Purdue University Department of Agronomy

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Yield Response of Corn to Plant Population in Indiana

RL (Bob) Nielsen, Jim Camberato, & Jason Lee
Agronomy Department, Purdue University
West Lafayette, IN 47907
Nielsen's email: rnielsen@purdue.edu

Summary:
Results from 97 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 32,150 PLANTS per acre (ppa), equal to seeding rates of about 33,840 SEEDS per acre (spa). **Economic optimum populations are several thousand lower than the agronomic optimum.** 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 (e.g., actual drought, non-irrigated center pivot corners, non-irrigated sandy fields with minimal rainfall).

The cost of seed corn is the largest single variable input cost for most Indiana corn growers (Dobbins et al., 2019). Minimizing that cost involves a combination of shrewd purchasing skills and wise selection of seeding rates. This summary focuses on our recent research evaluating the yield responses of corn to plant populations in field scale trials conducted around the state of Indiana since 2008.

Reported corn plant populations have increased steadily in Indiana for the past several decades, at an annual increase of approximately 315 plants per acre (ppa) per year, based on historical data summarized by the USDA National Agricultural Statistics Service. In 2018, the average reported plant population for Indiana was approximately 30,400 PLANTS per acre (USDA-NASS, 2019). Considering stand establishment success typically ranges from 90% to 95%, the average reported population suggests that the average seeding rate statewide is 32,000 to 33,800 seeds per acre (spa). Among the agronomic factors that support the steady annual increase in 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 Plant Population Trials

Since 2008, we have conducted 97 field scale trials at Purdue Ag. Research Centers and in collaboration with growers around the state. Typical trial sizes ranged from 30 to 100 acres and commercial farming equipment was used for all field operations. Individual plots were typically length of field by twice the width of the combine header.

All of the trials involved 30-inch row spacings, with the exception of a couple of twin-row planter trials (data not included because too few trials). Five to six seeding rates were evaluated in each replicated trial, ranging from about 25,000 to about 42,000 spa. Most of the trials were planted using variable seeding rate technologies and “prescription” seeding rate files developed with GIS software prior to planting.

Most of the trials involved individual hybrids commonly grown by farmers, but 29 trials were split-planter comparisons using pairs of hybrids deliberately chosen for their advertised differences in response to population. For most of the trials, a single nitrogen (N) fertilizer rate, determined by the farmer’s normal N rate, was applied to all seeding rate treatments. However, 8 trials evaluated yield response to plant population at normal and higher than normal N rates.

Grain yields were estimated at harvest with commercial combines equipped with GPS-enabled yield monitors. The resulting spatial yield data were processed after harvest with GIS software to eliminate any obvious anomalies that might unfairly skew yields of individual plots (e.g., wet holes, gullies, planter skips).

The mean yield and grain moisture for each individual plot were calculated from yield monitor data extracted from each plot. The statistical quality of the data from these field scale trials was generally excellent and better than what we typically obtain with small-plot trials.

Eleven of the 97 trials exhibited no yield response to plant populations greater than 22,000 to 26,000 ppa. For two of those trials, the lack of yield response was due to unexplainable excessive variability in the trial data. A third trial was severely stressed early in the season by excessively wet soil conditions. The other eight trials were fairly uniform with minimum stress and average yields, but there was simply no yield response to population.

Average yields among the 97 trials ranged from less than 100 bushels per acre (bpa) to nearly 250 bpa. For each of those trials, the grain yield response to plant population was quantified using regression analysis.

We characterized fourteen of the trials as “severely stressed”, primarily due to extremes in soil moisture conditions (excessively wet or excessively dry). Yield response to population was clearly different for those "severely stressed" sites versus those that represented what we characterized as a "normal" range of growing conditions. 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. For each of the two groups of trials, regression-based yield estimates for the individual trials were aggregated to estimate the overall average grain yield response to plant population for "severely stressed" and "normal" growing conditions.

It is important to note that yield responses were analyzed with respect to actual PLANT populations rather than targeted seeding rates because the two are rarely identical in the field. 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 97 trials, the average percent stand (final population divided by seeding rate) was 95%, but ranged from 79% to 100%.

> ***Example:*** *If the recommended PLANT population is 30,000 ppa 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 a realistic goal.

Results of the trials

"Normal" Growing Conditions. For the bulk of the trials that represented a "normal" range of growing conditions (minimal to moderate stress), the Agronomic Optimum Plant Population[1] (AOPP) averaged 32,150 ppa (Fig. 1). Using an average percent stand of 95%, that would translate to a SEEDING rate of 33,840 spa.

The AOPP among the individual trials ranged from just under 24,000 to just under 44,000 ppa with 66% of the trials ranging from 26,000 to 35,000 ppa (Fig. 2). We were not able to identify specific factors (e.g., hybrids, yield level, planting dates, soil type, region of state, rainfall) that correlated well with the observed range of optimum populations.

There was essentially no relationship between yield level (field productivity) and AOPP for these 83 trials, even though yield levels among the trials varied from 140 to 245 bpa (Fig. 2). This result suggests that if spatial variability for grain yield within a specific field was within this range of yields, there may be minimal value to variable rate seeding.

To date, we have not been able to distinguish differences among regions of the state for average yield response to plant population. Consequently, we believe the average AOPP of 32,150 ppa to be widely applicable throughout Indiana, except for severe stress conditions as noted in the following sub-section.

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

Economics. Market price for grain, cost of seed, and the absence of a strong yield response to population all influence the marginal dollar return to seed. The non-linear nature of corn yield response to plant population (Fig. 1) results in **Economic Optimum Plant Populations (EOPP)** much lower than the AOPP. Table 1 provides estimates of EOPP calculated for a range of grain prices and seed costs, using the average grain yield response curve for the 83 trials that represent "typical" growing conditions in Indiana. The nearly "flat" nature of the yield response curve (Fig. 1), combined with the effects of

[1] **Definitions:** Agronomic Optimum Plant Population (AOPP) is that which maximizes grain yield per acre. Economic Optimum Plant Population (EOPP) is that which maximizes dollar return per acre.

market price and seed cost, results in economic populations (maximum dollar return) several thousand lower than the agronomic optimum populations.

The estimates for EOPP shown in Table 1 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-nine of the trials included a side by side comparison of pairs of hybrids characterized by their respective seed companies as being either "less" or "more" responsive to plant populations. The pairs of hybrids represented 8 different seed companies. Significant differences between purposely-paired hybrids for yield response to plant population were detected in only 12 of 29 trials (data not shown). In 3 of those 12 trials, the hybrid rated as "less responsive" actually had a slightly higher optimum population than the "more responsive" hybrid, i.e., opposite of what the seed company ratings would suggest (data not shown).

Confused? The "take home" message from these 29 paired hybrid trials is that hybrid ratings for yield response to plant population are apparently not "black and white". Consequently, hybrid choice may not be as critical when choosing a seeding rate, contrary to what is often advertised.

Effect of Nitrogen (N) Fertilizer Rate. Eight of the trials included both the farmer's normal N rate and a rate 50 to 75 lbs. higher than normal with the objective of determining whether yield response to plant population might be facilitated by higher N rates. 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 97 field scale trials around Indiana suggest that **agronomic optimum plant population** (i.e., maximum yield) for corn grown under typical yield levels and growing conditions is approximately 32,150 ppa, equal to seeding rates of about 33,840 spa based on 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" and non-linear yield response to population. The magnitude of the difference between agronomic and economic optimum plant populations is 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

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Figures & Table on following pages…

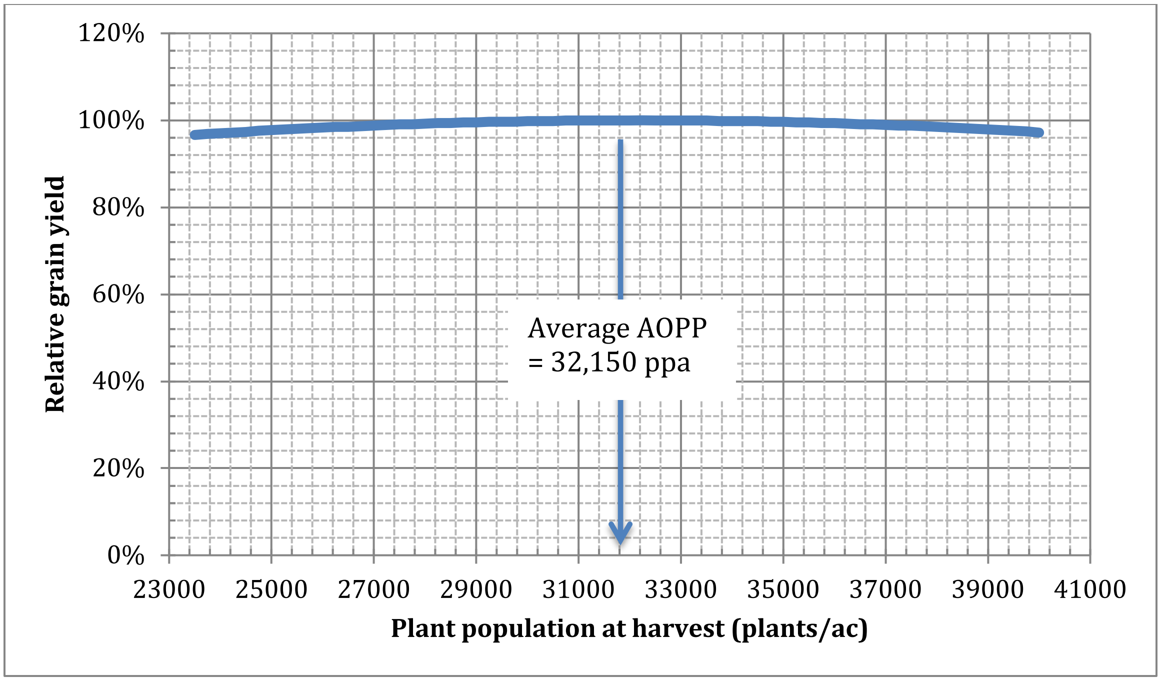

Fig. 1. Average grain yield response of corn (relative yield, 0 to 100%) to plant populations at harvest (plants per acre), based on the aggregated results of 83 field scale trials conducted across Indiana from 2008 to 2018 that represented a normal range of growing conditions (minimal to moderate stress). The agronomic optimum population (AOPP) for this group of trials was 32,150 plants per acre at harvest with an average yield of 195 bushels per acre.

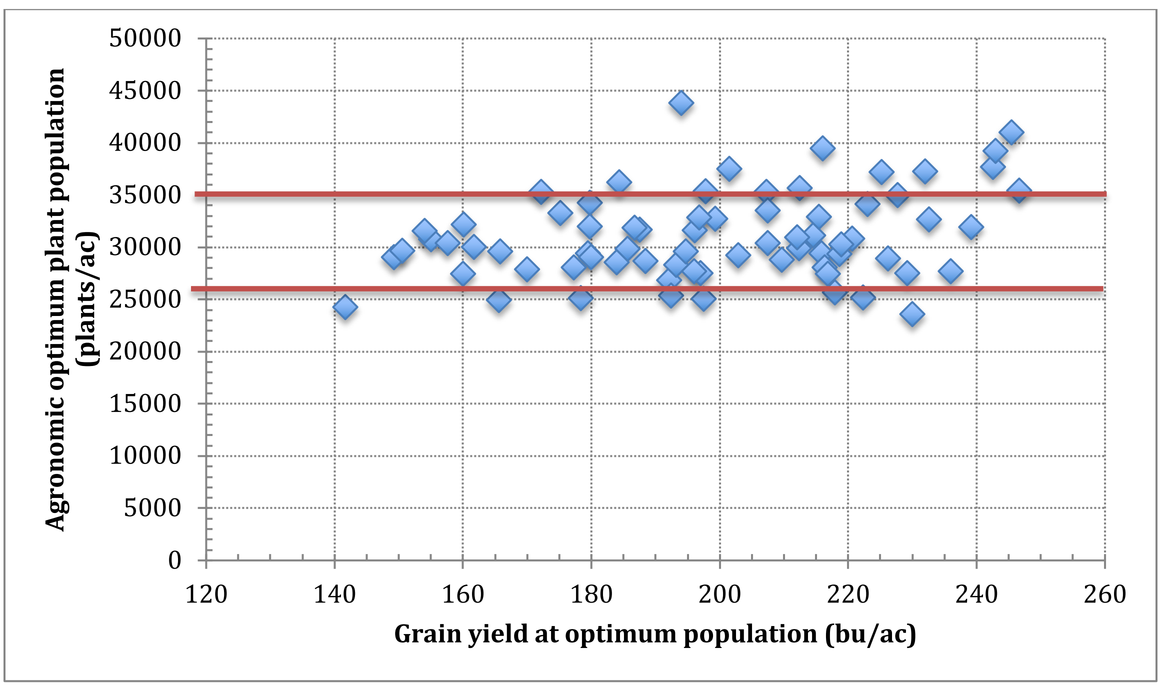

Fig. 2. Agronomic optimum plant population versus grain yield at the agronomic optimum population for each of 83 field scale trials across Indiana from 2008 to 2018 that represented a normal range of growing conditions (minimal to moderate stress). The average agronomic optimum PLANT population was 32,150 ppa and 66% of the individual trial optimum PLANT populations were between 26,000 and 35,000 ppa (between the dark lines on the graph).

Table 1. PLANT populations that maximize marginal return to seed (i.e., **economic optimum plant populations**) for combinations of market grain price per bushel and seed cost per 80,000 seed unit, based on average yield response to population in 83 Indiana trials conducted from 2008 – 2018 that represented a normal range of growing conditions (not severe stress conditions).

	Grain $ ➔							
Seed $ 🡻	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00	$5.50	$6.00
$150	27026	27880	28490	28947	29303	29588	29821	30015
$175	26172	27168	27880	28414	28829	29161	29433	29659
$200	25317	26456	27270	27880	28354	28734	29044	29303
$225	24463	25745	26660	27346	27880	28307	28656	28947
$250	23609	25033	26050	26812	27405	27880	28268	28591
$275	22755	24321	25440	26278	26931	27453	27880	28236
$300	21901	23609	24829	25745	26456	27026	27492	27880
$325	21047	22898	24219	25211	25982	26599	27103	27524

NOTE: To calculate seeding rates from the values in this table, divide by your expected percent stand. For example, 26000 plants per acre divided by 95% stand = 26000 divided by 0.95 = 27368 seeds per acre.