Variable Rate Application to Increase P Use Efficiency and Minimize Water Quality Impairment

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Current General Situation

• Lower grain prices and returns to cropping and stable fertilizer prices
• Real or perceived serious agriculture impacts on water quality
• Relatively lower cost of soil sampling, testing, and fertilizer application compared to other inputs or fixed costs
• Investing on better soil testing and P fertilization pays and improve water quality
Key Issue: Soil Sampling and Testing

- Soil testing isn’t perfect but is a useful site-specific tool, key for VRT use
- Use good soil sampling and testing methods to know P fertilizer needs
  - The soil sample should represent well the field variation in a cost-effective way
  - Use methods and sampling depths calibrated with crop response to fertilization
  - Send samples to certified laboratories that use proved soil-test methods
Soil-Test P and Yield Response

![Graph with data points showing the relationship between Bray-1 Soil-Test P (ppm) and Relative Grain Yield (%). The graphs are divided into two sections: Corn and Soybean. The data points are color-coded and categorized into different interpretation classes: VL, L, Op, H, and VH.](image-url)
Another Key Issue: Removal with Harvest

- The yield level doesn’t affect the optimum soil P level or rate to maximize yield
- But removal-based application is a key to maintain desirable soil-test levels over time in most soils, need to know
  - Prevailing yield level, not a yield goal
  - P concentration of harvested plant parts
- Yield/removal can vary greatly within fields, yield monitor is a site-specific tool; another key for effective VRT use
Soil Sampling Spatial Variability

- Soil sampling in the field is the most common and important source of error in soil testing for P and K

- Labs get the blame most of the times, but the sampling most often is the problem

- Spatial variability at various scales
  - Number of composites samples per field or from where within a field
  - Number of cores per composite sample
  - Sampling depth consistency
Sampling by Soil Map Unit

Most states recommend one sample every 10 to 15 acres.
The Problem of Sampling by Soil Type

• Theory or assumptions
  - A stratified sampling approach
  - Soil formation factors and topography may influence nutrient levels (parent materials mineralogy, chemistry, texture)
  - Soil physical properties may influence yield potential and nutrient removal

• Problem
  - Seldom the case in Iowa and regions with initial low P or K levels and long histories of fertilizer or manure applications
Effect of the Soil Sampling Method on Estimates of Soil-Test P for Three Fields

Field 1
Soil-Test P
VL
L
O pt
H
VH

Field 2
Soil-Test P
VL
L
O pt
H
VH

Field 3
Soil-Test P
VL
L
O pt
H
VH

A.P. Mallarino, ISU
Within-Field Soil P Variation

Field 1

Field 2

Field 3

Field 4

Mallarino, ISU
Variation is Real: Yield Response to P

Yield Increase (%)

Field 1

Field 2

Field 3

Field 4

Mallarino, ISU
Grid Sampling is Better but More Costly

- More samples are taken with grid sampling which describes nutrient availability better, but costs are higher.
- Cell sampling, point sampling, various sampling density.
- Most common in Iowa and the Corn Belt:
  - Grid point sampling, 2.5 - 5 acres, systematic or unaligned “points” 20 to 50 feet radius, 4 to 8 cores per sample.
  - Few consider yield as it should.
Avoid Systematic Grid Sampling

VARIATION FOR 10-CORE COMPOSITE SAMPLES

FIELD WITH LOW P

FIELD WITH HIGH P

FIELD WITH MANURE

VARIATION FOR SINGLE SOIL CORES

FIELD WITH LOW P

FIELD WITH HIGH P

FIELD WITH MANURE
Unaligned or Random Grid-Point

Few adjust sampling points to avoid soil map units borders

(sampling points overlaid on soil map units)
Management Zones Sampling

- Improve the sampling by soil type method and provide an alternative to a blind and costly “well done” grid sampling
- Delineate sampling areas using additional information layers: aerial/satellite images maps of yield, elevation/slope, electrical conductivity, all kinds of sensing
- Assumes that these factors are the cause or are related to different nutrient availability or crop needs
Management Zones Soil Sampling
A.P. Mallarino, ISU

Soil Survey Maps

Aerial Photos

Previous Yield Maps

Elevation Maps

Soil Electrical Conductivity

Areas for Sampling
Efficacy Based on Crop Response

- Iowa research (Sawchik & Mallarino)
- Sampling Efficacy Index: Capacity of a sampling method to identify within-field areas with different crop response:
  - Dense 0.3 to 0.5 acre grids: 100 (best)
  - 2.5 acre grids: 50%
  - Zone sampling: 39%
  - Sampling by soil type: 22%
Why Isn’t Zone Sampling Better?

• Long histories of fertilization/manure in originally low-testing soils mask soil properties effects on P and K variation

• Within-field removal variation has to be large and consistent over time to clearly influence soil P and K levels

• Zoning is better and cost-effective regions with larger fields, more contrasting soils within fields, and/or shorter fertilization histories
Need Many Cores Even with Grid Sampling

More cores is better, but the gain decreases exponentially

19 ppm Average Soil-Test P (Optimum Class)
New Automated Soil Samplers

Taking Many Samples with Many Cores Can be Easy (but costly?)

AutoProbe™, courtesy Jeff Burton, AgRobotics Inc.

Falcon Soil Sampler, courtesy Jerry Romine
On-Farm Research: Uniform vs Variable

70 trials over the years, collaboration with coops
Corn and Soybean, P, K, or lime
Dense grid sampling, yield monitors, and GIS
VRT Sometimes Doesn't Increase Yield

Wittry and Mallarino, ISU
VRT Doesn't Always Increase Yield

- Sell a technology for the right reasons!
- Most farmers are maintaining soil-test values at or above optimum levels
  - Small low-testing areas or do not exist
- Sometimes high small-scale variability: How representative are test values?
- Rates for low-testing soils are designed to get maximum yield, so additional P or K applied with VRT to low-testing areas may will not increased yield further
Amounts of P Fertilizer Applied

• Difference Variable - Uniform application across all fields and years:
  - -52 to 71 lb P$_2$O$_5$/acre, average -9 lb/acre

• The difference varies greatly across fields according to soil-test ranges in each field and percent area testing within different interpretation categories
  - Shown by several studies for P, K, and lime
Variable P Fertilizer and STP Change

From Bermudez and Mallarino, 2007
Variable Rate Manure P and STP Change

From Mallarino and Wittry, 2010
Prices, Profitability, Soil-Test Levels

ISU recommended rates in publication PM 1688 for Very Low and Low categories, and removal-based rates for Optimum or higher categories assuming 180 bu/acre for corn and 55 bu/acre for soybean.
With Unfavorable Crop/Fertilizer Prices

• More justification for dense sampling/VRT

• Low-testing areas:
  - Don't cut recommended rates, high probability response and profits
  - Why buildup with bad prices?

• Optimum/medium areas
  - Maintain based on removal, but temporarily can reduce the rate or switch to starter

• High testing areas: Do not apply!!
Soil-Test P and P loss from Fields

Toxic algal terror engulfs Toledo!

IT came from the lake
Runoff P Loss and Soil-Test P Level

Allen and Mallarino, 2006

Allen and Mallarino, 2009
Soil-Test P and P in Tile Drainage

Haq, Mallarino, et al., ISU
Soil P, Yield Response, and Water Quality

Applying P to high-testing soils is not good for farm profitability, efficient fertilizer use, and water quality.

Mallarino, 2013
Water Quality and Management Zones

• The concept of defining management zones for soil sampling, fertilization, and crop management is being used in production agriculture

• Can expand the zoning concept to include considerations for environmental P management when applying manure

• In Iowa, regulations allow use of the P index to zone fields for N-based or P-based manure application
Zoning for Variable Rate N or P Manure

**Soil Series**
- 485
- 642
- 138

**Soil-Test P (ppm)**
- 180
- 118
- 150
- 106
- 74

**Slopes (%)**
- 9-14
- 2-5
- 14-18
- 5-9

**P Index Rating**
- 2.8
- 1.0
- 2.0
- 1.3
- 5.1

**Erosion (ton/acre)**
- 1.5
- 6.7
- 3.4

**N or P Based Manure**
- N
- N
- N
- P

Mallarino, Wittry, & Stewart. ISU & NRCS
Effective Use of Technologies

• Use recommended soil-test methods calibrated with yield response
• Use grid sampling or zone sampling, but move on from sampling by soil type
• Benefits from VRT and dense sampling increase with high soil-test variation, yield variation, and unfavorable price ratios
• Good technologies will not work well with wrong fertilizer recommendations
Soil Fertility Web Site
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