WHAT DOES IT TAKE TO GROW CORN AT ITS YIELD POTENTIAL?

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Crop yield potential (Ymax)

What is it?
Theoretically achievable yield solely determined by genetic characteristics and climate (solar radiation, temperature).

How to measure it?
(a) Calculated from components of yield and radiation use efficiency.
(b) Measured in fully-controlled, small-scale experiment in which all biotic and abiotic stresses (water, nutrients, pests) are eliminated.
(b) Estimated by crop simulation models.

How to increase & utilize it?
(a) Genetics: breeding/germplasm improvement
(b) Management: optimization of planting date in relation to variation in Ymax that is due to the seasonal pattern of radiation and temperature
(c) Management: minimize abiotic/biotic stresses and crop loss
U.S. Corn Yields 1964 - 2001

Grain yield (bu/acre)

- $b = 1.74$ bu/acre per year
- $R^2 = 0.78$

Source: Annual USDA cropping practices surveys of >2000 farms
Corn Yield Trends in Iowa and Nebraska

IOWA: rainfed corn

- Contest winners 1966-1991
  - 124 kg/ha/yr
  - 2.0 bu/A/yr
- State average
  - 102 kg/ha/yr
  - 1.6 bu/A/yr

NEBRASKA: irrigated corn

- Contest winners 1992-2002
  - 1246 kg/ha/yr
  - 19.8 bu/A/yr
- State average
  - 102 kg/ha/yr
  - 1.6 bu/A/yr
Yield potential and yield gaps

Yield potential Water-limited yield Actual yield

Gap 1

Gap 2

Yield potential:
- Solar radiation
- Temperature
- Genotype
- Plant density

Water-limited yield with available water supply:

Other limiting factors:
- Nutrients
- Weeds
- Pests
- Others

Actual yield with available water supply
To achieve yield potential of an environment:

- Utilize the entire growing season
  (= optimal planting date and variety choice)
- Optimize plant population
- Grow the crop with minimal possible abiotic and biotic stresses (nutrients, water, pests)
# Ecological Intensification of Maize-based Cropping Systems

<table>
<thead>
<tr>
<th>Contribution</th>
<th>Research Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timothy J. Arkebauer</td>
<td>Environmental crop physiology</td>
</tr>
<tr>
<td>Kenneth G. Cassman</td>
<td>Crop physiology and plant nutrition</td>
</tr>
<tr>
<td>Rhae A. Drijber</td>
<td>Soil microbial ecology</td>
</tr>
<tr>
<td>Achim Dobermann</td>
<td>Soil fertility and plant nutrition</td>
</tr>
<tr>
<td>John L. Lindquist</td>
<td>Corn ecophysiology &amp; modeling</td>
</tr>
<tr>
<td>John P. Markwell</td>
<td>Biochemistry</td>
</tr>
<tr>
<td>Lenis A. Nelson</td>
<td>Plant breeding and crop production</td>
</tr>
<tr>
<td>James E. Specht</td>
<td>Soybean genetics</td>
</tr>
<tr>
<td>Daniel T. Walters</td>
<td>Soil fertility, C sequestration</td>
</tr>
<tr>
<td>Haishun Yang</td>
<td>Soil and crop modeling</td>
</tr>
</tbody>
</table>

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Nebraska Corn Board, Nebraska Soybean Board, United Soybean Board
Ecological Intensification of Maize-based Cropping Systems

- Understand the yield potential of corn and soybean and how it is affected by management.
- Develop a scientific basis for extrapolation to other locations based on understanding of the key yield-determining processes.
- Develop practical technologies for managing systems at 80-90% of the yield potential.
- Conduct integrated assessment of productivity, profitability, input use efficiency, energy balance, and environmental consequences.
## EI Lincoln, NE: Treatments

### Crop rotation (main plots)
- **CC**: Continuous corn
- **CS**: Corn – Soybean (corn in odd years)
- **SC**: Soybean – Corn (corn in even years)

### Plant Population (subplots)
- **P1**: Corn: 30k, 28-31,000 plants/acre
- **P2**: Corn: 37k, 35-41,000 plants/acre
- **P3**: Corn: 44k, 38-47,000 plants/acre

### Management Intensity (sub-subplots)
- **M1**: Recommended fertilizer management based on soil testing. Maize: UNL recommendation for 200 bu/acre yield goal
- **M2**: Intensive management aimed at yields close to yield potential. Maize yield goal 300 bu/acre, higher NPK rates, micronutrients, N in 3-4 splits
El Lincoln, NE: Management

Soil: Kennebec silt loam
pH 5.2-6.0, 2.5-3.0% SOM, 60-70 ppm Bray-1 P, 300-400 ppm K

Lime: applied in fall 1999 and fall 2001 to increase pH to about 6.0-6.5

Irrigation: 1999-2000 surface drip tape
2001-2002 sub-surface drip tape
2003 sprinkler

Tillage: 1999-2002 fall disk & moldboard plow, spring field cultivator/disk
2003 fall disk & mini-moldboard plow, spring field cultivator

Hybrids: 1999-2000 Pioneer 33A14
2001-2002 Pioneer 33P67
2003 Pioneer 31N28
El Lincoln, NE: Fertilizer Program

Continuous corn (CC):
- CC - M1: 170 lb N/acre (190 kg/ha), no P, no K
- CC - M2: 270 lb N/acre (300 kg/ha)*,
  - 92 lb P₂O₅/acre (45 kg P/ha) and
  - 92 lb K₂O/acre (85 kg K/ha)

Corn after soybean (CS):
- CS - M1: 116 lb N/acre (130 kg/ha), no P, no K
- CS - M2: 219 lb N/acre (246 kg/ha),
  - 92 lb P₂O₅/acre (45 kg P/ha) and
  - 92 lb K₂O/acre (85 kg K/ha)

N splitting: M1: pre-plant & V6    M2: pre-plant, V6, V10, V12-VT
*CC-M2: includes fall application of about 45 lb N/acre as UAN (since 2001)

Average rates applied during 1999-2003
EI Lincoln, NE: Yields

<table>
<thead>
<tr>
<th>Density</th>
<th>Fertilizer</th>
<th>Average</th>
<th>Grain yield 1999-2003 (bu/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1999</td>
</tr>
<tr>
<td><strong>Continuous corn</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>M1</td>
<td>217</td>
<td>214</td>
</tr>
<tr>
<td>P2/3</td>
<td>M2</td>
<td>247</td>
<td>229</td>
</tr>
<tr>
<td><strong>Corn after soybean</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>M1</td>
<td>236</td>
<td>219</td>
</tr>
<tr>
<td>P2/3</td>
<td>M2</td>
<td>256</td>
<td>257</td>
</tr>
</tbody>
</table>

M2 treatment with highest-yielding plant density:
- P2: 2000 and 2003
Seed Yield Components as Affected by Plant Density and Nutrient Management

1000 SEEDS / m²

<table>
<thead>
<tr>
<th>Population</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.0</td>
<td>3.5</td>
<td>4.0</td>
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<tr>
<td></td>
<td>4.5</td>
<td>5.0</td>
<td>5.5</td>
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</table>

SEEDS / EAR

<table>
<thead>
<tr>
<th>Population</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>300</td>
<td>350</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>500</td>
<td>550</td>
</tr>
</tbody>
</table>

1000 SEED WEIGHT, g

<table>
<thead>
<tr>
<th>Population</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
<td>24</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>36</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>44</td>
<td>48</td>
<td>52</td>
</tr>
</tbody>
</table>

P1 = 30,000 p/acre
P2 = 37,000 p/acre
P3 = 44,000 p/acre
Corn Grain Weight per Ear as Affected by Plant Density and Nutrient Management

Plant density (1000 plants/ha)

Grain dry weight (g/ear)

1999-2001 (Pioneer 33A14 and 33P67, M1 and M2)

M1, $R^2=0.902$

M2, $R^2=0.933$

CS and CC, 1999-2001
Cumulative Carbon and Nitrogen Input from Crop Residues, 1999-2002

Total input of aboveground crop residues during 4 years (1999 to 2002). Belowground residues add another 15-20% of aboveground biomass inputs.
Soil CO\textsubscript{2} Emissions in 2003 (sprinkler irrigated)

Cumulative emission of CO\textsubscript{2}-C during the growing season:
- CC-P1-M1 5200 kg C/ha
- CC-P3-M2 5600 kg C/ha
- CS-P1-M1 3600 kg C/ha
- CS-P3-M2 4200 kg C/ha

Vented closed chamber + photoacoustic trace gas analyzer, fluxes measured a.m.
EI Lincoln, NE: N rates

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>N rate 1999-2003 (lb N/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1999</td>
</tr>
<tr>
<td><strong>Continuous corn</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>170</td>
<td>181</td>
</tr>
<tr>
<td>M2</td>
<td>268</td>
<td>324</td>
</tr>
<tr>
<td><strong>Corn after soybean</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>116</td>
<td>116</td>
</tr>
<tr>
<td>M2</td>
<td>224</td>
<td>201</td>
</tr>
</tbody>
</table>

M1: pre-plant & V6      M2: pre-plant, V6, V10, V12-VT
M1: no adjustment made yet for increasing SOM over time
CC-M2: 2002 includes fall application of 65 lb N/acre in 2001 (UAN, on residue)
2003 includes fall application of 45 lb N/acre in 2002 (UAN, on residue)

Nitrogen rates applied to corn during 1999-2003
### El Lincoln, NE: N Use Efficiency

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>M1</td>
<td>170</td>
<td>217</td>
<td>1.28</td>
<td>1.18 1.25 1.11 1.59</td>
</tr>
<tr>
<td>P2/3</td>
<td>M2</td>
<td>268</td>
<td>247</td>
<td>0.94</td>
<td>0.71 0.94 0.94 1.18</td>
</tr>
</tbody>
</table>

#### Continuous corn

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>M1</td>
<td>116</td>
<td>236</td>
<td>2.04</td>
<td>1.89 1.83 1.98 2.06 2.31</td>
</tr>
<tr>
<td>P2/3</td>
<td>M2</td>
<td>224</td>
<td>256</td>
<td>1.16</td>
<td>1.28 0.93 1.16 1.26 1.28</td>
</tr>
</tbody>
</table>

#### Corn after soybean


- 1999-2000: surface drip tape
- 2001-2002: sub-surface drip tape
- 2003: sprinkler irrigation
## El Lincoln, NE: Nutrient Uptake and Removal

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (bu/acre)</th>
<th>Total uptake (lb per bu yield)</th>
<th>Net removal with grain (lb per bu yield)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N</td>
<td>P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt;</td>
</tr>
<tr>
<td>CC-P1-M1</td>
<td>208</td>
<td>0.98</td>
<td>0.45</td>
</tr>
<tr>
<td>CC-P3-M2</td>
<td>239</td>
<td>1.12</td>
<td>0.42</td>
</tr>
<tr>
<td>CS-P1-M1</td>
<td>222</td>
<td>1.02</td>
<td>0.44</td>
</tr>
<tr>
<td>CS-P3-M2</td>
<td>243</td>
<td>1.10</td>
<td>0.43</td>
</tr>
</tbody>
</table>

Lincoln El: Treatment averages of 1999-2002
# El Lincoln, NE: Row Spacing Study 2003

<table>
<thead>
<tr>
<th>Row spacing inches</th>
<th>Target density plants/acre</th>
<th>Actual density plants/acre</th>
<th>Grain yield bu/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>30000</td>
<td>29714</td>
<td>294.8</td>
</tr>
<tr>
<td>15</td>
<td>30000</td>
<td>29297</td>
<td>314.3</td>
</tr>
<tr>
<td>15</td>
<td>40000</td>
<td>37725</td>
<td>316.1</td>
</tr>
<tr>
<td>15</td>
<td>50000</td>
<td>42229</td>
<td>301.2</td>
</tr>
</tbody>
</table>

Row spacing x plant density study, Lincoln, NE, 2003

- **Hybrid:** 31N28 (119 d)
- **Management:** irrigated, very high nutrient rates (520 lb N, 210 P$_2$O$_5$, 210 K$_2$O)
- **Planting:** 13-May
- **Emergence:** 22-May
- **Maturity:** 25-Sep
Summary 1

- Average climatic corn yield potential about 300 bu/acre for most of the Corn Belt, with an amplitude of perhaps ±30 to 70 bu/acre, depending on location and year.


- Yield increased with increasing plant density, provided nutrient supply was also increased. Highest yields: 35-40k.

- Total uptake of N and K per bushel yield increased at high yield levels. Net grain nutrient removal per unit yield was not affected by management or yield level.
Summary 2

- Large amounts of crop residue C and N are returned to the soil. Amounts and proportions of C and N in residue vary widely among the cropping systems evaluated. Impact on soil C and N dynamics is likely to be significant in terms of sequestering C and N.

- Very high NUE in M1 treatments, improving over time in M2.

- Yields of at least 80% of the yield potential are achievable and profitable under production conditions, without excessive input use.