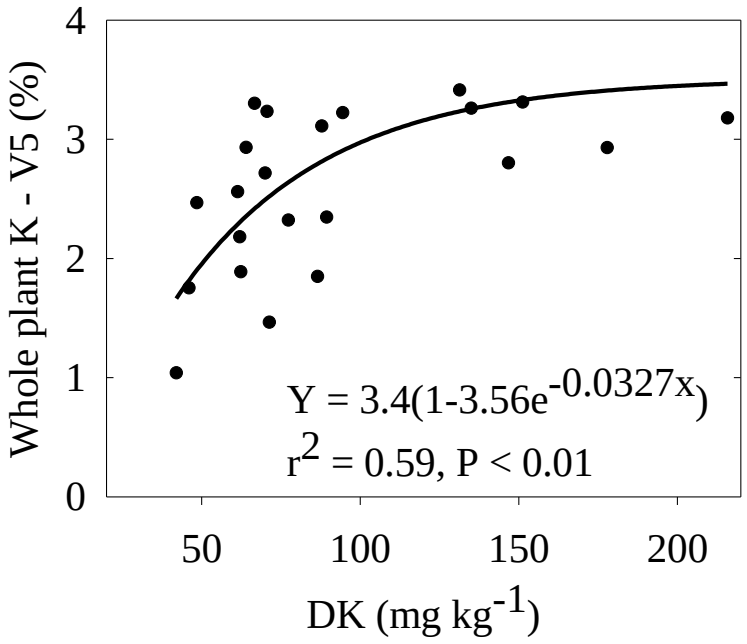
Nutrient In The Soil		Interpretation			
		VLow	Low	Med	High
0-6" Nitrate	52 lb/acre	**********	**********	**********	******
Olsen Phosphorus	11 ppm	**********	**********	**********	
Potassium	321 ppm	**********	**********	**********	******
0-6'' Chloride	7 lb/acre	***			
0-6" Sulfur	120 +lb/acre	**********	**********	**********	******
Boron	2.0 ppm	**********	**********	**********	******
Zinc	0.62 ppm	**********			

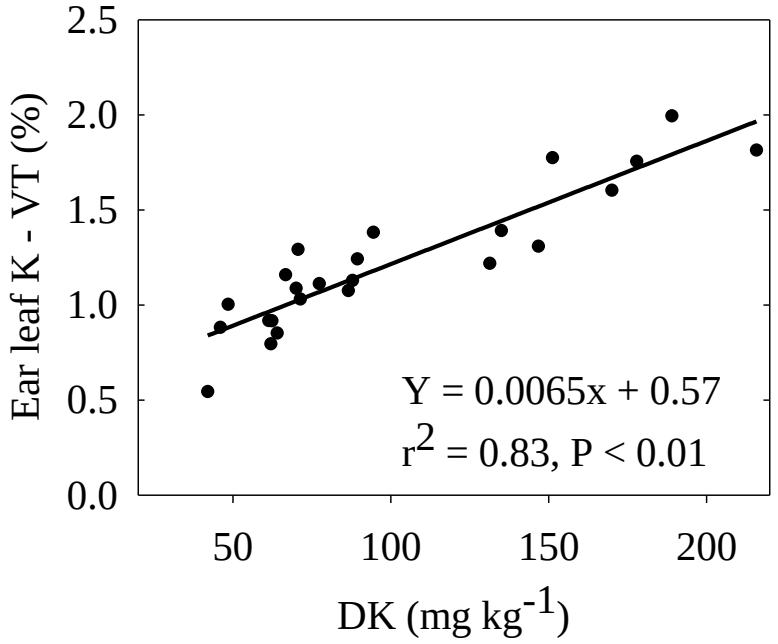
medium rating

1st Crop Choice			2nd Crop Choice		
Wheat-Spring			Wheat-Spring		
YIELD GOAL			YIELD GOAL		
70 BU			70 BU		
SUGGESTED GUIDELINES			SUGGESTED GUIDELINES		
Broadcast			Band		
LB/ACRE		APPLICATION	LB/ACRE		APPLICATION
N	107		N	107	
P_2O_5	65	Broadcast	P_2O_5	34	Band *
K_2O	10	Band (Starter)*	K_2O	10	Band (Starter)*
Cl	26	Broadcast	Cl	26	Broadcast
S	0		S	0	
B	0		B	0	
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

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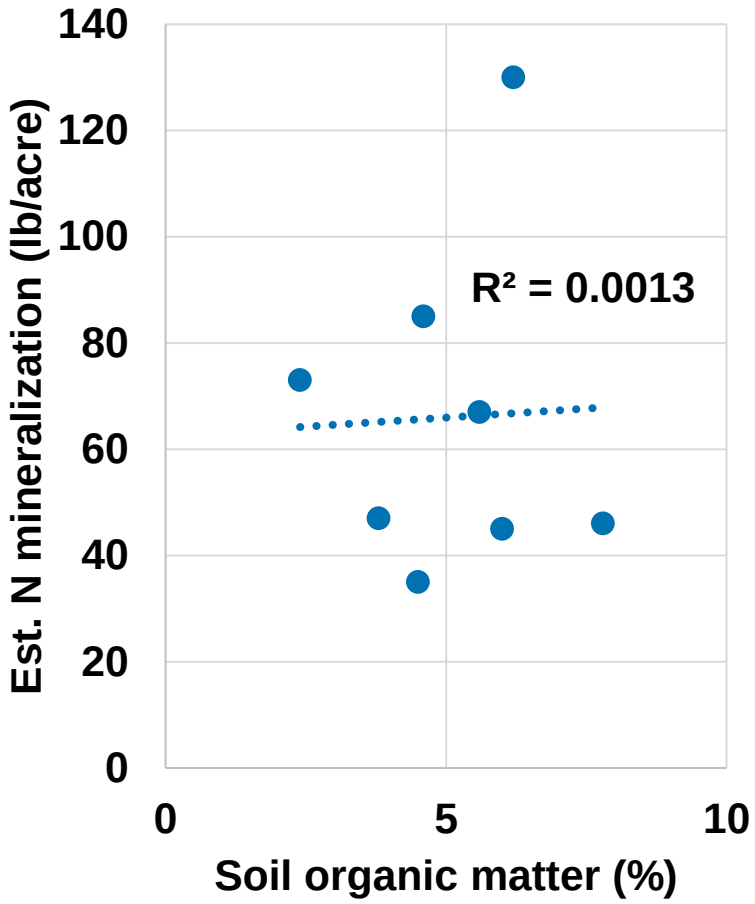
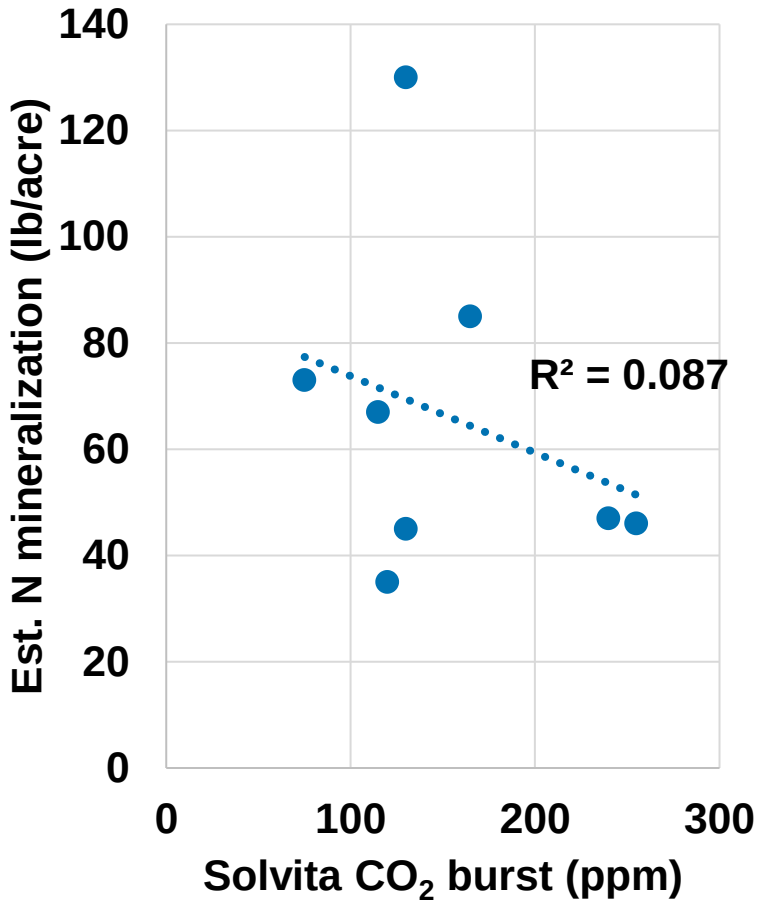
Breker, J.S. 2017. Recalibration of soil potassium test for corn in North Dakota. M.S. thesis. North Dakota State Univ., Fargo, ND.

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)

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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 AND interpretation is unearthed with numerous field research trials (i.e., a lot of data and statistics)

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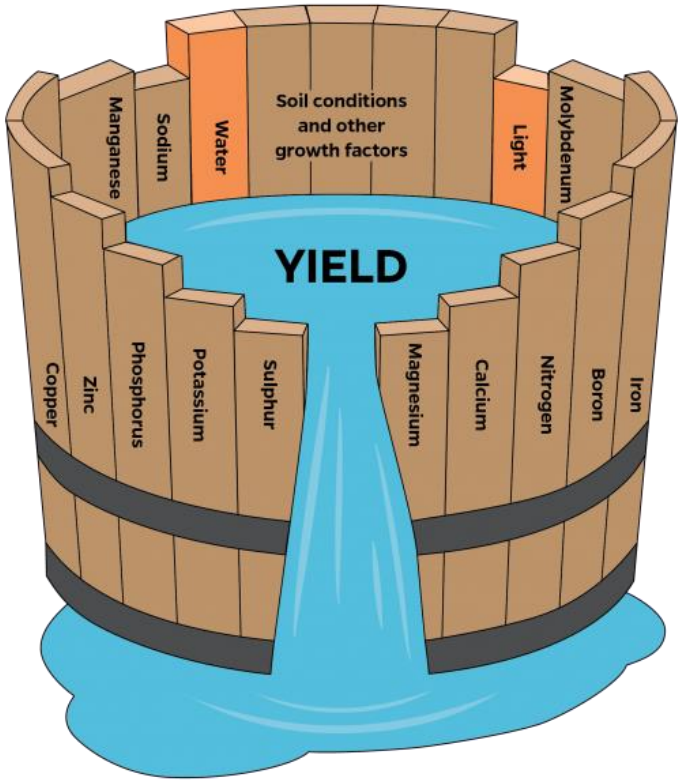
Them is the nuts and bolts.

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 most limiting nutrient, 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.

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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.

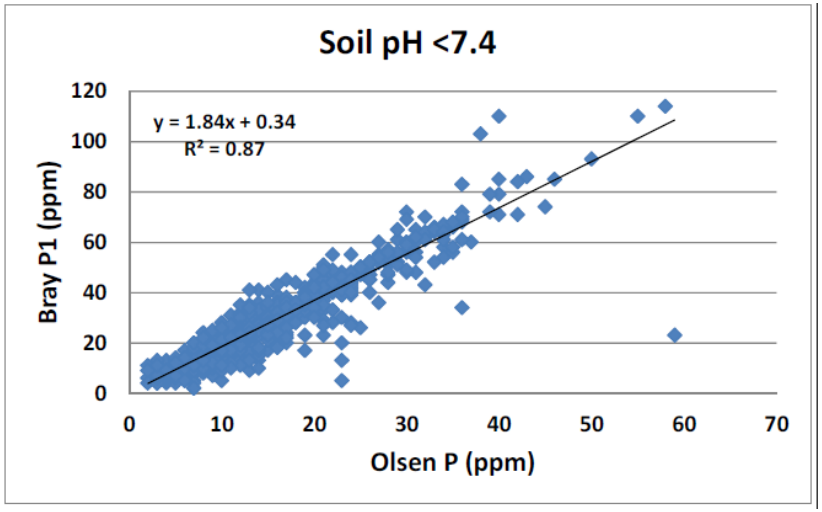
Olsen P was developed later, designed to work across low and high pHs.

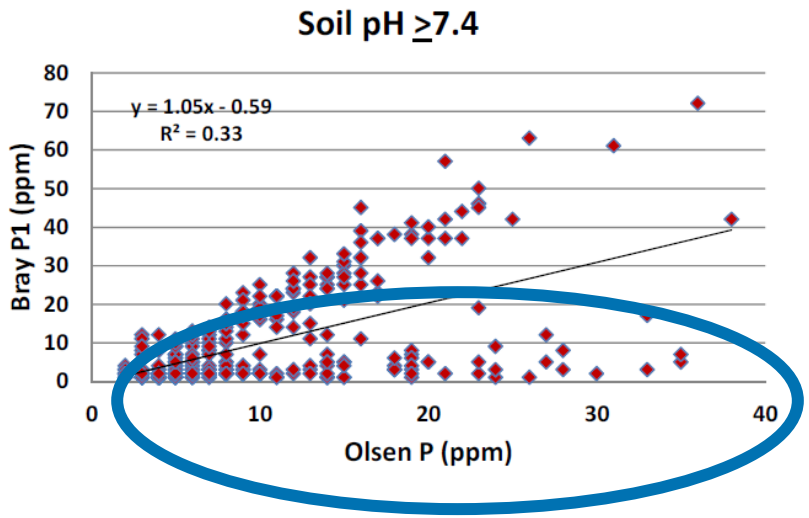
Soil test category	Soil test P (ppm)	
	Bray P1	Olsen P
	pH<7.3	pH 5.5-8.5
Very Low	<5	<3
Low	6-10	4-7
Medium	11-15	8-11
High	16-20	12-15
Very High	>20	>15

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.





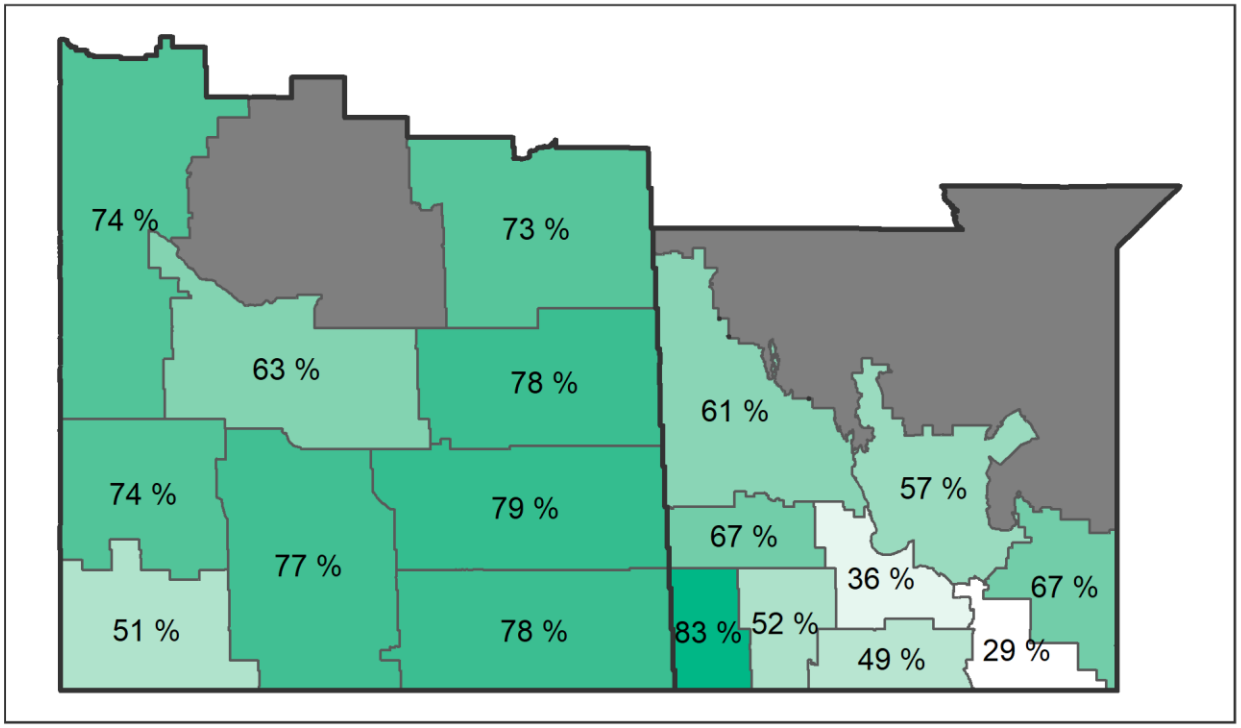
Failed Bray P1

The fix

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

Kaiser, D.E., L.M. Leverich, J.A. Vetsch, and J.S. Strock. 2016. Prediction of corn and soybean grain yield response to P in Minnesota using the Haney H3A and Mehlich-III tests. Proceedings of the 46th North Central Extension-Industry Soil Fertility Conference. Des Moines, IA. 2-3 Nov. 2016. Intl. Plant Nutr. Inst., Brookings, SD. p. 179–190

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

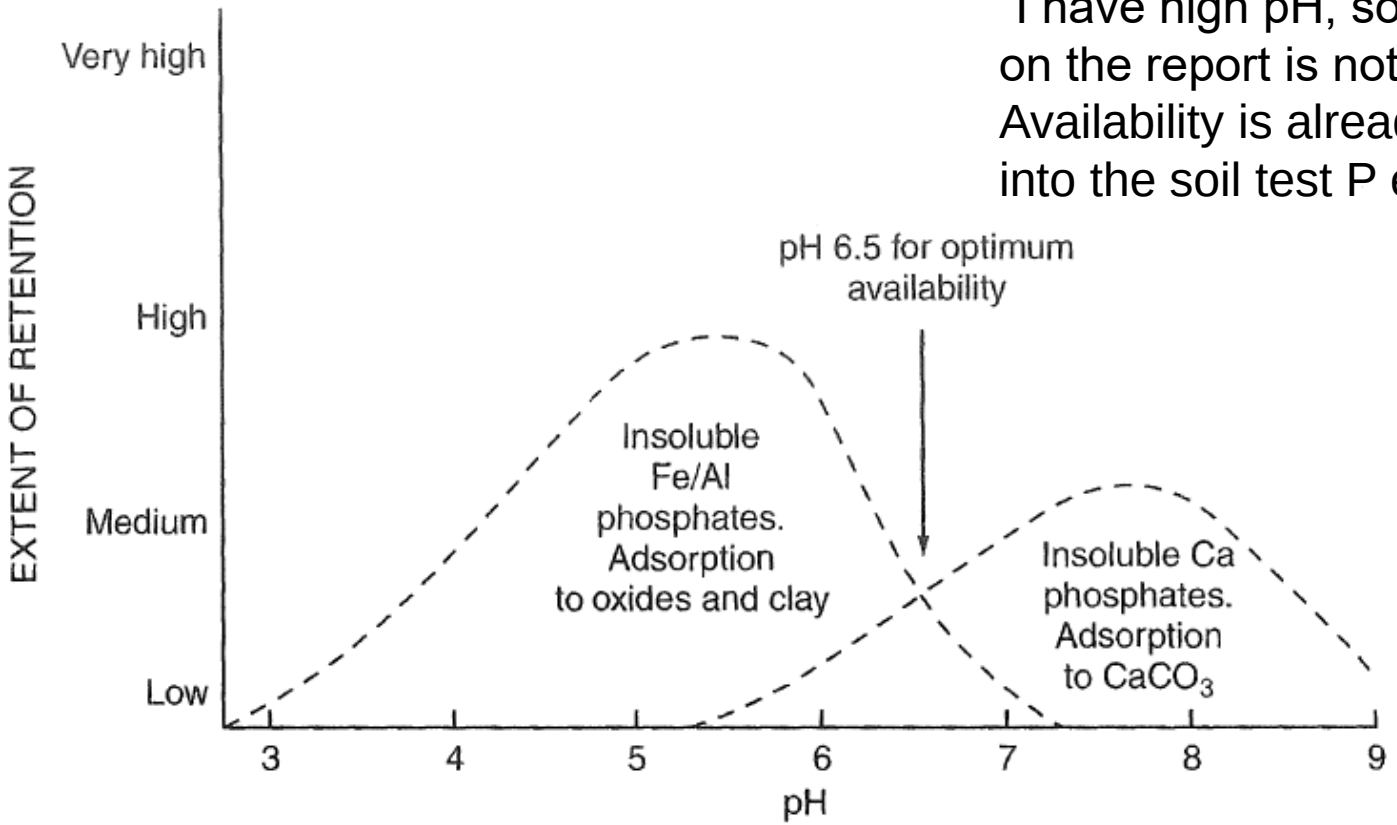


Data not shown where n< 100
AGVISE Laboratories, Inc.

Soil pH controls soil phosphorus availability

Common misconception

"I have high pH, so soil test P on the report is not available." Availability is already factored into the soil test P extraction.



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

Havlin, J.L., J.D. Beaton, S.L. Tisdale, and W.L. Nelson. 2005. Soil Fertility and Fertilizers: An Introduction to Nutrient Management. 7th ed. Pearson Prentice Hall, Upper Saddle River, NJ.

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

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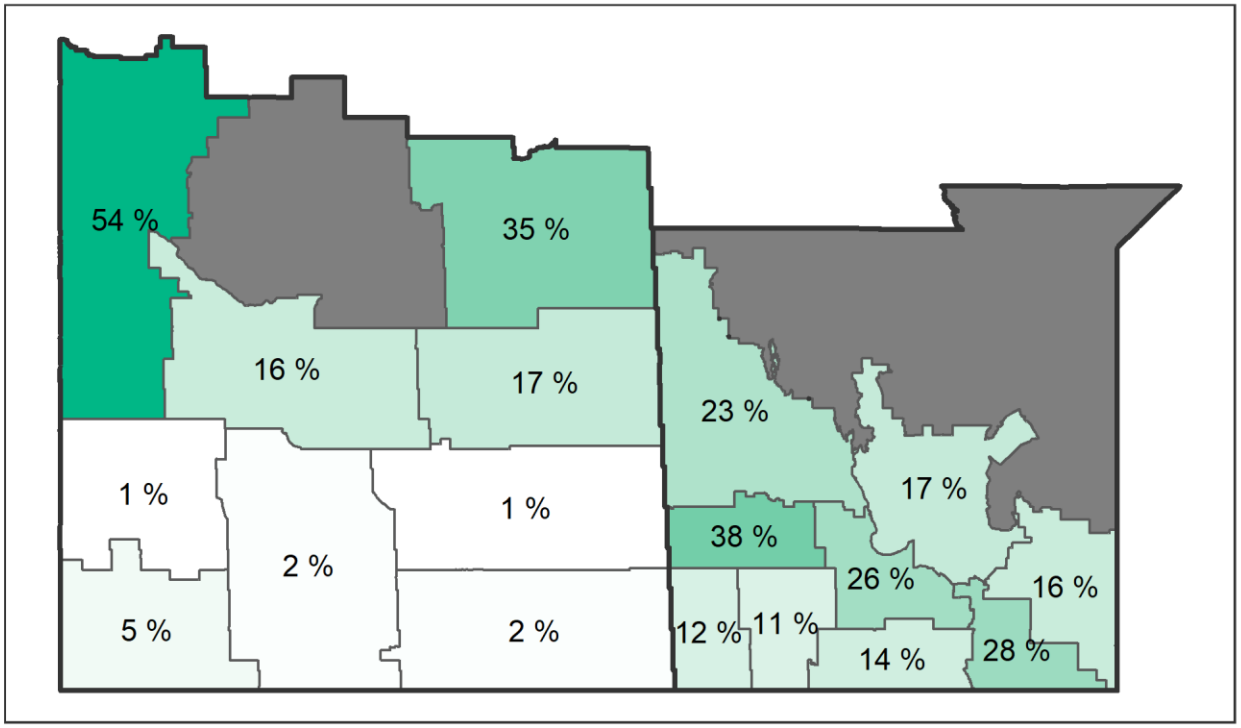
Soil samples with soil test potassium below 150 ppm in 2022



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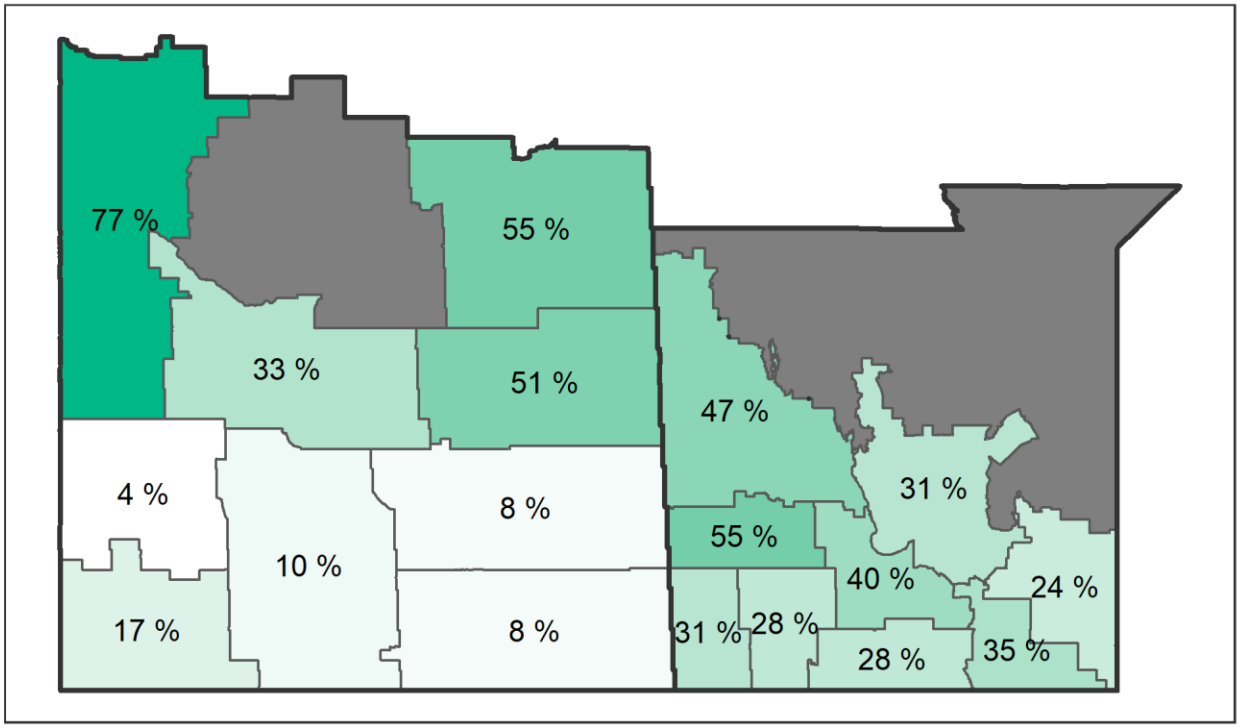
Soil samples with soil test potassium below 200 ppm in 2022



Data not shown where n< 100
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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

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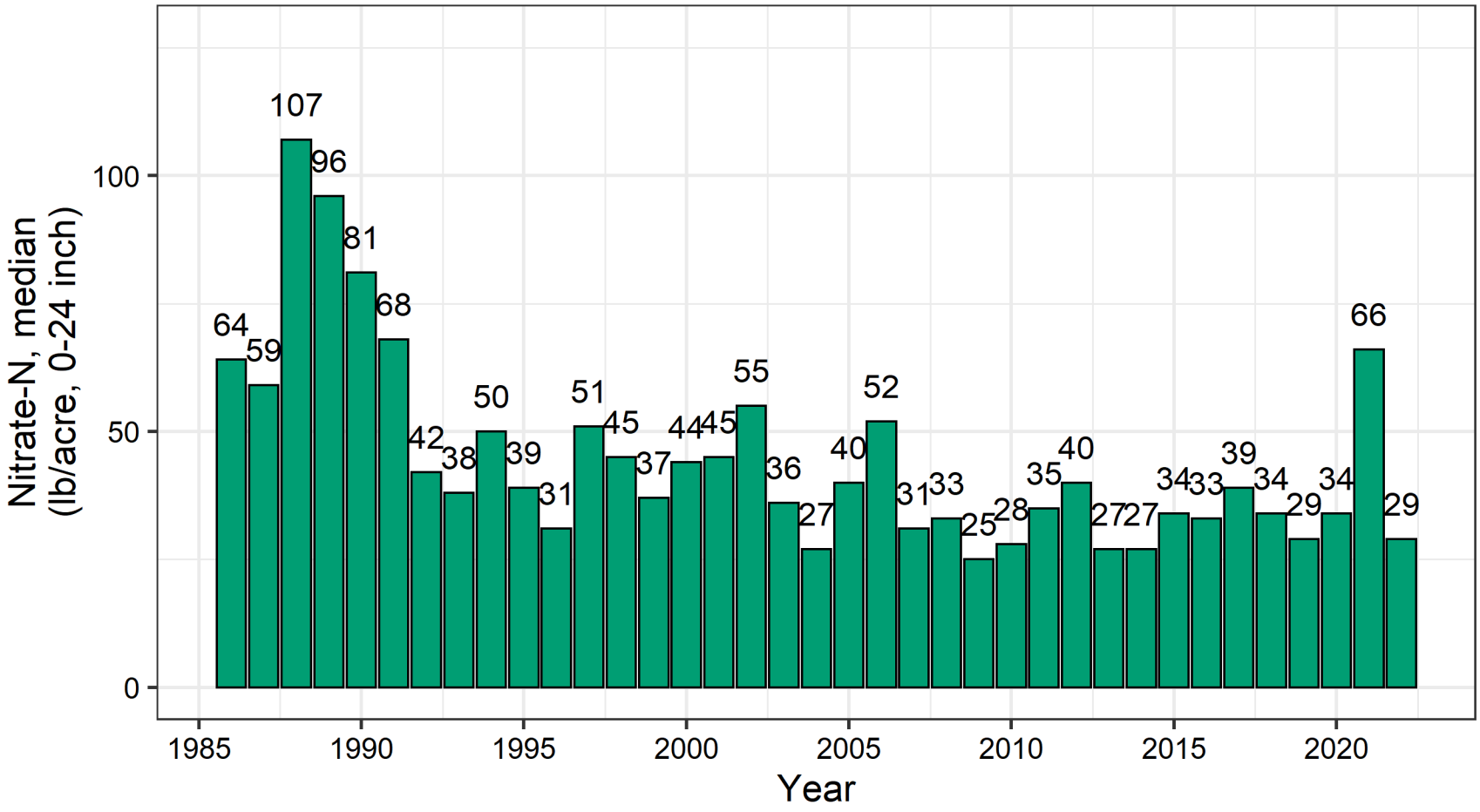
Residual nitrate following wheat

Trend from 1986 to 2022



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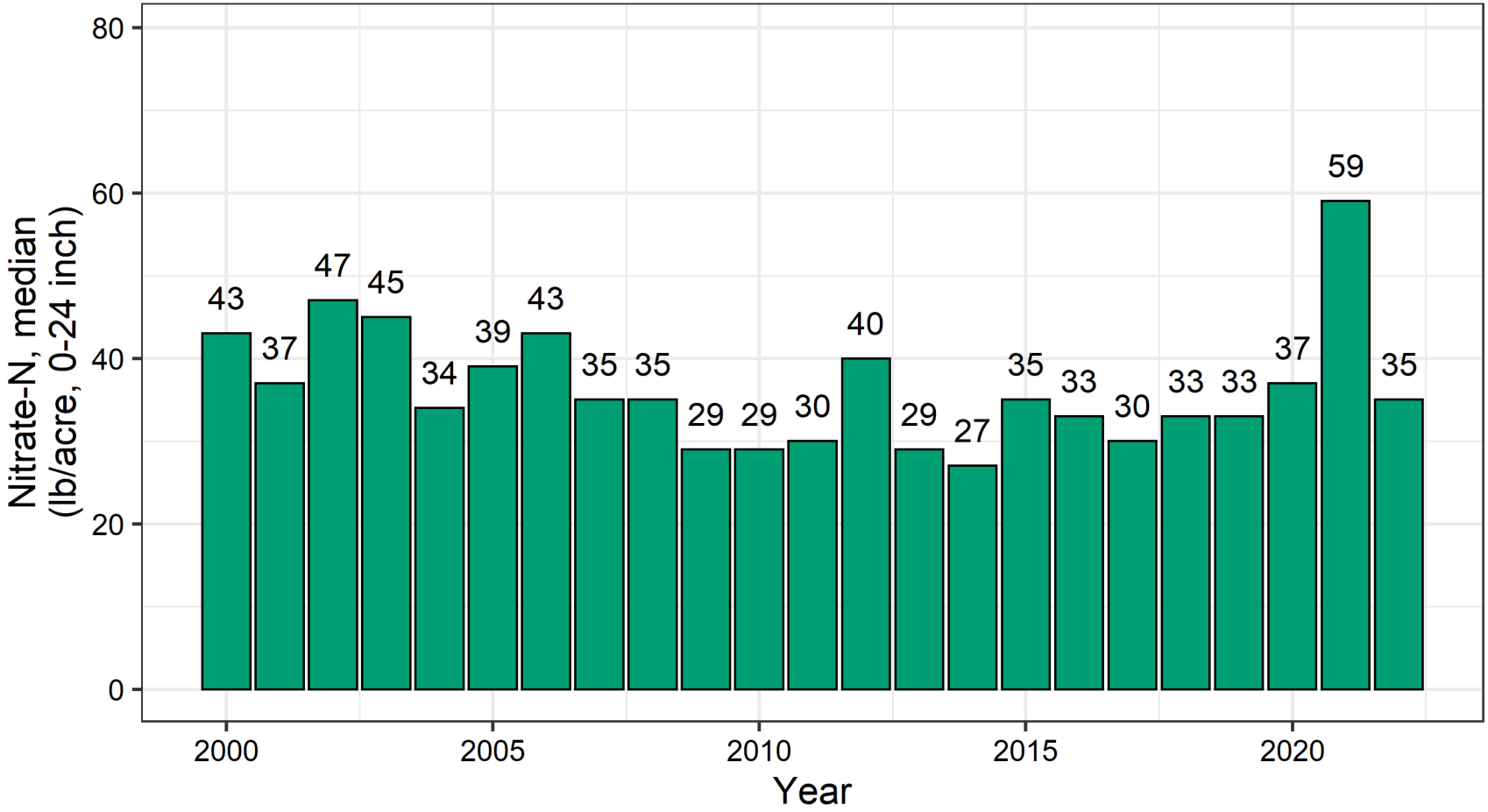
Residual nitrate following canola

Trend from 2000 to 2022



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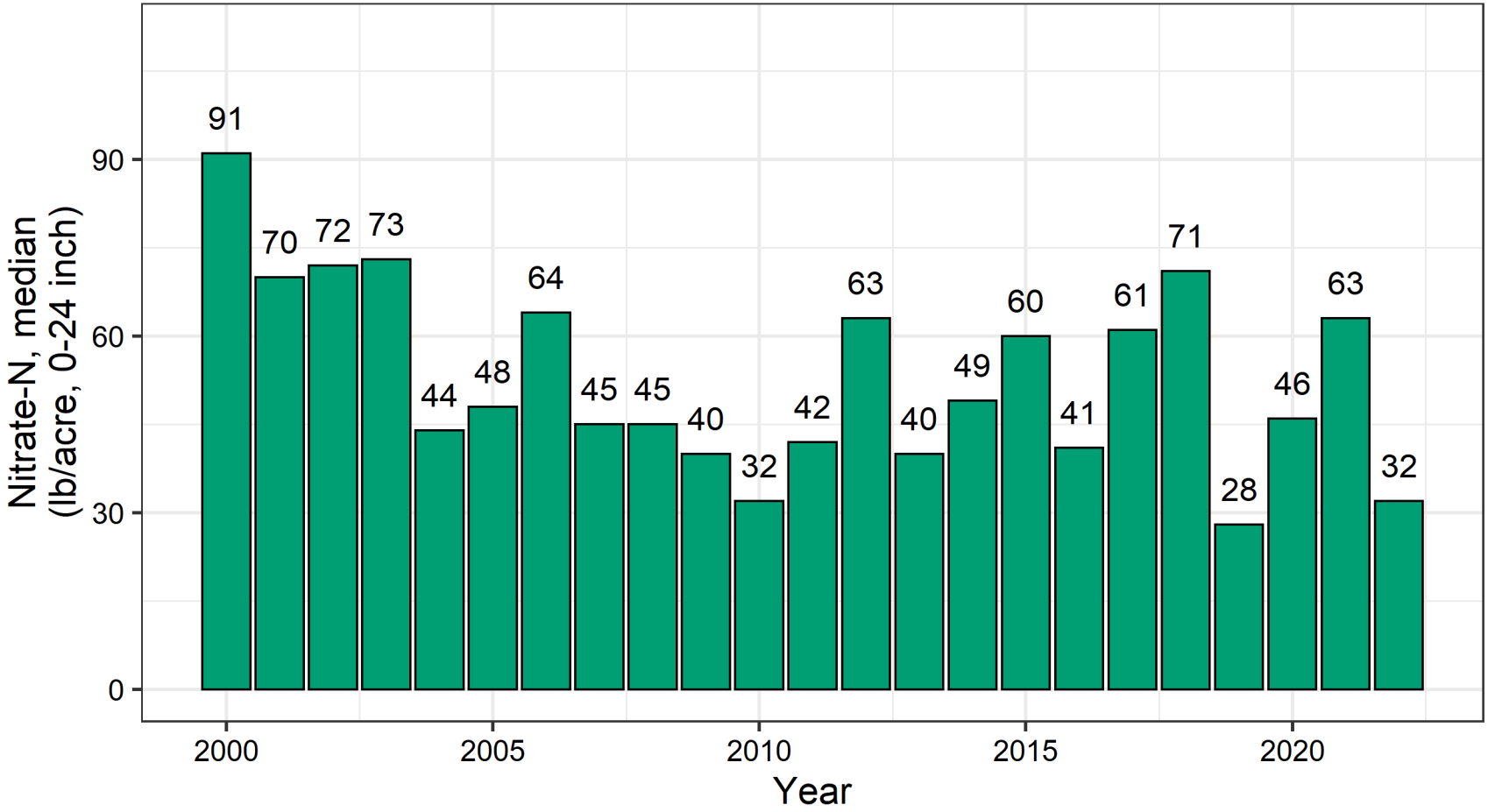
Residual nitrate following corn

Trend from 2000 to 2022



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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 N credit lb N/acre		University N credit lb 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

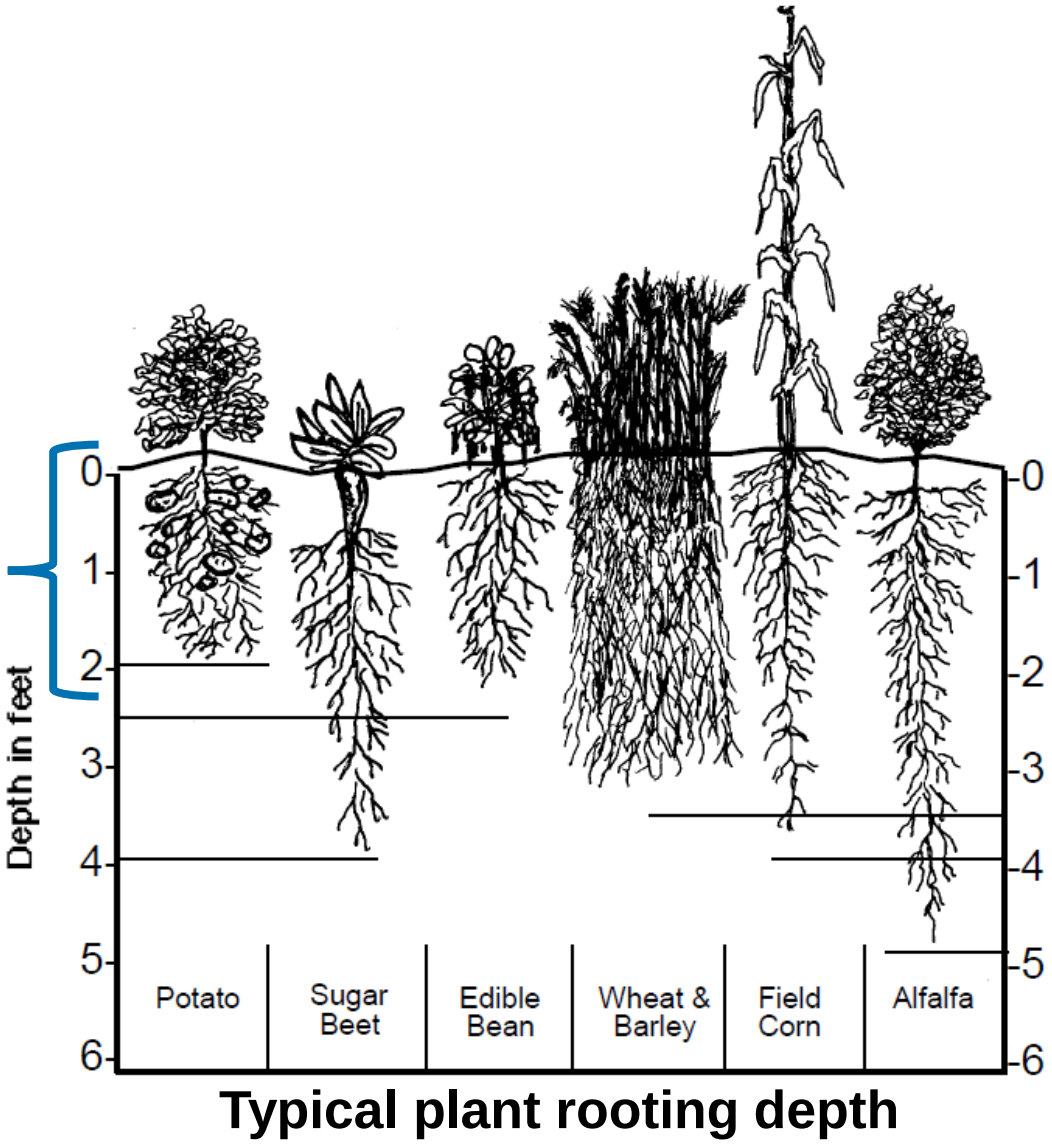
Sampling depth (inch)	Plant N uptake explained by soil nitrate-N (r^2)
0-6	32%
0-12	64%
0-24	**84%**
0-36	82%
0-48	78%

Soper, R.J., G.J. Racz, and P.I. Fehr. 1971. Nitrate nitrogen in the soil as a means of predicting the fertilizer nitrogen requirements of barley. Can. J. Soil Sci. 51(1):45–49.

Plant roots reach deeper than most people think

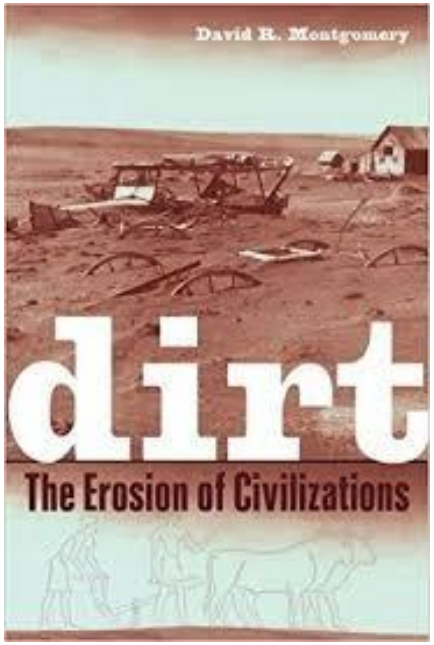
Plant roots can access subsoil nitrate-nitrogen as long as there is water

Standard 0-2 ft soil sampling depth



Typical plant rooting 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.

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