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Corn Plant Populations: A Critical Component in the Yield Equation

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Corn plant populations: A critical component in the yield equation

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Introduction

Hybrid development and yield advancements have primarily been associated with increasing stress tolerance, i.e. modern hybrids yield more under a resource-limited environment relative to older hybrids. Yield potential per acre has increased dramatically in the past fifty years, while the potential yield per plant has changed little, if any. Hybrids tolerate their neighbors better today and are therefore able to withstand higher plant densities while still producing an ear. Older hybrids have significant lodging and/or barrenness when planted at today's seeding rates. A significant portion of the observed yield increase over the last several decades is directly correlated with increased plant populations.

It takes high seeding rates paired with high yielding hybrids, that can tolerate increased plant-to-plant competition, to maximize yields. Iowa plant populations have increased approximately 425 plants per acre (ppa) per year since 2001.

Although plant populations continue to increase, producers and agronomists must consider whether the yield advantage of planting more seed is economically productive. Corn seed prices have increased dramatically. As seeding rates and seed prices increase, adding an additional unit of seed should be determined in light of whether the return is greater than the cost (Elmore, R. and L. Abendroth, 2008). In calculations made during February 2007, we used a corn price of $3.00 per bushel and seed prices ranging between $1.00 and $2.50 per 1,000 seed; this equated to $80 to $200 per 80,000 seed unit. Today, hybrids containing a triple stack of resistant traits are the highest priced seed on the market with retail price projected above $300 per bag this season.

Objectives

The objective of this research and presentation is to develop and present recommendations for Iowa producers and agronomists; as well as gain understanding of how and why yield responses to seeding rates vary across locations and years. The following questions will be addressed during this presentation:

1) How are plant population and yield potential related? How has yield potential been increased by corn breeders?
2) What is the optimum seeding rate (or plant population) for maximum yield?
3) What is the optimum seeding rate (or plant population) for economic yield?
4) What response variables (kernel weight, lodging, barrenness, etc.) are changed in addition to yield when seeding rates (or plant population) are increased?
5) What agronomic criteria are important and should be considered when selecting a seeding rate for a specific field?
6) What *environmental* criteria are important and should be considered when selecting a seeding rate for a specific field?

**Literature review: Influence of agronomic factors**

Plant population research has been conducted in surrounding states as well as Iowa. Here, we will examine research published in the last decade (1998-2008) in Illinois, Iowa, Michigan, Nebraska, and Wisconsin regarding some of the agronomic factors that may or may not affect seeding rate responsiveness. During the conference we will discuss our current research in Iowa (2006-2008) in light of these findings and identify differences and similarities.

**Seeding rate and nitrogen**

Irrigated research in northeast Nebraska (Shapiro and Wortmann, 2006) investigated yield responsiveness to plant population across two row widths (20 and 30 inches) and four nitrogen levels (0 to 225 pounds N per acre). Row width (20") and nitrogen increased yield when evaluated individually, by 4% and 24%, respectively. Surprisingly, plant population did not alter yield levels. Yield levels were relatively low (ranged from 114 to 168 bushels per acre (bpa)). Factors other than plant population likely limited yield at this site. The rate of nitrogen did not affect the yield response to plant population.

A recent publication (Ping et al., 2008) of research conducted in central Nebraska investigated variable rate nitrogen (pre-plant nitrogen rates ranged from 30 to 150 pounds per acre) and variable plant populations (range of 21,900 to 36,800 ppa) at two locations and two years based on within-field yield zones. Yield zones were predetermined using soil organic matter, seasonal NO₃ status, and six years of yield maps. Forty to fifty pounds of sidedress N were applied uniformly across all treatments within a site; only pre-plant N varied based on the yield zones. Neither variable rate nitrogen nor variable plant population improved grain yields (Table 1). In addition, the plant population response was similar at different N levels.

Nafziger (2007) continues to conduct plant population research in Illinois and found similar results in that the yield response to plant population is similar regardless of nitrogen rate.
Table 1. Nitrogen applied, established plant population, and grain yield of site-specific research with varying plant populations and nitrogen levels used (Ping et al., 2008).

<table>
<thead>
<tr>
<th>Nitrogen</th>
<th>Plant Population</th>
<th>Average N lbs/a</th>
<th>Average Plant Population ppa</th>
<th>Grain Yield bpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Year 2003</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uniform</td>
<td>Uniform</td>
<td>119 a</td>
<td>31900 a</td>
<td>246 bc</td>
</tr>
<tr>
<td>Variable</td>
<td>Uniform</td>
<td>106 b</td>
<td>31900 a</td>
<td>254 a</td>
</tr>
<tr>
<td>Uniform</td>
<td>Variable</td>
<td>119 a</td>
<td>31300 a</td>
<td>242 c</td>
</tr>
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<td>Variable</td>
<td>Variable</td>
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<td>251 bc</td>
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<tr>
<td>Year 2004</td>
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<td></td>
</tr>
<tr>
<td>Uniform</td>
<td>Uniform</td>
<td>176 a</td>
<td>32000 a</td>
<td>243 a</td>
</tr>
<tr>
<td>Variable</td>
<td>Uniform</td>
<td>173 a</td>
<td>32000 a</td>
<td>248 a</td>
</tr>
<tr>
<td>Uniform</td>
<td>Variable</td>
<td>176 a</td>
<td>30800 a</td>
<td>240 a</td>
</tr>
<tr>
<td>Variable</td>
<td>Variable</td>
<td>175 a</td>
<td>30800 a</td>
<td>246 a</td>
</tr>
</tbody>
</table>

Site 2

| Year 2003  |                  |                 |                              |                |
| Uniform    | Normal           | 219 a           | 32000 a                      | 213 a          |
| Variable   | Normal           | 218 a           | 32000 a                      | 211 a          |
| Uniform    | High             | 219 a           | 37000 a                      | 218 a          |
| Variable   | High             | 228 a           | 37000 a                      | 215 a          |

| Year 2004  |                  |                 |                              |                |
| Low        | Average over all N rates | 179 a | 27000 c | 194 a |
| Normal     | Average over all N rates | 179 a | 32000 b | 197 a |
| High       | Average over all N rates | 179 a | 37000 a | 192 a |

† Means within a column followed by the same letter are not different from one another.

Seeding rate and row spacing

Widdicombe and Thelen (2002) determined that the yield response to plant population (range from 23,000 to 36,000 ppa) did not differ based on row width (10, 20, or 30 inches) in Michigan. Farnham (2001a and 2001b) identified a similar response in Iowa where he investigated the impact of plant population (24,000 to 36,000 ppa) and row width (15 and 30 inches) across six locations for three years in Iowa. Overall, yield in 30" rows was greater than 15" rows, 167 and 164 bpa, respectively. Yet, the population response was similar in both row widths. In the research stated above (Shapiro and Wortmann, 2006), the yield response to plant population was consistent across both row widths (20 and 30 inches) also.
Seeding rate and crop rotation

Researchers in Michigan observed no seeding rate response to crop rotation, although five of the six sites were corn following soybean and one was following corn (Widdicombe and Thelen 2002). Nafziger (2007) does not think increased plant populations will benefit corn following corn more than corn following soybean.

Seeding rate and hybrid response

In Michigan, Widdicombe and Thelen (2002) evaluated six hybrids. The hybrids responded differently to plant population although the reason why could not be pinpointed. Hybrid characteristics evaluated were: different ear types (flex/fixed, determinate/indeterminate), plant height, and leaf orientation. Their inability to find causes for the difference in response to increasing plant populations for hybrids with differing characteristics is consistent with research reports from Illinois and Ohio.

Wisconsin researchers (Stranger & Lauer, 2006) investigated hybrids with (Bt) and without (non-Bt) resistance to European corn borer (ECB). Hybrids were grown at ten locations over three years. The plant population associated with the highest yield (i.e. maximum yield plant population (MYPP)) varied for Bt and non-Bt corn; 42,300 and 40,000 ppa, respectively (Figure 1). Yields were 4.2% greater when the Bt and non-Bt hybrids were planted at MYPP instead of the recommended 30,000 ppa. Although MYPP was at or above 40,000 ppa, the economically optimum plant population (EOPP) was 33,900 ppa. Maximum and economic yield differ by 8400 ppa (Bt corn) and 6100 ppa (non-Bt corn). Overall, Bt hybrids yielded more yet the plant population needed to maximize yield resulted in greater seed costs; these added costs nullified the extra yield coming from the Bt hybrid. Yield increases usually taper off as population rises.

Figure 1. Grain yield response of Bt and non-Bt hybrids to varying plant populations; Wisconsin 2002-2004 (Stanger and Lauer, 2006). Data in Figure represent individual plot data. Adapted with English units by Elmore and Abendroth.
above 30,000 ppa; a greater yield increase (bpa) occurs when the population is increased from 25,000 to 30,000 ppa, rather than 30,000 to 35,000 ppa.

**Overall environment**

Nafziger (2007) recommends 35,000 ppa for Illinois, given favorable growing conditions and productive soils. A lower population (between 25,000 and 30,000 ppa) is recommended on less productive soils or a fairly dry growing season. Yield is less responsive to plant population in yield limiting environments or during stressful growing seasons. Therefore, to optimize yield while managing risk, he recommends higher populations to take advantage of good weather rather than using lower populations to protect against unfavorable weather.

Farnham (2001a) investigated the impact of plant population (24,000 to 36,000 ppa) and row width (15” and 30”) in Iowa as discussed above. Yield and plant population were correlated linearly with one another at 10 of the 18 site-years; interestingly two of the ten site-years had a negative relationship. One site-year had a quadratic response and the remaining seven locations were nonresponsive to plant population. Farnham summarized these research findings along with additional data and published it the ISU Corn Planting Guide. Recommended plant populations varied based on location and year which suggests the optimum plant population will vary based on growing season and location.

**Stalk integrity and lodging**

Stranger and Lauer (2006) identified greater lodging (22% more) with non-Bt hybrids as population increased compared to Bt hybrids. Across all hybrids, lodging increased from 5% to 16% as plant population increased from 26,000 to 50,000 ppa. Stalk rot was a contributing factor at some locations.

**Summary points**

(1) Plant population responses are affected little by row widths or nitrogen rate

(2) Environment and location cause significant variation year to year in optimum plant population

(3) Plant lodging and degraded stalk quality may be greater with increased plant populations

(4) Grain yield reduces more when a population is used that is significantly below the optimum population rather than significantly above.

**Materials and methods – Iowa 2006 to 2008**


**Figure 2.** Seeding rate research conducted in Iowa during 2006-2008.

**Field management:** Fields were planted primarily between April 25 and May 15 during the three years. Conventional tillage (fall and/or spring) was used except at locations where tillage was a treatment (see below). Fertilizer and pesticides were applied appropriately to meet crop demand and control weed pressure. Yield was collected from the center two rows of each four-row plot.

**Plot design:** Plots were arranged in a randomized complete block design (RCBD) with three or four replications. Individual plot dimensions varied yet the majority of sites had plots that were 4 rows wide (10 feet) by 20 feet in length.

**Treatments:**

1. **Seeding rate:** Varied by location yet half of the locations (15 of 31 site years) had identical treatments: four seeding rates beginning at approximately 31000 seeds per acre and increasing incrementally to 47000 seeds per acre. The complete range in seeding rates used across all 31 locations was 21000 to 47000 seeds per acre.

2. **Management practices:** Seeding rate was evaluated alone and/or in combination with the following factors at some locations: tillage intensity (no-tillage, strip-tillage/conventional tillage, deep tillage), hybrid genetics (quantity of resistant traits) and relative maturity, cropping system (corn following corn and corn following soybean), and row width (30" spacing and twin row configuration).
Data collected:
Final plant population (ppa)
Percent root and stalk lodging at harvest (when present)
Percent barrenness (plant with an ear that has no kernels present)
Grain moisture (%) at harvest
Grain yield (bpa) adjusted to 15% moisture basis
Kernel weight (gram) per 100 kernels
Percent greensnap (where applicable)
Extended leaf plant height

Results and discussion
At the time of writing this proceeding, the collection and analysis of 2008 data has not been completed. Data will not be analyzed by year; instead all 31 site-years will be analyzed collectively to develop recommendations for Iowa. Yield and overall plant response to seeding rates/plant populations will be discussed relative to known agronomic and environmental criteria.

References
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