HYBRID AND PLANT DENSITY EFFECTS ON NITROGEN RESPONSE IN CORN

Robert Clark and Emerson Nafziger
Department of Crop Sciences, University of Illinois, Urbana-Champaign

Abstract

The development of corn hybrids that may be improved for nitrogen use efficiency along with the emphasis on higher plant density for maximum yields of modern hybrids have raised questions about interactions between N rate and plant density. We planted four hybrids (Pioneer 33D49, 33K44, 33W84, and 34F07) to represent a range of responses to N rate and plant density at four sites in Illinois at combinations of densities of 44,460, 83,980, and 123,500 plants ha^{-1} and N rates of 0, 90, 179, and 269 kg N ha^{-1}. At two productive locations (DeKalb and Monmouth), the lowest density (44,460 plants ha^{-1}) responded little to N rates above 90 kg N ha^{-1}, and yields at the two higher N rates, and at the two higher densities, were nearly identical. The Urbana site experienced very dry conditions and the Brownstown site was wet early and dry late. At both of these sites, the two lower densities (44,460 and 83,980 plants ha^{-1}) produced higher yields than the highest density across all N rates. At Urbana, there was little yield response to N rates above 90 kg N ha^{-1} at any plant density, while at Brownstown, yields responded linearly to N rate. Hybrid responses to N rate-density combinations were inconsistent. We found no support for the idea that increasing corn yields requires increases in both plant density and N rate. These results advance our understanding of N rate-plant density response within varying environmental conditions, but understanding the complexities of hybrid interactions with N rate and plant density will require much more work.

Introduction

With the expected commercialization of “nitrogen-use-efficient” hybrids within the next few years, the hybrid x N rate question is going to take on more importance. Nitrogen nutrition of NUE hybrids will presumably need to be managed differently than it is with “normal” hybrids, whether that be using the same rates of N with the expectation of higher yields, or the use of less N with expectation of similar yields. The improvement of nitrogen use efficiency continues to evolve as hybrids develop and cultural strategies progress, raising questions of suitable nitrogen management (Bundy et al. 2011).

The question about differential responses of corn hybrids to plant density is also an important one, and one that has been relevant for a long time. Hybrids have long been characterized as to their position along the scale from “fixed-ear” (or determinate) or “flex-ear” (indeterminate) types, with the former better able to maintain ear size as plant density is increased, and the latter better able to expand ear size if conditions are very good or plant density is low. Most high-performing hybrids tend to be characterized as “fixed-ear”, and with higher densities recommended for high yields.

While a physiological link between ear flex characteristics and N responsiveness has not been well-established, we hypothesize that simultaneous measurement of responses to N rate and density might prove to be of value in terms of characterizing corn hybrids. Because responses to density are easier to see with consistency than are responses to N rate, which are subject to considerable variation over fields and years (Miao et al., 2006), we think that it might be possible to develop a system to more easily characterize hybrids – perhaps a “flexibility index” that would have elements of responsiveness to both N and density.

Results of some preliminary work in Illinois showed, rather surprisingly, that two lower densities (49,400 and 65,867 plants ha^{-1}) actually required more N to reach optimum yield than did two higher plant densities (Nafziger, unpublished.) Raising the N rate from 202 to 269 kg N ha^{-1} also resulted in lower yields with the two lower densities but not with the two higher densities, for reasons that are not clear.

A recent publication from Indiana (Boomsma et al., 2009) showed, using rather extreme ranges for density and N rate, that higher densities required more N. Producers also tend to express disbelief in our results, illustrating the need to generate more data. Even though we have some data on the interaction between density and N rate, the data are conflicting and inadequate to answer the important management question regarding these inputs.

The objectives of this study are to answer the question about whether different commercial corn hybrids respond differently to N, and how consistent such responses might be over years and locations; to answer the question of how differently hybrids respond to plant density; and to determine whether or not N and plant density responses among hybrids are related to one another.

Materials and Methods

A small-plot study was conducted at four locations in Illinois in 2011: on a Flanagan silt loam soil at DeKalb; a Muscatune silt loam soil at Monmouth; a Drummer silty clay loam soil at Urbana; and on a Cisne silt loam soil at Brownstown, in south-central Illinois. Trials were planted in fields on which corn grew in 2010, and all fields were tilled. Herbicide was applied before final tillage and planting. Trials were all planted between May 3 and May 15.

Main plots in the study were N rate, with rates of 0, 90, 179, and 269 kg N ha^{-1} applied as sidedress UAN (28%) at about growth stage V3. Plant densities of 44,460, 83,980, and 123,500 plants ha^{-1} were assigned to subplots, and the four Pioneer® hybrids used in the study were assigned to sub-subplots within each N rate-plant density subplot. Plant densities were established by planting exact densities; plots were not thinned. Final stands as a percentage of dropped seed numbers were as follows: DeKalb – 90%; Monmouth – 94%; Urbana – 97%; and Brownstown – 96%.

The Pioneer® hybrids used, and their characterization (provided by M. Rupert of Pioneer Hi-Bred International) with regard to N and density responsiveness, were: 33D49 (flex-ear, more responsive to N); 33K44 (flex, less responsive to N); 33W84 (fixed, more N responsive); and 34F07 (fixed, less N-responsive).

Each sub-subplot was 4 rows (10 ft.) wide by 23 ft. long, with narrow (2-ft.) alleys between ends of plots. Yields were taken by machine-harvest of the center two rows of each sub-subplot, and were converted to 15% moisture.

Results and Discussion

The 2011 growing season in Illinois ranged from favorable in the northern part of the state to below-average in central and southern Illinois, with a delayed planting season followed by above-average precipitation in May and June to below-average rainfall in July and August. Temperatures were well above average in July and August throughout the state. The corn crop was stressed due to lack of adequate water beginning in mid-July, and as a result kernel numbers and yields were reduced, especially at the Urbana location. At Brownstown, the crop suffered from saturated soil conditions shortly after planting, and while growing season rainfall was close to average, the crop never recovered fully, and yields were very low (and the CV was very high). Yields were good at DeKalb and Monmouth.

At DeKalb and Monmouth, overall yields were similar, but hybrids performed differently at the two locations, with 33K44 producing the lowest yield at DeKalb and near the top at Monmouth, and 33W84 showing the inverse of this. Response to N rate and plant density were similar at these two locations, with yields at the three densities similar at zero N, 83,980 and 123,500 plants ha^{-1} both responding to N in a curvilinear fashion, and the low density (44,460 plants ha^{-1}) responding little to N at rates above 90 kg N ha^{-1}. Hybrids did not respond very consistently to changes in N rate-density combinations; as an example, changing the density from 83,980 and 123,500 plants ha^{-1} at the 269 kg N ha^{-1} rate decreased yield of 33D49 by 815 kg ha^{-1} and increased yield of 34F07 by 1129 kg ha^{-1} at DeKalb, but had little effect on yield of any of the hybrids at Monmouth. Raising both N rate (from 179 to 269 kg N ha^{-1}) and density (from 83,980 and 123,500 plants ha^{-1}) did, however, raise yields of hybrids 33W84 and 34K07 at both locations and had much less effect, or even lowered yields, of the other two hybrids.

At Urbana, where stress from dry weather was severe, the overall yield was only 5,769 kg ha^{-1}. At this location, yields without N decreased as density increased, from 3,763 kg ha^{-1} at 44,460 plants ha^{-1} to only 1,254 kg ha^{-1} at 123,500 plants ha^{-1}. Here, the two lower densities (44,460 and 83,980 plants ha^{-1}) responded similarly to N rate, though at 44,460 plants ha^{-1}, yields leveled off at 7,525 kg ha^{-1} with 90 kg N, while at 83,980 plants ha^{-1}, yield responded up to 179 kg N before dropping back at the highest N rate. In contrast, yields at the highest density (123,500 plants ha^{-1}) leveled off at only 5,017 kg ha^{-1} at 90 kg N and responded little to higher rates. Among the hybrids, yields averaged over treatments ranged from 6,271 kg ha^{-1} for 33D49 to only 5,080 kg ha^{-1} for 34F07. Probably because water was the main factor limiting yield, yield responses to increasing input levels were mostly negative; increasing plant density from 83,980 to 123,500 plants ha^{-1} reduced yield more at 269 kg N than at 90 kg N, while going from 179 kg N and 83,980 plants ha^{-1} to 269 kg N and 123,500 plants ha^{-1} dropped yields by more than 3,000 kg ha^{-1}. Differences among hybrids were not very consistent: at 123,500 plants ha^{-1}, 33D49 and 33K44 responded positively to increasing the N rate from 90 to 179 kg N ha^{-1}, while the other two hybrids responded negatively.

Due to the unusual degree of damage and failure to recover at Brownstown there is likely little to be learned from the results there, though it is somewhat interesting that yields without N were less than 200 kg ha^{-1} at the two highest densities, and were nearly 900 kg ha^{-1} at the lowest density. The response to N was nearly linear up to 269 kg N ha^{-1}, indicating that either a considerable amount of N was lost after application (which is quite likely), that roots were unable to reach what N was there (also likely), or both. The response to N rate was similar at all three densities, though as we saw at Urbana, yields were higher at the two lower densities than at the highest density. Performance of hybrids was unlike that at Urbana, however, and responses to changing combinations of inputs was also unlike those at Urbana, providing support to the idea that the type of stress was different at these two low-yielding locations.

The 2011 growing season was favorable at the two northern Illinois locations, and yields responded similarly to increasing rates of N and plant density, though hybrids did not respond very consistently. Optimum N rates were about 224 kg N ha^{-1} at DeKalb and 179 at Monmouth, in line with previous findings in these soils. Responses to N were almost exactly the same at 83,980 and 123,500 plant densities, however, and we found no support for the idea that the way to higher corn (following corn) yields is to increase both density and N rate. Still, 123,500 plants ha^{-1} is a high density, and it's possible that an intermediate density around 100,000 plants ha^{-1} might have yielded more than 123,500 plants ha^{-1} did. In the stress environments at Urbana and Brownstown, the two lower densities yielded about the same, and considerably more than the highest density, showing that corn plant density can indeed be too high under some conditions, and further, that adding more N does not alleviate the yield decrease at high density. While different hybrids responded to input combinations differently, there was little consistency in hybrid responses over sites, even where stress was low and yields were good.

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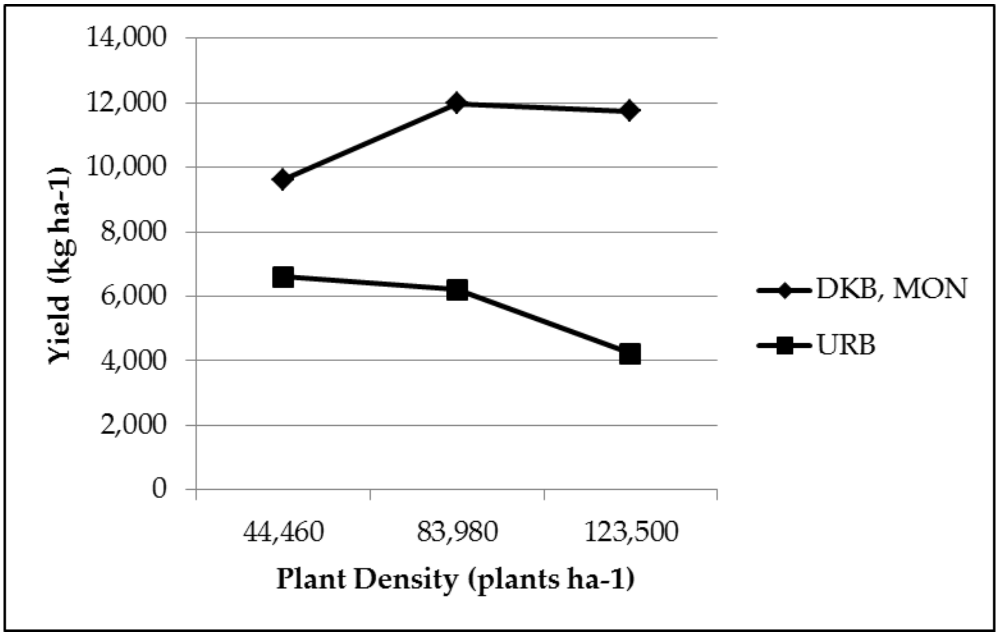

Figure 1: Response to plant density averaged over four hybrids and four N rates at Urbana and averaged across Monmouth and DeKalb, 2011.

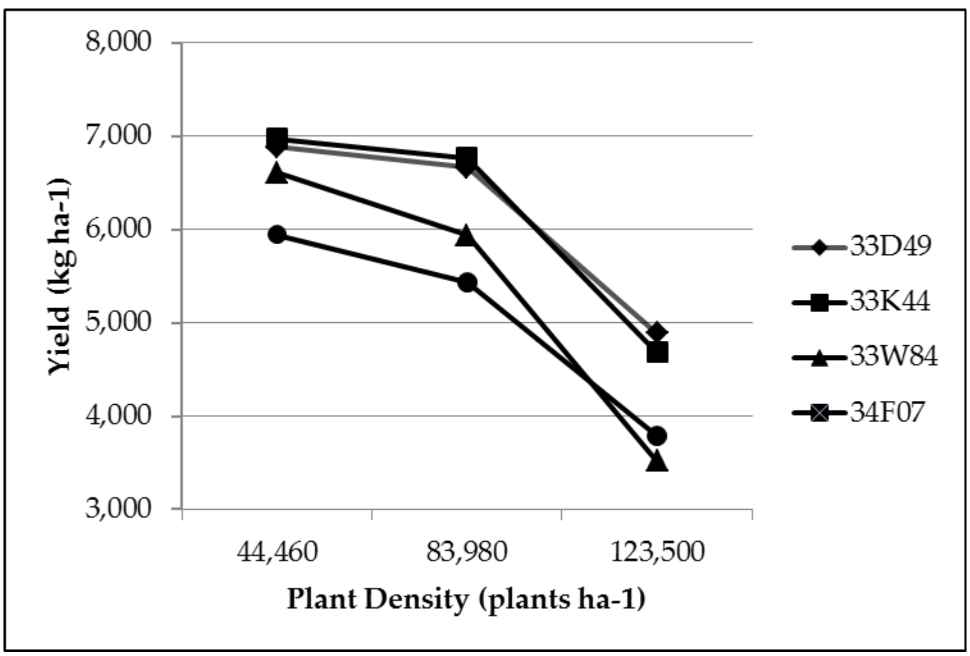

Figure 2: Response of four hybrids to plant density averaged over four N rates at Urbana, 2011.

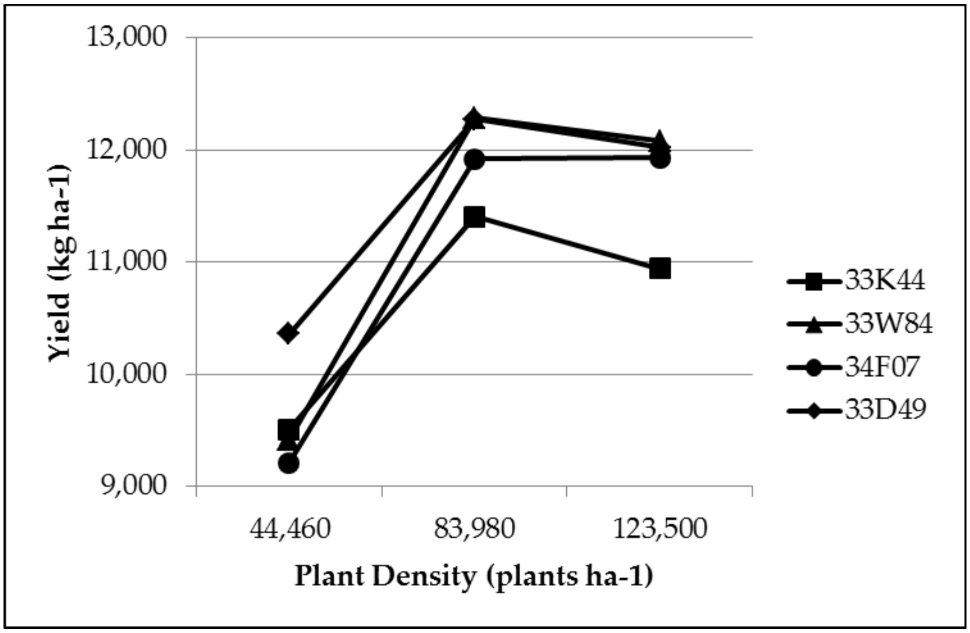

Figure 3: Response of four hybrids to plant density averaged over four N rates and two locations – Monmouth and DeKalb, in 2011.

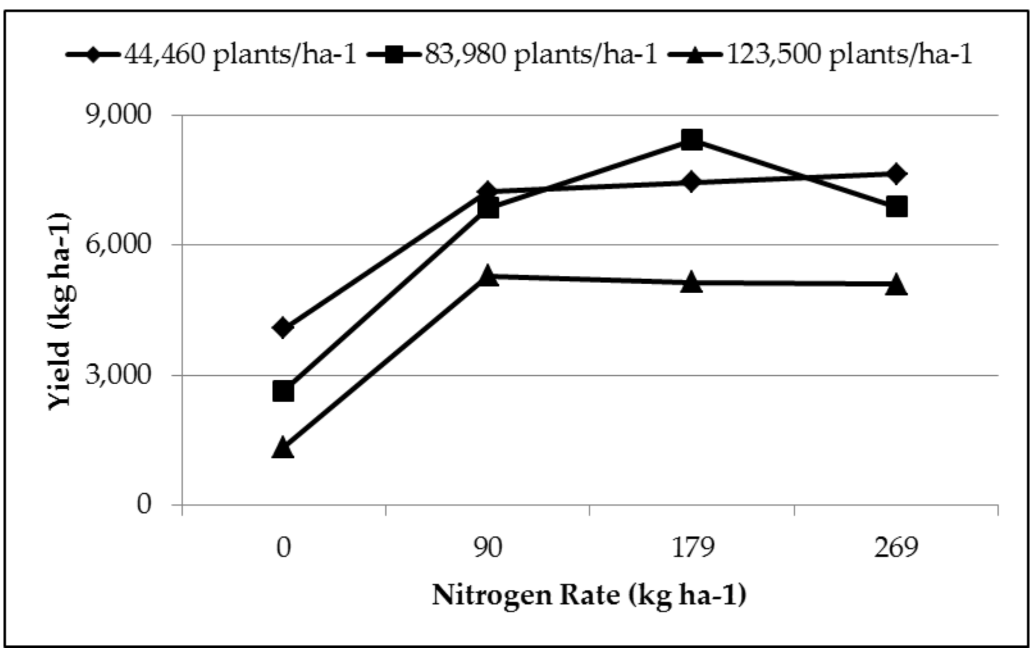

Figure 4: Yield response to plant density and N rate at Urbana, 2011. Data are averages over four hybrids.

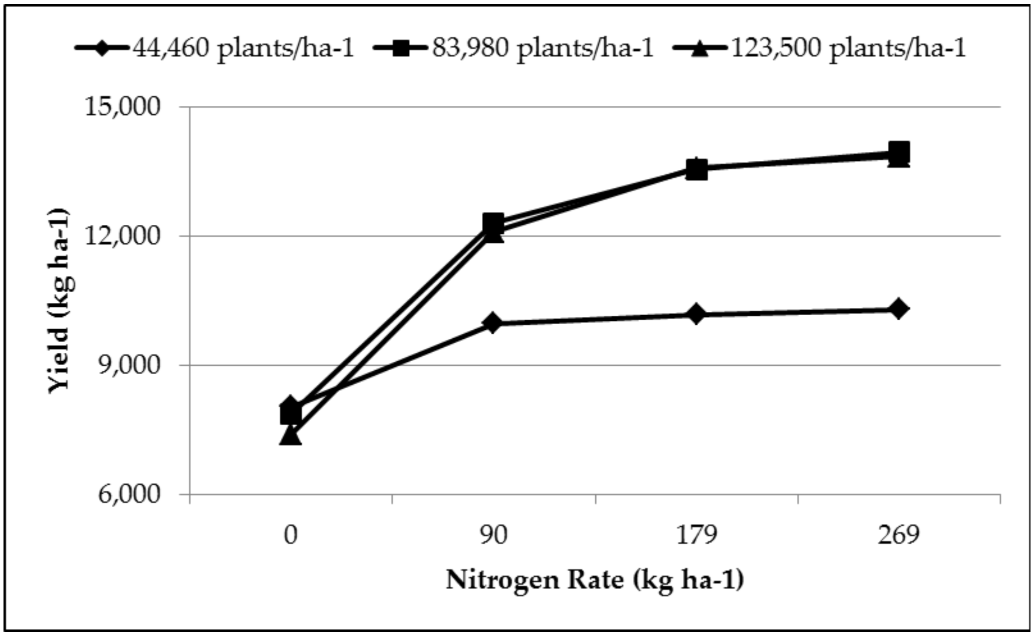

Figure 5: Yield response to plant density and N rate averaged over Monmouth and DeKalb, 2011. Data are averages over four hybrids.

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Program Chair:

David Franzen
North Dakota State University
Fargo, ND 58108
(701) 231-8884
David.Franzen@ndsu.edu

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2301 Research Park Way, Suite 126
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