Yield Response of Corn to Plant Population in Indiana

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Summary:
Results from 80 field-scale trials around Indiana since 2008 suggest that maximum yield response to plant populations for 30-inch row corn grown under minimal to moderate stress conditions occurs at about 32,000 PLANTS per acre (ppa), equal to seeding rates of about 34,000 SEEDS per acre (spa). Corn grown under extremely challenging conditions (e.g., severe drought stress) may perform best at PLANT populations no higher than 22,800 ppa and perhaps as low as 21,000 ppa under truly severe growing conditions (actual drought, non-irrigated center pivot corners, non-irrigated sandy fields with minimal rainfall, etc.). Economic optimum populations are several thousand lower than the agronomic optimum.

One of the reasons that plant population is a popular topic in coffee shops, Internet chat rooms, the farm press, and crop seminars is that variable rate seeding technology is rapidly becoming a standard accessory on corn planters. Another factor that spurs the interest in plant populations is the not uncommon belief that today’s hybrids will respond dramatically to aggressively high plant populations. The harvest populations often associated with national corn yield contest winning entries, coffee shop scuttlebutt, and encouragement from seed company marketing efforts fuel this belief.

Corn plant populations have steadily increased in Indiana for almost 30 years at approximately 340 plants per acre (ppa) per year, based on historical data from the USDA National Agricultural Statistics Service (NASS). In 2015, the estimated average plant population statewide was approximately 29,950 PLANTS per acre (USDA-NASS, 2016). Considering stand establishment success typically ranges from 90% to 95%, average statewide seeding rate is between 32,500 and 34,300 seeds per acre (spa). Among the agronomic reasons for the steady annual increase plant populations has been the genetic improvement in overall stress tolerance that has resulted in a) ear size and kernel weight becoming less sensitive to the stress of thicker stands of corn and b) improved late-season stalk health.

Field-Scale Seeding Rate Trials

Background on the trials
This report summarizes our evaluations of yield response to plant population in 80 field-scale trials at Purdue Ag. Research Centers and with growers around the state conducted since 2008. The trials range in size from about 30 acres to 100 acres with commercial
field equipment used for all operations. Individual plots are typically length of field by twice the width of the combine header.

All of our trials to date have involved 30-inch row spacings, with the exception of a couple of twin-row trials. Five to six seeding rates are evaluated in each trial, ranging from about 25,000 to 42,000 in several thousand seed increments. Most of the trials are planted using variable seeding rate technologies and “prescription” seeding rate files that we develop prior to planting with our GIS software.

Grain yields at harvest are typically estimated with GPS-enabled yield monitors and the subsequent spatial yield data are processed after harvest with GIS software to eliminate any obvious non-treatment field variability that might unfairly skew the results (e.g., wet holes, gullies, planter skips, etc.). The statistical quality of the data from these field-scale trials is often better than what we can obtain with small-plot trials and thus yield response to plant population can be more accurately quantified.

Most of the trials to date have involved individual hybrids that represent those commonly grown by farmers, but 26 trials were split-planter comparisons using pairs of hybrids purposely chosen for their advertised differences in response to population. Most of the trials were conducted at the farmer’s normal nitrogen (N) fertilizer rate. However, 8 trials evaluated yield response to plant population at normal and higher than normal N rates.

For an individual trial, the grain yield response to plant population is determined using regression analysis and the response curve equation is then used to estimate grain yield for the trial in 250-plant increments from 20,000 to 40,000 ppa. The regression-based yield estimates are then aggregated with similarly calculated yield estimates from the other trials to determine the overall grain yield response to plant population.

Yield responses are analyzed with respect to PLANT populations rather than seeding rates because final populations are usually lower than the seeding rates due to germination problems, emergence problems, or subsequent plant mortality. Knowledge of your historical stand establishment success allows you to convert recommended final PLANT populations to SEEDING rates. In our 80 trials, the average percent stand (final population divided by seeding rate) is 95%, but ranges from 79% to 100%.

**Example:** If the recommended PLANT population is 30,000 and your historical percent stand is 95%, then the targeted SEEDING rate would be 30,000 divided by 0.95 or 31,579 SEEDS per acre.

To document historical percent stand establishment, growers should routinely calibrate the seed drop of their planters, count established plants no earlier than V6 (six visible leaf collars), and calculate percent stand in all of their fields every year to determine whether there is room for improvement in stand establishment. With today’s planter technologies and seed quality, aiming for a percent stand of no less than 95% is certainly achievable.

**Results of the trials**

Six of the 80 trials exhibited no yield response to plant populations greater than 22,000 to 26,000. For two of those trials, the apparent lack of yield response was due to excessive and unexplainable variability in the trial data. A third trial was severely stressed early in the season by excessively wet soil conditions. The other three trials were fairly uniform
with minimum stress and average yields, but there was no yield response to population. None of these trials were included in the subsequent aggregated data analysis.

The overall average yield level of the remaining 74 trials ranged from less than 100 bushels per acre (bpa) to nearly 250 bpa. Fourteen of the 80 trials were characterized as “severely stressed”, primarily due to extremes in soil moisture conditions (excessively wet or excessively dry). The results of these 14 trials provide us insight into the relative risk of higher seeding rates for crops under severe stress. Consequently, the results are presented separately for the bulk of the trials that experienced what we consider to be a "normal" range of growing conditions and the 14 trials that we characterized as “severely” stressed.

“Normal” Growing Conditions. For the 60 trials characterized as experiencing a “normal” range of growing conditions (minimal to moderate stress), yield response to plant population was quadratic (non-linear) in nature and maximum grain yield occurred at an average PLANT population of about 32,000 ppa (Fig. 1). Using an average percent stand of 95%, that would translate to a SEEDING rate of about 34,000 spa.

Individual optimum PLANT populations for the 60 trials ranged from just over 24,000 to just under 44,000 ppa with 68% of the trials ranging from 26,000 to 34,000 ppa (Fig. 2). We have not identified specific factors (hybrids, yield level, planting dates, rainfall, etc.) that correlate with the observed range of optimum populations.

There was a weak relationship between yield level and optimum plant population even though optimum yields among the 60 trials varied from 140 to nearly 250 bpa (Fig. 2). This result suggests that if spatial variability for productivity within a specific field was similar to this range, there may be minimal value to variable rate seeding.

Consequently, we believe the average agronomic optimum plant population of 32,000 ppa to be widely applicable throughout Indiana, except for severe stress conditions as noted in the next section.

Severe Stress Conditions. The average optimum PLANT population for the 14 severely stressed trials that averaged 116 bpa was 22,800 ppa (data not shown). At 95% stand establishment rate, the 22,800 PLANT population would equal a SEEDING rate of about 24,000 spa. Among the 14 individual trials, optimum PLANT populations ranged from 20,400 to 33,000 ppa and optimum yields ranged from 71 to 168 bpa (data not shown).

Economics. The “agronomic” optimum populations discussed in previous paragraphs are those that result in maximum grain yield, regardless of cost. Market price for grain, cost of seed, and the mathematical nature of the yield response curve all influence the marginal dollar return to seed. Table 1 provides estimates of economically optimum PLANT populations calculated for a range of grain prices and seed costs, using the average grain yield response curve in the 60 trials that represent “typical” growing conditions. The nearly "flat" nature of the yield response curve (Fig. 1), combined with the effects of market price and seed cost, results in economic populations several thousand lower than the agronomic optimum populations.

The estimates also factor in the extra seed cost associated with a 95% stand establishment rate. If percent stand in your fields is historically lower than that, then you either need to figure out how to improve the success of stand establishment or you need to use a higher
seeding rate just to achieve the desired economically optimum final stand and, therefore, incur even more seeding cost.

**Note:** Improving your historical stand establishment from 90 to 95% allows you to use less seed to achieve your desired final stand and would be worth about $6 per acre in saved seed costs at $300 per bag.

**Hybrid Comparisons.** Twenty-six of the 80 trials included a side by side comparison of pairs of hybrids that were characterized by the seed company as being either “less” or “more” responsive to plant populations. Among the 26 trials, 18 of them included different pairs of hybrids, 7 included the same pair, and 2 included another shared pair. The objective was to document whether or not such advertised hybrid population “ratings” resulted in significantly different optimum plant populations. Of the 26 such trials, only 10 trials resulted in significant differences between paired hybrids for yield response to plant population. Of those 10 trials, different pairs of hybrids were used in 7 trials, while three trials involved the same pair of hybrids. In five of the first seven trials, the hybrid rated as “more responsive” indeed had a higher optimum plant population, but for two of those seven trials, the hybrid rated as “less responsive” had a slightly higher optimum population than the “more responsive” hybrid (opposite of what the ratings would suggest). For the three trials that evaluated the same pair of hybrids, the optimum plant population for the “more responsive” hybrid was higher that that of the “less responsive” hybrid in 2 trials, but lower in the third trial. Furthermore, these same two hybrids were evaluated in 5 other trials in which they responded identically to plant population. Confused? The “take home” message from these 26 paired hybrid trials is that hybrid ratings for yield response to plant population are apparently not “black and white”.

**Effect of Nitrogen (N) Fertilizer Rate.** Eight of the 80 trials included both the farmer’s normal N rate and a rate from 50 to 75 lbs higher than normal with the objective of determining whether yield response to plant population might be influenced by N availability. However, yield response to plant population was not influenced by N rate in any of these eight field trials (data not shown).

**Summary**

Results from 80 field-scale trials around Indiana suggest that agronomic optimum (maximum yield) plant population for corn grown under typical yield levels and growing conditions is approximately 32,000 ppa or seeding rates of about 34,000 spa at 95% stand. The results further suggest that corn grown under severely stressful conditions may perform best at plant populations no higher than 22,800 ppa and perhaps as low as 21,000 ppa under truly severe growing conditions (actual drought, non-irrigated center pivot corners, non-irrigated sandy fields with minimal rainfall, etc.).

Economic optimum plant populations are several thousand ppa less than agronomic optimum plant populations because of the nearly “flat” yield response to population. The magnitude of the difference between agronomic and economic optimum plant populations is also influenced by grain price and seed cost.

There is little evidence from these trials that hybrids characterized as “more” responsive to population respond consistently differently to plant population than hybrids.
characterized as being “less” responsive. There is also no evidence from these trials that higher than normal N fertilizer rates influence yield response to plant population.

**On-Farm Field-Scale Seeding Rate Trials: We Need Your Help!**

The field-scale trials summarized in this report were scattered throughout the state and represent a wide range of growing conditions. However, more such trials are needed to better identify the possible effects of different growing conditions, hybrids, and N fertilization levels on yield responses to plant population. Field-scale on-farm seeding rate trials are simple to conduct if your planter is equipped with GPS-enabled variable rate controls because we can create a “prescription” file for the trial that “tells” the VR controller where to automatically change seeding rates during planting. With a bit more effort, on-farm seeding rate trials can also be conducted without variable rate controls.

We encourage you to consider collaborating with us to conduct field-scale seeding rate trials on your farm. These trials can be customized to include two or more nitrogen fertilizer rates or two hybrids. Such trials will help you better identify the “ballpark” optimum plant populations for your conditions and can also be used to evaluate yield response to plant population in different areas or “zones” within fields to help address the question about the relative merits of variable rate seeding.

If you would like to participate in one or more on-farm seeding rate trials with corn, please download the protocol for this at the following URL and contact Bob Nielsen (rnielsen@purdue.edu) for additional information.

http://www.agry.purdue.edu/ext/ofr/protocols/PurdueCornSeedingRateProtocol.pdf

**Acknowledgements**

The field-scale research summarized in this update has been supported, in part, by funds from the Indiana Corn Marketing Council, the Purdue Mary S. Rice Farm Fund, and the Indiana Certified Crop Adviser Program. Donation of seed corn by DuPont-Pioneer and Stine Seed Company for field trials at Purdue Ag. Research Centers is gratefully acknowledged. Finally, the collaboration of the participating farmers, crop consultants, retail agronomists, county Extension Educators, and Purdue Ag. Research Center personnel is gratefully acknowledged.

**Cited references**


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Figures & Table on following pages…
Fig. 1. Average grain yield response of corn (relative yield, 0 to 100%) to plant populations at harvest (plants per acre), based on the aggregated results of 60 field-scale trials conducted across Indiana from 2008 to 2015 that represented a normal range of growing conditions (minimal to moderate stress). The agronomic optimum population for this group of trials was 31,929 plants per acre at harvest with an average yield of 196 bushels per acre.

Fig. 2. Optimum plant population versus grain yield at the optimum population for each of 60 field-scale trials across Indiana from 2008 to 2015 that represented a normal range of growing conditions (minimal to moderate stress). The average optimum PLANT population was 31,929 ppa and 68% of the individual trial optimum PLANT populations were between 26,000 and 34,000 ppa (between the dark lines on the graph).
Table 1. PLANT populations that maximize marginal return to seed calculated with market grain price (per bu.) and seed cost (per 80,000 seed unit), based on average yield response to population in 60 Indiana trials that represent a common range of growing conditions (not severe stress conditions).

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NOTE: To calculate seeding rates from the values of this table, divide by your expected percent stand. For example, 29000 plants per acre divided by 95% stand = 29000 divided by 0.95 = 30,526 seeds per acre.