Irrigated Maize Response to Nitrogen and Populations

Julie Baniszewski and Chad Lee
Plant and Soil Sciences Department, University of Kentucky, Lexington, KY
jbaniszewski@uky.edu

Introduction

Higher maize population densities may increase yield potential due to more equidistant spacing in narrow rows and quicker canopy closure[1,2,5]. Modern maize hybrids are more efficient in nitrogen use than their previous counterparts[3,6,7] and are more tolerant to stresses such as high plant densities[4]. When maize is not limited by water or nutrients, especially nitrogen, light interception may become the most limiting factor to grain yields. Consequently, increased plant densities may take advantage of maximizing potential light interception in a high yielding environment. It is hypothesized that higher plant population densities will have higher yield potential but will demand higher nitrogen fertilizer compared to lower plant population densities. Narrow 38 cm rows were used to achieve high plant densities. Irrigation and other nutrients were supplied so as to not be limiting at three locations in Kentucky (Fig. 1) in 2014 and 2015.

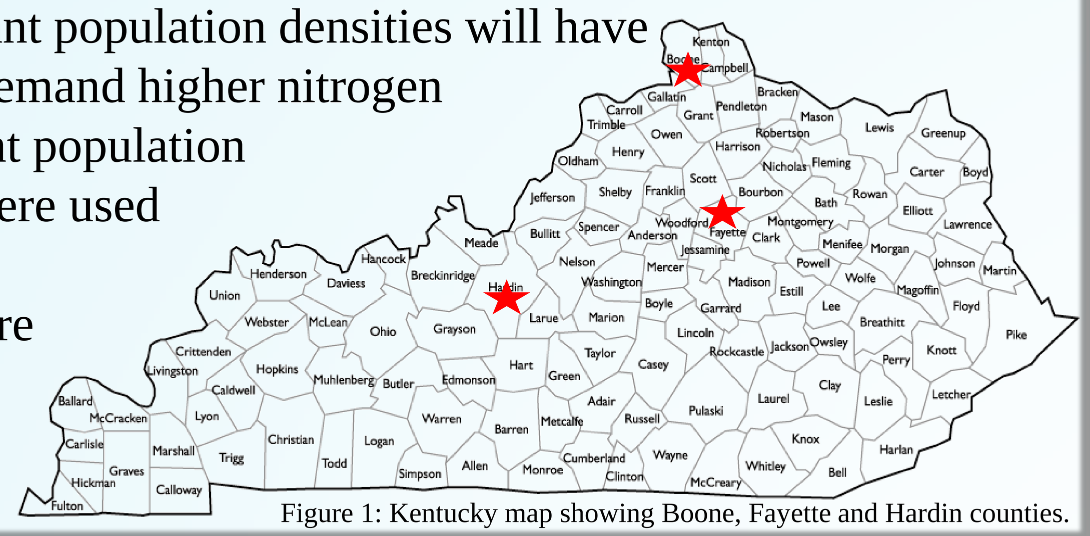


Figure 1: Kentucky map showing Boone, Fayette and Hardin counties.

Methods

Planting

- Randomized split plot block design
- Nitrogen rates (196, 252, 308 & 364 kg N ha^{-1}) applied pre-plant, side-dress, and at tassel
- Seed rates (74, 99, 124 & 148 K seeds ha^{-1}) planted in 38 cm rows (Fig. 2)
- AgriGold A6517 Hybrid (flex ear)

Figure 2: A Wintersteiger pneumatic seeder with Kinze row units was used to plant four different corn populations (left). Nitrogen was applied as UAN with a backpack sprayer at V4-V6 (right).

In-Season

- Pollination (tassel/silk) (VT/R1)
- NDVI recorded (R2-R5; Fig. 3)
- N deficiency rated (R5; Fig. 3)

Figure 3: NDVI recorded by an active Crop Canopy Sensor (left). A corn plant with leaves numbered according to position below the ear leaf (right). This scale was used for nitrogen deficiency ratings.

Harvest/Post-Harvest

- Lodging and stalk strength
  - scales 0-10 and 1-5
- Yield components
  - kernel number/mass
- Four center rows harvested (Fig. 4)
  - hand harvested sub-plot
- Partial return calculated (Eq. 1 & 2)

Figure 4: Measuring plot area and harvesting with a Wintersteiger plot combine.

Eq. 1
Partial Return = **Gross Income** ($15/100 kg) **- Costs**

Eq. 2
Costs = Seed ($240/80 K seeds) **+ N** ($1.10/kg N) **+ Fuel** ($0.39/kg)

Results

Yield Response

Population had a much larger effect on yield and yield components than nitrogen rate (Fig. 5). Kernel number ear^{-1} and kernel mass were decreased by higher populations (Fig. 6 & 7). Kernel number ha^{-1} was increased by population across all environments (Fig. 6).

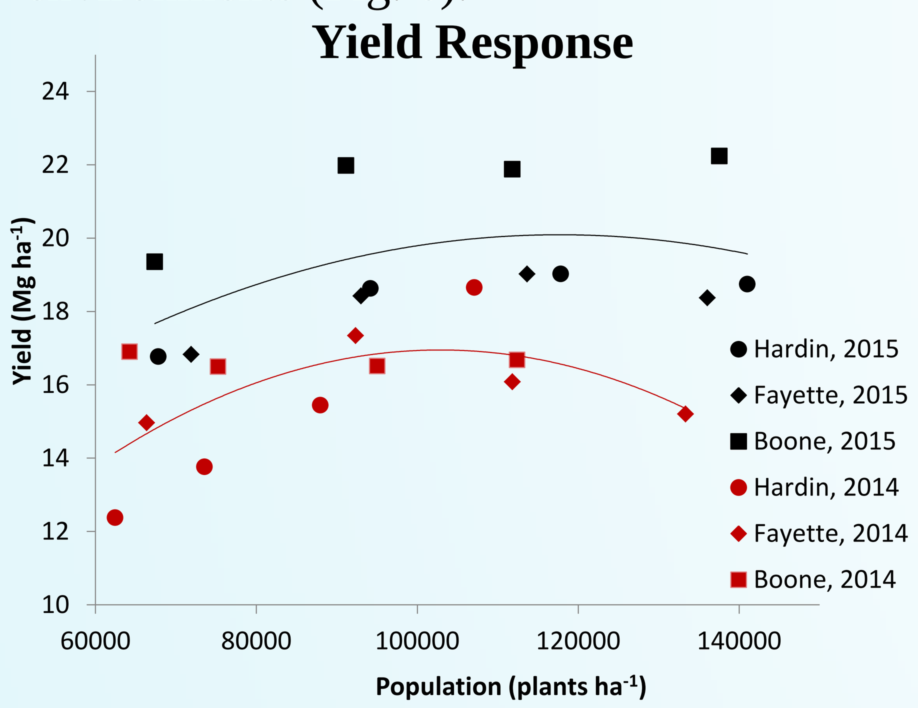


Figure 5: Population significantly affected yield at all sites in 2015 and at Hardin in 2014. Fayette was significantly affected by applied nitrogen in 2015 as well and there was a population * nitrogen interaction at Fayette in 2014. There was no effect at Boone in 2014 (α=0.1).

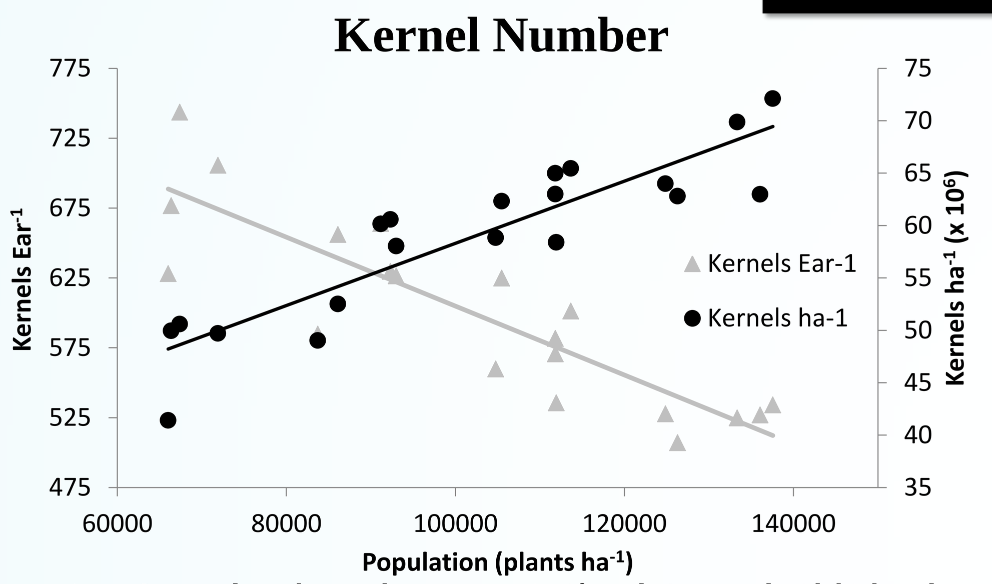


Figure 6: Kernel number per hectare was significantly increased with higher plant density (p<0.0001) across all environments. Kernel number per ear was decreased with higher plant densities with an environmental interaction (p=0.0831).

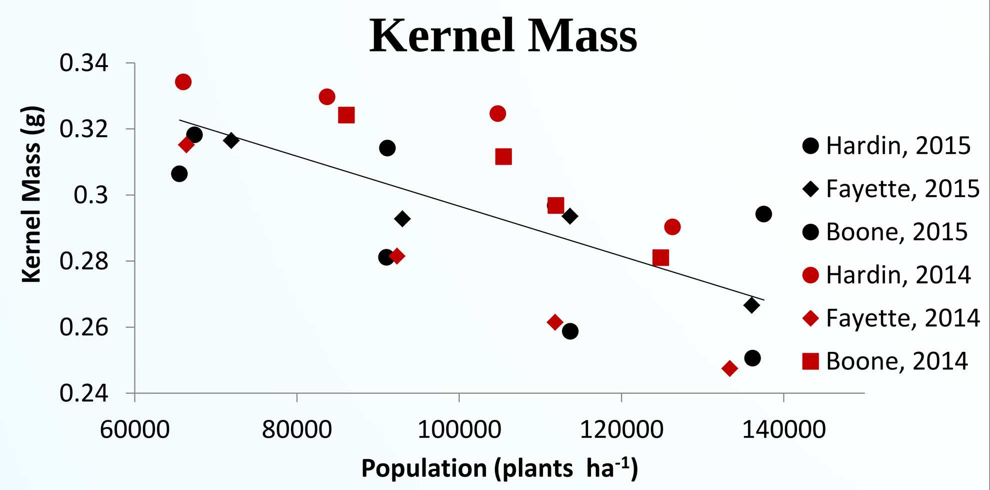
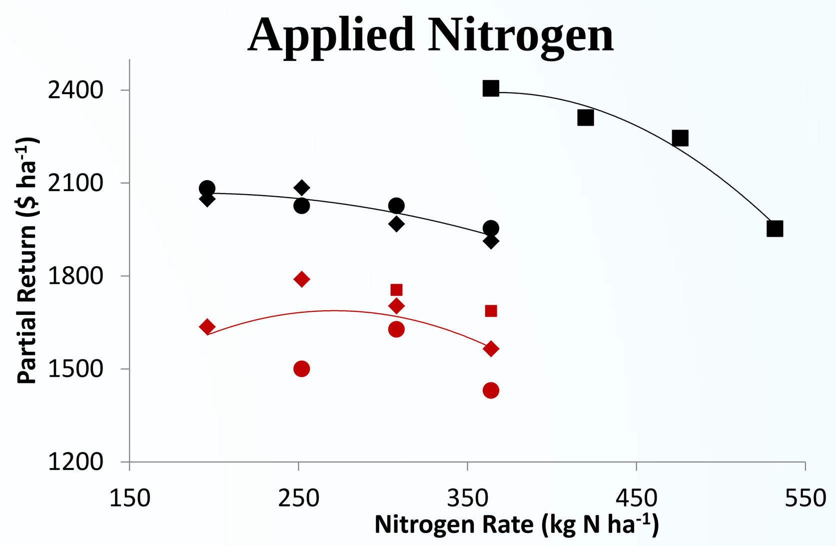


Figure 7: Kernel mass decreased with higher plant density but interacted with separate environments (p=0.0120).

Partial Return

Partial return diminished with higher applied nitrogen rates. A quadratic response was observed with planting rate in most environments, but there was a negative linear trend in Boone 2014 and a positive linear trend in Hardin 2014 (Fig. 8).



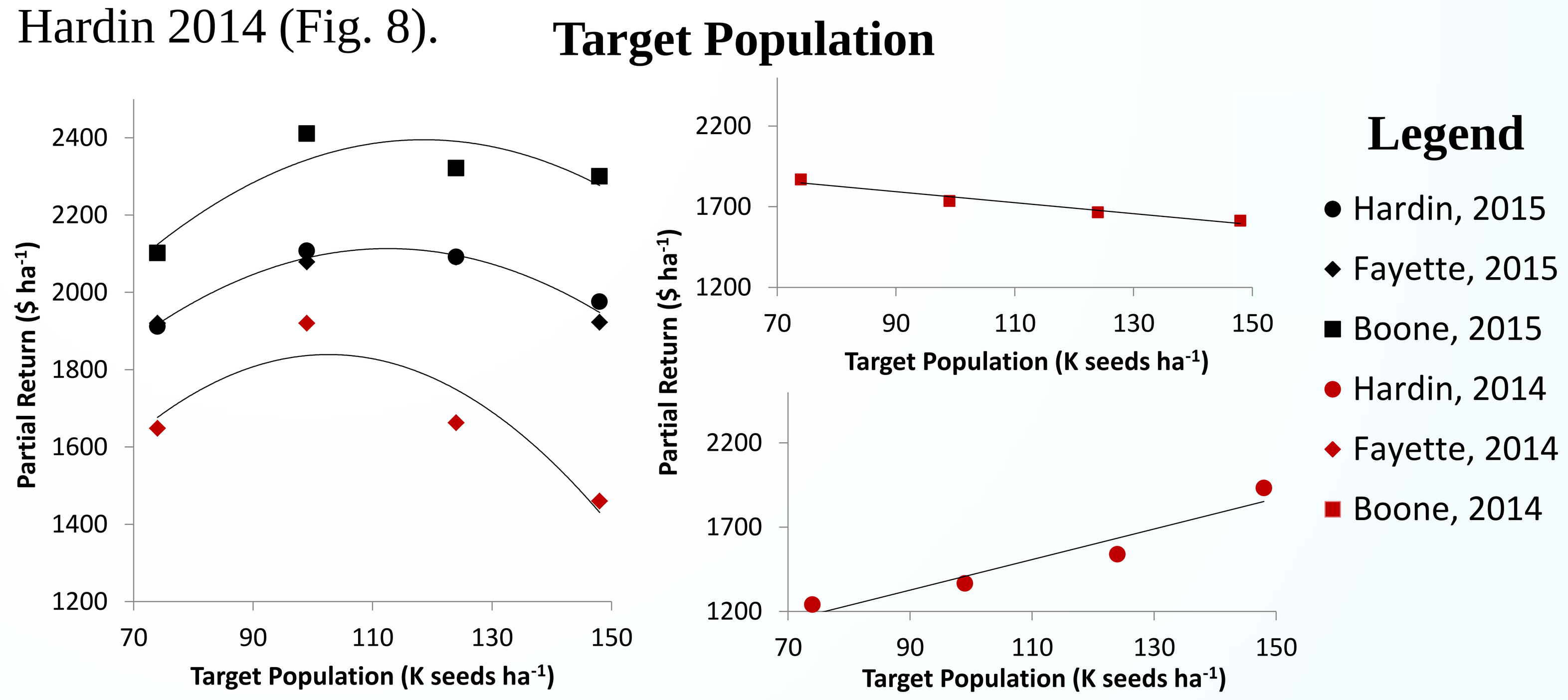


Figure 8: Partial return was significantly affected by population and nitrogen rate for all locations in 2015 and Hardin in 2014 (α=0.1). There was a population*nitrogen rate interaction at Fayette in 2014 (p=0.0327) and no effect at Boone in 2014 (ANOVA, p=0.3605).

Light Interception

Normalized differential vegetative index (NDVI) of 0.6 - 0.8 indicates a healthy canopy. In both years, NDVI was increased with higher plant populations (Table 1). There was a greater difference in NDVI at earlier reproductive stages compared to later reproductive stages indicating an earlier canopy closure may be correlated with higher plant density (Fig. 9).

2014 NDVI		
Population (Seeds ha^{-1})	R3	R5
74,000	0.7360	0.6909
99,000	0.7291	0.6874
124000	0.7465	0.6923
148,000	0.7551	0.6990
	p=0.0033	p=0.0002

Table 1: In 2014, NDVI was significantly increased by higher plant populations across all sites at both R3 & R5.

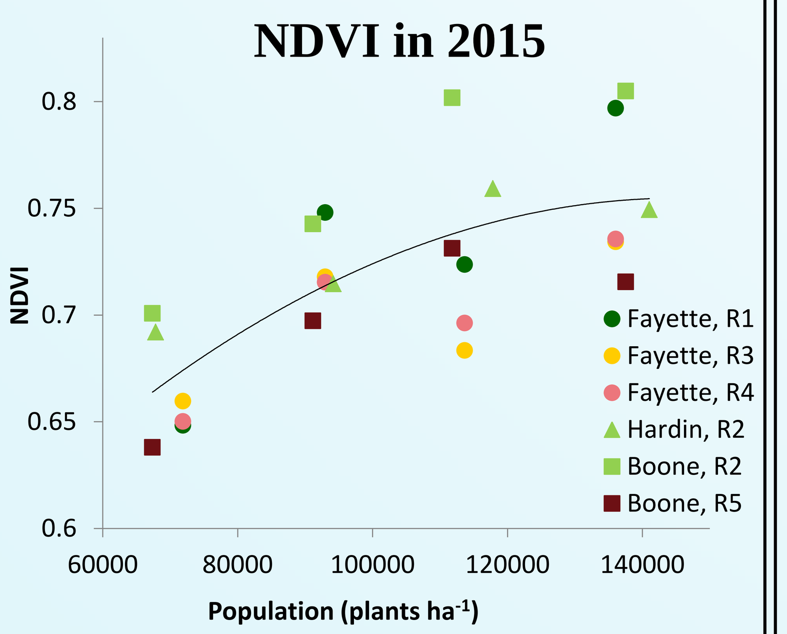


Figure 9: Data in 2015 confirms that higher populations increased NDVI at stages R2-R5 (α=0.1).

Nitrogen Deficiency

Higher plant populations had nitrogen deficiency significantly higher on the plant, closer to the ear (p<0.0001; Fig. 10). Plant populations created a larger gradient of nitrogen deficiency than applied nitrogen rate (p<0.0001; data not shown).

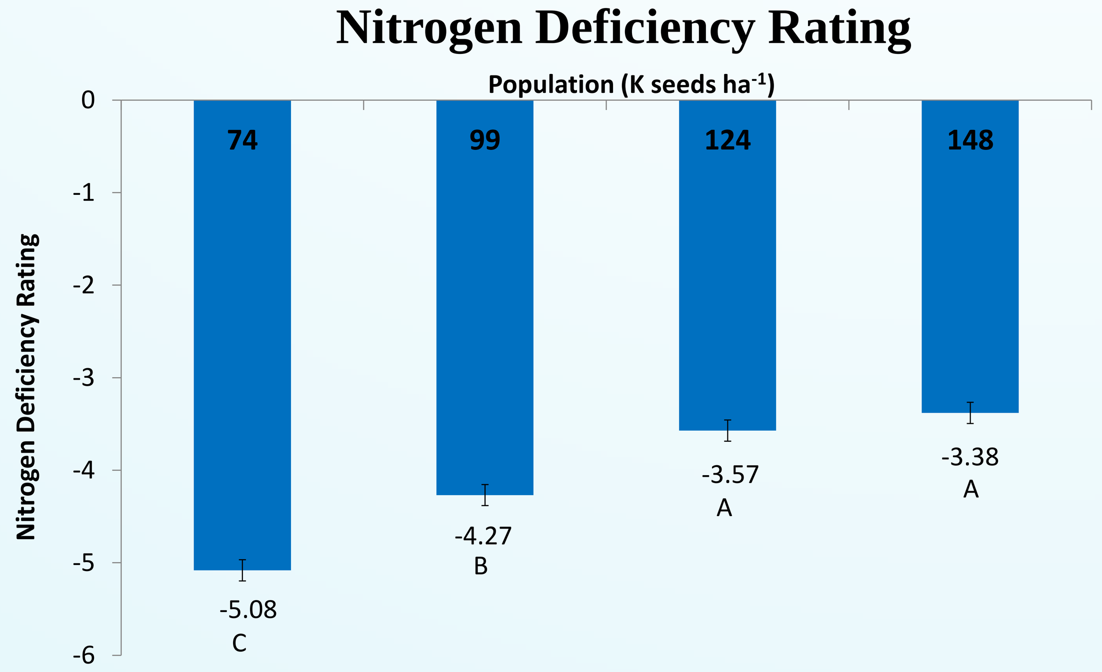


Figure 10: Nitrogen deficiency ratings are expressed as means ± SE for Boone and Fayette counties in both 2014 and 2015. The negative value indicates the number of leaves below the ear leaf to show visible nitrogen deficiency.

Pollination

Pollen shed peaks around 3 days after tassel emergence and typically lasts 5 - 8 days, whereas silk longevity is only about 10 days. Data at Fayette indicate that peak pollen shed may occur before all silks emerge from high density populations (Fig. 11).

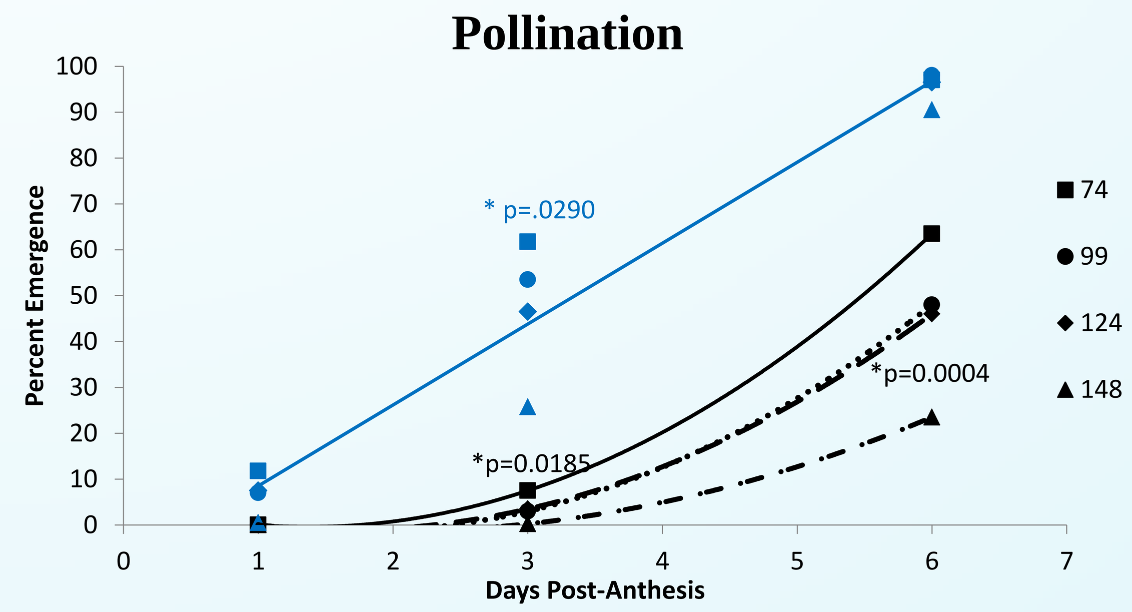


Figure 11: Plant population densities are shown by symbols. Blue symbols indicate tassel emergence and black symbols indicate silk emergence. Data is shown for Fayette 2015. Tassel and silk emergence were only affected by population, not by nitrogen rate or their interaction (α=0.1). Tassel emergence was significantly reduced with increased populations only 3 days after anthesis. Silk emergence was significantly reduced by population at both 3 and 6 days after anthesis.

Conclusion

- Yield response diminished after populations reached 99 K plants ha^{-1} due to reduced yield components.
- Partial return was maximized between 99 - 124 K plants ha^{-1} in most environments.
- Nitrogen above an adequate rate of 252 kg N ha^{-1} had little effect on yield, but decreased partial return.
- No population resulted in nitrogen deficiency at the ear leaf by R5, implying that nitrogen did not limit yield in these studies.
- NDVI shows increased light interception with higher population densities, but little effect from applied nitrogen. Thus, in a system not limited by water or nutrients, canopy closure could become the most limiting factor.
- Pollination suggests potential problems with pollination synchrony at high plant populations.
- Increasing plant density could maximize solar radiation and increase potential yield. However, populations greater than 99 K seeds ha^{-1} did not better utilize higher nitrogen rates as predicted. Instead, 99 K seeds with 252 kg N ha^{-1} maximized yield response while minimizing input costs.

References

[1]**Andrade, FH, PA Calviño, A Cirilo, PA Barbieri. 2002.** Yield responses to narrow rows depend on increased radiation interception. Agron. J. 94:975-980.
[2]**Barbieri, PA, H Echevarria, H Sainz Rozas, F Andrade. 2008.** Nitrogen use efficiency in maize as affected by nitrogen availability and row spacing. Agron. J. 100:1094-1100.
[3]**Below, FE, M Uribelarrea, M Ruffo, SP Moose, AW Becker. 2007.** Triple-stacks, genetics, and biotechnology in improving nitrogen use of corn. North Central Extension-Industry Soil Fertility Conference. Vol. 23. Des Moines, IA.
[4]**Boomsma, CR, JB Santini, M Tollenaar, TJ Vyn. 2009.** Maize morphological responses to intense crowding and low nitrogen availability: an analysis and review. Agron. J. 101(6):1426-1452.
[5]**Bullock, DG, RL Nielsen, WE Nyquist. 1988.** A growth analysis comparison of corn grown in conventional and equidistant plant spacing. Crop Sci. 28:254-258.
[6]**Burzaco, JP, IA Ciampitti, TJ Vyn. 2014.** Nitrapyrin impacts on maize yield and nitrogen use efficiency with spring-applied nitrogen: field studies vs. meta-analysis comparison. Agron. J. 106 (2):753-760.
[7]**Crozier, CR, RJ Gehl, DH Hardy, RW Heiniger. 2014.** Nitrogen management for high population corn production in wide and narrow rows. Agron. J. 106(1):66-72.