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Romulo P. Lollato
Kansas State University, lollato@ksu.edu

Nicolas Giordano
Kansas State University

Jazmin Gastaldi
Kansas State University

See next page for additional authors

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Summary

Wheat response to seeding rate varies and depends on resource availability during the growing season (e.g., fertility, moisture, and temperature). Our objective was to evaluate winter wheat population and grain yield responses to seeding rate and its interaction with variety. The wheat varieties tested were WB4792, Langin, WB4422, and KS Big Bow in the trial conducted in Leoti (western KS), and all but Langin in the trial conducted in Belleville (north central KS). The trial included five seeding rates increasing exponentially from 100,000 to 1,600,000 seeds per acre. The trials were established after a long summer fallow in sorghum residue during late September 2023. Growing season total precipitation ranged from 11.1 to 15.4 inches. There were significant effects of seeding rate on final stand count, with greater rates resulting in greater stand counts; however, final stand count was closer to the target in lower seeding rates. At both locations, grain yield was affected independently by seeding rate and by variety, but not by their interaction, suggesting that varieties performed similarly as a function of seeding rate. In Belleville, yields ranged from 53.4 to 85.6 bushels per acre as a function of seeding rate, whereas in Leoti the range was 66.7 to 92.7 bushels per acre. At both sites, grain yield increased from the lowest seeding rate to 800,000 seeds per acre, plateauing thereafter. The variety KS Big Bow was the highest-yielding variety across sites. In Belleville, the highest yield of KS Big Bow could be attributed to the presence of wheat streak mosaic virus in the study site. Results here suggest that wheat yield varied as a function of variety and seed rate separately, highlighting opportunities to manage both variables independently.

Introduction

Wheat responses to seeding rate are inconsistent, ranging from quadratic to positive linear, quadratic-plateau, plateau-negative linear, and even inexistent (Jaenisch et al., 2019, 2022; Fischer et al., 2019; Lollato et al., 2019, 2024). The quadratic response suggests that there is an optimum population to optimize yields. In this case, populations below the optimum may limit crop yields due to sub-optimum stands, and populations above the optimum may limit crop yields due to increased disease pressure, insects, lodging, or insufficient resources such as fertility. Recently, some Kansas evidence suggested that wheat responses to seeding rate were dependent on the level of resource availability in the environment (Bastos et al., 2020). In high-yielding environments (greater than 90 bu/a) where the crop is not limited by resources (including fertility levels, and optimal temperatures and moisture for tillering), crop yield was unresponsive to plant population. Similar results were derived from the Kansas Wheat

Yield Contest (Lollato et al., 2019) and from studies with intensively managed wheat in Kansas (Jaenisch et al., 2019; Lollato et al., 2024) and in Mexico (Fischer et al., 2019). Meanwhile, in average (65 bu/a average) and low (45 bu/a average) yielding environments, wheat responded to increases in plant population up until about 25 to 31 plants per square foot (approximately 1.1 to 1.35 million plants per acre), leveling out at greater populations (Bastos et al., 2020; Lollato et al., 2024). The optimum plant population might also depend on the variety's tillering potential (Bastos et al., 2020), as varieties with greater tillering potential might require less population to maximize yields when compared to varieties with lower tillering potential (Jaenisch et al., 2022).

The majority of the studies evaluating wheat yield response to seeding rate were performed under standard management conditions, not excessively high fertility levels, or other management factors (e.g., Whaley et al., 2000; Lloveras et al, 2004; Bastos et al., 2020). Thus, in this study we aimed to understand wheat response to seeding rate in a scenario with highly available resources. This is relevant in a context in which increases in food production are needed to feed an increasing global population, especially in regions characterized by actual yields well below the potential yields, such as in Kansas and neighboring states (Couedel et al., 2025; Jaenisch et al., 2021; Lollato and Edwards, 2015; Lollato et al., 2017; 2019; Patrignani et al., 2014). Since resource availability and variety-specific tillering capacity seem to govern wheat yield response to plant population, our objective was to evaluate the grain yield response of different winter wheat varieties to seeding rate, including extremely low seeding rates, in a highly-managed commercial field in western Kansas.

Procedures

Field experiments were conducted in two locations during the 2023-2024 winter wheat growing season: a commercial wheat field near Leoti, KS; and the Kansas State University North Central Experiment Field near Belleville, KS. The research plots were sown on September 28 and 29, 2023 at Belleville and Leoti, and comprised seven 7.5-inch spaced rows wide and were 30 ft long. A two-way factorial treatment structure was established in a completely randomized block design and included four commercial wheat varieties (i.e., WB4792, Langin, WB4422, and KS Big Bow) and five seeding rates (100,000, 200,000, 400,000, 800,000, and 1,600,000 seeds/a). All seeds were treated with insecticide and fungicide seed treatment to avoid potential stand losses due to pests (Pinto et al., 2020). The experiments were sown after a long summer fallow in sorghum residue. In Leoti, wheat was the second crop after manure application (5 tons per acre, providing about 150 pounds of nitrogen and phosphorus). In-furrow diammonium phosphate was applied with the seed at 50 pounds of product per acre both locations. Management of the field consisted of 40 pounds of N per acre, with 3.5 ounces per acre Rave herbicide in February, 180 pounds of N per acre as urea on March 10, and 13 ounces per acre of Nexicor fungicide at heading. Combined with the soil fertility available at sowing, all the manageable stresses were likely reduced. Harvest occurred using a Massey Ferguson XP8 small-plot, self-propelled combine in early July 2024.

A total of 15 individual soil cores (0- to 24-inch depth) were collected from each location and divided into 0- to 6-inch and 6- to 24-inch increments for initial fertility analysis. The individual cores were mixed to form one composite sample, which was later analyzed for base fertility levels (Table 1). In-season measurements included stand count (measured about 20–30 days after sowing) and grain yield at harvest maturity (corrected for 13% moisture content). Statistical analysis of the data collected in this experiment was performed using a two-way ANOVA in PROC GLIMMIX procedure in SAS v. 9.4. Linear and non-linear regression analysis was used to test the population and grain yield responses to seeding rate.

Results

Weather conditions

The 2023-2024 growing season was extremely variable in terms of weather patterns, in particular of precipitation amount and distribution. In the context of this study, total in-season precipitation was 11.1 inches in Belleville and 15.3 inches in Leoti (Table 2). The fall had 2.4 to 3.5 inches of precipitation and the winter, 1.2 to 2.9 inches (Table 2). The spring had 7.5 and 8.8 inches, respectively. Temperature ranges were comparable across locations. This limited amount of water in the growing season is typical of the study region, which is characterized by a high likelihood of water, temperature, and combined stresses (Couedel et al., 2021; Lollato et al., 2020; Sciarresi et al., 2019; Zhao et al., 2022).

Seeding Rate and Variety Effects on Stand Establishment and Grain Yield

There was a significant seeding rate effect on final stand establishment in both locations (Table 3). Stand count ranged from 347,491 to 683,773 plants per acre in Belleville and from 257,521 to 969,022 plants per acre in Leoti. Overall, increases in seeding rate resulted in greater stand count, as expected, although there was some variability in the response at Belleville (Table 4). We note that final populations were closer to the target population at lower seeding rates as compared to higher seeding rates. In Leoti, there was also a variety effect on final stand establishment, where KS Big Bow had greater final population than WB4792 and Langin (638,227 versus ~490,000 plants per acre) (Table 4).

Grain yield was affected by seeding rate and by variety independently, with no variety × seeding rate interaction, suggesting that varieties responded similarly to seeding rate (Table 3). At both locations, grain yield increased from the lowest seeding rate to the highest seeding rate, with the peak occurring at the 800,000 seeds per acre seeding rate (Table 5). In Belleville, yields increased from 53.4 bushels per acre at the lowest rate to 85.6 bushels per acre at the peak, while at Leoti grain yield increased from 66.7 bushels per acre at the lowest rate to 96.9 bushels per acre at the highest rate (Table 5). There was also a significant effect of wheat variety on grain yield at both locations, with the variety KS Big Bow consistently outyielding the other varieties. In Belleville, KS Big Bow averaged 92.1 bushels per acre as compared to ~63 bushels per acre for the other tested varieties (Table 5). This large difference may likely be associated with the incidence of wheat streak mosaic virus in this trial coupled with the improved genetic resistance of this variety to the disease; or potentially to the low soil pH at the studied sites (Table 1). In Leoti, yields were more comparable, with KS Big Bow averaging 93.1 bushels per acre with the other varieties ranging from 75.3 to 85.1 bushels per acre (Table 5).

Preliminary Conclusions

This trial provided information about the yield response of different wheat varieties to a large range of seeding rates, suggesting that 800,000 seeds per acre were sufficient to maximize yield in two separate locations. While there were significant differences in grain yield among varieties, with KS Big Bow yielding more than the other varieties at both locations, multiple site-years of data are needed for proper variety comparison. The lack of variety by seeding rate interaction in the data also suggested that varieties responded similarly to seeding rate, potentially precluding the need for variety-specific seeding rates.

Acknowledgments

We acknowledge Horton Seed Services for providing seed, land, and labor for the completion of this project. This research was initiated following discussions with Rick Horton about wheat management for high yields. We also appreciate the help in trial conduction provided by Scott Dooley at the K-State North Central Experiment Field.

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Table 1. Initial soil fertility measured at wheat sowing during the 2023-2024 growing season for the trials conducted near Belleville and Leoti, KS

		Belleville		Leoti	
Variable	**Unit**	**0-6 in.**	**6-24 in.**	**0-6 in.**	**6-24 in.**
O.M.	%	2.8	2.9	1.9	2
pH	---	4.8	5.3	7.1	7.8
NO_3-N	ppm	45	40	14	15
P	ppm	55	42	87	59
K	ppm	357	311	623	577
S	ppm	7.3	5.4	4.1	4.9
Ca	ppm	2163	2520	2502	4967
Mg	ppm	320	358	336	446
CECS	meq/100g	26	27	17	30
Sand	%	18	18	24	22
Silt	%	53	49	52	50
Clay	%	29	33	24	28

Variables include, respectively, soil organic matter, pH, nitrate-N, Mehlich III phosphorus, potassium, sulfur, calcium, magnesium, cation exchange capacity, and soil texture (sand, silt, and clay percent).

Table 2. Weather conditions including average maximum (Tmax) and minimum (Tmin) air temperatures, and cumulative precipitation near Belleville and Leoti, KS, during the 2023–2024 growing season

Timeframe	Variable	Unit	Belleville	Leoti
Season	Precipitation	Inch	11.1	15.33
	Tmax	°F	63.4	61.0
	Tmin	°F	34.8	36.1
Fall	Precipitation	°F	2.4	3.6
	Tmax	°F	60.5	58.0
	Tmin	°F	32.0	33.6
Winter	Precipitation	°F	1.2	2.9
	Tmax	°F	50.8	47.0
	Tmin	°F	23.1	23.6
Spring	Precipitation	°F	7.5	8.8
	Tmax	°F	79.5	78.6
	Tmin	°F	49.7	51.6

*Fall: September 28 - December 31. Winter: January 1 - March 31. Spring: April 1 - July 1.

Table 3. Results from the two-way analyses of variance for wheat stand count and grain yield for the main effects variety and seeding rate, as well as their interaction, in trials conducted near Belleville and Leoti, KS, during the 2023-2024 growing season

Source of variation	Belleville		Leoti	
	Stand count	Grain yield	Stand count	Grain yield
	---------- *P* ----------			
Variety (V)	0.006	< 0.001	< 0.001	< 0.001
Seeding rate (SR)	0.31	< 0.001	< 0.001	< 0.001
V × SR	0.77	0.94	0.64	0.65

Table 4. Mean stand count of winter wheat as a function of seeding rate or variety for trials conducted near Belleville and Leoti during the 2023-2024 growing season

Treatment	Belleville	Leoti
Seeding rate (seeds/acre)	---------- Stand count (plants per acre) ----------	
100,000	347491 B*	257521 D
200,000	414747 AB	330530 D
400,000	369910 B	463272 C
800,000	669024 A	702209 B
1,600,000	683773 A	969022 A
Variety		
WB4792	536281	485308 B
WB4422	415927	562829 AB
KS Big Bow	538759	638227 A
Langin	---	491679 B

*Significance of fixed effects resulting from the ANOVA as well as post-hoc mean grouping. Means followed by the same letter are not significantly different at $P = 0.05$.

Table 5. Mean grain yield of winter wheat as a function of seeding rate or variety for trials conducted near Belleville and Leoti during the 2023-2024 growing season

Treatment	Belleville	Leoti
Seeding rate (seeds/acre)	---------- Grain yield (bushels per acre) ----------	
100,000	53.4 D*	66.7 D
200,000	64.1 C	77.7 C
400,000	76.1 B	88.7 B
800,000	85.6 A	96.9 A
1,600,000	83.6 A	92.7 AB
Variety		
WB4792	62.4 B	85.1 B
WB4422	63.1 B	75.3 C
KS Big Bow	92.1 A	93.1 A
Langin	---	84.6 B

*Significance of fixed effects resulting from the ANOVA as well as post-hoc mean grouping. Means followed by the same letter are not significantly different at $P = 0.05$.