Reaching the 300 bu/A Corn Yield Threshold

What Have We Done?

What Do We Need To Do?

Dr. Harold F. Reetz
International Plant Nutrition Institute
Monticello, Illinois
Thank you!

- For the 2009 Fluid Fellow Award
High Yield Corn Production:

Where have we been, what have we learned, where are we going, what do we need to know ???

• 1970s --- Presentation to NFSA on High Yield Corn Production
• 2010 --- Presentation to FFF Fluid Forum on High Yield Corn Production
Growing Population Means Growing Need for Food, Feed, Fiber, and Fuel from Crop Production
The tools used may be different, but the site-specific management concept still fits.

In some cases, each field may be a management zone.

The High Yield Management Concepts Fit Small Farms…

….or Large Farms…
Land availability is most often the primary limiting resource.
The most productive land is already being used. Higher yields improve efficiency.
Percent of total global harvested cereal area attributable to each crop: 2007

- Wheat, 31.08
- Maize, 22.57
- Barley, 8.09
- Rice, paddy, 22.40
- Sorghum, 6.26
- Rye, 0.99
- Oats, 1.71
- Quinoa, 0.01
- Mixed grain, 0.26
- Millet, 5.12
- Triticale, 0.53
- Buckwheat, 0.42
- Canary seed, 0.04
- Cereals, nes, 0.45
- Fonio, 0.07

FAO, 2008
Our Task:
To use emerging technology combined with proven science to continue to feed a growing world population

Our Approach:
Grow more yield per unit of land and do it at a higher profit by lowering unit production costs
The Global Production Challenge

Double 2007 grain production by 2030

Rob Fraley
Monsanto
Sources of Increased Yield Potential

Potential yield - Realized Yield =

- Profit opportunity for farmers
- Food for another 2.5 billion people
- Relief for the environment
  - more land for buffer strips and wetlands
  - more land for rainforests and recreation
  - high nutrient use efficiency
- Growth opportunity for agribusiness and rural communities
Hybrid-Maize Model

A user friendly simulation model developed for on-farm use ... site specific attainable yields & N needs

http://www.hybridmaize.unl.edu/
The Situation has Changed

- Goal has increased – raising the bar – new challenges
- New tools
  - New genetics
  - New products
  - New equipment
  - New data
Ultimate Goal: Maximize Profit

As a crop manager, you know your customers are relying on you to maximize their profits per acre.
Goal: Maximum Corn Profit

- Profit = Production value – Input costs
Projections of world maize yields

Bending yield lines upward is a huge challenge and will require cooperation across disciplines, geographies, and sectors.
U. S. Corn Yield Trend & Need

Breaking the 1.8 barrier will require our
best agronomic science + best agronomic management
Field Scale to Global Scale
---One Field at a Time

• *Site-specific management applied at the local scale throughout the world creates aggregated benefits at the global scale.*

• As more farmers adopt better practices through site-specific management and *better-informed decision-making on each field*, the larger-scale results can be realized for *agriculture* and *society* in general, *locally* and *globally.*
“Right” Nutrient Management

Precision farming …and the various component technologies of precision farming…are essential to “Right” management…to the 4R System for Fertilizer BMPs.

Right Source
Right Rate
Right Place
Right Time
The Global Framework for 4R Nutrient Management---
---with *Performance Indicators*

See [www.ipni.net](http://www.ipni.net) for more information
Right Source

- Ensure a balanced supply of ALL essential nutrients, considering soil-supplied, commercial fertilizer, and manure sources, and considering characteristics of specific products, to meet daily plant needs throughout the growing season.

- Tools
  - Regular scouting of fields to monitor for deficiencies
  - Plant analysis in-season to check plant nutrient status
  - Modeling of crop growth and nutrient needs
  - Placement choices may affect best source choice
  - Slow-release fertilizer products; additives
    - ESN, Agrotain, N-Serve, Nutri-Sphere, etc.
Fig. 1. Abbreviated general N cycle. Because the N cycle is more complex than other nutrients, timing discussions are most commonly centered on N fertilizer.
Right Rate

- Assess soil nutrient supply and plant demand.

- Tools
  - Soil testing and plant analysis
  - Remote sensing
  - Yield monitor data
  - GIS mapping and analysis
    - *ArcGIS, FarmWorks, GeoAgro, etc.*
  - Data integration and interpretation; modeling
    - *Hybrid-Maize; Maize-N*
  - GIS analysis
    - *Grid or zone sampling*
    - *Field level nutrient budget and GIS analysis*
  - Variable-rate application
VRT - Variable Rate Technology

Field average is not good enough…”fine-tune” management for high yields.
Interactions for Right Rate

Fig. 1. High yields of corn are obtained with less N when other nutrients, such as K, are present in adequate concentrations (Ohio). Balanced nutrition is key to improving yields and minimizing N fertilizer loss. SOURCE: Murrell and Munson. 1999. Better Crops 83(3):28–31.
On-Farm Research

- Building a local database
- Fine-tuning recommendations

Kdnvr-kint.shp

Plot Rate 1

Plot Rate 2

0
108
152
180
212
244
275
305
325
332
361

0.1 0 0.1 0.2 Miles
Are Our Soil Test Goals Adequate for High Yield Systems?

<table>
<thead>
<tr>
<th>Treatment</th>
<th>P&lt;sub&gt;1&lt;/sub&gt; Soil Test (ppm)</th>
<th>K Soil Test (ppm)</th>
<th>Corn Yield (bu/A)</th>
<th>P&lt;sub&gt;1&lt;/sub&gt; Soil Test (ppm)</th>
<th>K Soil Test (ppm)</th>
<th>Soybean Yield (bu/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard P and K Soil Tests</td>
<td>20</td>
<td>161</td>
<td>152</td>
<td>32</td>
<td>184</td>
<td>57</td>
</tr>
<tr>
<td>High P and K Soil Tests</td>
<td>32</td>
<td>237</td>
<td>190</td>
<td>41</td>
<td>222</td>
<td>57</td>
</tr>
</tbody>
</table>

38 bu/A (2.3 T/ha) more corn!!
Grid Sampling vs. Field Average

640 acres --- Central Illinois

Based on over 1 million soil sample points

(Bullock, IL, BETTER CROPS)
Right Time

• Assess dynamics of crop uptake, soil supply, and logistics of field operations. Determine timing of nutrient loss risks.

• Tools
  – Plant and soil analysis
    • *With GPS, GIS, VRT application*
  – Nutrient sensing
    • *Soil sensors --- pH, K, organic matter, etc.*
    • *Greenseeker*
    • *SPAD, Cardy meter, color charts*
  – Weather monitoring
    • *Simulation models*
  – Integrated remote sensing and GIS analysis
Uptake Timing

Know the timing of nutrient uptake throughout the growing season.

Fig 2. Corn N uptake throughout the growing season (SOURCE: Ritchie et al., 1993).
Right Place

• Recognize **root-soil dynamics**. Manage spatial variability within the field to meet site-specific **crop needs** and to **limit potential losses** from the field.

• Tools
  – Models
  – GIS database and maps
  – Digital soil survey
  – RTK guidance and placement systems
Managing K Variability

- **Field Average**
  Soil test: 170 ppm
- **Total Applied:**
  None

- **Site-Specific**
  Soil Test Range: 111 – 279 ppm
  Total K Applied: 10032 lb K (4550 kg K)

35 bu/A more corn!
Plant Uptake Varies with Depth

Percentage of Phosphorus Uptake by Corn from Different Depths in Selected Soils.

<table>
<thead>
<tr>
<th>Soil Depth (in)</th>
<th>Miami Silt loam</th>
<th>Dodge Silt Loam</th>
<th>Parr Silt loam</th>
<th>Kewaunee Silty-clay loam</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6</td>
<td>36.4</td>
<td>43.1</td>
<td>27.0</td>
<td>19.4</td>
</tr>
<tr>
<td>6-12</td>
<td>45.9</td>
<td>33.3</td>
<td>23.7</td>
<td>41.8</td>
</tr>
<tr>
<td>12-18</td>
<td>6.0</td>
<td>11.7</td>
<td>12.1</td>
<td>21.8</td>
</tr>
<tr>
<td>18-24</td>
<td>5.1</td>
<td>8.4</td>
<td>6.5</td>
<td>17.0</td>
</tr>
<tr>
<td>24-30</td>
<td>6.6</td>
<td>3.5</td>
<td>30.8</td>
<td>---</td>
</tr>
</tbody>
</table>

Source: Murdock and Englebert (1958)

1. Affected by tillage, moisture/drainage, fertilizer placement, etc.
2. Genetic modification of root system since this research was done.

Has the pattern changed?
Interactions are Important

The right source, rate, time, and place are interdependent considerations in selecting the proper management for any individual site.

The 4Rs work together for best management.
Think “Systems” Management

• Right management
  – Components interact for management decisions.

• “System” considers:
  – all component practices,
  – the data (information).
  – Results of the management decisions.
    • Agronomic responses (yield).
    • Economic evaluation.
    • Environmental consequences.

• Where do fluids fit?
  – Timing
  – Placement
  – Source
  – Rate control
Conservation Impact of High Yield Systems

...build nutrient management plans around the concept of right source, right rate, right place, right time...

...manage for high yields on our more productive lands, so that we can reduce the need to put marginal land into production...

USDA-NRCS Chief, Dave White
National Association of Conservation Districts Annual Convention
Orlando, Florida, February, 2010
“…whoever makes two ears of corn, or two blades of grass to grow where only one grew before, deserves better of mankind, and does more essential service to his country than the whole race of politicians put together.“

--- from Gulliver’s Travels
Early passion for high yield corn

Illinois 4-H High Yield Contest---1965

Iroquois County Winner

146 bu/A
Maximum Yield Think Tank---Indiana mid-1970’s
“Fine tuning . . . removing the next limiting factor”

W. L. Nelson
Purdue Extension
185 bu/A 1st year
Purdue 300/100 Project
After 3 years 235/85
300 bu/A Producers – 1970s & 1980s

Researchers
• Roy Flannery – New Jersey (Rutgers)
• Sterling Olsen – Colorado State U.
• Fred Welch – U. of Illinois
• Bob Lambert – U. of Illinois

Farmers
• Herman Warsaw – Illinois - 370 bu/A
• Roy Lynn, Jr. – Michigan – 321 bu/A
• Schmidt Brothers – Nebraska – 306 bu/A
• Francis Childs – Iowa – 393 bu/A (?)
Fred Welch
University of Illinois

307 bu/A
Herman Warsaw---
---World Record Corn Producer

370 bu/A = 23.2 metric tons/ha in 1985
# Soil Tests on Herman Warsaw’s 338 bu/A Field 1978

## TABLE 1. Soil test results collected from Herman Warsaw’s farm in March 1978.

<table>
<thead>
<tr>
<th></th>
<th>Sample depth, inches</th>
<th>0-3”</th>
<th>3-6”</th>
<th>6-9”</th>
<th>9-12”</th>
<th>12-18”</th>
<th>18-24”</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P-1, lb/A</strong></td>
<td>Normal production area</td>
<td>202</td>
<td>134</td>
<td>76</td>
<td>38</td>
<td>28</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>High yield-lighter subsoil</td>
<td>234</td>
<td>192</td>
<td>58</td>
<td>20</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>High yield-darker subsoil</td>
<td>252</td>
<td>204</td>
<td>108</td>
<td>42</td>
<td>44</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Fence row sample</td>
<td>44</td>
<td>26</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td><strong>K, lb/A</strong></td>
<td>Normal production area</td>
<td>914</td>
<td>470</td>
<td>346</td>
<td>348</td>
<td>366</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>High yield-lighter subsoil</td>
<td>740</td>
<td>404</td>
<td>270</td>
<td>232</td>
<td>300</td>
<td>382</td>
</tr>
<tr>
<td></td>
<td>High yield-darker subsoil</td>
<td>1,400</td>
<td>556</td>
<td>412</td>
<td>332</td>
<td>328</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td>Fence row sample</td>
<td>652</td>
<td>452</td>
<td>320</td>
<td>338</td>
<td>284</td>
<td>262</td>
</tr>
<tr>
<td><strong>O.M., %</strong></td>
<td>Normal production area</td>
<td>6.6</td>
<td>5.4</td>
<td>5.5</td>
<td>5.4</td>
<td>4.1</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>High yield-lighter subsoil</td>
<td>5.9</td>
<td>5.7</td>
<td>4.9</td>
<td>4.9</td>
<td>3.2</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>High yield-darker subsoil</td>
<td>4.7</td>
<td>4.3</td>
<td>4.0</td>
<td>3.7</td>
<td>4.3</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>Fence row sample</td>
<td>5.8</td>
<td>4.5</td>
<td>4.0</td>
<td>3.3</td>
<td>2.7</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>Normal production area</td>
<td>5.5</td>
<td>5.7</td>
<td>5.7</td>
<td>5.6</td>
<td>5.8</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>High yield-lighter subsoil</td>
<td>5.0</td>
<td>5.5</td>
<td>5.8</td>
<td>6.1</td>
<td>6.1</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td>High yield-darker subsoil</td>
<td>5.2</td>
<td>5.7</td>
<td>5.6</td>
<td>5.5</td>
<td>5.3</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>Fence row sample</td>
<td>6.0</td>
<td>5.9</td>
<td>6.0</td>
<td>5.8</td>
<td>6.0</td>
<td>6.7</td>
</tr>
</tbody>
</table>
Table 2 shows the soil test results from samples collected in 1985, the year Warsaw produced the 370 bu/A yield. P and K tests are well above University of Illinois recommendations. Nitrogen applied that year was approximately 485 lb/A, compared to the recommended level of 444 lb/A (based on 1.2 lb N per bushel of expected yield).
Was his 370 bu/A system profitable?

Table 3 shows a partial budget for the production costs on the record-breaking field. The 370 bu/A yield would be $925 at $2.50/A; $1125 at $3.00/bu. In fact, breakeven price for out-of-pocket costs was $1.25/bu; $1.60/bu if land charge is included. Yes, it was a very profitable system.
Warsaw’s Secret ….

- Farm plan designed for specific soil, climate, and management system
- Plan was site-specific…using the right management for the right reasons in the right place at the right time
- Concept fits anywhere in the world on any crop and soil management system
- “There is no better fertilizer than a farmer's footsteps”
Francis Childs - Manchester, IA
National Corn Growers Assoc. Champion: 97 & 98

- 1997: 332 bu/A
- 1998: 338 bu/A
- 1999: (393 bu/A)

1/1000 Acre
44 ears
Moving Toward Higher Yields

154 bu/A (10.3 T/ha) Soybeans
---Kip Cullers, Missouri 2007

Also a champion corn grower

High yields require working with the details to fine-tune management practices.
Building a Local Management Database

High-Tech Tools for Site-Specific Crop Nutrient Management

- Grid sampling guided by GPS gives more accurate soil test data.
- Variable rate fertilizer application can improve efficiency.
- Variable rate seeding, variety changes, and starter can adjust for soil properties and productivity.
- Crop scouting with new technology improves yields records.
- On-the-go yield monitors can quickly track variability in the field.
Integrating Data from Precision Ag

Precision Agriculture tools include more than equipment. The real power of precision ag is in decision support --- integrating data, models, GIS maps, etc., to support better-informed management decisions.
Consider the Whole System

Precision farming technology helps to **systematically** include all components to define the best fertilizer management system.

The real power of precision technology is in using **GIS analysis** to determine the **interactions** among data layers.

- use with research results
- make **better-informed, site-specific** decisions.
Field-Average Management Is Not Good Enough

- Over-fertilize low yielding areas
- Under-fertilize high yielding areas
- Each year of field average management increases variability and potentially decreases productivity
Reviving High Yield Management

- Increased world demand
- Increased farmer awareness
- Untapped research information
- Better awareness of opportunity through site-specific management
- Better-trained dealers and farmers
- On-farm research
- More efficient use of resources and inputs
Management “Team”

- Farmer
- Resource providers
  - Landowners, farm managers
  - Investors
- Input suppliers
  - Seed, fertilizer, chemicals, machinery
- Information suppliers
  - NRCS, Extension, industry
  - Publications, meetings, field days, internet
- Markets
  - Grain companies, other farmers, consumers
Management & Physical Factors

Analysis Tools

Fertilizer Map

Profit Map
  • Projected
  • Actual

Yield Map
Major Hurdles Ahead

- Lack of research on interactions
  - Correlation among layers of GIS
- Shortage of trained agronomists
  - Education
  - Continuing education
    - “Hands-on” field training
    - “Hands-on” computer training
    - Multi-tiered approach needed
  - CCA program is helping
- Need to revive MYR to set the bar for new genetics
- Need to revive MEY to study economic of new high yield systems management
Dare to Dream

Don’t hesitate to dream….be creative!

Danger in being too much in the reactive mode.

Bridge the gap between researchers and practitioners

Carry the science to the field.

Follow the dream….be proactive.

Be the facilitator of change---lead, *from in front or from behind*---but be a leader!
Soil Nutrient Resources

Are We Maintaining Our Base for the Future?
Mean organic C and total N profile mass by time period
IPNI/FAR Soil Test Change Project

Sample Locations 1960s

Sample Locations 2006
Sites for Subsoil Sampling from Archived and Map Validated Sites.

Dixon 1927 - Sampled by horizon
Ewing 1918 – Sampled by depth
LaMollie 1925 - Sampled by horizon
Lebanon 1927 - Sampled by horizon
Newton 1937 - Sampled by depth
Raleigh 1918 - Sampled by depth
Toledo 1927 - Sampled by horizon
Unionville 1927 - Sampled by horizon
West Salem 1927 - Sampled by horizon
Antioch 1927 - Sampled by horizon
Phosphate and Potassium Levels

Archived Soil Dixon 1927 by Horizon

Archived Soil Dixon 1927 by Horizon

Soil Horizon

Lbs per Acre

A1

A2

A3

B1

C1

C2

Ave P

Ave K

0 50 100 150 200 250 300

117 180 201 209 235 211 82 265
Dekalb County

P1 Chart

K Chart

ISNT Chart
Sites for Subsoil Sampling from Archived and Map Validated Sites.

Dixon 1927 - Sampled by horizon
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West Salem 1927 - Sampled by horizon
Antioch 1927 - Sampled by horizon
Better Technology – Better Data

• Developments in technology combining GIS, sensors, record-keeping, and monitoring of various parameters.
• Better data means *better-informed decisions*
Information Management

- Assemble a database for each field
  - Soil survey---digitized if possible
  - Yield history---data and GIS maps
  - Weather data
  - Soil test and plant analysis
  - Fertilizer application---data and GIS maps
  - Production practice records
  - Scouting reports
  - Harvest data
    - Yield, moisture, test weight, quality
  - Data storage, backups, analysis
- Record of history
- “Roadmap” for the future
Think “Systems” Management

• Right management requires thinking about how all of the components, and the decisions to be made about managing the crop, interact to produce the final product.

• A “System” considers all component practices, the data (information), and the results---agronomic responses (such as yield), economic evaluation, and environmental consequences of the management decisions.
You Can’t Afford to Wait

• Build high-yield management systems NOW!
• Putting a high-yield system in place prepares for the good years…so you can participate!
• New genetics and new technology are raising the bar.
• The average farmer is heading out-of-business in many areas.
• We work with 3 kinds of farmers:
  – Some *make* things happen
  – Some *watch* things happen
  – Some *wonder* what happened!
Focus on cutting costs per unit of production by managing fertilizer and other inputs to grow higher yields.

What are the advantages for fluids in high yield systems?
Sometimes you have to dig deep for the answers!
Dare to Dream!!

In your dreams.

Source: AutoFarm Ad, *Agricultural Technology/Irrigation*, October 2007
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