Soil Testing for P and K: From the Sample to Recommendations

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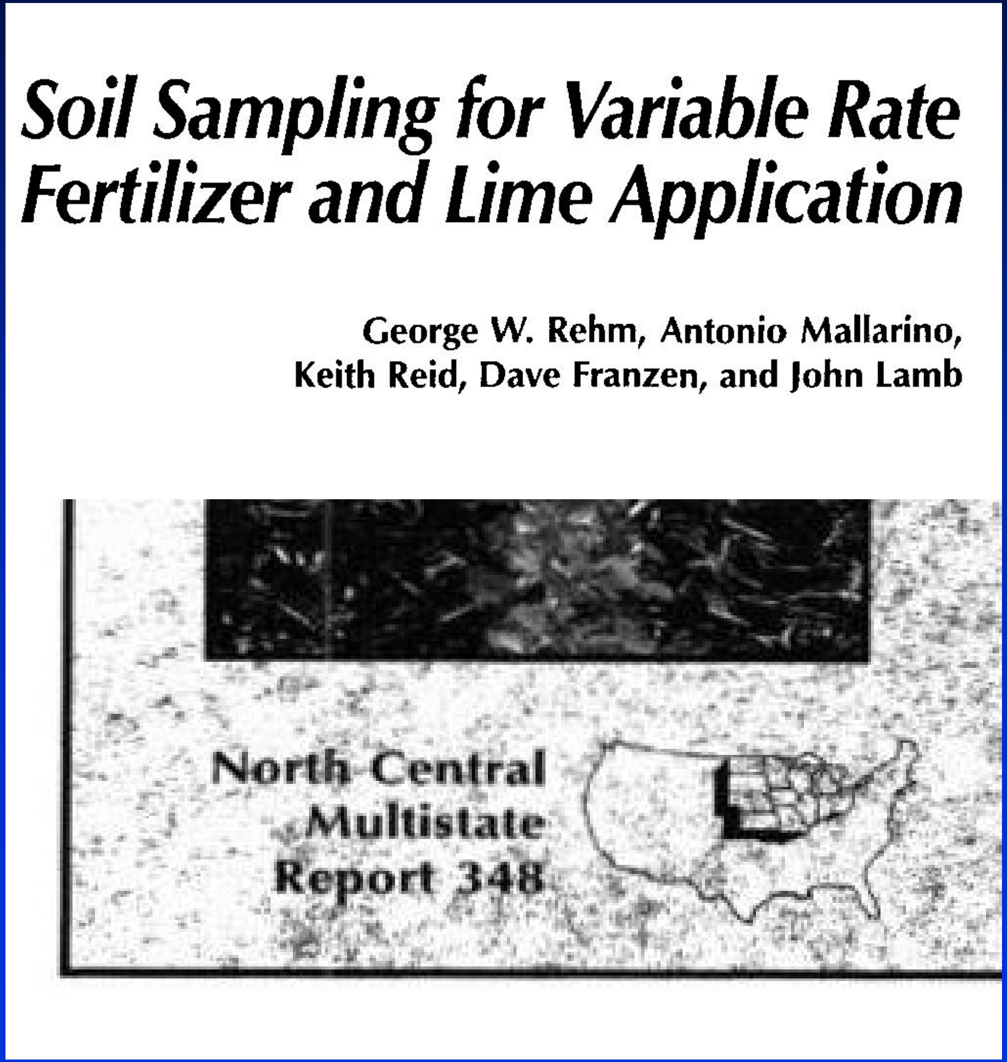
Soil Testing Elements

- Soil sampling: A representative soil sample
- Sample handling and preparation
- Chemical extraction of the nutrient
- Measuring the extracted nutrient
  - The extractant often defines a soil test with few exceptions but not always
- Units to express results
- Interpretation of soil-test results
- Nutrient recommendations

Soil Sampling: Key First Step Often Done Too Quickly

http://www.agronext.iastate.edu/soilfertility/



Soil sampling Methods: Spatial Variation

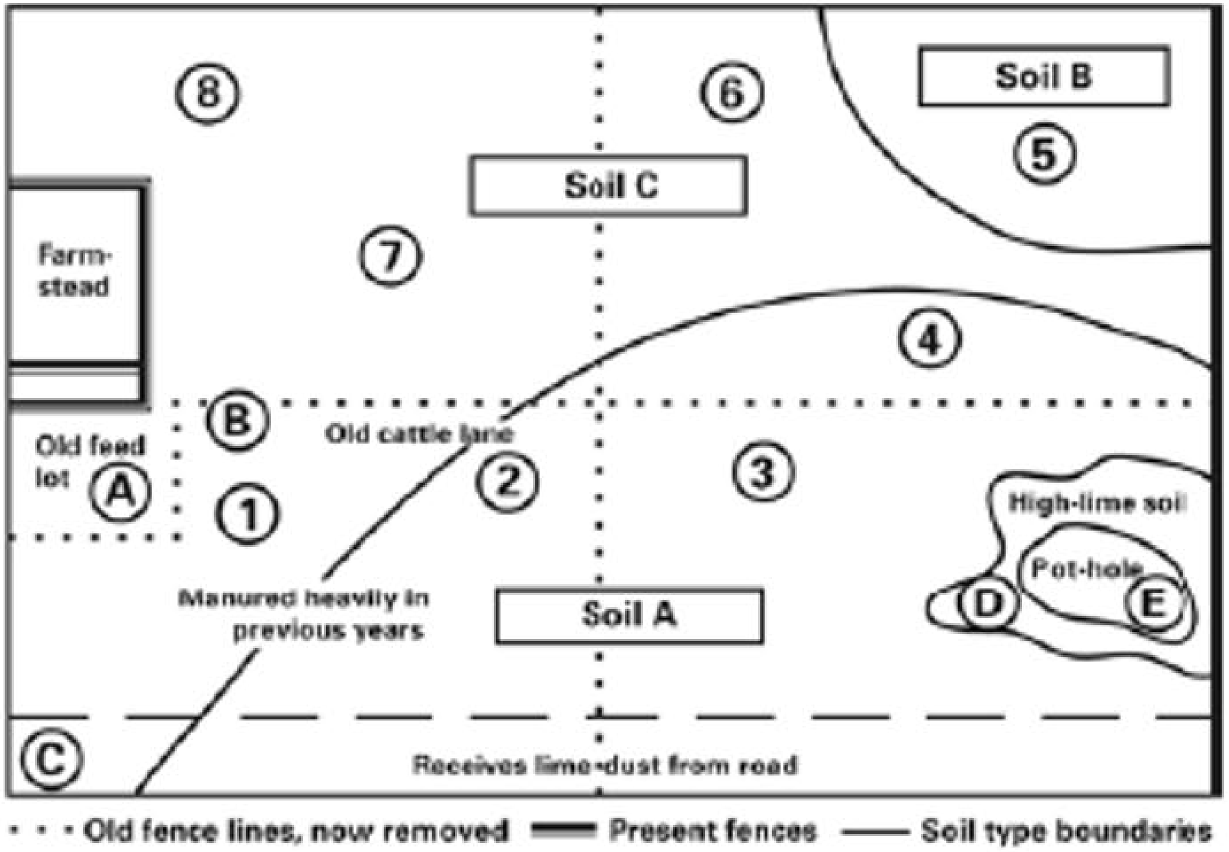


Figure 4. Example of sampling map for an 80-acre tract, which is now farmed as one field. Numbers designate soil sample areas and letters designate areas either not sampled or sampled separately.

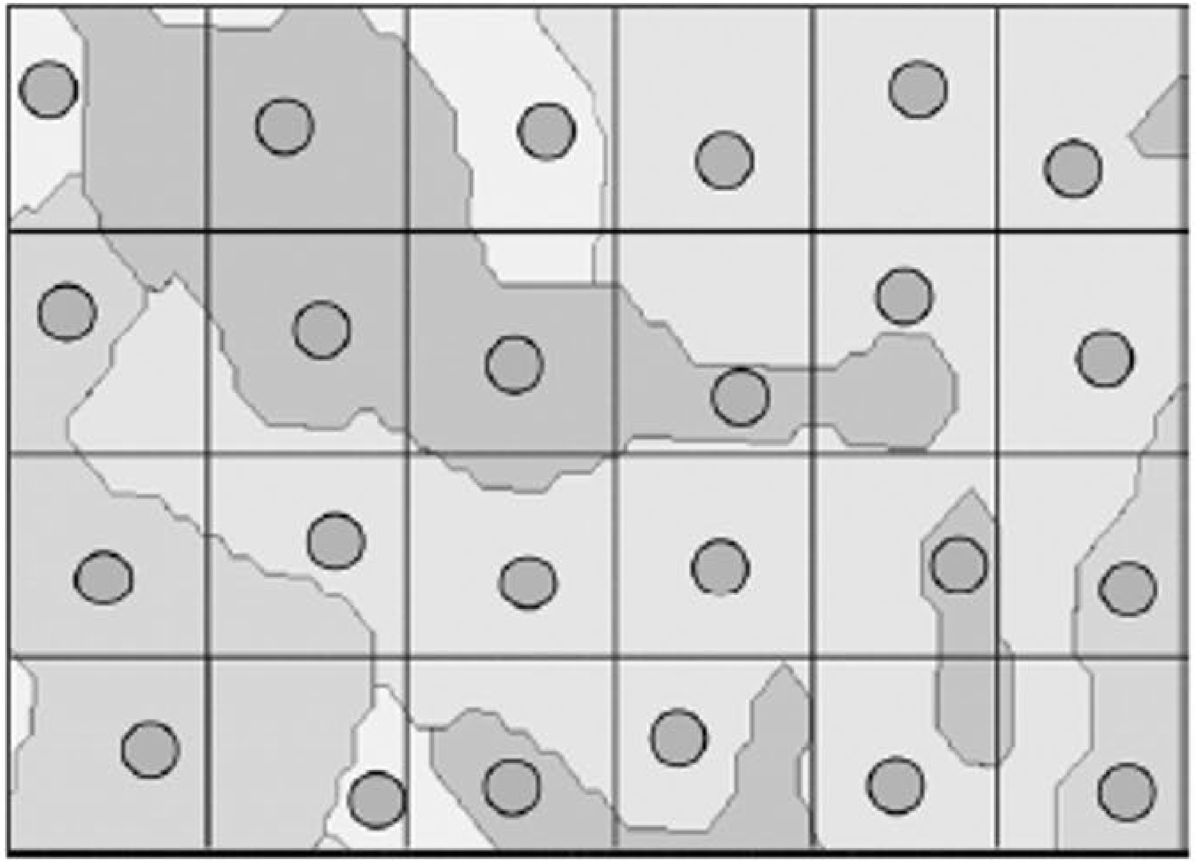


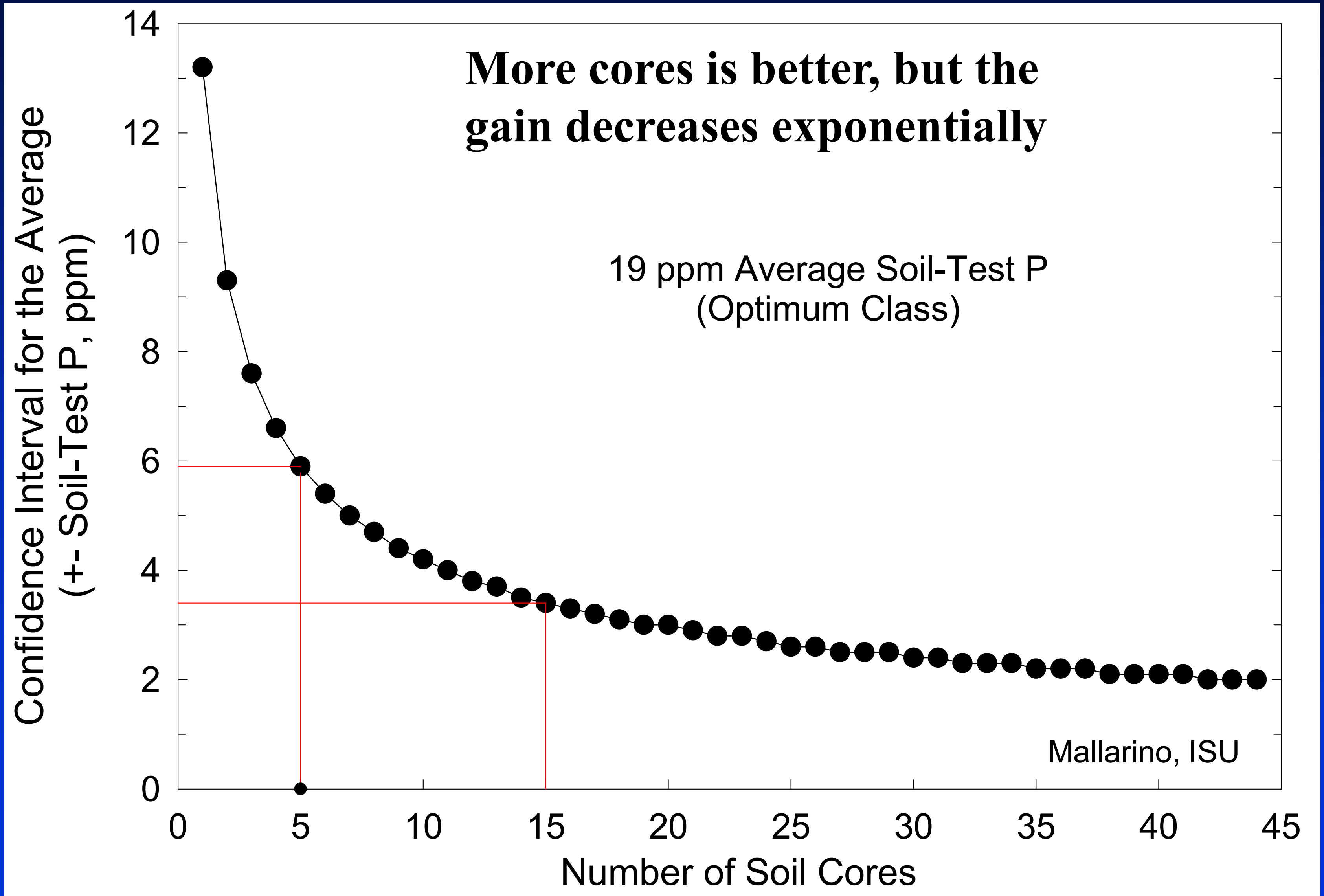
Figure 5. Non-aligned 2.5 acre grid-point sampling design of a 60 acre field with one of many ways in which the sampling can avoid borders between soil map units. Irregular polygons represent the soil map units.

Soil Sampling Issues

- Soil sampling methods:
  - By soil survey map unit (traditional): often very large variation within map units
  - Zone sampling – Better, but often still large P, K, and pH variation within zones
  - Grid sampling 2.5-5 acres - Best for P and K, sometimes also for pH
- Number of cores per sample
  - Take the most you can, at least 10 or 12 even with grid sampling

Large Small Scale Variation Often Present

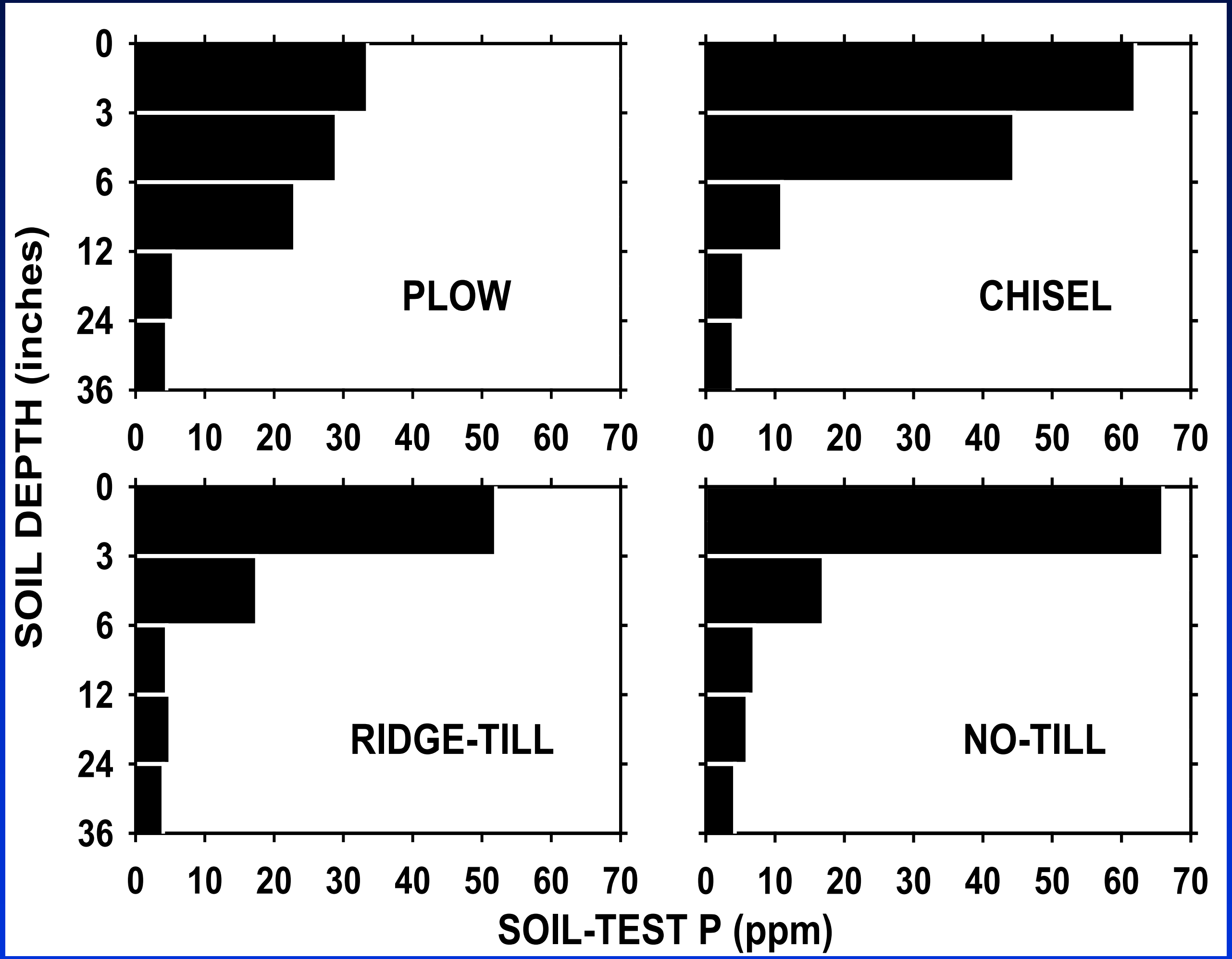
Need many soil cores per composite sample, even with dense grid sampling



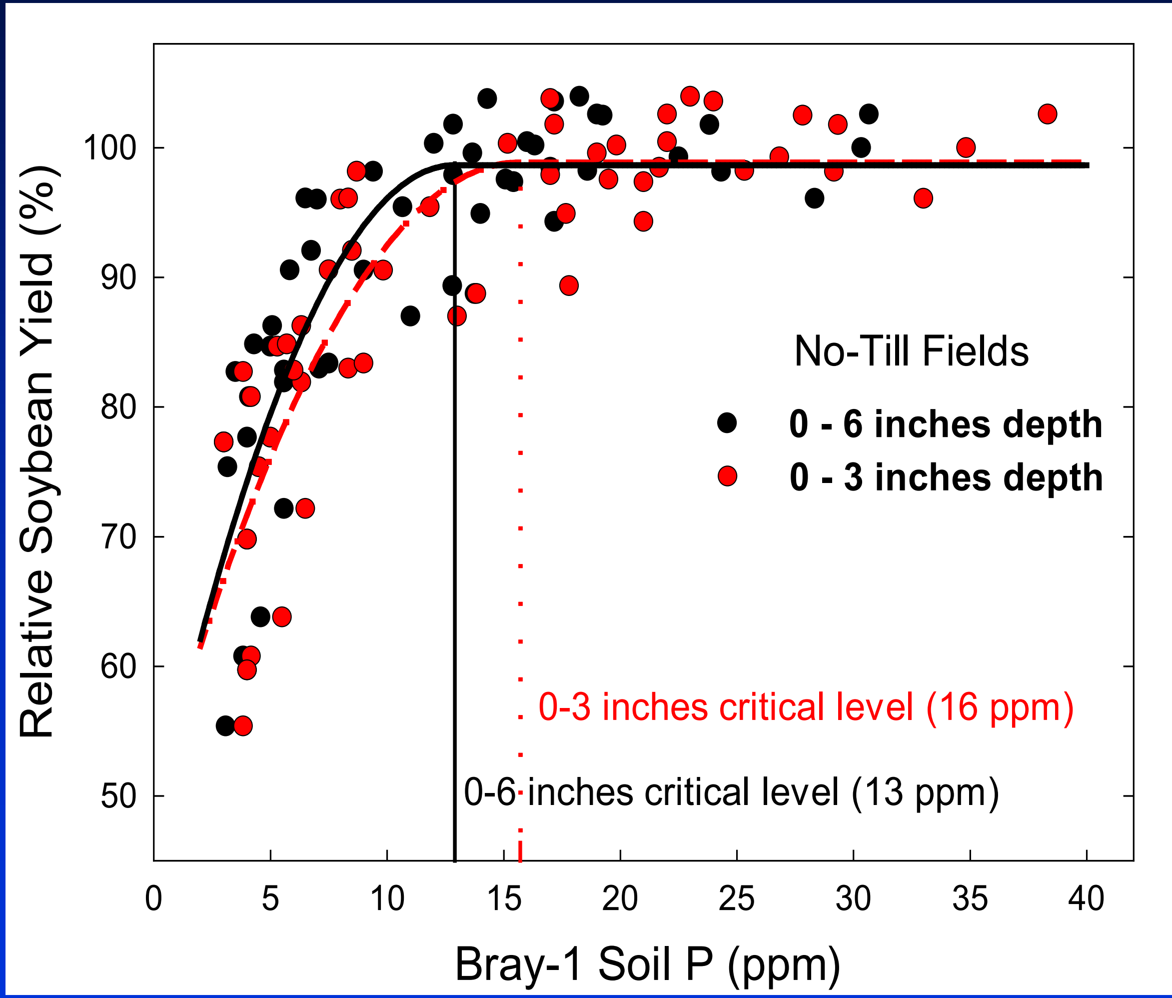
Standardize Soil Sampling Depth

- The “best” sampling depth is the one that predicts crop response better, not necessarily where most nutrient is
- And, it must match the depth used for the test calibration
- Soil sampling depths in Iowa
  - 6 inches for P, K, and micros for all tillage systems
  - 2-3 inches for lime in no-till or pasture because is the depth liming can affect
  - 1 foot for the LSNT (or PSNT) nitrate test: Is an index, deeper sampling seldom is much more useful and isn't practical

P Distribution in the Soil Profile and Sampling



Mallarino and Pecinovsky, ISU

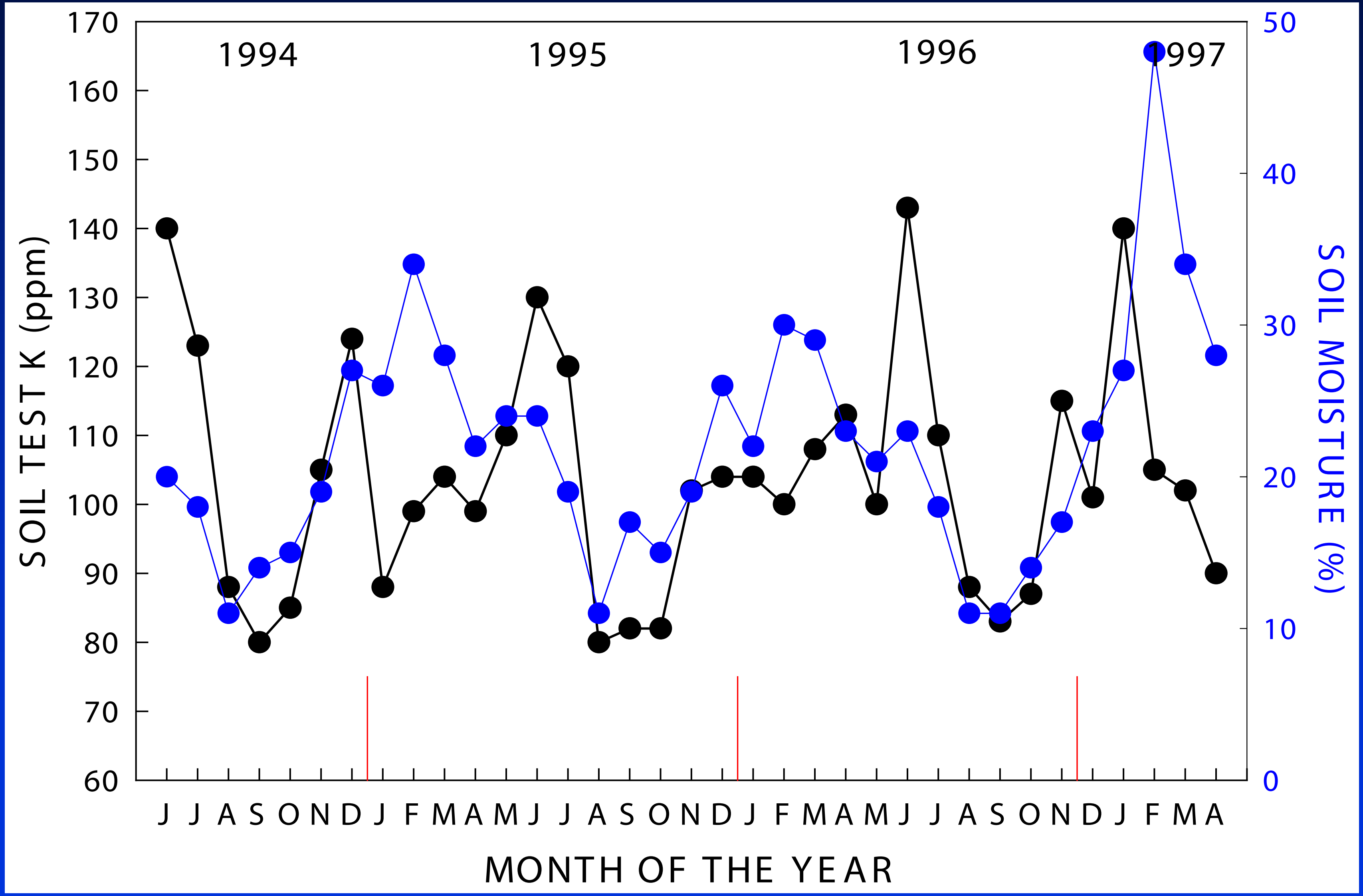


Prater and Mallarino, ISU 2007

Consider Sampling Time Effects

- Nitrate: very mobile nutrient
  - Late-spring or PSNT soil nitrate test
  - Corn stage 6 to 12" tall
- Soil-test K can be greatly affected by the sampling time
  - Exchangeable/non-exchangeable pools reactions
  - Fast recycling with residue but greatly affected by rainfall
- Soil pH very affected by sampling in dry conditions, get more acidic results. pH-$CaCl_2$ in western states
- Manganese and soil redox
- P is less affected, inconsistent results

Soil Moisture, Crop Growth, and Soil-Test K



Adapted from separate work by Steve Ebelhar & Ed Varsa and by Ted Peck; University of Illinois and University of Southern Illinois

What is a Soil Test Result?

- Soil test values are indices, estimate sufficiency and don’t provide "the" amount available
  - Only a small fraction difficult to define is available at a certain time
  - A tiny sample is taken from a small fraction of the soil explored by roots
  - A test result is an amount proportional to what may be available during a season
- A soil test result is meaningless without field calibration with crop yield response in contrasting soils over several years

Century-Old Known Facts

- Some methods for a specific nutrient are better than others or may extract different amounts across contrastingly different soils (P in calcareous soils)
- Nutrient levels often differ for different sampling depths and may differ for different sampling times (pH, K)
- The sample handling in the lab can affect the amounts measured (K dry and field-moist tests)
- Again, soil-test results are meaningless without good field calibration with yield response

What Do We Measure and Why?

Fast **Slow**

Soluble ↔ **Exchangeable K**
Labile, most reactive P
< readily available > ↔ **Nonexchangeable K forms**
low solubility or insoluble P forms
<< More available Less available >>

- **For P:** No clear correspondence between "plant available" and chemical forms (solubility, adsorption of different strength)
- **For K:** Tests measure exchangeable and soluble forms, but some forms of non-exchangeable K also become available over time, faster then most believe
- Many factors can influence the amounts extracted across contrastingly different soils
- “Fixation”, incorrect word, easily defined in the lab, NOT at the field!

Field Calibration of Soil Test Methods

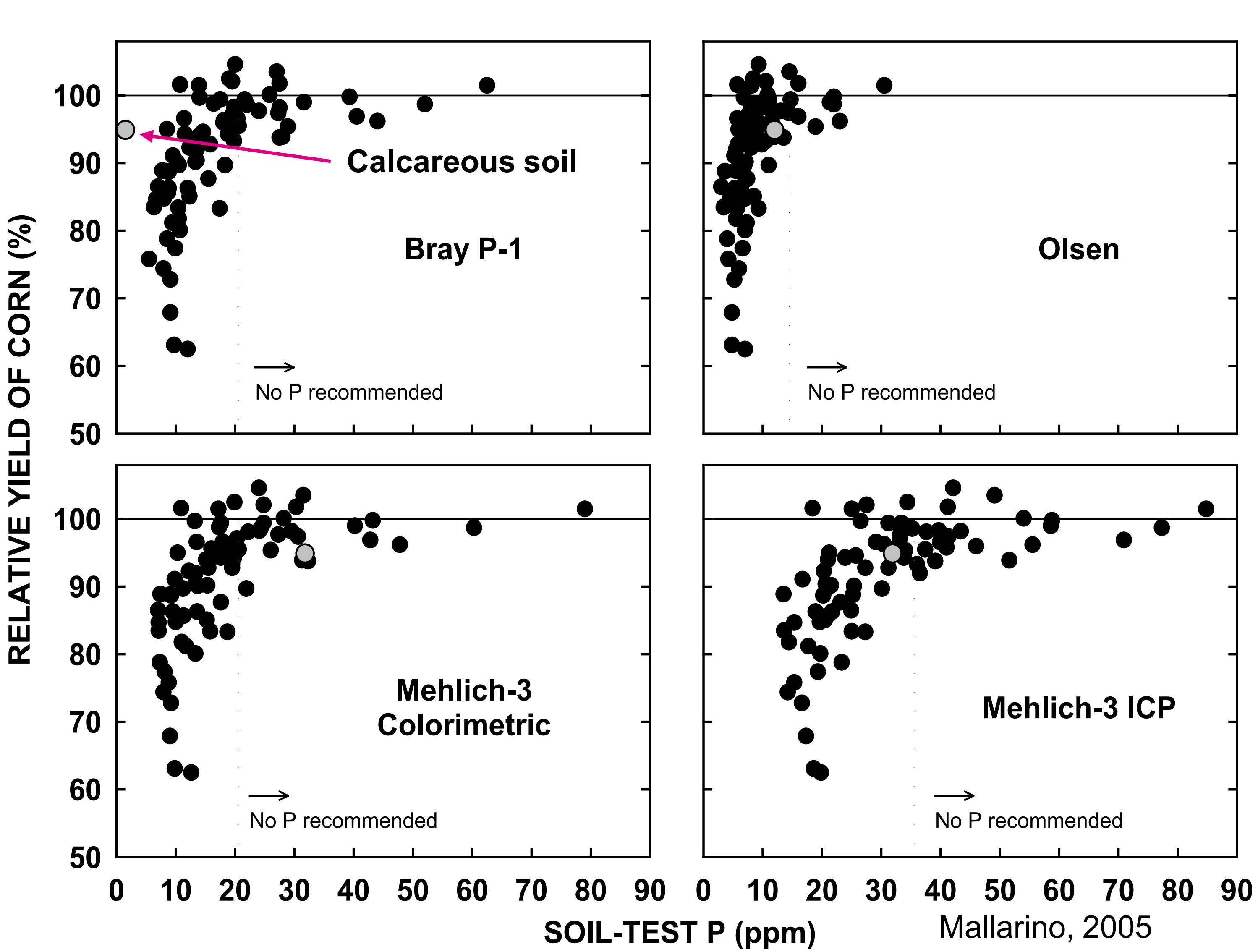
- **Field Correlation:** Relate test values to crop response across many sites/years
  - Find the critical concentration or range
  - Find relative yield response for different deficient values
  - Treatments can be just a control and one non-limiting but not excessive rate
- **Field Calibration:** Find the application rate needed for a range of deficient values
  - Need trials with several application rates

P Tests Supported by ISU and NCERA-13

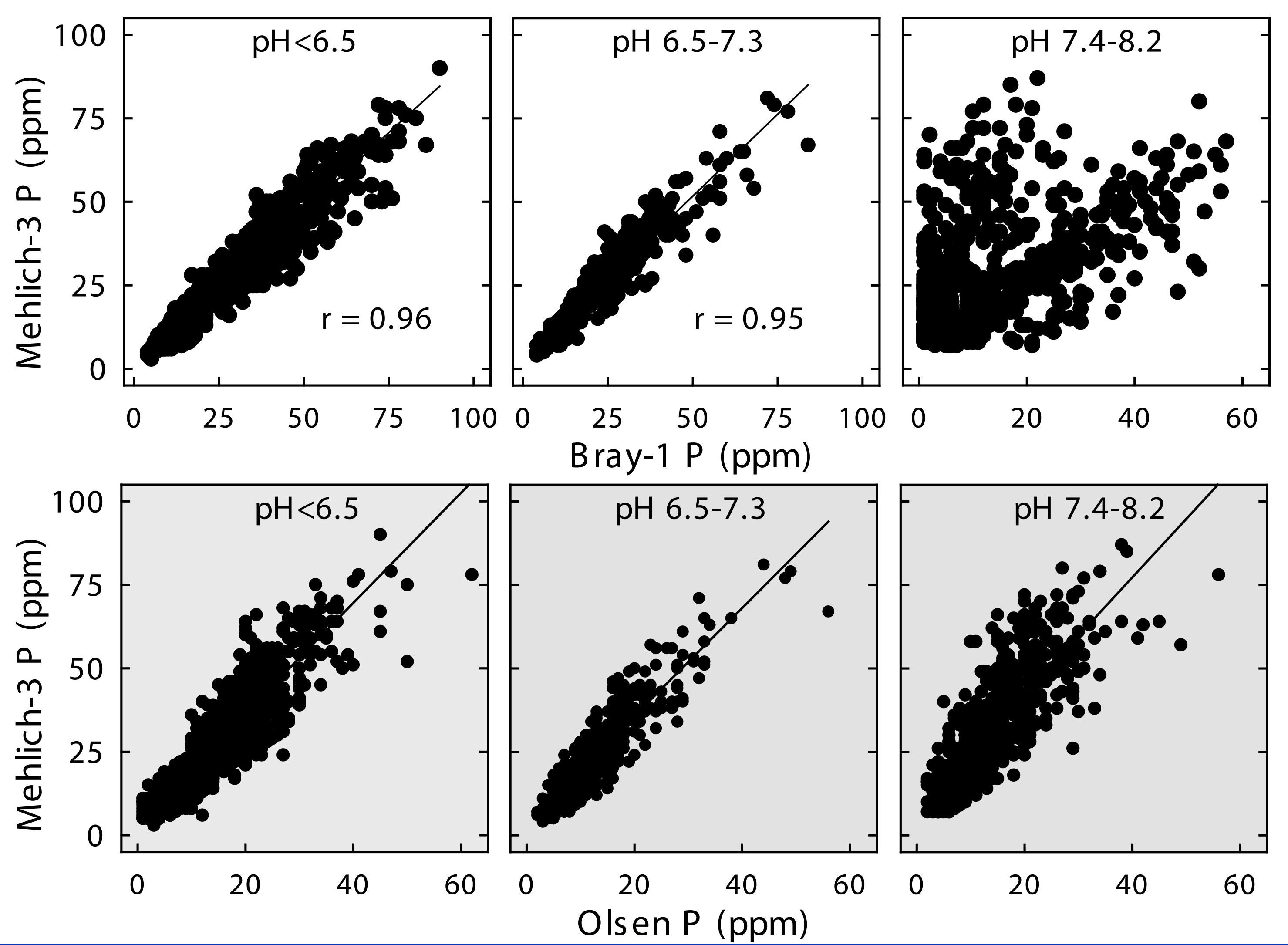
- Extractive solutions:
  - Bray-1: HCl + NH_4F (weak acid)
  - Olsen: $NaHCO_3$ (alkaline, pH 8.5)
  - Mehlich-3: CH_3COOH + NH_4F + NH_4NO_3 + HNO_3 + EDTA
- Determination of extracted P:
  - Colorimetric measures orthophosphate P only
  - ICP, inductively coupled plasma, measures all forms of dissolved P, so almost always measures more P in the extracts

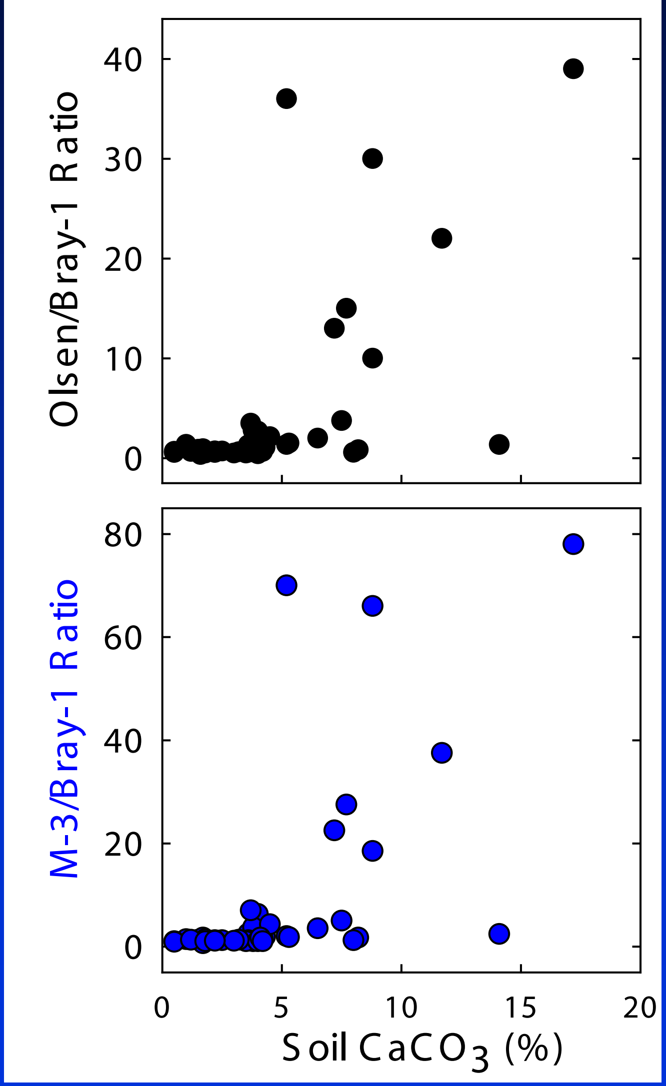
Iowa Example: P Tests Correlation

- Main issues for P in the NC region:
  - Bray-1 underestimates available P in many calcareous soils
  - M3 works well in most Iowa calcareous soils, but may fail with much higher calcareous content
  - Olsen works across all soils but labs don’t like it
  - ICP measures more P than colorimetric with all extractants



Bray-1, Olsen, and Mehlich 3 in Calcareous Soils



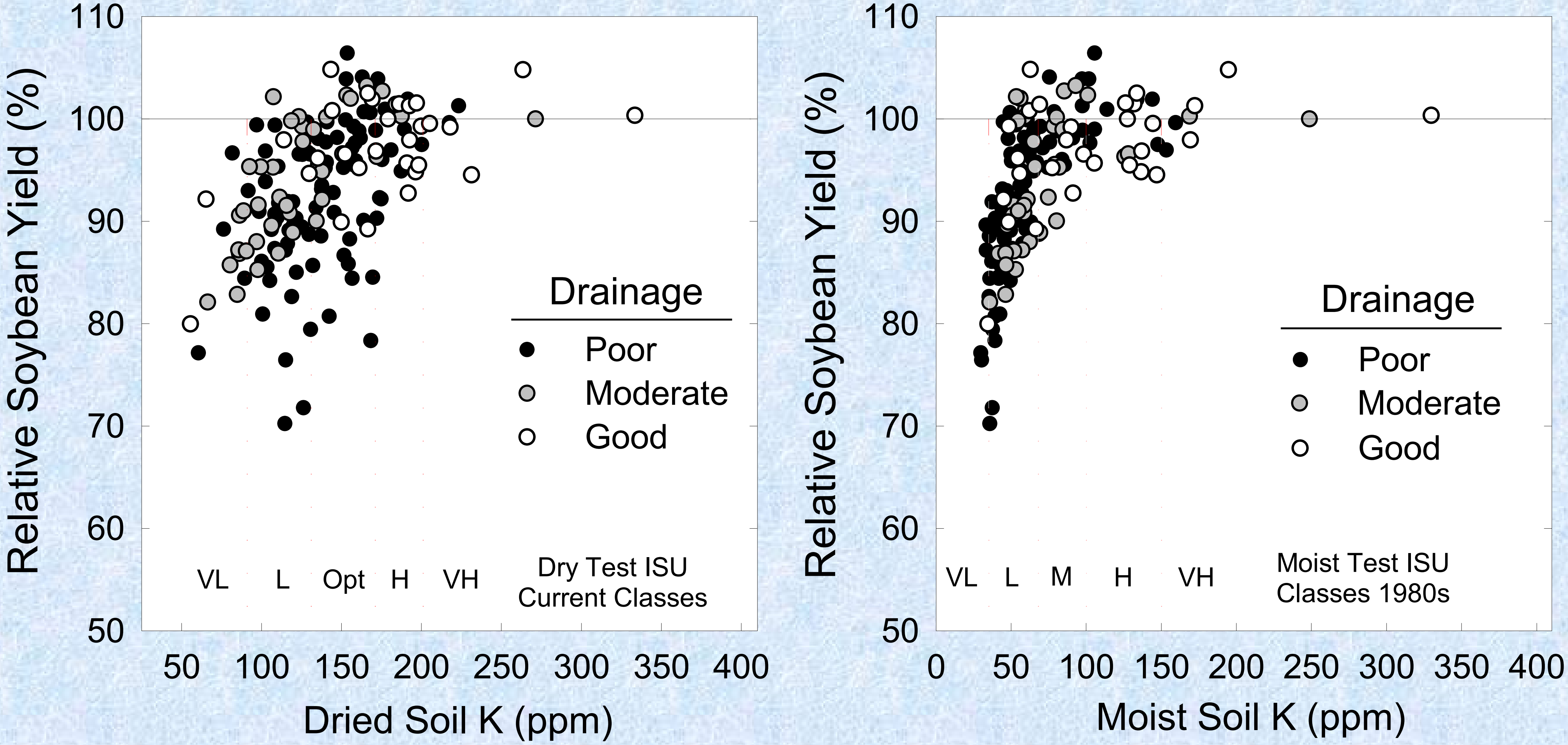


Mallarino, 2004 NC Soil Plant Analyst Workshop

K Tests Supported by ISU and NCERA-13

- Extractive solutions
  - Ammonium acetate
  - Mehlich-3
- Determination of extracted K
  - Atomic emission (low temp flame)
  - ICP (very high temp flame)
- All these methods give the same results
- But the sample drying changes the test results: Dry and moist (slurry) K testing

Iowa Example: K Dry and Moist Tests Correlation

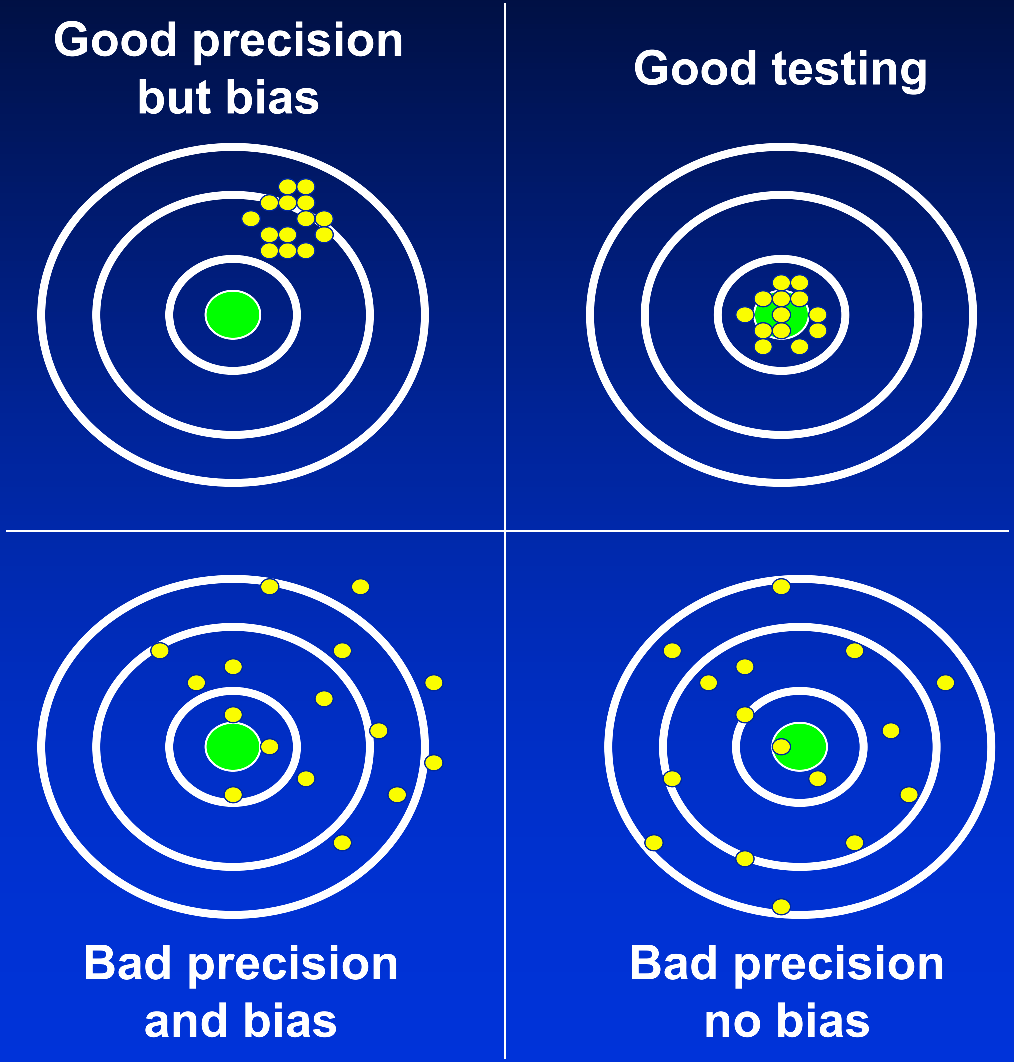


Mallarino et al., 2012 (data 2001 - 2006)

Laboratory Testing Quality

Precision of the measurement
Uncertainty

Accuracy of the measurement
Bias



Adapted from Robert Miller

Soil Testing Proficiency Programs

- Several states certify soil testing laboratories
- Voluntary enrollment in Iowa, but DNR and NRCS require use of certified labs
- The state uses the North American Proficiency Testing Program (NAPT), administered by the SSSA
- ALP, used in some states
- These programs have significantly reduced lab bias, but is still a big problem

The Basic Concepts

- In low-testing soils:
  - Why risk yield loss by applying low rates when there is a high probability of large yield increases and profits?
  - Why apply rates higher than needed to maximize yield? Why buildup faster?
- Removal-based rates for the Optimum catch any possible low response and maintain levels
  - Can adjust rate for prices, land tenure, risk management philosophy
- Why maintaining high-testing levels?

The Strict Sufficiency Level Concept

- Each nutrient has a sufficiency value or range below which crops will likely respond to fertilization and above which a response is unlikely
- No maintenance of a certain level
- Emphasizes short-term economic returns
- Requires precise calibrations and testing, annual applications, frequent sampling
- Reasonable for really “high fixing” soils of the world, where buildup and maintenance is not reasonable

Build-up and Maintenance Concept

- Build-up soil-test values up to a certain "adequate" level and maintain it based on removal with harvest
- Excess N application one year is money wasted but not necessarily for P and K
- In many soils can "bank" P-K, and buildup or drawdown as needed
- Does not make sense in “high fixation” soils or with bad crop/fertilizer price ratios

Predominant Concepts for P and K

- For most NC region states a compromise between strict sufficiency level and build-up & maintenance approaches, but some states are closer to one or the other
- Recommendations for low-testing soils are based on crop response data to maximize yield or MEY, which often result in a gradual buildup over time
- Maintenance of "adequate" soil-test levels based on nutrient removal with harvest
- Exceptions: Illinois (build-up & maintenance), Kansas (dual system), North Dakota (sufficiency level)

Objective of the Recommendations?

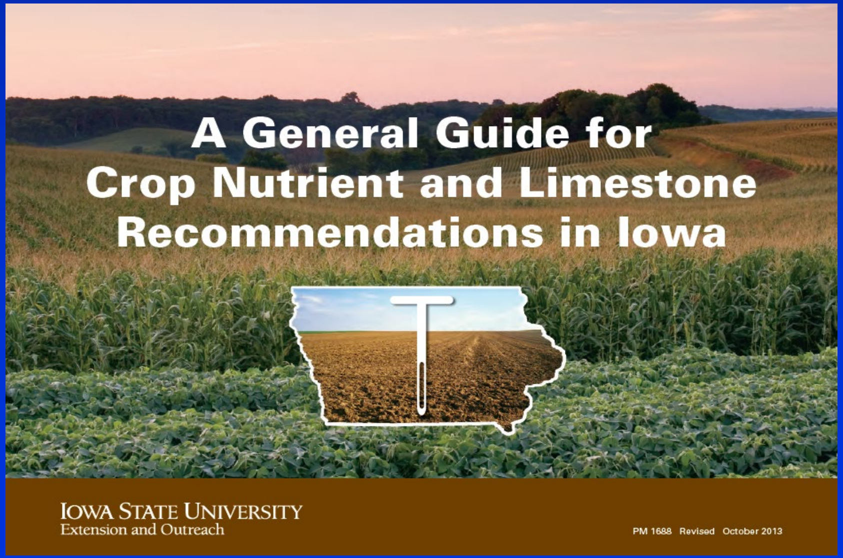
- What is the objective of fertilizer rates we or crop advisers recommend?
  - Target maximum net return each year?
  - Assure that fertility doesn't limit yield?
  - Short-term or long-term productivity?
- Iowa philosophy for P, K, Lime rates:
  - There is high probability of a large response in the low-testing classes
  - Emphasize the long-term profitability of the system
  - Can adjust soil-test values over time

Decisions and Type of Risk Assumed

- It's tough to know 6 to 12 months ahead the rate for maximum economic yield needed each year
- Risk being short to assure high return per pound of fertilizer applied?
  - May limit yield and the profitability of the system, but good with bad price ratios and uncertain land tenure?
- Apply to be sure that yield is not limited?
  - May reduce the short-term returns and maybe of the system, but may work with good price ratios and safe land tenure?

Example of Interpretations

- Iowa philosophy for P and K rates:
  - High probability of a large response in the low-testing classes, rates for low-testing soils to get maximum yield; NOT to buildup fast or to get “maximum economic yield"
  - Removal-based maintenance for the Optimum category
- Well defined categories based on measured probabilities
  - Very Low: about 80%
  - Low, about 65%
  - Optimum (maintenance): < 25%
  - High, less than 5%
  - Very High, less then 1%



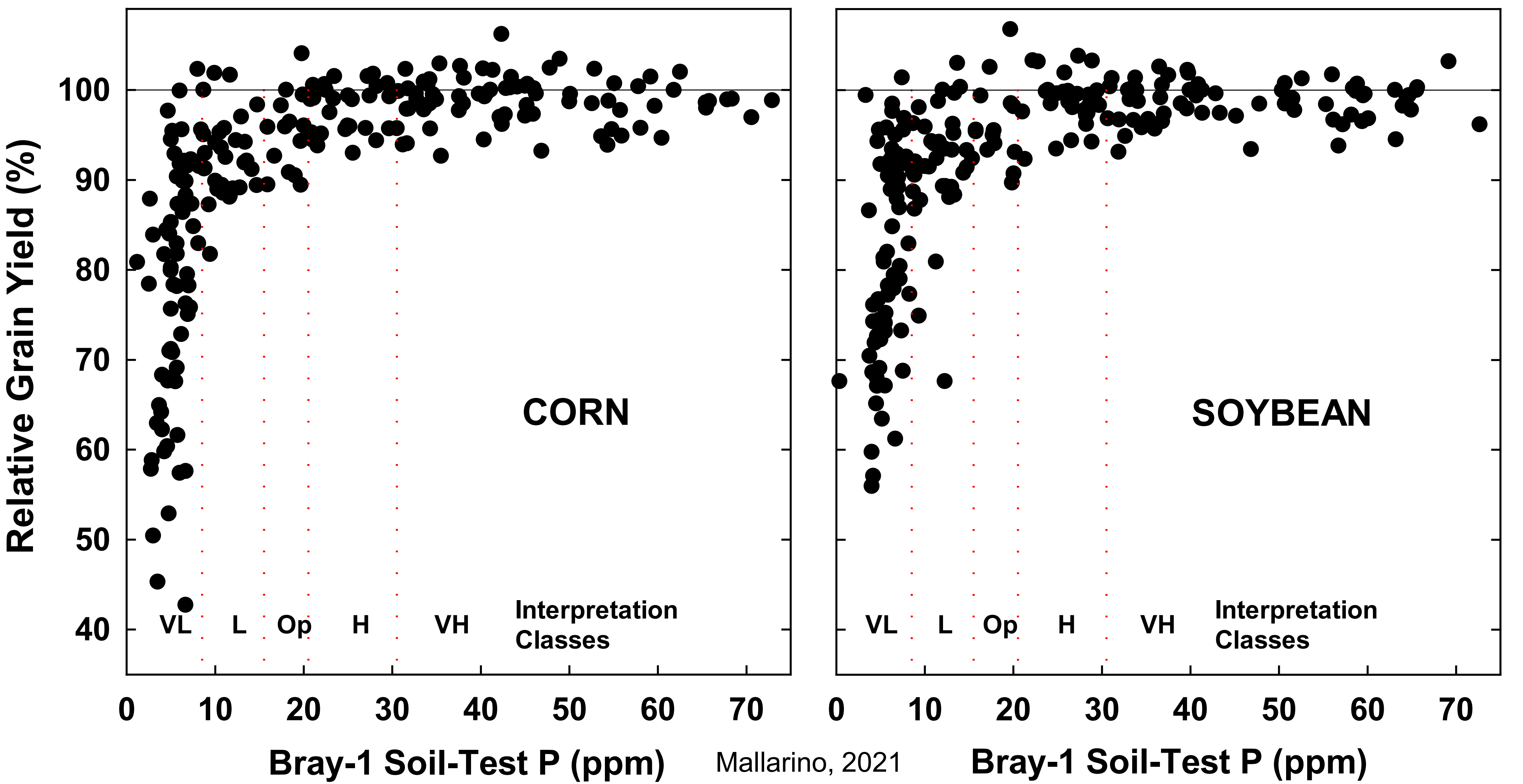
Rates for Low-Testing Soils

- Why risk yield loss by applying low rates when there is a high probability of large yield increases and large profits?
- Why apply rates higher than needed to maximize yield? Why buildup faster, especially with rented land?
- Recommendations vary greatly based on these type of assumptions
- Some recommendations include a yield level or buildup component others don't

Maintenance P Fertilization

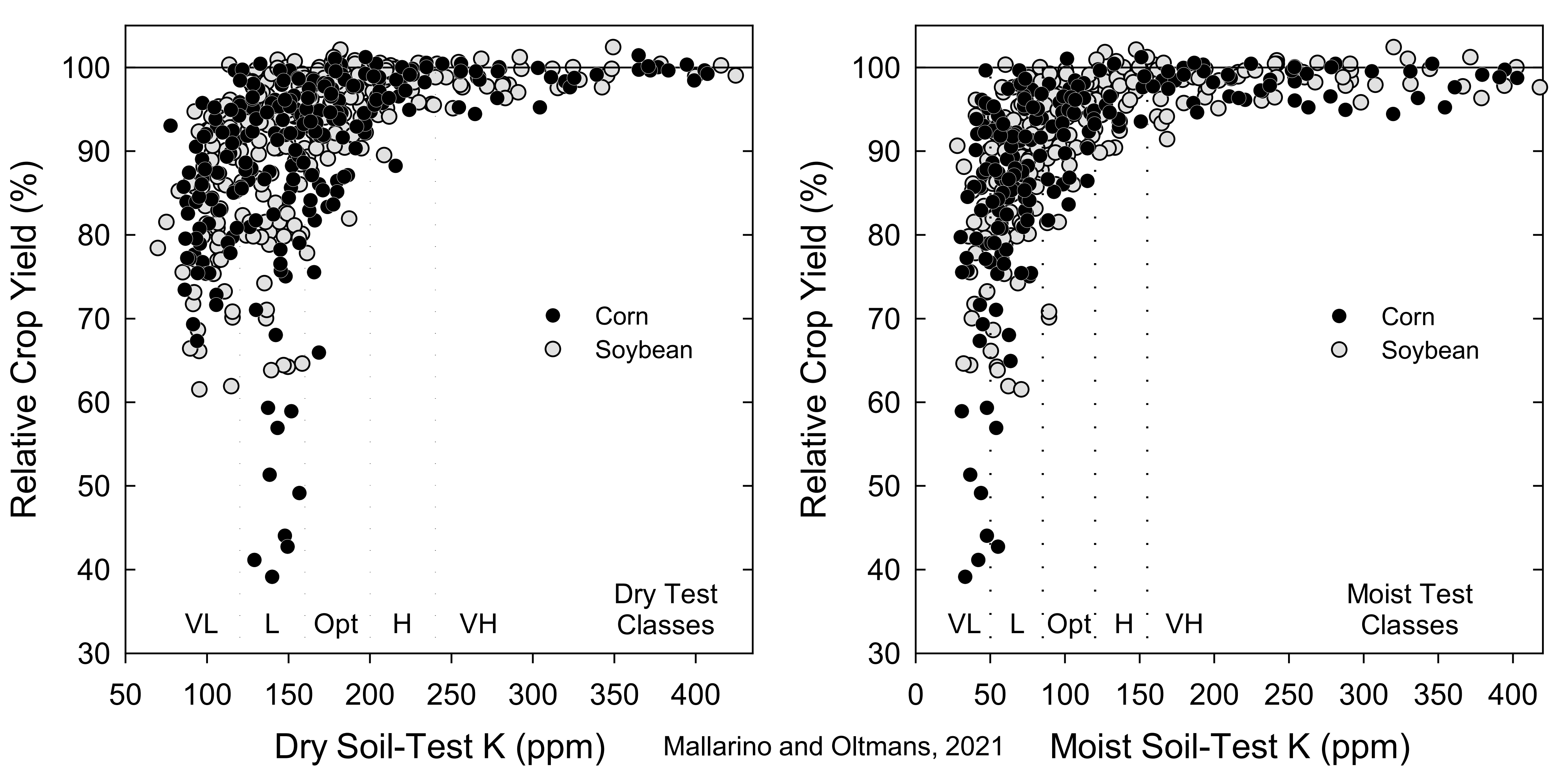
- Removal-based rates are designed to maintain soil-test values but not necessarily attain the best short-term economic return to one crop
- Maintain what soil-test level, what magnitude and probability of response?
- The level to maintain depends on prices, land tenure, risk management philosophy, and farmer “stomach”
- Some recommendations clearly establish what is the criterion assumed, but many do not

New Data Since 2013 - Soil-Test P and Response

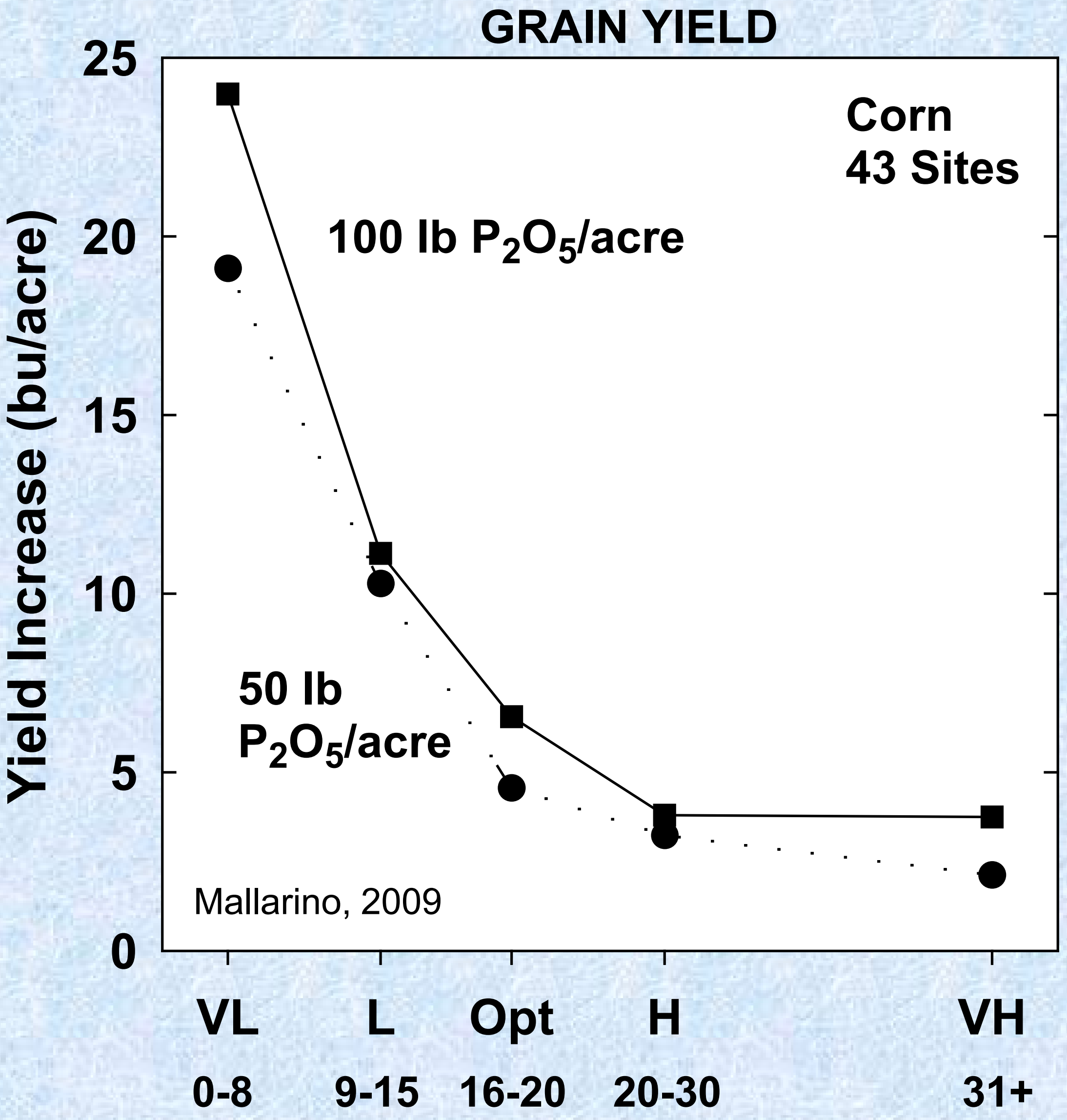


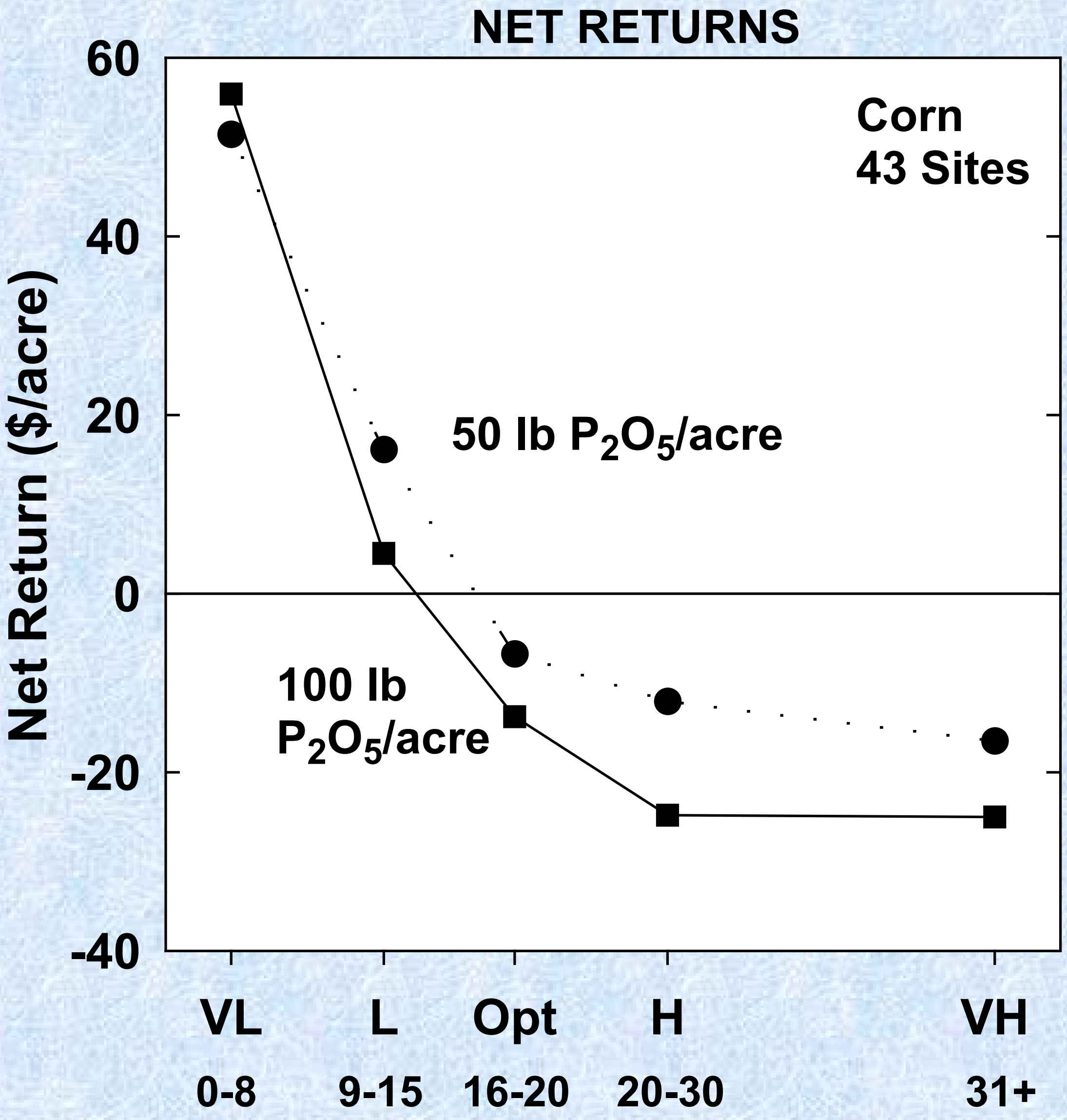
Mallarino, 2021

New Data Since 2013 - Soil-Test K and Response

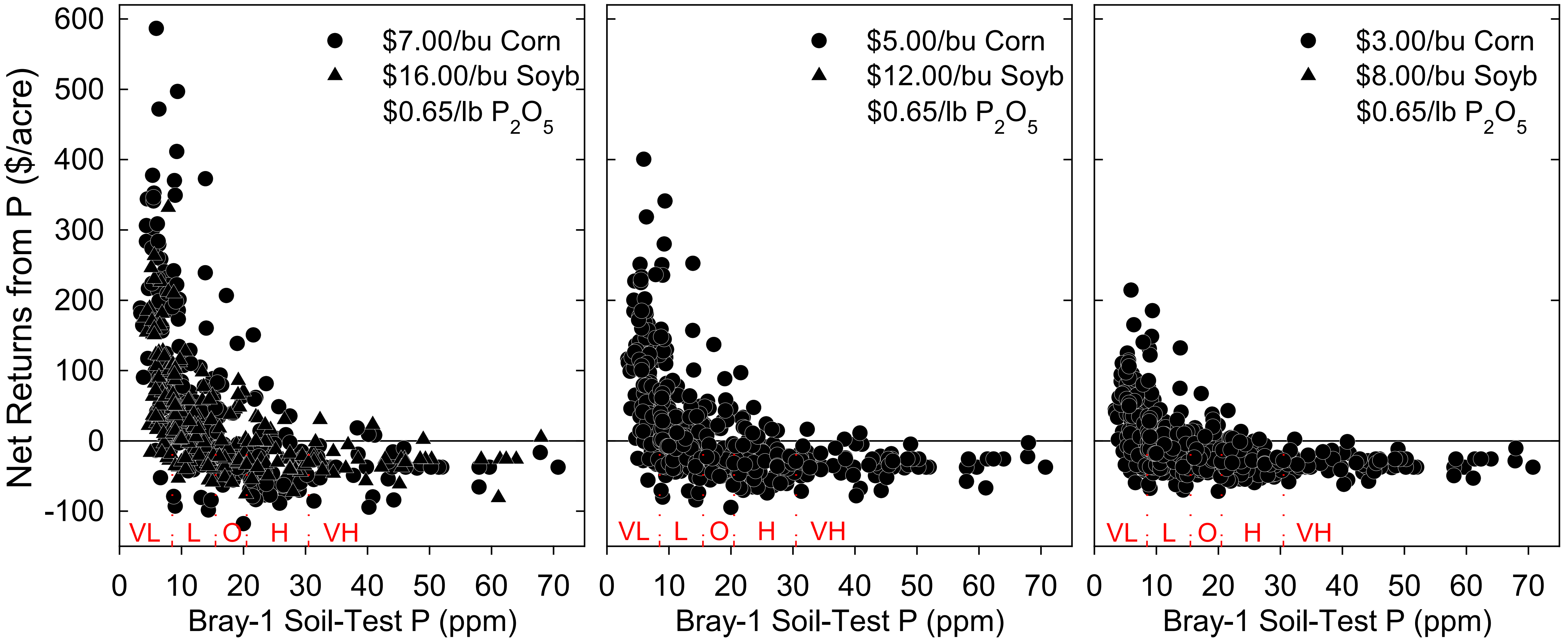


Rates, Yield and Economic Net Returns





Soil-Test P Levels, Prices and Benefits

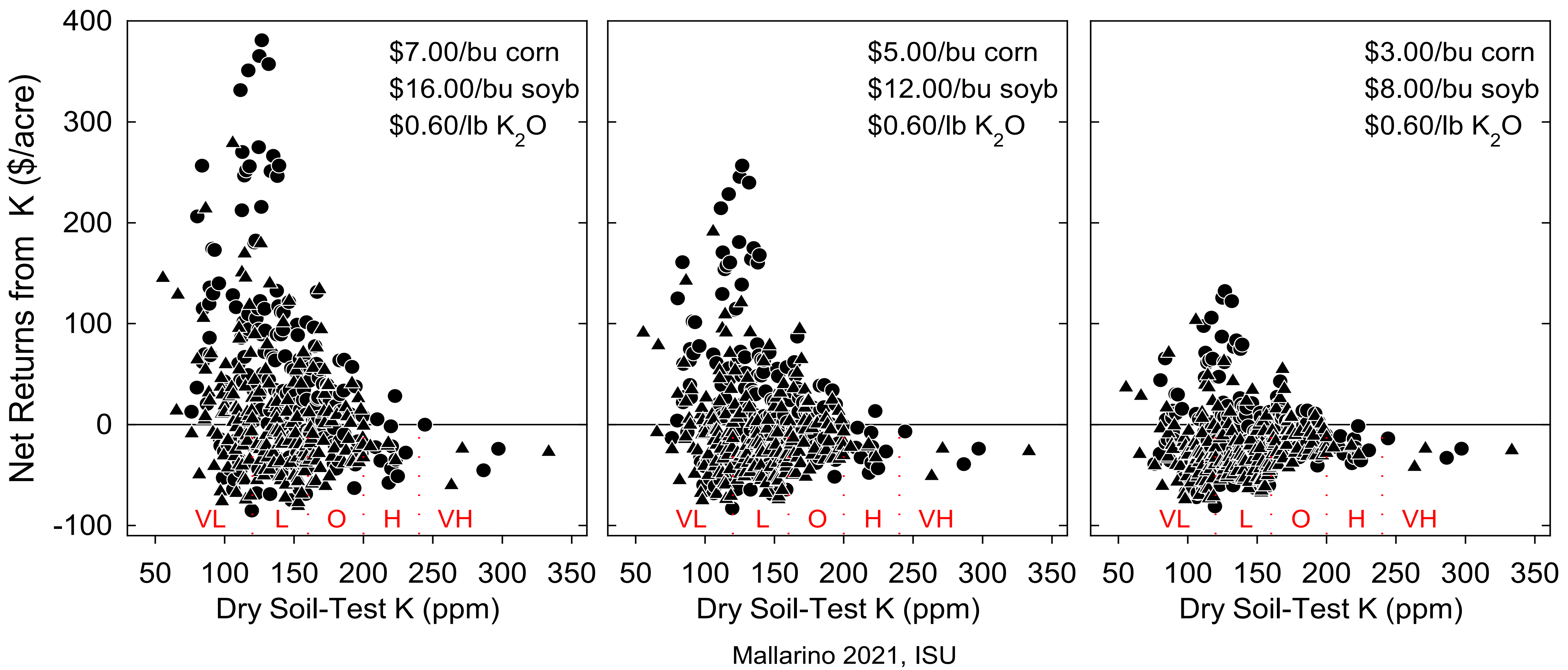


Mallarino 2021, ISU

Removal-based rates were used for the High and Very High categories although is not recommended

Soil-Test K Levels, Prices and Benefits

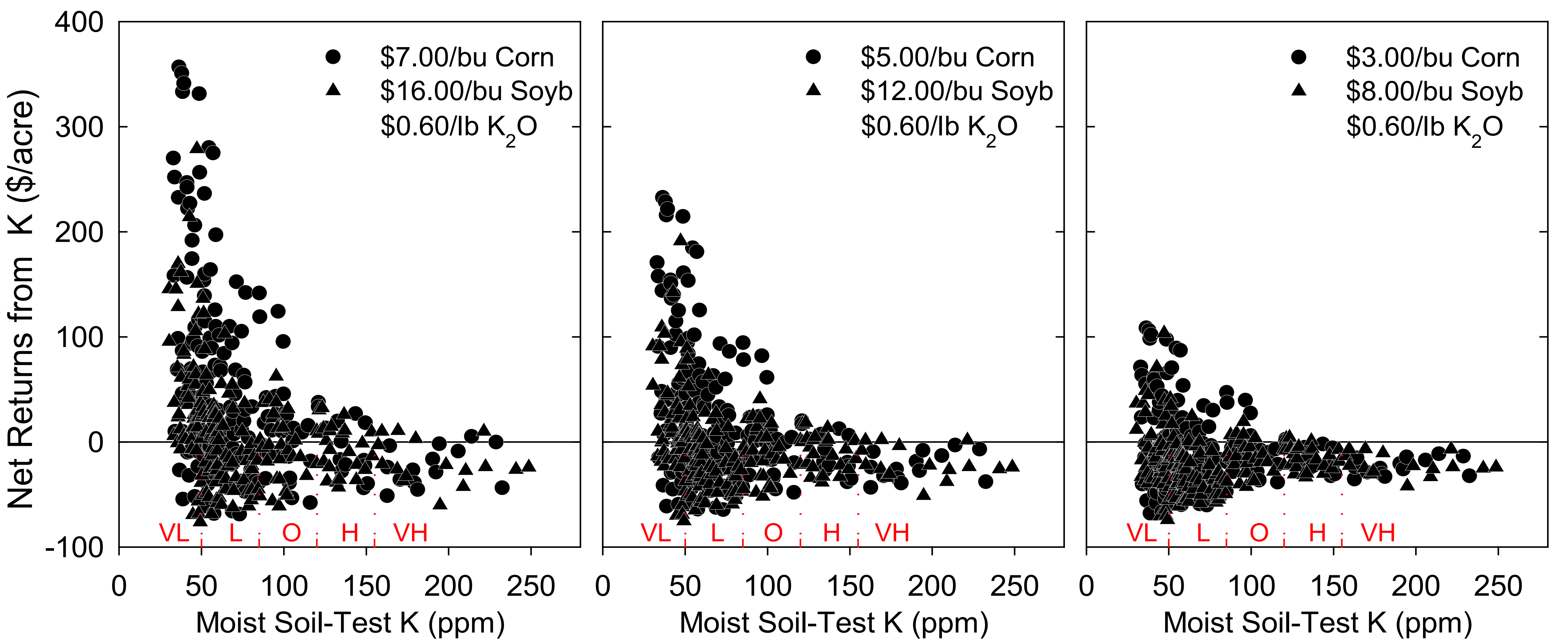
Common Potassium Soil Test by Drying Soil Samples in the Laboratory



Removal-based rates were used for the High and Very High categories although is not recommended

Soil-Test K Levels, Prices and Benefits

Using the Moist Test for K, it is a More Reliable Diagnostic Tool in Most Iowa Soils



Mallarino 2021, ISU

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From Soil Tests to Recommendations

- There is uncertainty in assessing crop nutrient needs for crops and in the research to make recommendations
- Seldom there is a single "right" soil-test interpretation and recommendation
- For most nutrients and soils, several right options adapt to various management and risk-taking philosophies
- Researchers, extensionists, and crop consultants should explain well to farmers their assumptions and concepts behind their recommendations

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http://www.agronext.iastate.edu/soilfertility