Economics of Soil Fertility Management

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With Cooperation Of:
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Kevin Dhuyvetter, Ph.D., Technical Consultant, Elanco

Where are we now?

- Historical and Current Price Ratios
- Understanding Crop Response to Fertilizer
- Economics of Soil Testing and Data Quality
- Implications for site-specific management
- Products and Placement
- Current Research
Wheat:Nutrient Price Ratio

Lbs of wheat to buy one lb of nutrient
Monthly Kansas NASS Price Received and Urea/DAP FOB Gulf
December 1985 – October 2017

--- Wheat:P  ---- Wheat:N

Corn:Nutrient Price Ratio

Lbs of corn to buy one lb of nutrient
Monthly Kansas NASS Price Received and Urea/DAP FOB Gulf
December 1985 – October 2017

--- Corn:P  ---- Corn:N
# Grain: Nutrient Price Ratios

<table>
<thead>
<tr>
<th></th>
<th>Historical</th>
<th>Oct. 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn: Nitrogen</td>
<td>3.29</td>
<td>4.48</td>
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<tr>
<td>Wheat: Nitrogen</td>
<td>2.61</td>
<td>4.47</td>
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<tr>
<td>Corn: Phosphorus</td>
<td>5.02</td>
<td>5.86</td>
</tr>
<tr>
<td>Wheat: Phosphorus</td>
<td>4.01</td>
<td>5.85</td>
</tr>
</tbody>
</table>

## Understanding Crop Response to Fertilizer

[Diagram showing response to nutrient additions]
Understanding Crop Response to Fertilizer
Low Soil Test Levels

- Low yields without additional fertilizer
- EOR range is narrow
- Optimum rate is minimally affected by grain:nutrient price ratio

Understanding Crop Response to Fertilizer
Medium Soil Test Levels

- Expected yield without fertilizer is higher
- Range of potentially optimal rates is wider
- In a single-year decision framework, EOR is very sensitive to grain:nutrient price ratio
- As price ratio ↓ EOR ↑
Understanding Crop Response to Fertilizer High Soil Test Levels

- No or minimal response to added fertilizer

Wheat Response to Soil Test P Level

2018 Soil Fertility Update
Understanding Sufficiency vs. Build-Maintain Programs for P and K

- Sufficiency fertility programs
  - Intended to estimate the long-term average amount of fertilizer P required to, on average, provide optimum economic return in the year of application. There is little consideration for future soil test values
Build-Maintenance

- Apply enough P to or K to build soil test values to a target soil test value over a planned timeframe (e.g. 4-8 years), then maintain based on crop removal and soil test levels
- NOT intended to provide optimum economic returns in a given year, but minimize the probability the P or K will limit crop yields while providing for near maximum yield potential

P Sufficiency Recommendations for Wheat

From K-State Publication MF2586 – Soil Test Interpretations and Fertilizer Recommendations

<table>
<thead>
<tr>
<th>Olsen (ppm)</th>
<th>0-3</th>
<th>3-6.3</th>
<th>6.3-9.4</th>
<th>9.4-12.5</th>
<th>12.5+</th>
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</thead>
<tbody>
<tr>
<td>Yield Goal (Bu/A)</td>
<td>50</td>
<td>40</td>
<td>25</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Lb P₂O₅/A</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Nutrient recommendations are for the total amount of broadcast and banded nutrients to be applied. At low to very low soil test levels applying at least 25-50% of total as a band is recommended.
Phosphorus removal values

<table>
<thead>
<tr>
<th>Crop</th>
<th>Unit</th>
<th>$P_2O_5$ (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>bushel</td>
<td>0.33</td>
</tr>
<tr>
<td>Grain Sorghum</td>
<td>bushel</td>
<td>0.40</td>
</tr>
<tr>
<td>Wheat</td>
<td>bushel</td>
<td>0.50</td>
</tr>
<tr>
<td>Sunflowers</td>
<td>pound</td>
<td>0.02</td>
</tr>
<tr>
<td>Oats</td>
<td>bushel</td>
<td>0.25</td>
</tr>
<tr>
<td>Soybeans</td>
<td>bushel</td>
<td>0.80</td>
</tr>
</tbody>
</table>

P Build-Maintain Recommendations for Wheat

From K-State Publication MF2586 – Soil Test Interpretations and Fertilizer Recommendations

0-3
3-6
6-9
9-12.5
12.5+

2018 Soil Fertility Update
Grain Sorghum P and K Recommendations

Phosphorus Sufficiency Recommendations for Grain Sorghum

<table>
<thead>
<tr>
<th>Bray P1 Soil Test (ppm)</th>
<th>Yield Goal (Bu/A)</th>
<th>Lb P2O5/A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>0-5</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>5-10</td>
<td>35</td>
<td>40</td>
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<tr>
<td>10-15</td>
<td>20</td>
<td>25</td>
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<tr>
<td>15-20</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>20+</td>
<td>0 ±</td>
<td>0 ±</td>
</tr>
<tr>
<td>Crop Removal²</td>
<td>16</td>
<td>32</td>
</tr>
</tbody>
</table>

120 bu x 0.4 lb/bu = 48 lb P2O5 removed
Factors Affecting Strategy Selection

- Anticipated length of time to recapture soil test building investment
  - Age, length of career
  - Anticipated land tenure
    - Owned land, long-term landlord relationship, short-term lease
- Current-year economics
- Current soil test levels
Change in profit if true STN varies from expected STN
STP = 16; OM = 1.6; Expected STN = 40
Corn @ $3.37, Wheat @ $3.39, N @ $0.33, P @ $0.43

Change in profit if true STP varies from expected STP
STN = 40; OM = 1.6; Expected STP = 16
Corn @ $3.37, Wheat @ $3.39, N @ $0.33, P @ $0.43
Data Quality

• The proceeding economics are based on having good data, as good of a representation of “truth” as we can reasonably obtain.
• Good decisions require good data
• Good soil test data comes from good procedures in the field

Number of Cores to Make a Good Sample

• Soils vary across very short distances in nutrient supply due to many factors including:
  – Position on the landscape
  – Past erosion
  – Parent material of the soil
• We also induce variability on the soil
  – Band applications
  – Livestock grazing
• To account for this variation you should take 10-20 cores per sample
EXAMPLE OF THE RELATIONSHIP BETWEEN NUMBER OF SOIL CORES PER COMPOSITE SAMPLE AND ERROR

MEAN SOIL P = 19ppm

Economics of Accuracy

Profits from soil sampling at different number of points relative to an all-point composite

2018 Soil Fertility Update
The Role of Soil Testing

- Generating profits from soil testing is dependent on the tradeoff between the cost of gathering the information (labor and lab fees), and the benefits from having that information (more appropriate fertilizer rates)

Useful soil tests in Kansas

- Profile Nitrate-N
- Bray P-1 Extractable P
- Olsen Extractable P
- Mehlich III Extractable P
- Exchangeable K
- DTPA Extractable Zn
- Chloride
- Sulfur/Sulfate
- Soil pH
- Lime Requirement / Buffer pH
- Soil Organic Matter
Phosphorus Soil Test Methods

- Bray P1 roughly equivalent to Mehlich III, use for soil pH < 7.0
- Bray P2 – NOT USEFUL!, Developed for rock phosphate applications in Indiana
- Olsen Bicarbonate – Developed at CSU for high pH soils especially > 7.0
- Mehlich III, equivalent to Bray P1, but valid over a wider range of soil pH

Long-term Corn Fertility

1961-2015

0 40 80 120 160 200
N Rate, lb/a

0 50 100 150 200 250
Yield, bu/a

0 P
40 P

Long-term corn fertility, Tribune, KS
Options

• Economics of grid sampling
• In-Furrow Placement of Urea with Wheat
• Humic Acid for Iron Chlorosis in Sorghum
• Wheat Protein

VRT Phosphorus Example

• No other data is available (i.e. yield data)
• Field is located in NW Kansas and was grid sampled on 2.5 ac grids
• Samples consisted of 15 cores, so an estimated CI of +/- 3.5 ppm
Soil Test Bray P1

Soil Test P Histogram

Max = 217
Min = 7
Average = 21.7
(20.1 without outlier)

Interpolated Soil Test Phosphorus

NOT A GOOD EXAMPLE OF INTERPOLATION!
Returns to VRT

• Average gross return on VRT P for wheat = **$3.81/acre/year**
• Average gross return on VRT P for corn = **$4.49/acre/year**
• The above gross figures would need to cover sampling cost and the portion of machinery and labor cost related to VRT implementation
Can we stretch the value of intensive sampling?

• ROI on intensive sampling increases dramatically as the number crops benefiting from the information increases (spreading fixed cost)

• Checkbook approach for nutrients using initial intensive soil test and removal rates from yield monitor data

Nitrogen Uptake and Key Timings
Placement

Soil test P and application method

Common generalized depiction of broadcast vs. band
Interest in fertilizer efficiency through placement

![Graph showing effect on yield of wheat of applying superphosphate broadcast and in the row with the seed](image)

KS, 1932

**Phosphorus removal values**

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</tr>
<tr>
<td>Soybeans</td>
<td>bushel</td>
<td>0.80</td>
</tr>
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Crop Removal – the next step

- Calculate crop removal
- Depending on over/under applications after crop removal, soil test levels will change.
- 18 lbs $P_2O_5$ is required to change STP one ppm.

- One cycle of a W-C-F rotation (using field averages)
  - Wheat yield = 60 bu/a, Corn yield = 110 bu/ac
  - STP = 22 ppm, $P_2O_5$ applied during seeding = 30 lb/a
  - Wheat Removal = 60 * 0.50 = 30 lbs $P_2O_5$ removed
  - Corn Removal = 110 * 0.33 = 36 lbs $P_2O_5$ removed
  - Total Crop Removal = 30+36 = 66 lbs $P_2O_5$ removed
  - STP change = 66-30=36 lb net removal, 36/18 = 2 ppm estimated drop
  - Final STP = 22 – 2.4 = 19.6 ppm

Crop Removal – the next step

- Perform crop removal and STP calculations at a site-specific scale for the field
- Potential Decision Rules
  - Land ownership/tenancy makes a difference
  - Decisions based on STP
    - IF STP > 30 then apply 0 or very minimal amount (intentional mining)
    - IF STP is >20 and <30 then apply removal rates
    - IF STP is <20 then apply removal + build (build rate?)
  - VRT apply P to meet management goals
Using yield monitor data to look back...
4 Years of P Removal

$P_2O_5$ (lbs/ac)

- 15 to 45
- 45 to 65
- 65 to 85
- 85 to 105
- 105 to 130

In-Furrow Placement of Enhanced Efficiency Urea Fertilizers in Wheat

Lucas Haag, Northwest Area Agronomist
*K-State Northwest Research-Extension Center, Colby*

Alan Schlegel, Agronomist-in-Charge
*Southwest Research-Extension Center, Tribune*

Dorivar Ruiz-Diaz, Soil Fertility Specialist
*Department of Agronomy, Manhattan*
In-Furrow Urea

- Current K-State recommendations state no urea should be placed in-furrow with seed
- In the Northern Plains data would suggest that some low levels of urea in-furrow are safe
- New products on the market: ESN, NBPT, etc. may provide some level of safety

In-Furrow Urea Materials and Methods

- Western Sites: No-till into chem-fallow, Certified CSU-Byrd, target 1.05 million seeds/ac
- Hunter 2017: No-till into wheat stubble, Certified KSU-Larry
- Hunter 2018: No-till into soybean stubble, Cert. KSU-Larry
- Treatments (in addition to grower practice):
  - 10, 20, 30, 60 lbs/ac N as ESN, NBPT, or Urea
  - MAP to get 10 lbs/ac N (91 lbs/ac of MAP)
  - Control
- Locations:
  - Tribune, Colby, Herndon, and Hunter (2017)
- Measurements
  - Fall stand count
  - Spring Vigor
  - Head Counts
  - Grain Yield and Protein
Visual – Mitchell Co. 2/9/17

60 lb/acre Urea  60 lb/acre ESN

Visual response to in-furrow MAP – Mitchell Co. 2/9/17

Control  MAP for 10 lbs of N (91 lb/acre material)
Conclusions

• Some indication that ESN and NBPT coated urea provides some safety over untreated urea if used in-furrow
• Not enough site-years yet to truly evaluate the risk of various levels
• Low levels (10 lb/ac) of ESN urea appear to offer minimal risk

In-Furrow Humic Acid in Grain Sorghum – Year 1

Lucas Haag, Northwest Area Agronomist, NWREC-Colby
Jeanne Falk Jones, Sunflower Dist. Agronomist
Alan Schlegel, Agronomist-in-Charge, SWREC-Tribune
Rationale

- We had received reports of in-furrow applications of humic acid reducing the occurrence of iron chlorosis

Materials and Methods

- Two Products Used
  - Raw Humic Acid (Soil Boost), 72% humic acid
  - Humic DG (The Andersons), 70% humic acid
- IDC Tolerant Hybrid, P87P06 used
- Planted in 30” rows, 45,000 seed drop
- 4 Replications per location
- 4 Locations
  - Colby, Wallace 1, Wallace2, Wallace 3
## In-Furrow Rates

<table>
<thead>
<tr>
<th>Product</th>
<th>30&quot; Rate</th>
<th>Equivalent 10&quot; Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Chipped Humic Acid</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>120</td>
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<tr>
<td></td>
<td>70</td>
<td>210</td>
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<tr>
<td>Humic DG</td>
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<td></td>
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<td>63</td>
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<td></td>
<td>28</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>105</td>
</tr>
</tbody>
</table>

## Locations - Wallace

![Image of soil fertility update with locations #1, #2, #3 showing ratings of 8.0, 8.2, 7.8]
Locations - Colby

Results – Wallace 1

2018 Soil Fertility Update
Results – Wallace 2

2016 Sorghum Humic Acid - Wallace 2

Grain Sorghum Yield (bu/ac)

Control
Raw @ 10 lb/ac
Raw @ 20 lb/ac
Raw @ 30 lb/ac
Raw @ 40 lb/ac
Raw @ 50 lb/ac
DG @ 7 lb/ac
DG @ 14 lb/ac
DG @ 21 lb/ac
DG @ 28 lb/ac
DG @ 35 lb/ac

n.s. p=0.4709

Results – Wallace 3

2016 Sorghum Humic Acid - Wallace 3

Grain Sorghum Yield (bu/ac)

Control
Raw @ 10 lb/ac
Raw @ 20 lb/ac
Raw @ 30 lb/ac
Raw @ 40 lb/ac
Raw @ 50 lb/ac
DG @ 7 lb/ac
DG @ 14 lb/ac
DG @ 21 lb/ac
DG @ 28 lb/ac
DG @ 35 lb/ac

n.s. p=0.7895
Summary

• In year one of the study, across four locations, we did not see a statistical or numerical response to in-furrow applications of humic acid in grain yield or IDC score
• We are considering extending the study another year
Questions?
Ihaag@ksu.edu / 785.462.6281
Twitter: @LucasAHaag
www.northwest.ksu.edu/agronomy

Wheat Protein

Lucas Haag, Ph.D., Northwest Area Agronomist
K-State Northwest Research-Extension Center
Colby, Kansas
Importance of Protein

• Bread rises because of yeast and gluten
• Gluten – is a “sticky” protein complex
• Proteins are made up of amino acids
• Amino acids are stored in the seed as they are the foundation of plant growth (seedlings)

Amino acid arginine (C₆H₁₂N₄O₂)

Amino nitrogen N

32% by weight is N
Making Protein

- Nitrogen is a basic component of amino acids
- Amino acids are the building blocks of plant growth and are stored for seedling development
- The protein in the kernel is generally considered to be laid down first before most of the carbohydrates

Nitrogen Uptake

- Most of the N used by wheat is taken up before flowering and later moved to the kernel during grain fill
- Photosynthesis occurring during grain fill largely determines kernel starch contents
Plant Use of N

**Figure 2.** Approximate cereal growth stages and N application timing effects on yield and protein. This figure was modified from its original (4).

Jones et al., Montana State Univ. EB0206

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N supply effects on Grain Yield and Protein

**Figure 1.** The response of wheat yield and grain protein to increasing N (1).

Jones et al., Montana State Univ. EB0206
USDA-ARS Central Great Plains Research Station, Akron, Colorado

**Wet and Cool**

**Dry and Hot**

N rate, lbs/acre

Wheat grain yield, bushels/acre

1995
1996
1997
1998

11.3 P
11.6 P
12.5 P
13.2 P
13.6 P
14.8 P
16.5 P
17.2 P

“The dilution effect”

K-STATE
Research and Extension

2018 Soil Fertility Update
Wheat Grain Protein, %

protein = 15.169 - 0.088 (bu/acre) \( R^2 = 0.40 \)

protein = 17.903 - 0.082 (bu/acre) \( R^2 = 0.64 \)

protein = 18.086 - 0.11173 (bu/ac) \( R^2 = 0.72 \)
ARS-Akron Wheat Proteins versus Yield 1996-2009

Wheat Grain protein %

ARS-Akron Wheat Proteins versus Yield 1996-2009

Wheat Grain rel-yield % of maximum

N sufficient for 90% of maximum yield

N insufficient for 90% of maximum yields

2011 Crop Year

All plots received 30 pounds N at seeding

<table>
<thead>
<tr>
<th>N added Feekes 9</th>
<th>Randolph Yield</th>
<th>Randolph Protein</th>
<th>Rossville Yield</th>
<th>Rossville Protein</th>
<th>Scandia Yield</th>
<th>Scandia Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>39</td>
<td>12.2</td>
<td>52</td>
<td>12.2</td>
<td>20</td>
<td>13.9</td>
</tr>
<tr>
<td>25</td>
<td>38</td>
<td>11.9</td>
<td>58</td>
<td>12.6</td>
<td>23</td>
<td>15.3</td>
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<tr>
<td>50</td>
<td>40</td>
<td>12.1</td>
<td>55</td>
<td>13.1</td>
<td>23</td>
<td>16.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>N added Feekes 9</th>
<th>Gypsum Yield</th>
<th>Gypsum Protein</th>
<th>Nfarm F Yield</th>
<th>Nfarm F Protein</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>34</td>
<td>13.6</td>
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<td>60</td>
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<tr>
<td>90</td>
<td>38</td>
<td>16.3</td>
<td>65</td>
<td>15.6</td>
</tr>
</tbody>
</table>

2012 Crop Year

2018 Soil Fertility Update
What Role Does Variety Play?

• Anyone who wants to have a conversation about varieties and protein without talking yield isn’t really having a conversation

• Varietal differences have been difficult to identify, takes large datasets

• Work by CSU and others has looked at Grain Protein Deviation as a potential indicator
### CSU Variety Database Protein Ratings for common Kansas Varieties

<table>
<thead>
<tr>
<th>Northwest Varieties</th>
<th>Protein Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avery</td>
<td>7</td>
</tr>
<tr>
<td>Brawl CL Plus</td>
<td>1</td>
</tr>
<tr>
<td>Byrd</td>
<td>7</td>
</tr>
<tr>
<td>Hatcher</td>
<td>8</td>
</tr>
<tr>
<td>Langin</td>
<td>6</td>
</tr>
<tr>
<td>SY Monument</td>
<td>5</td>
</tr>
<tr>
<td>TAM114</td>
<td>3</td>
</tr>
<tr>
<td>WB-Grainfield</td>
<td>6</td>
</tr>
<tr>
<td>Tatanka</td>
<td>7</td>
</tr>
<tr>
<td>LCS Chrome</td>
<td>4</td>
</tr>
<tr>
<td>T158</td>
<td>4</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>North Central Varieties</th>
<th>Protein Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winterhawk</td>
<td>5</td>
</tr>
<tr>
<td>SY Wolf</td>
<td>4</td>
</tr>
<tr>
<td>Overley</td>
<td>1</td>
</tr>
<tr>
<td>KanMark</td>
<td>5</td>
</tr>
<tr>
<td>Larry</td>
<td>5</td>
</tr>
<tr>
<td>SY Monument</td>
<td>5</td>
</tr>
<tr>
<td>TAM114</td>
<td>3</td>
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<td>WB-Grainfield</td>
<td>6</td>
</tr>
<tr>
<td>WB-Cedar</td>
<td>3</td>
</tr>
<tr>
<td>WB-4458</td>
<td>2</td>
</tr>
</tbody>
</table>

Relative grain protein content (grain protein deviation), 1=very high to 9=very low
Closing Thoughts on Protein

• Selecting a variety with a good protein score doesn’t mean you can get by with less N
• Varieties with a good protein score will still be affected by dilution at high yields
• Protein can be used as a valuable post-hoc evaluation of your N program
  – If protein is consistently less than 11.5% then you are leaving yield on the table!

Protein Control Module

ENVIRONMENT MANAGEMENT VARIETY
Challenges to Protein Management

• Semi-arid environment
  – Timing of N is key to maximizing protein response
  – Need moisture to move the N
    • Slow release N?

• Are you going to get paid?

Other Thoughts for 2018 Crop Planning

• Good 2017 wheat, with low protein (<11.5)
• In some areas a record fall 2017 crop
• Wheat yield potential >>> Top-dress Decisions
• Environmental Effects on Applying N
• Even at current prices, broad sweeping reductions in fertilizer application without any guiding information could cost you money