

2018

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### Recommended Citation

Lollato, R. P.; Zhang, G.; Jaenisch, B. R.; Maeoka, R.; Bonassi, L.; and Fritz, A. K. (2018) "Wheat Variety Response to Seeding Rate in Kansas During the 2015–2016 and 2016– 2017 Growing Seasons," *Kansas Agricultural Experiment Station Research Reports*: Vol. 4: Iss. 7. <https://doi.org/10.4148/2378-5977.7614>

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## Authors

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# **Wheat Variety Response to Seeding Rate in Kansas During the 2015–2016 and 2016–2017 Growing Seasons**

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## **Abstract**

Plant density is among the major factors determining a crop's ability to capture resources such as water, nutrients, and solar radiation; therefore, different wheat varieties might require different seeding densities to maximize yield. The objective of this project was to better understand the response of different wheat varieties to seeding rate. Two field experiments were conducted during 2015–2016 and repeated during 2016–2017, evaluating seven wheat varieties subjected to five different seeding rates (0.6, 0.95, 1.3, 1.65, and 2.0 million seeds/a). Crop was managed for a 70 bu/a yield goal and pests were controlled using commercially available pesticides. Final stand and grain yield were measured, and all statistical analyses were performed for relating emerged plants per acre to grain yield. At each individual environment and across varieties, grain yield usually was maximized at approximately 0.9 million emerged plants per acre. There were significant differences among varieties in grain yield, with Joe and Tatanka usually outperforming the remaining tested varieties. Across environments, grain yield usually was maximized at populations between 0.6 and 0.7 million plants per acre for less responsive varieties (1863, Everest, and Tatanka), at approximately 0.9 million plants per acre for average responsive varieties (Joe, Bob Dole, KanMark, and Zenda), and more than 1.05 million emerged plants per acre for more responsive varieties (Larry and AG Icon). These preliminary data suggest that there is the potential to manage each wheat variety according to its individual tillering potential; however, more data are needed to make definite conclusions about each variety's optimum seeding rate. Thus, this experiment is currently being conducted at five sites during the 2017–2018 growing season.

## **Introduction**

Plant density is among the major factors determining the crop's ability to capture resources such as water, nutrients, and solar radiation (Satorre and Slafer, 1999). The response of wheat to plant density is largely determined by competition for resources with neighboring plants, and increased competition can result in reduced survival, dry matter production, and grain yield of individual wheat plants (Satorre, 1988). Wheat plants subjected to high density generally have fewer tillers and grains than widely spaced plants (Rana et al., 1995). On the other hand, too widely spaced plants can result in few plants per unit area and consequently less grains per unit area, explaining

the typical parabolic response of grain yield to plant density (Holliday, 1960). Consequently, appropriate management of population density may allow maximum yields per unit area to be achieved (Satorre and Slafer, 1999). Given the difference in wheat varieties regarding their ability to tiller as well as their response to intra-canopy competition for resources, it is possible that different varieties require different seeding densities to maximize yield. Therefore, the main objective of this project was to better understand the response of different wheat varieties to seeding rate.

## Procedures

One experiment was conducted at four site-years: at the South Central Experiment Field near Hutchinson, KS, during 2015–2016 and 2016–2017; at the Agronomy North Farm in Manhattan, KS, during 2015–2016; and at the North Central Experiment Field in Belleville, KS, during 2016–2017. Trials were established in a randomized complete block design with four replications. Seven varieties (i.e. Everest, KanMark, 1863, Larry, Zenda, Tatanka, and Joe during 2015–2016; and KanMark, Larry, Zenda, Tatanka, Joe, Bob Dole, and AG Icon in 2016–2017) and five seeding rates (0.6, 0.95, 1.3, 1.65, and 2 million seeds/a) were tested, for a total of 35 treatments and 140 plots per location. Plots were 7 rows wide at a 7.5-in. row spacing in Manhattan and at both locations during the 2016–2017 growing season, and 6 rows wide at a 10-in. row spacing in Hutchinson. The harvestable portion of the plots was approximately 20-ft long at all locations.

Management practices adopted at all locations are described in Table 1 and initial soil fertility is listed in Table 2. Nitrogen (N) fertilization at all locations was performed with a yield goal of approximately 70 bu/a. Weeds and foliar diseases were controlled at both locations. Agronomic measurements included stand count approximately 3–4 weeks after planting, percent canopy cover measured several times during the growing season using digital imagery, and a 1-meter row subsample clipped from each plot at harvest time for biomass, harvest index, head count, average grain weight, and head size. The latter samples were still being processed at the time this report was prepared, therefore, results are not shown in the current report. Plots were harvested using a small plot combine at all locations, and grain yield was adjusted to a 13% moisture basis.

## Results

### *Growing Season Weather*

The weather during the 2015–2016 growing season was characterized by a warm and moist fall, followed by a dry and mild winter and a cool and moist spring (Table 3). Meanwhile, the 2016–2017 growing season started with a drier fall with similar temperature totals, received earlier moisture during the winter, and had a similar spring to that observed during the previous season, with plenty of precipitation and below-average temperatures (Table 3). Growing season precipitation total was 20.5 in. in Hutchinson and 24.4 in. in Manhattan (2015–2016), and 18.2 in. in Hutchinson and 14.8 in. in Belleville (2016–2017). Despite the high precipitation totals, cumulative solar radiation during the growing season was well above 3,000 MJ m<sup>-2</sup> at all studied site-years, indicating that solar radiation should not have been a yield-limiting factor in this study.

### *Stand Establishment*

The trials were sown into adequate moisture at all locations, which ensured good germination and stand establishment. Average percent establishment (final stand over targeted seeding rate) was 72% in 2015–2016 and 92% in 2016–2017. At all site-years, increasing seeding rate increased the final stand count for all varieties at all locations (Figure 1).

### *Wheat Grain Yield: Individual Site-Year Analysis*

There was a great difference in yield potential among study-locations, with average yield across all varieties and plant population densities ranging from 44 bu/a in Manhattan 2015–2016, 78 bu/a at both Hutchinson 2015–2016 and Belleville 2016–2017, and 101 bu/a in Hutchinson 2016–2017 (Figure 2). Yields were normally distributed across all locations. At all individual studied locations, grain yield was significantly affected by variety and by planting density, but there was no significant interaction (Table 4). In other words, there were grain yield differences among varieties and among population densities; however, the different varietal responses to planting density were not captured in each individual site-year analysis (all varieties responded similarly to the change in population density in each individual location). At all locations and years, wheat grain yield response averaged across varieties was well represented by an exponential rise to the maximum on a non-linear regression model, with wheat grain yields reaching 95% of the asymptotic maximum at approximately 890,000–911,000 emerged plants per acre in three out of four sites (Figure 3). The only exception was Hutchinson during 2015–2016, when grain yields maximized at 530,000 plants per acre. The lowest population density treatment at each location, which ranged from 445,000 to 721,000 plants per acre depending on site-year, resulted in grain yields statistically similar to the very next plant population density at all site-years, but had lower yields than the following greater population density treatments (greater than approximately 850,000 to 1,000,000 plants per acre, Figure 3).

### *Wheat Grain Yield: Analysis Pooled Across Site Years*

The pooled analysis of variance was first performed over the entire dataset using raw yield data. Subsequently, due to the differences in yield environment among the four site-years in this study (Figure 2), the analysis was performed using relative yields. Relative yields were calculated for each variety at each site-year using the highest yielding plot for a particular variety as the denominator for all plots for that same variety. Wheat varieties behaved differently at each location and year, but some trends were observed. Grain yield averaged across seeding rates for each variety is shown in Figure 4. In Hutchinson, Larry, Joe, Tatanka, and KanMark were in the highest yielding group for both growing seasons; as well as 1863 and Bob Dole during the 2015–2016 and 2016–2017 growing seasons, respectively. In Manhattan 2015–2016 and Belleville 2016–2017, Joe had the highest grain yield as compared to the other varieties (Figure 4).

The initial analysis using the raw yield data allowed us to screen for varieties more responsive to plant population (i.e. varieties that showed large yield increases at higher stands), average responsive varieties, and less responsive varieties (varieties that tended to maximize yields at very low seeding rates). Among varieties that maximized yields at low seeding rates were Tatanka, Everest, and 1863, all of which maximized yields

between 650,000 and 695,000 plants per acre (Figure 5). It is important to highlight that Everest and 1863 were only tested during 2015–2016 and thus reflect only one year's data, which gives us less confidence in the results. Tatanka has now a total of two years of data, providing greater strength to assume its good performance under low population densities. The majority of the varieties belonged to the average response group, including Joe, KanMark, Zenda, and Bob Dole – the latter only evaluated in one year of the experiment. This group maximized yields between 785,000 and 900,000 plants per acre (Figure 5). Varieties that required more plants to maximize yields included Larry and AG Icon (single year of data for the latter one), which required 1,080,000 to 1,060,000 plants per acre to maximize yields (Figure 5).

The previous results were later confirmed by the subsequent analysis, which discriminated among varieties but evaluated relative rather than raw grain yield. In the relative grain yield analysis pooled across site-years, Joe, KanMark, and Zenda again maximized yields between 775,000 and 870,000 plants per acre, which reflects the average response group (Figure 6); Larry and AG Icon maximized yields at populations beyond 950,000 plants per acre (more responsive varieties; Figures 6 and 7); and Tatanka, Bob Dole, Everest, and 1863 maximized yields at populations less than 690,000 plants per acre (less responsive varieties; Figures 6 and 7). Everest and 1863 showed no significant response to plant densities (Figure 7). Bob Dole was the only variety that showed discrepant results between the relative yield and raw yield data analyses, as it was categorized as an average responsive variety using the raw data and a less responsive variety using the relative yield data. Results for Everest, 1863, Bob Dole, and AG Icon should be interpreted with more caution than the remaining ones because they only reflected one year's data, and more tests are needed to increase the power of the analysis.

### *Preliminary Conclusions*

With four site-years of data, we start gathering firm conclusions about each variety's response to plant population. Zenda, KanMark, and Joe seem to have an intermediate response to seeding rate and maximize yields around 800,000 to 900,000 plants per acre. Tatanka seems to be less responsive to plant population, maximizing yields with populations as low as 565,000 to 660,000 plants per acre. Larry has shown greater response to plant population, and yield was only maximized at populations above 1,060,000 plants per acre. While preliminary data suggest Everest and 1863 are not responsive to plant population, Bob Dole is intermediate, and AG Icon is more responsive, the limited number of observations (two site-years of data only) limit the power of this analysis and the breadth of these conclusions, not allowing for broader implications from the data. This study is currently being conducted at five locations during the 2017–2018 growing season so that more definite recommendations can be drawn for each variety.

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**Table 1. Location (latitude, longitude, and elevation), soil type, and management practices adopted at all study locations during the 2015–2016 and 2016–2017 growing seasons**

	2015–2016		2016–2017	
	Hutchinson	Manhattan	Hutchinson	Belleville
Latitude	37.9313°N	39.2181°N	37.927501°N	39.81841°N
Longitude	98.0246°W	96.5907°W	98.026516°W	97.671968°W
Elevation	1535 ft	1020 ft	1535 ft	1545 ft
Soil type	Ost loam	Kahola silt loam	Ost loam	Crete silt loam
Tillage	Conventional till	No-till	Conventional till	Conventional till
Previous crop	Wheat	Corn	Wheat	Wheat
Planting date	10/07/2015	10/08/2015	10/13/2016	10/03/2016
Row spacing	10 in.	7.5 in.	7.5 in.	7.5 in.
Topdress N rate	107 lb N/a	99 lb N/a	113 lb N/a	75 and 35 lb N/a
Topdress N date	02/19/2016	02/28/2016	2/21/2017	9/24/2016 and 2/17/2017
Herbicide rate	Powerflex – 2 oz/a MCPE – 1 pt/a AMS 2.8 lb/ 100 gal mix	Harmony Extra – 0.7 oz/a MCPA Ester – 16 oz/a NCIS – 16 oz / 100 gal mix	Powerflex 2 oz/a + MCPA ester 1.5 pt/a 15 gal water/a	0.4 oz of Affinity BroadSpec, 0.75 pt Sword (MCPA), 1 qt/100 gal NIS
Herbicide date	02/19/2016	03/10/2016	11/15/2016	11/14/2016
Fungicide rate	Quilt Xcel 12 fl. oz/a	Quilt Xcel – 14 fl. oz/a	Aproach Prima 6.8 oz/a	Aproach Prima 6.8 oz/a
Fungicide date	4/25/2016	04/22/2016	4/26/2017	5/10/2017
Harvest date	06/16/2016	06/24/2016	6/20/2017	6/28/2017



**Table 2. Initial soil fertility at both study locations**

Nutrient	2015–2016				2016–2017			
	Hutchinson		Manhattan		Hutchinson		Belleville	
	0–6 in.	6–24 in.	0–6 in.	6–24 in.	0–6 in.	6–24 in.	0–6 in.	6–24 in.
pH	4.9	6.3	6.6	7.0	7.86	7	5.9	5.9
NO <sub>3</sub> -N (lb/a)	20.6	33.6	19.4	21	25.4	26.9	9.1	11.4
Phosphorus (ppm)	74.7	21.4	39.8	15.3	63.3	---	41.7	11.6
Potassium (ppm)	238	170	210	227	201	---	474	224
Calcium (ppm)	1379	2976	4045	5383	2172	---	1532	2005
Magnesium (ppm)	231	293	311	279	181	---	202	245
Sodium (ppm)	17.9	42.7	22.8	23.9	12.8	---	13.3	18.7
SO <sub>4</sub> -S (ppm)	7.9	7.4	7	4.4	7.8	---	2.9	2.5
Chlorine (ppm)	9	4.8	4.8	3.3	4.8	---	5.0	3.3
CEC (meq/100 g)	15	17.4	26.8	23.1	12.9	---	21.1	23.5
Organic matter (%)	2.2	---	3.9	---	1.9	---	3.0	---

Soil samples were collected at sowing.

**Table 3. Summary of the observed weather during the 2015–2016 (Manhattan and Hutchinson) and 2016–2017 (Hutchinson and Belleville) growing seasons**

Season	2015–2016					
	Hutchinson			Manhattan		
	Average temperature	Precipitation	Solar radiation	Average temperature	Precipitation	Solar radiation
	°F	in.	MJ m <sup>-2</sup>	°F	in.	MJ m <sup>-2</sup>
Fall	47.9	7.2	837	48.7	8	765
Winter	41	2.2	1156	40.9	1.3	1041
Spring	62.9	11.1	1578	67.3	15.2	1905

Season	2016–2017					
	Hutchinson			Belleville		
	Average temperature	Precipitation	Solar radiation	Average temperature	Precipitation	Solar radiation
	°F	in.	MJ m <sup>-2</sup>	°F	in.	MJ m <sup>-2</sup>
Fall	46.6	1.6	768	44.8	3.6	841
Winter	44.1	5.8	943	38.6	2.6	992
Spring	64.2	10.8	1640	62.4	8.6	1888

Average temperature, and cumulative precipitation and solar radiation are shown for the fall (planting – December 31), winter (Jan 1 – March 31), and spring (April 1 – harvest date) for all locations.

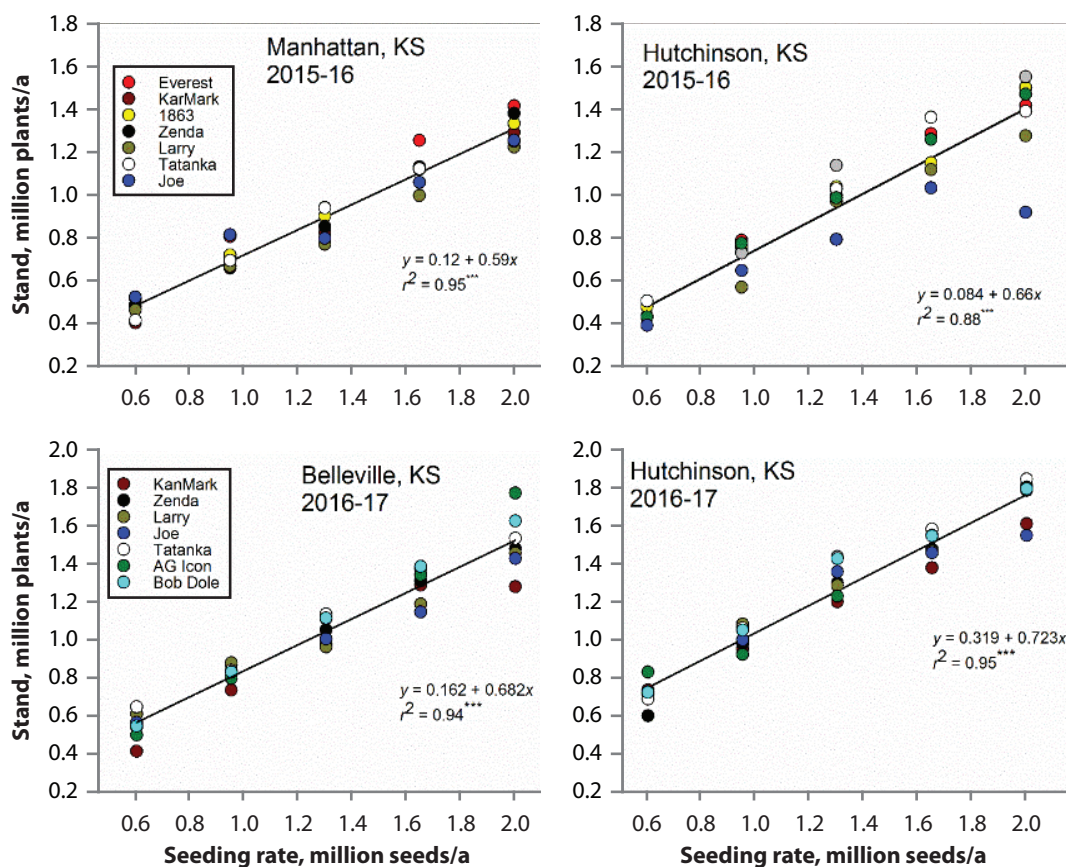


**Table 4. Significance of the source of variation on wheat grain yield in Hutchinson, Manhattan, and Belleville, KS, during the 2015–2016 and 2016–2017 growing seasons**

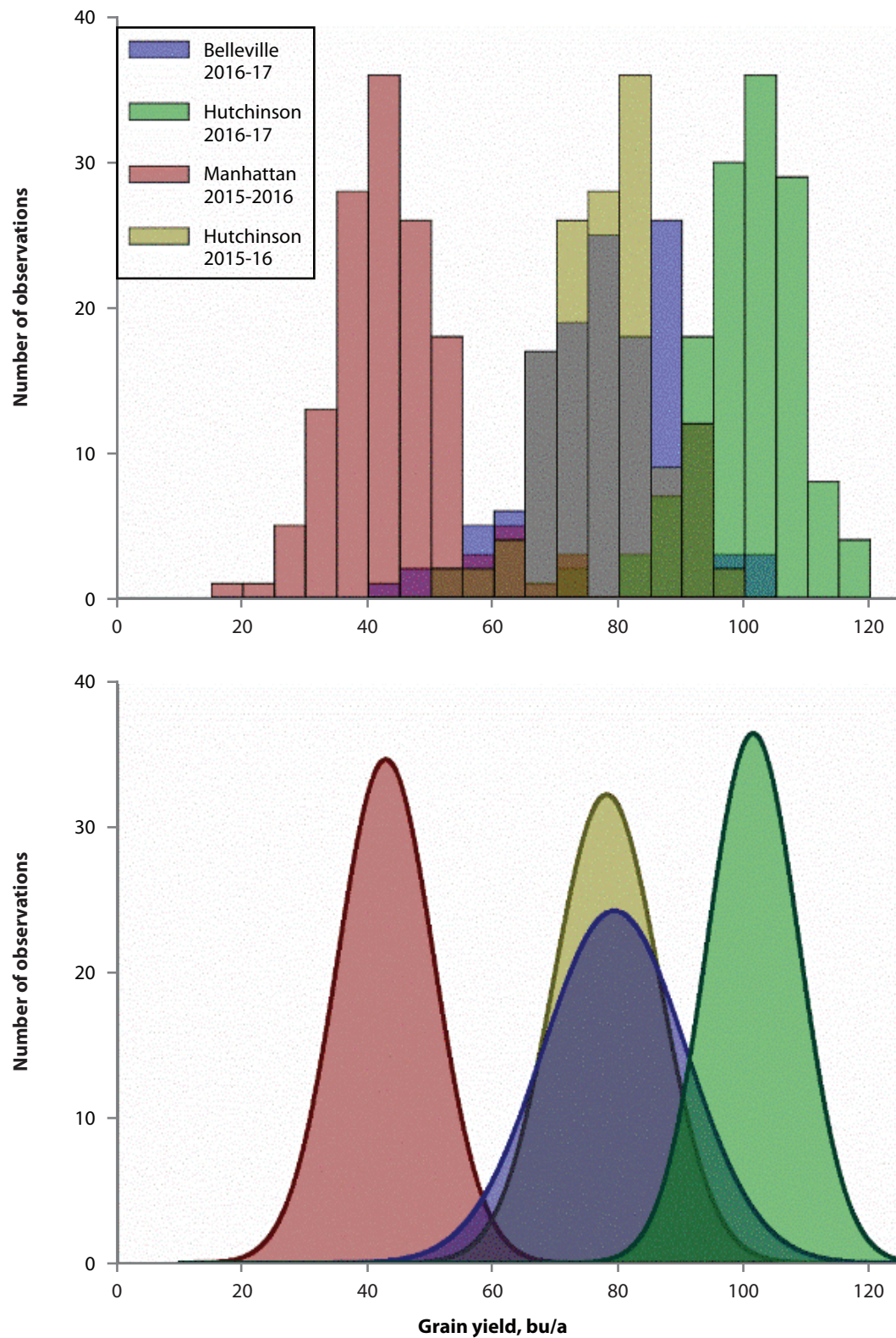
Source of variation	2015–2016		2016–2017	
	Hutchinson	Manhattan	Hutchinson	Belleville
Variety	***	***	***	***
Plant population	*	***	***	***
Variety × Plant population	ns	ns	ns	ns

\*, \*\*\* = significant at  $P < 0.05$  and  $0.001$ , respectively.

ns = not significant.



**Figure 1. Final plant stand as affected by seeding rate in Hutchinson and Manhattan during the 2015–2016 growing season (upper panels) and Hutchinson and Belleville during the 2016–2017 growing season (lower panels). \*\*\*Indicates that the regression coefficient was significant at  $P < 0.001$ .**



**Figure 2. Wheat grain yield distribution across all studied site-years shown as histograms (upper panel) and the Gaussian model fit around each respective histogram (lower panel).**

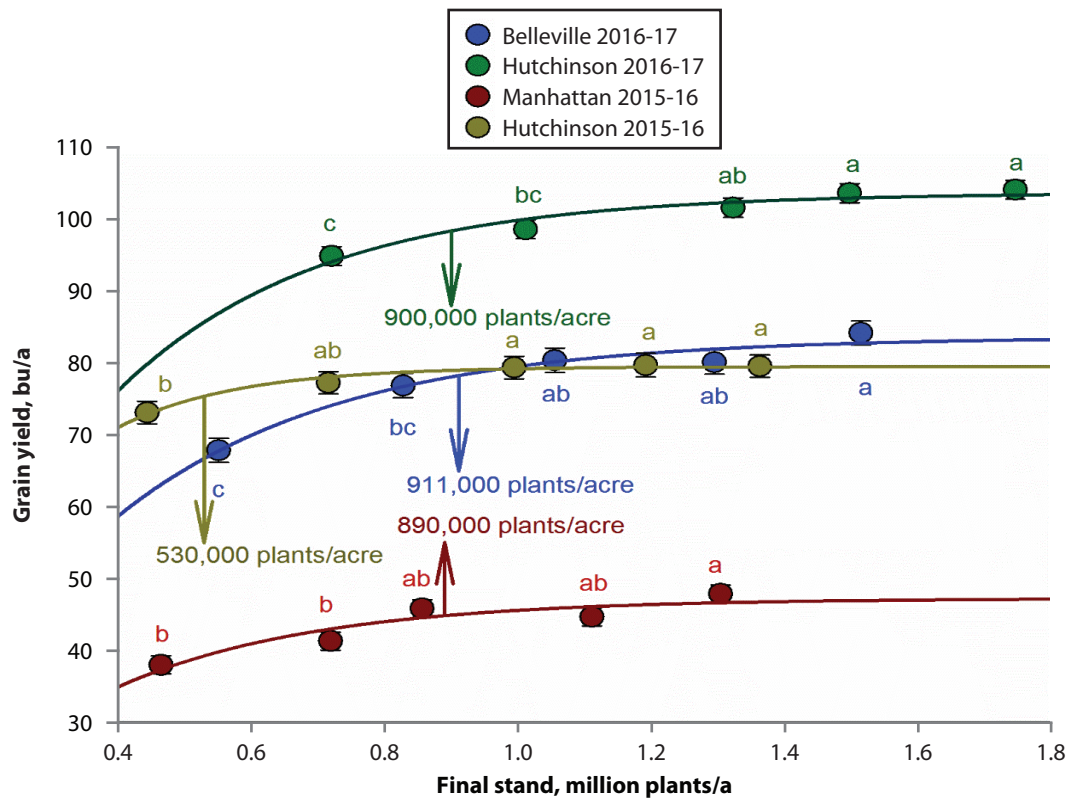


Figure 3. Wheat grain yield response to plant population at the four site-years included in this report. Wheat yields are averages across varieties due to the non-significance of variety  $\times$  seeding rate interaction.

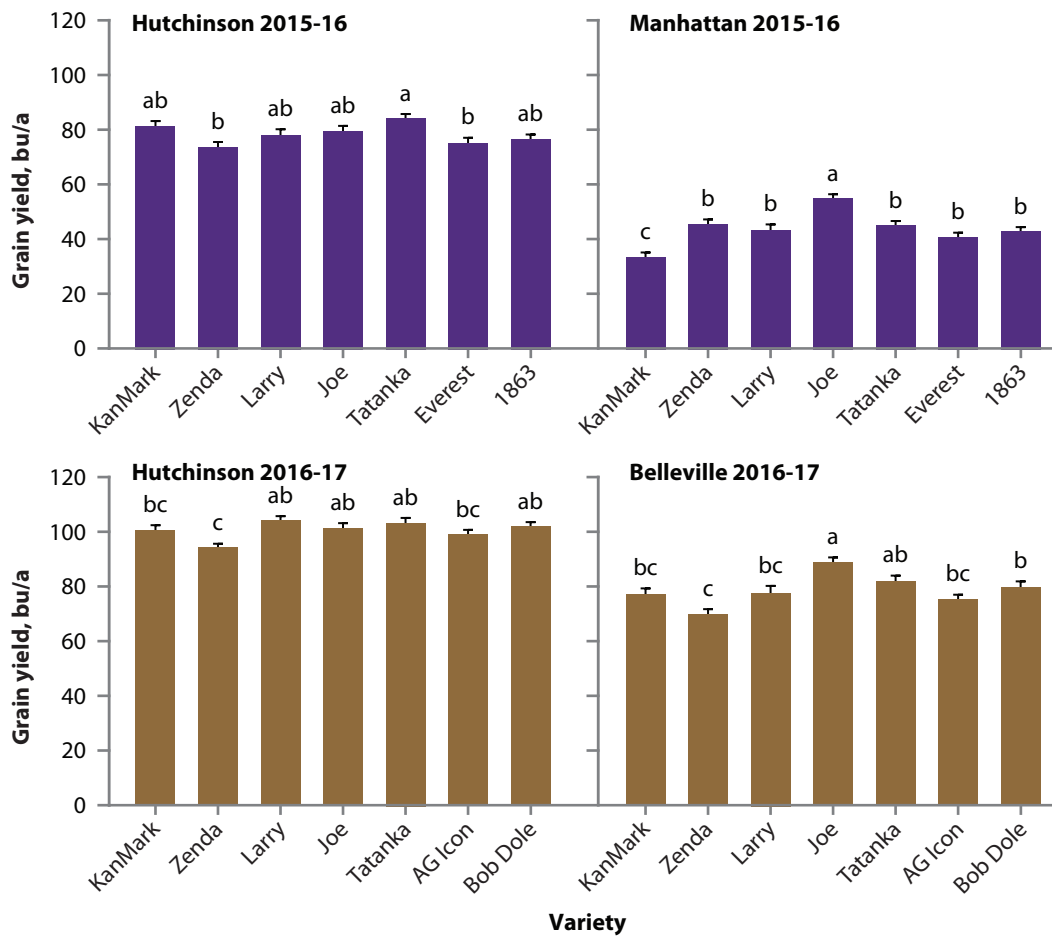


Figure 4. Wheat grain yield as affected by wheat variety and pooled across seeding rates during the 2015–2016 (upper panels) and 2016–2017 (lower panels) growing seasons.



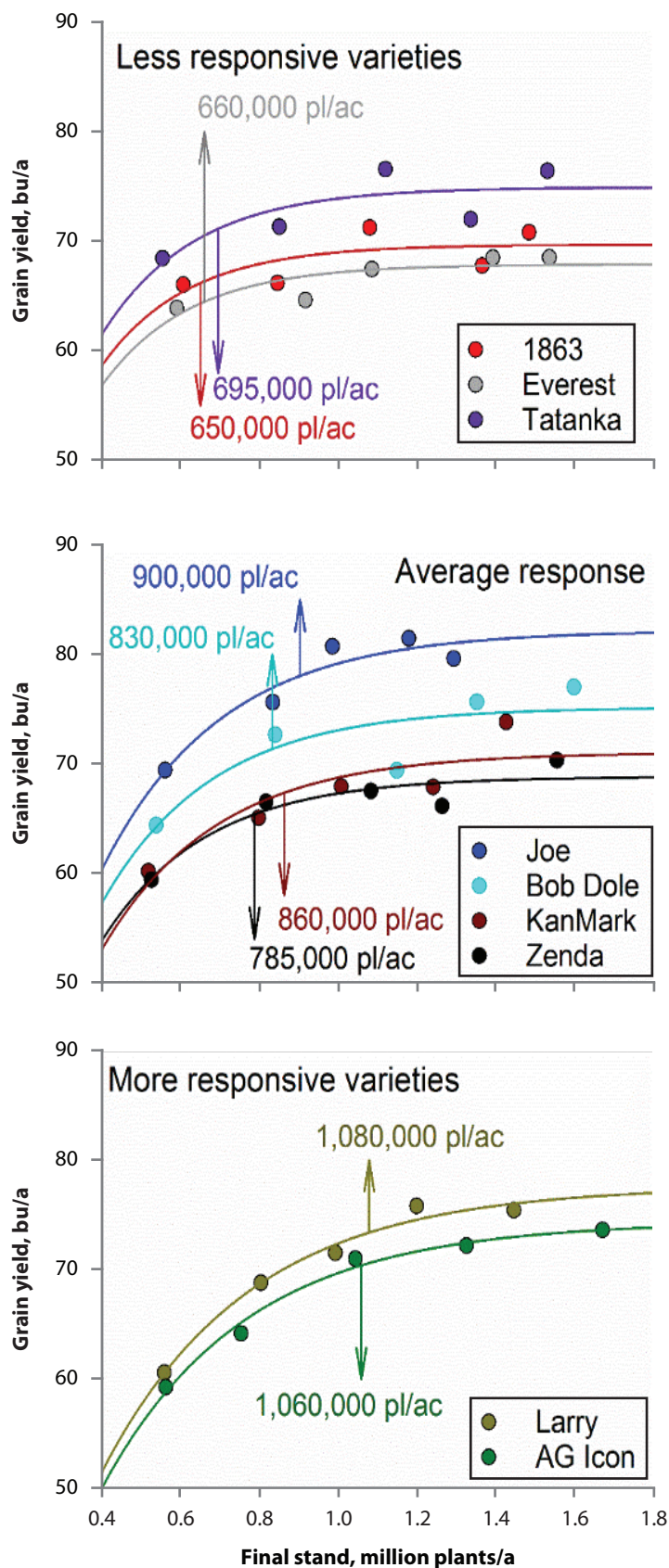


Figure 5. Wheat grain yield as affected by plant population for nine wheat varieties. Data shown are pooled over the entire dataset reflecting four (Larry, Joe, KanMark, Zenda, and Tatanka) and two (AG Icon, Bob Dole, Everest, and 1863) site-years of data.

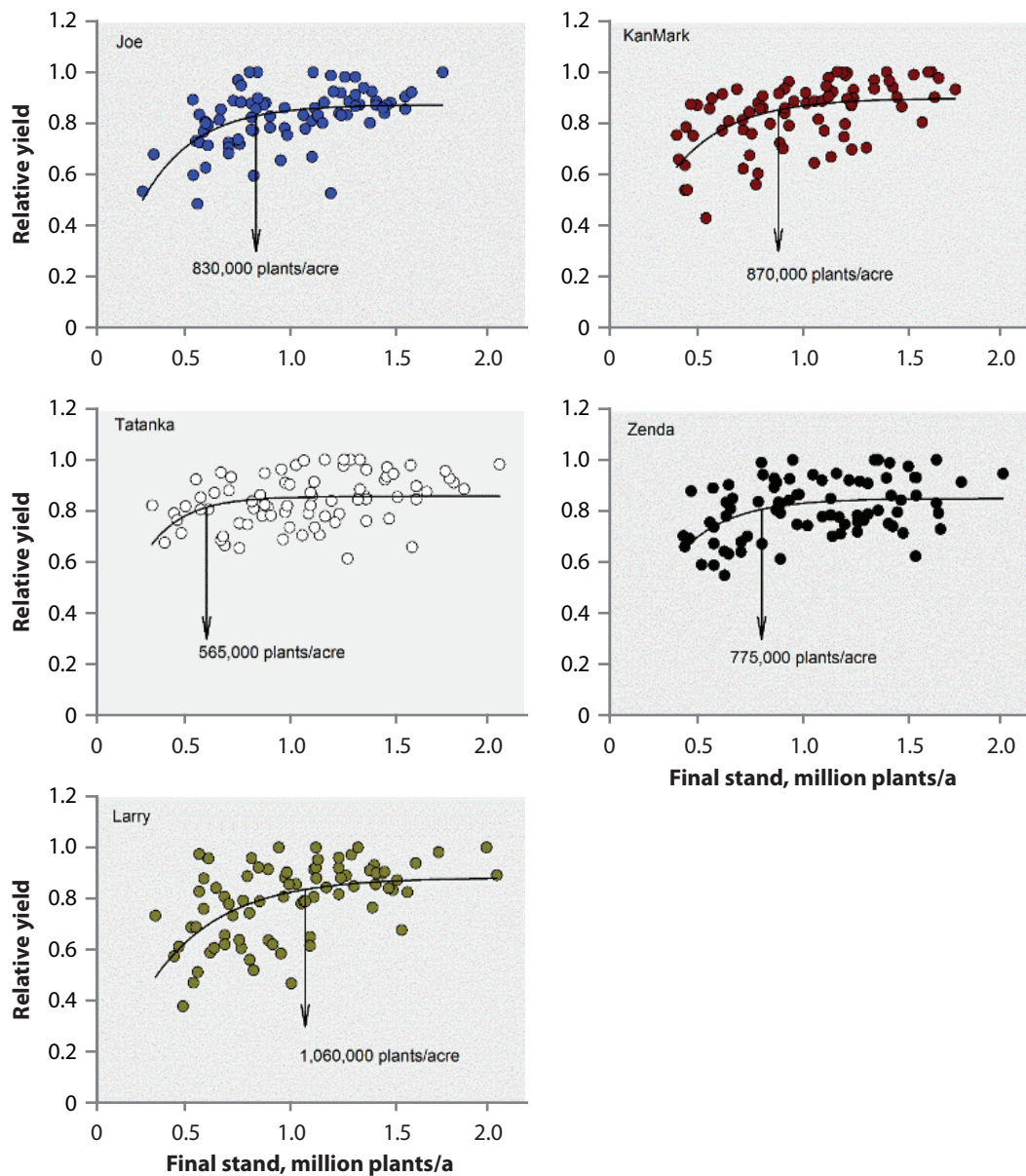
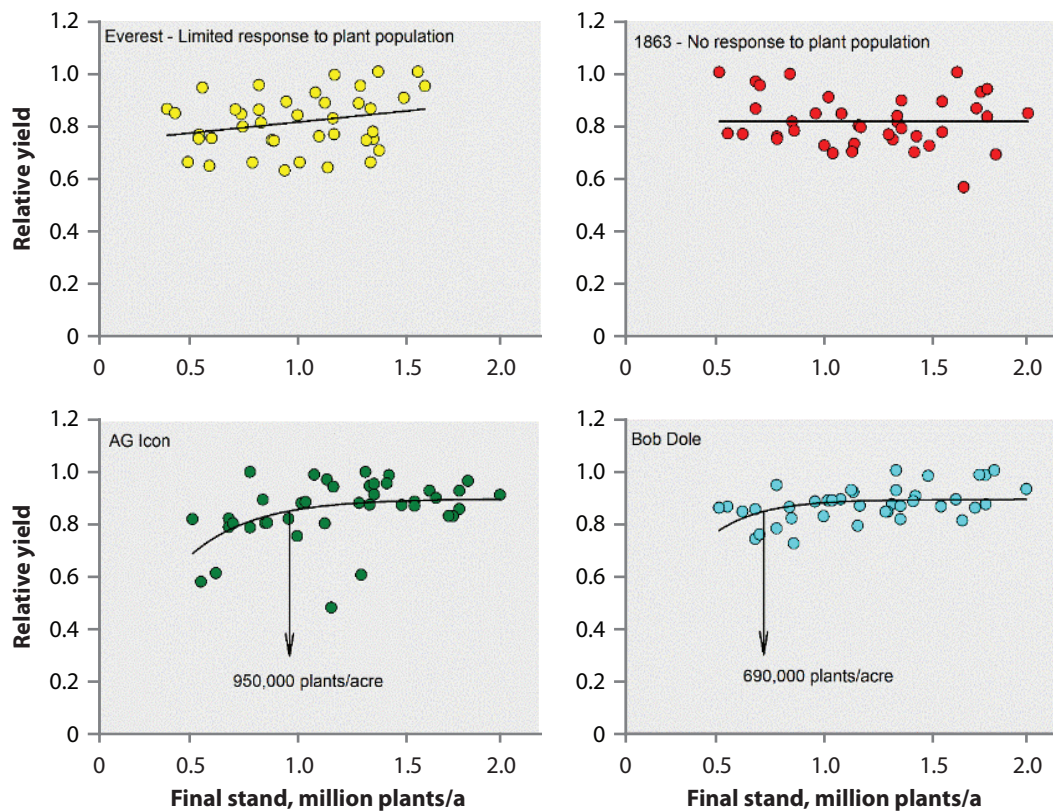


Figure 6. Relative wheat grain yield as affected by plant population for five wheat varieties. Data shown are pooled over the entire dataset reflecting four site-years of data.



**Figure 7. Relative wheat grain yield as affected by plant population for four wheat varieties. Data shown are pooled over the entire dataset, but the selected varieties have only two site-years of data.**