Current Impact of Changes in Corn Plant Density

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Corn yield in Wisconsin since 1866

- Top Hybrid = 2.6 bu/A yr
- Arlington = 2.7 bu/A yr
- Marshfield = 2.6 bu/A yr

(source: UW Hybrid Trials)

- 1866 to 1930 = 0.0 bu/A yr
- 1931 to 1995 = 1.4 bu/A yr
- 1996 to 2006 = 1.9 bu/A yr

(source: USDA Statistics)

The yield march continues …

Open Pollinated Era

Hybrid Era

Transgenic Era
Annual Increase (bu/ A yr) in Wisconsin Counties

Source: Mitchell, NASS 1986-2006
Corn Yield Progress in Wisconsin Top Producer in Category (1983-2006)

All = 3.6 bu/A yr

- PEPS Cash Corn = 4.8 bu/A yr
- PEPS Livestock Corn = 4.4 bu/A yr
- NCGA Non Irrigated = 4.8 bu/A yr
- NCGA No Till/Strip Till Non Irrigated = 4.5 bu/A yr
- NCGA No Till/Strip Till Irrigated = 3.0 bu/A yr
- NCGA Irrigated = 3.2 bu/A yr
- NCGA Ridge Till Irrigated = 3.3 bu/A yr
- NCGA Ridge Till Non Irrigated = 3.5 bu/A yr

Data derived from grower yield contests (PEPS = 1987 to 2006; NCGA = 1983 to 2006)
Yield Contest Winners – Plant at High Populations

Herman Warsaw, Saybrook, IL
- 1985: 370 bu/ A
- 36,000 plants/ A

Ken Beaver, Sterling, NE
- 2001: 319 bu/ A
- 39,000 plants/ A

Francis Childs, Manchester, IA
- 2002 World Record = 442 bu/ A
- 30+ years continuous corn
- 45,000 plants/ A
### Summary of estimates of grain yield gain and genetic gain of corn hybrids.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Yield gain</th>
<th>Genetic gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frey</td>
<td>1971</td>
<td>---</td>
<td>56</td>
</tr>
<tr>
<td>Darrah</td>
<td>1973</td>
<td>1.6</td>
<td>33</td>
</tr>
<tr>
<td>Russell – plot</td>
<td>1974</td>
<td>1.2</td>
<td>79</td>
</tr>
<tr>
<td>Russell – state</td>
<td>1974</td>
<td>1.2</td>
<td>63</td>
</tr>
<tr>
<td>Duvick</td>
<td>1977</td>
<td>1.4</td>
<td>57</td>
</tr>
<tr>
<td>Duvick</td>
<td>1977</td>
<td>1.4</td>
<td>60</td>
</tr>
<tr>
<td>Tapper – plot</td>
<td>1983</td>
<td>---</td>
<td>42</td>
</tr>
<tr>
<td>Tapper – machine</td>
<td>1983</td>
<td>---</td>
<td>67</td>
</tr>
<tr>
<td>Castleberry et al.</td>
<td>1984</td>
<td>1.8</td>
<td>75</td>
</tr>
<tr>
<td>Duvick</td>
<td>1984</td>
<td>1.6</td>
<td>89</td>
</tr>
<tr>
<td>Duvick</td>
<td>1984</td>
<td>1.6</td>
<td>71</td>
</tr>
<tr>
<td>Russell</td>
<td>1984</td>
<td>1.4</td>
<td>79</td>
</tr>
<tr>
<td>Russell</td>
<td>1984</td>
<td>1.4</td>
<td>56</td>
</tr>
</tbody>
</table>
Factors Contributing to Continued Corn Yield Gain

- Resistance to root and stalk lodging
  - Necessary for machine harvesting at higher plant densities
- Resistance to diseases - little data to support
- Resistance to insects
- Improvement of stay-green
  - Continuous improvement of 2nd ECB resistance (Duvick, 1984)
- Use of single-cross hybrids
- Resistance to barrenness
- Better pollen production
  - Production under higher population
- Earlier planting date
  - Better seed quality
  - Improved cold tolerance, better germination and emergence
- Use of commercial fertilizers
- Pest control techniques

Source: Duvik, 1987
http://corn.agronomy.wisc.edu
Rationale and Situation

• Optimum plant densities in corn have been steadily increasing. Wisconsin recommendations:
  ✓ 1930s: check-row planting 40 inches - 12,000 plants/A
  ✓ 1940s: 18,000 plants/A
  ✓ 1960s: 22,000 plants/A
  ✓ 1980s: 26,000 plants/A
  ✓ Current: 30,000 plants/A

• Many reasons given for observed increase. Many workers.
  ✓ Due to stress tolerance? (Tollenaar, 1989)
  ✓ Due to breeding? Duvick (1977)
  ✓ Due to better management? (Cardwell, 1982)

• Transgenic technologies have directly addressed the major constraint of plant lodging.
Yield Components of Corn

- Ears per area
- Number of rows
- Kernels per row
- Kernel number
- Kernel weight
- Grain
- Yield

http://corn.agronomy.wisc.edu

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University of Wisconsin - Agronomy
Potential Grain Yield Using Calculated Components

Assume 90,000 kernels/bu and 56 lb/bu; kernel mass = 282 mg

<table>
<thead>
<tr>
<th>Plant density (number/A)</th>
<th>Row spacing</th>
<th>Kernels/ear</th>
<th>Grain(lb)/ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 000</td>
<td>15 in</td>
<td>28</td>
<td>0.12</td>
</tr>
<tr>
<td>25 000</td>
<td>15 in</td>
<td>17</td>
<td>0.25</td>
</tr>
<tr>
<td>30 000</td>
<td>15 in</td>
<td>14</td>
<td>0.37</td>
</tr>
<tr>
<td>35 000</td>
<td>15 in</td>
<td>12</td>
<td>0.50</td>
</tr>
<tr>
<td>45 000</td>
<td>15 in</td>
<td>9</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>30 in</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Objectives

• To determine the optimum plant population for corn.
  ✓ Range: populations at 95% of optimum grain yield
  ✓ Model form
  ✓ Influence of time

Thanks to Pioneer Hi-Bred for use of data.
Materials and Methods

- **Total data set = 80,822 plots from 123 locations (631 hybrids)**
  - Wisconsin = 10,155 plots from 18 locations (275 hybrids)
  - Pioneer = 70,667 plots from 105 locations (350 hybrids)
  - GxE cases = 5571

- **Data cut conditions**
  - Trial had to have 4 or more plant density treatment levels
  - Plant density treatment range $\leq 28,000$ and $\geq 34,000$ plants/A

- **Traditional regression analysis**
  - Plots averaged across plant density treatment.
  - Means used for regression.
  - Max/Min kept within the treatment range.
  - What do you do about non significant cases?
    - Discard: too much variance, wrong model, or no relationship
    - Include

- **Proc Mixed analysis**
  - All data is included.
  - Year, Rep and Hybrid = random effects.
  - Fixed effects = Location, State, Maturity Belt or Hybrid Maturity
What Does the Relationship Between Grain Yield And Plant Density Look Like?

Total forms = 8; GxE n= 5571 cases
Trials with min PD≤ 28,000 and max PD≥ 34,000

- + Linear and - Quadratic: 15%
- + Linear: 26%
- + Quadratic: 5%
- None: 50%
- L= 1%
- Q= 2%
- L+Q= 1%
What Does the Relationship Between Grain Yield And Plant Density Look Like?

Total forms = 8; GxE n= 2373 cases
Trials with min PD≤ 24,000 and max PD≥ 40,000

Optimum
95% of optimum
23%

+ Linear and - Quadratic
26%

+ Quadratic
3%

None
44%

-L= 1%
-Q= 2%
-L+Q= 0%
The relationship between plant population and grain yield for Bt and non-Bt hybrids in Wisconsin during 2002-2004. Points represent individual plots.

\[ y \text{(Bt)} = 6.11 + 1.27x - 0.061x^2 \]
\[ R^2 = 0.86 \]

\[ y \text{(non-Bt)} = 5.90 + 1.20x - 0.061x^2 \]
\[ R^2 = 0.89 \]

Source: Stanger and Lauer, 2006

Annual grain yield increase at optimum plant density = 2.8 bu/A

\[ y = 0.42x - 813 \]

\[ R^2 = 0.38 \]
This ain’t good!
Risk Distributions

- Normal
- Low Standard Deviation
  - Low risk
- Positive Skew
  - High "upside" risk
- Positive Kurtosis
  - Infrequent extremes
- High Standard Deviation
  - High risk
- Negative Skew
  - High "downside" risk
- Negative Kurtosis
  - Frequent extremes
Analyzing risk with increasing plant density
(1987 to 2005 at Arlington, WI, n= 867 plots)

\[ y = -0.07x^2 + 5.69x + 77.67 \]

\[ R^2 = 0.24 \]
What about drought?

Chippewa Falls
September 19, 2003

Marshfield
October 6, 2003
Response of corn to plant density during 1988

Grain yield (bu/A)

Chippewa Falls

Marshfield

NS

18000
24000
30000
36000
Response of corn to plant density during 2003

Grain yield (bu/A)

- 26000
- 32000
- 44000
- 50000

Chippewa Falls

- NS

Marshfield

- NS
Should We Be Concerned About Seed Costs?

- Seed costs have dramatically increased over the last few years.
  - Transgenic hybrids and technology fees has driven the cost of seed
    - Premium hybrids cost $160-$180 per bag,
    - Ten years ago, premium seed would run about $80-$100 per bag.
- When corn prices are low farmers are concerned about the cost of all inputs for corn production
  - High energy prices have
    - Increased fertilizer price
    - Increased gasoline/diesel/LP for field operations and grain drying after harvest.
  - Minimizing field operations (especially moving towards no-till), early planting date, and appropriate hybrid maturity selection are management options that reduce energy costs.
- Yield response of corn to plant density has increased over time.
- Ultimately, optimum plant density is affected by both seed cost and corn price.
Profitable N Rates

A range of N rates can produce profitable yields.

Economics clearly drives the profitable N rate.

- N: Corn price ratio
  - 0.05
  - 0.10
  - 0.15
  - 0.20

Net return to N ($/a)

CC - High Yield Potential Soils

N rate (lb/a)
# Price Ratio of Seed:Corn

(i.e. $/1000 seeds ÷ $/bu corn)

<table>
<thead>
<tr>
<th>Price of seed</th>
<th>Price of corn ($/bu)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$1.00</td>
</tr>
<tr>
<td>$/80 K bag</td>
<td></td>
</tr>
<tr>
<td>$/1000 seeds</td>
<td></td>
</tr>
<tr>
<td>$40</td>
<td>0.50</td>
</tr>
<tr>
<td>$60</td>
<td>0.75</td>
</tr>
<tr>
<td>$80</td>
<td>1.00</td>
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<tr>
<td>$100</td>
<td>1.25</td>
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<tr>
<td>$120</td>
<td>1.50</td>
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<td>$140</td>
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<tr>
<td>$160</td>
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<tr>
<td>$180</td>
<td>2.25</td>
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<tr>
<td>$200</td>
<td>2.50</td>
</tr>
<tr>
<td>$220</td>
<td>2.75</td>
</tr>
</tbody>
</table>
As Seed:Corn price ratios increase, economic optimum plant density decreases ...

- Symbols represent the economic optimum return to plant density (EOPD).
- Error bars are the low and high ends of the range of profitability (within $1/A of EOPD) at each seed:corn price ratio.
Bt-CB corn should be grown at higher plant density than conventional corn...
Conclusions

• Optimum plant populations for grain yield are higher than currently recommended levels.
  ✓ At Arlington, optimum plant density has been annually increasing 420 plants/A
  ✓ Plant density at 95% of optimum has changed little.

• About half of the environments (46%) do not respond to plant population. But,
  ✓ High plant populations rarely reduce grain yield (<4%)
  ✓ Need to manage for the opportunities in a responsive environment.
Guidelines for Choosing an Appropriate Plant Density for Corn

- May have the most potential to move a farmer from current yield levels.
  - Might be the place to start for moving off the “yield plateau.”
- Optimum plant densities seem to be increasing as newer hybrids are commercialized.
  - Grain yield increases to plant densities of 39,400 plants/A.
- The EOPD for seed:corn price ratios between 0.5 and 1.5 is 29,800 to 36,200 plants/A.
  - The plant density of 32,700 plants/A is within $1.00 of the EOPD for ratios between 0.5 and 1.5.
- In general, silage yield increases as plant density increases.
  - A trade-off exists where quality decreases with increasing population.
  - Thus, the EOPD is the same for corn grown for silage or grain.
  - Corn silage is often more valuable than grain, thus the EOPD follows more closely seed:corn price ratios less than 1.0.
One place to begin is evaluate your plant density for each field ...

Reference Strips for On-Farm Testing Plant Density

- Field specific
- At least one strip per field. Total of 3-4 strips per farm.
- Increase plant population 10% in one-strip.

✓ Plant majority of field to normal plant density
✓ Ideally 2-3 strips per field
Future Directions

• Mixed analysis of models
  ✓ Linear
  ✓ Quadratic
  ✓ Linear-Linear (Quadratic) segmented
  ✓ Linear-Plateau segmented
  ✓ Quadratic-Plateau segmented
  ✓ Negative exponential
  ✓ Carmer-Jakobs

• What is risk of higher plant populations?
• Economics of seed costs to grain prices
• What causes lodging?
The End of the Row - Questions?

Thanks for your attention!