Overview

- Introduction/Background
- Project Creation
- Plant density review
- Objectives
- Material and Methods
- Results and Discussion
- Summary
Background

- Grain and Livestock Farm
  - Mendota, IL
- Education
  - Associate of Science
    - Southwestern Community College; 1998-2000
    - Major: Agricultural Business
  - Bachelor of Science
    - Iowa State University; 2001-2003
    - Major: Agricultural Studies
    - Minor: Agronomy
  - Masters of Agronomy Program
    - Fall 2005-Current
Background

- Monsanto- Williamsburg, IA
  - 2003, Research Technician
  - 2004, Research Assistant

- Monsanto- Thomasboro, IL
  - 2008, ICB Coordinator
Project Creation

• Field research project during the 2008 growing season

• Plant density trial conducted

• Idea was to evaluate thinning of yield trial plots by looking at hybrid response to plant density
Project Creation

• Why??
  - Corn plant densities continue to rise in commercial agriculture
  - Private sector must evaluate new hybrids at higher densities
  - General interest in how hybrids respond to plant density
  - Monsanto’s commitment to double yield by 2030
Project Creation

- World population of over 9 billion by 2040
- U.S. planted 86.5 million acres of corn in 2009
- A 1.5% annual increase in corn grain yield is needed
- The last 30 yrs we have had a 1.3% annual increase
Project Creation

• Plant densities are going to play a significant role in doubling grain yield by 2030.
• Important to evaluate new hybrids at commercially recommended densities.
• Thinning of yield trial plots is a major job task involving many people and hours.
  – Is there a chance it could be reduced?
Plant Density Review

• Advancement in corn genetics has led to hybrids withstanding higher levels of stress
• Adoption of traits since the mid-90’s has given farmers additional measures to protect yield
• Research has shown that hybrids with Bt have increased yields
  - Singer et. al. showed 5-8% yield increase with Bt hybrids
  - Cox et. al. (2009) showed double and triple-stack hybrids yielded 2.7% more than their base genetics
Plant Density Review

- Abundance of plant density data available
- Data from recent years has shown that the optimum plant density has increased
  - University of Minnesota recommends target planting rate of 33,000 seeds/acre
  - Purdue University recommends no less than 30,000 plants/acre for a final stand
  - Iowa State University data in 2006 showed 36,000 seed/acre
  - Monsanto data shows 33,000-38,000 seeds/acre
Corn crop densities for states in the Corn Belt

![Bar chart showing corn crop densities for Illinois (IL), Indiana (IN), Iowa (IA), Minnesota (MN), Nebraska (NE), Ohio (OH), and Wisconsin (WI) from 1991 to 2009. The y-axis represents plants per acre, ranging from 0 to 35,000. Each state is plotted with five bars, one for each year, with different colors representing each year: 1991 (blue), 1995 (dark red), 2000 (light yellow), 2005 (light green), and 2009 (dark purple).]
Plant Density Review

- Research has shown that yields have increased when plant densities are increased.

- Continuing research will be vital to ensure farmers have knowledge of optimum planting densities.

- Private sector must test new hybrids under higher densities to see performance.

Effect of plant density by year averaged across locations, row widths and germplasm (figure from Monsanto, 2010).

Ear Growth Characteristics

- Companies characterize hybrids by ear type
  - Fixed (determinate)
  - Flexed (indeterminate)

- Why does ear type matter?
  - If a hybrid can truly flex then it could compensate for variations in plant density
  - Theory is as plant density is increased fixed-ear hybrids would yield better, conversely as plant density decreases flexed-ear hybrids would yield better
Ear Growth Characteristics

• Also important in the Western Corn Belt where water is limiting resource and plant densities are typically lower

• Very little scientific research comparing hybrid ear-type and their response to varying plant densities
  - Thomison and Jordan (1995) found that hybrid differences in ear growth had a small effect on yield response to density
  - Cox (1997) reported that ear type did not contribute much to hybrid variability for optimum plant density

• Interested in seeing if hybrid response to plant density varied by ear-type
Yield Components

- Four components
  - Plants per acre
  - Ears per plant
  - Kernels per ear
    - Kernels per row (KPR)
    - Kernel rows per ear (RPE)
  - Kernel weight
Kernel Rows per Ear (RPE)

- Determined between V5-V8 growth stages

- Will always be even because of the splitting of the ovules to produce two rows

- Mostly determined by genetics but early season stress can have negative impact
  - Subedi and Ma (2005) found that nitrogen deficiency before V8 caused substantial decrease in RPE as well as kernels per row

- Increasing plant density could potentially affect RPE for flexed-ear hybrids while fixed-ear hybrids would in theory continue to produce the maximum number of RPE
Kernels per Row (KPR)

- Varies much more due to environmental stresses
- Maximum KPR is determined just prior to pollination when ovule formation is complete
- Upwards of 1,000 potential ovules per ear
- Stresses leading up to V12 can reduce the KPR by reducing the number of ovules formed
- Stresses during and after silking can reduce the total number of kernels per ear
  - Select ovules are sacrificed so that the plant can supply others ovules
Kernels per Row (KPR)

- Flexed-ear hybrids in theory could compensate depending on the stress level from V5 to just prior to silking.

- Fixed-ear hybrids would not be able to respond to more favorable conditions.

- If fixed-ear hybrids respond to higher plant densities then it shows that they are able to set enough kernels to maximize yields under favorable conditions.
Kernel Weight

- Estimates show that 85% of the final yield is correlated with the total number of kernels and the final 15% is determined by the final kernel weight.

- Late-season stress caused by drought, insect, disease or loss of leaf area can severely reduce kernel weight.

- Studies have shown that as plant density is increased, kernel weight is decreased.
  - Lamm and Trooein (2001)
  - Cox (1996)
Monsanto testing footprint reaches hundreds of different environments
**Thinning**

- The removal of plants and plant competition within each plot
- Done prior to V6 growth stage
- Time consuming and costly on such a large scale
Thinning

• Research is very limited on effects of thinning
  - Hashemi et. al. showed that the greatest yield difference were when plant competition occurred between V5 and anthesis
  - Early-season competition (V5) had little effect on final grain yield
  - Nafziger showed that as thinning was delayed the ability for remaining plants to compensate decreased

• Within-row plant spacing and emergence could also affect final grain yield
Objectives

• Determine a range of plant density variability that could be tolerated without affecting yield comparison's among hybrids

• Look at effects of plant density on both fixed-ear and flexed-ear hybrids

• Determine if thinning could be reduced
Locations
<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Common Name (Taxonomic name),</th>
<th>Planting Date</th>
<th>Harvest Date</th>
<th>Fertilizer rates lbs/acre</th>
<th>Weed Control, Chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer City, IL</td>
<td>Ipava silt loam (fine, smectitic, mesic Aquic Argiudolls)</td>
<td>5 May</td>
<td>12 October</td>
<td>236 92 120</td>
<td>Bicep II, atrazine, callisto, cultivation</td>
</tr>
<tr>
<td>Bloomington, IL</td>
<td>Ipava silt loam (fine, smectitic, mesic Aquic Argiudolls)</td>
<td>5 May</td>
<td>17 October</td>
<td>170 40 120</td>
<td>Lumax, atrazine, callisto, cultivation</td>
</tr>
<tr>
<td>Thomasboro, IL</td>
<td>Drummer silty clay (fine-silty,mixed,superactive,mesic, Typic Endoaquolls)</td>
<td>4 May</td>
<td>3 October</td>
<td>290 NA* NA*</td>
<td>Harness Xtra, atrazine, callisto, option, cultivation</td>
</tr>
<tr>
<td>Oxford, IN</td>
<td>Darroch silt loam (fine-loamy, mixed, superactive mesic, Aquic argiudolls)</td>
<td>6 May</td>
<td>8 October</td>
<td>147.5 52 120</td>
<td>Degree Xtra, laudis, aatrex, cultivation</td>
</tr>
</tbody>
</table>
Planting Equipment
Experimental Design

- Split plot with whole plots in a RCB with two replications
- Densities were main plots
- Hybrids were sub-plots
- Density whole plots were completely randomized within replicates at each location and within each plant density, hybrids were randomized
Experimental Design

- Four locations
- Four hybrids
  - 113-115 RM, two fixed-ear, two flexed-ear
- Nine plant densities
  - 27,404-38,038 plants per acre
- Two replications
- Seeding rate of 42,000 seeds/acre
- Four 30-inch rows
  - All four rows thinned to final stand
- Data collected only on middle two rows
# Farmer City plot design

<table>
<thead>
<tr>
<th>27404</th>
<th>28631</th>
<th>29858</th>
<th>31085</th>
<th>33312</th>
<th>33539</th>
<th>35175</th>
<th>36402</th>
<th>38038</th>
</tr>
</thead>
</table>

| Col   | 1  | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  | 20  | 21  | 22  | 23  | 24  |
|-------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Rep1  | 3  | 64-24 | 63-42 | 64-44 | 64-79 | 63-42 | 64-79 | 64-24 | 64-79 | 64-24 | 63-42 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 63-42 | 63-42 |
| Rep2  | 4  | 64-24 | 63-42 | 64-44 | 65-44 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 63-42 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-79 | 64-79 |
| Rep2  | 5  | 64-24 | 63-42 | 64-79 | 64-24 | 64-79 | 64-24 | 63-42 | 64-79 | 64-24 | 64-79 | 64-24 | 63-42 | 63-42 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-79 |
| Rep2  | 6  | 64-24 | 63-42 | 64-79 | 63-42 | 64-24 | 64-79 | 63-42 | 64-24 | 64-79 | 63-42 | 64-24 | 63-42 | 63-42 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 |
| Rep2  | 7  | 64-24 | 64-79 | 64-24 | 65-44 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 |
| Rep2  | 8  | 63-42 | 65-44 | 64-24 | 63-42 | 64-79 | 64-24 | 64-79 | 64-24 | 65-44 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 |

| Rep1  | 3  | 64-24 | 63-42 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 | 64-24 | 64-79 |
|-------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
## Hybrids

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Relative maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>DKC63-42-Med Flex</td>
<td>113</td>
</tr>
<tr>
<td>DKC64-79- Flex</td>
<td>114</td>
</tr>
<tr>
<td>DKC64-24- Fixed</td>
<td>114</td>
</tr>
<tr>
<td>DKC65-44- Fixed</td>
<td>115</td>
</tr>
</tbody>
</table>

- Two fixed-ear, and two flexed-ear
- All hybrids contained Yieldgard VT triple trait combination
Field Data

- Stand counts
- Plant Height
- Stalk lodging
- Root lodging
- Harvest Data
  - Grain weight (lbs.)
  - Moisture
  - Test weight
Lab Data

- Six ears from center two rows collected
  - Used to collect RPE, KPR and kernel weight
- Kernels per row
  - Measured from base to tip
- Kernel rows per ear
  - Measured from center of ear
- Kernel weight
  - 100 seeds counted and weighed

16 Kernel Rows

14 Kernel Rows

Photo courtesy of: Elmore, R, 2006. Iowa State University Extension
2008 Weather

May - Oct 2008
National Climatic Data Center/NESDIS/NOAA

Precipitation

Temperature

Source
http://www.ncdc.noaa.gov oa/climate /research/2008/oct/6month.html
2008 Weather

2008 Monthly Temperatures
Departures from Average

2008 Monthly Precipitation & Snowfall
Departure from Average

Source: http://www.isws.illinois.edu/atmos/statecli/cuweather/index.htm
Results

• Traits analyzed
  - Yield
  - Moisture
  - Test weight
  - Kernel rows per ear
  - Kernels per row
  - 100 kernel weight
  - Stalk lodging
  - Root lodging
  - Plant height
Yield Results

† Means followed by same letter are not different
Yield Results

![Bar chart showing grain yield results for different hybrid-ear types.]

- **217AB+**
- **221A**
- **212B**
- **212B**

**Hybrid-Ear Type**

- **DKC63-42-Med Flex**
- **DKC64-79-Flex**
- **DKC64-24-Fixed**
- **DKC65-44-Fixed**

† Means followed by same letter are not different
Grain Moisture Results

† Means followed by same letter are not different
Grain Moisture Results

- DKC63-42 - Med Flex: 27.1A+
- DKC64-79 - Flex: 25.5C
- DKC64-24 - Fixed: 24.7D
- DKC65-44 - Fixed: 26.6B

† Means followed by same letter are not different.
Test Weight Results

Hybrid-Ear Type

† Means followed by same letter are not different
Kernel Rows per Ear

† Means followed by same letter are not different
Kernels per Row

† Means followed by same letter are not different
Kernels per Row

Hybrid-Ear Type

DKC63-42-Med Flex  DKC64-79-Flex  DKC64-24-Fixed  DKC65-44-Fixed

33.5A+  33.6A  31.3B  30.2C

† Means followed by same letter are not different
DKC65-44-Fixed Density: 27,412
DKC65-44-Fixed Density: 38,000
100 Kernel Weight

† Means followed by same letter are not different
## 100 Kernel Weight

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Grams/100K</th>
</tr>
</thead>
<tbody>
<tr>
<td>DKC64-24-Fixed</td>
<td>33.5A</td>
</tr>
<tr>
<td>DKC65-44-Fixed</td>
<td>33.3A</td>
</tr>
<tr>
<td>DKC64-79-Flex</td>
<td>33.0A</td>
</tr>
<tr>
<td>DKC63-42-Med Flex</td>
<td>31.8B</td>
</tr>
</tbody>
</table>

† Means followed by same letter are not different.
Root Lodging

† Means followed by same letter are not different
## Root Lodging

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Root Lodging Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>DKC64-79-Flex</td>
<td>2.1A</td>
</tr>
<tr>
<td>DKC63-42-Med Flex</td>
<td>1.9A</td>
</tr>
<tr>
<td>DKC64-24-Fixed</td>
<td>0.85B</td>
</tr>
<tr>
<td>DKC65-44-Fixed</td>
<td>0.22B</td>
</tr>
</tbody>
</table>
Conclusions

- No hybrid response to increasing density for:
  - Yield
  - Grain moisture
  - Test weight
  - Kernel row numbers
  - Kernels per ear
  - Kernel weight
  - Stalk lodging
  - Root lodging
  - Plant height
Conclusions

• The number of kernel rows per ear was less affected by density then was the number of kernels per row and kernel weights

• Difficult to conclude that a reduction in thinning could be warranted based on one year of data

• Could be worthwhile to continue to investigate if thinning could be reduced
  - If the range of plant densities can be increased without causing negative impact on yield comparisons
Conclusions

• This study showed that the two lowest densities limited the hybrids ability to yield and should be considered on the low end of what should be used to evaluate new hybrid performance

• Fixed-ear hybrids are not being given an advantage based on this data set

• Increasing density does not seem to favor either a fixed-ear or flexed-ear hybrid
Acknowledgements

• Iowa State University
• Drs. Elmore, Moore and Loynachan
• Dr. Mowers
• All of my colleagues at Monsanto
• Wife and family
Questions?