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Wheat Variety-Specific Response to Seeding Rate Under Intensive Management Conditions in Western Kansas in 2021–2022

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Summary

Wheat response to seeding rate is variable 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 in a highly-managed production system where manageable stresses were limited. This study was established to evaluate the response of the wheat varieties Joe, WB-Grainfield, Langin, and LCS Revere to five seeding rates ranging from 200,000 to 1,000,000 seeds per acre. The site was managed by growers who consistently win state and national wheat yield contests near Leoti, KS. The trial was established on September 25, 2021, after a long summer fallow in sorghum residue. A total of 0.75-in. rainfall surrounding sowing ensured good stand establishment. The entire growing season was dry, limiting grain yield to the 40 to 66 bu/a range, depending on treatment. There were significant effects of seeding rate and variety on stand count, with no interaction. Main effects suggested that the stand count increased with increases in the seeding rate (from 205,795 to 658,544 plants per acre), with the 800,000 and 1,000,000 seeds/a rates attaining the highest stands. WB-Grainfield had the greatest population (522,586 plants per acre), which was statistically greater than that of Langin (412,121 plants per acre) but similar to the other two varieties with intermediate population. Final populations were closer to the target population at lower seeding rates as compared to higher seeding rates. Grain yield also depended primarily on variety and on seeding rate, with no interaction between both effects. Grain yield ranged between 56.9 and 58.2 bu/a acre for the seeding rates ranging between 600,000 and 1,000,000 seeds/a, and from 49.3 to 55.0 bu/a for lower seeding rates. Langin and WB-Grainfield were the highest yielding varieties (57.6 bu/a), and LCS Revere and Joe had the lowest yield (53.1 bu/a). These results suggest that wheat grain yield responses to seeding rate were not dependent on variety, with optimum seeding rates as low as 600,000 seeds/a. We note that increasing seeding rates beyond 600,000 seeds/a led to numerical but not statistical increases in yield.

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). 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 yield results provided evidence suggesting that wheat responses to seeding rate were dependent on the level of resource availability of 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) 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). 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 the 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 (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

A field experiment was conducted during the 2021–2022 winter wheat growing season in a commercial wheat field near Leoti, KS. The research plots were sown on September 25, 2021, and comprised of seven 7.5-in. 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., Joe, Langin, WB-Grainfield, and LCS Revere) and five seeding rates (200,000, 400,000, 600,000, 800,000, and 1,000,000 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; wheat was the second crop after manure application (5 tons per acre, providing about 150 pounds of N and P). In-furrow diammonium phosphate was applied with the seed at 50 pounds of product per acre. 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 on July 5, 2022.

A total of 15 individual soil cores (0- to 24-in. depth) were collected from each location and divided into 0- to 6-in. and 6- to 24-in. 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. Non-linear regression analysis was used to test the grain yield response to plant population, and the residuals from this relationship were subjected to one-way ANOVA to test the effect of wheat variety.

Results

Weather Conditions

The 2021-2022 growing season was extremely dry. There was only 1.5 inches of precipitation in the fall, and the winter only received 0.4 inch, with water supply only representing 10% of crop water demand (Table 2). The spring had 4.3 inches of precipitation, which only represented 20% of crop water demand (Table 2). This water limitation restricted grain yields, which ranged from 40 to 66 bu/a. These dry conditions are typical of the study region, which is characterized by high likelihood of water and temperature stresses (Couëdel 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 (Table 3). Overall, increases in seeding rate resulted in greater stand count, as expected. However, we note that final populations were closer to the target population at lower seeding rates as compared to higher seeding rates. For instance, the target population of 200,000 plants/a resulted in 205,795 plants per acre; while the target of 1,000,000 plants/a resulted in 658,544 plants per acre. This is usually observed in seeding rate studies (Bastos et al., 2020). There was also a variety effect on final stand establishment, where WB-Grainfield resulted in more plants per acre than Langin, but both were not statistically different than LCS Revere or Joe (Table 3).

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). Overall, there was a linear-plateau grain yield response to seeding rate, increasing from 49.3 bu/a in the 200,000 seeds/a rate, to anywhere from 56.9 to 58.2 bu/a in the seeding rates ranging from 600,000 to 1,000,000 seeds/a, with no significant statistical differences among the higher seeding rates. The varieties Langin and WB-Grainfield had the highest grain yield (57.6 bu/a), followed by LCS Revere and Joe (53.1 bu/a).

The overall relationship between plant population and grain yield is shown in Figure 1a. Grain yield showed a quadratic relationship as a function of plant population, with the highest yields visually observed between the populations of 550,000 and 720,000 plants per acre. Analysis of the residuals of this relationship as affected by wheat variety indicated a significant variety effect (Figure 1b). This analysis evaluates the effect of variety on grain yield when the effect of plant population is accounted for. Langin and

WB-Grainfield out-yielded the expected yield for a given population by 1.4 to 3.9 bu/a, while Joe and LCS Revere were 1.7 to 2.1 bu/a below the expected yield for a given population.

Preliminary Conclusions

This trial provided information on wheat response to seeding rate within a highly managed scenario, during a dry growing season. At yield levels ranging between 40 and 66 bu/a, wheat response to seeding rate was independent of variety, and yield was maximized at 600,000 seeds per acre. The increases in yield reported for seeding rates beyond 600,000 seeds/a were not statistically significant.

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Table 1. Initial soil fertility measured at wheat sowing during the 2021–2022 growing season for the trial conducted near Leoti, KS

Depth	pH	NO_3-N	P	K	Ca	Mg	S	OM	CEC	Sand	Silt	Clay
inch	------------------------------- ppm -------------------------------							%	meq/100 g	----------- % -----------		
0 to 6	6.8	28.8	74.7	692.3	2767.9	390.3	6.8	1.7	19.01	26	46	28
6 to 18	7.4	20.9	32.7	677.3	4048.7	499.6	6.1	1.8	26.31	26	43	31

Variables include, respectively, soil pH, nitrate-N, Mehlich phosphorus, potassium, calcium, magnesium, sulfur, organic matter, 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 and reference evapotranspiration (ETo) near Leoti, KS, during the 2020–2021 growing season

Season*	Tmax	Tmin	Precipitation	ETo	WS:WD**
	---------------- °F	----------------	---------------- inch	----------------	
Fall	64.4	32.3	1.5	12.8	0.1
Winter	48.5	19.2	0.4	8.3	0.1
Spring	78.9	47.2	4.3	20.0	0.2

*Fall: September 25 to December 31. Winter: January 1 to March 31. Spring: April 1 to July 5.
**Water supply (WS) to water deficit (WD) ratio.

Table 3. Stand count and grain yield of four winter wheat varieties (WB-Grainfield, Joe, LCS Revere, and Langin) as affected by seeding rate ranging from 200,000 to 1,000,000 seeds/a

Factor	Plant population		Grain yield	
	plants/a		bu/a	
Seeding rate (seeds/a)				
200,000	205,795	b	49.3	c
400,000	387,691	b	55.0	b
600,000	503,202	b	56.9	ab
800,000	622,695	a	57.3	ab
1,000,000	658,544	a	58.2	a
Variety	522,586	a	57.5	a
WB-Grainfield				
Joe	487,535	ab	53.0	a
LCS Revere	480,099	ab	53.1	b
Langin	412,121	b	57.7	b
Test of fixed effects				
SRATE	<0.001		<0.001	
VAR	0.003		<0.001	
SRATE × VAR	0.37		0.89	

SRATE = seeding rate. VAR = variety.
*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 $P = 0.05$.

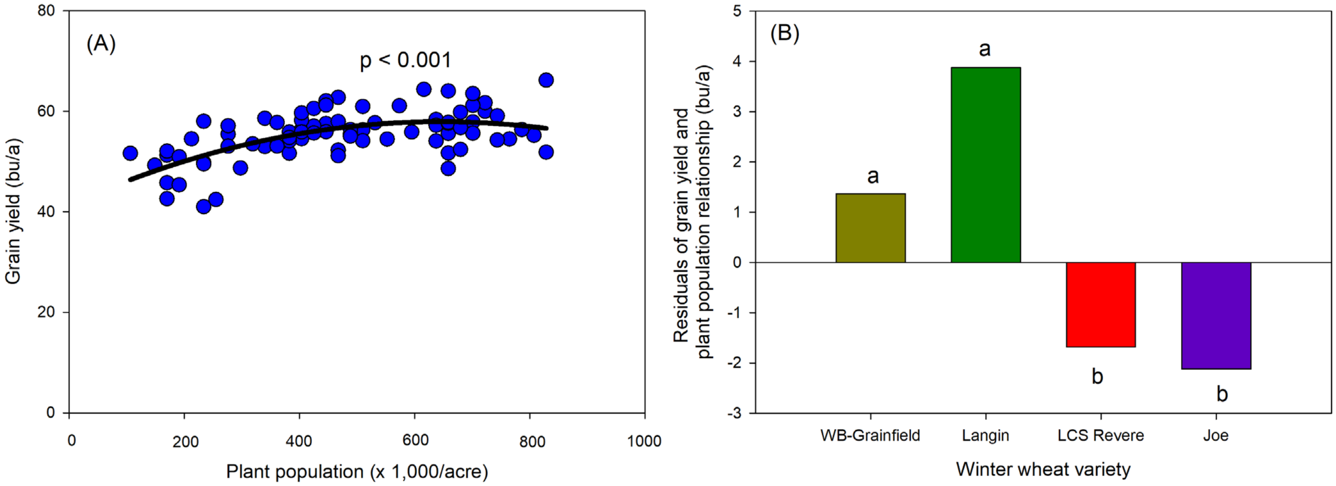

Figure 1. (A) Winter wheat grain yield as function of plant population across all varieties and seeding rates evaluated, and (B) analysis of variance of the residuals of the relationship of grain yield by plant population as affected by winter wheat variety. Data represent one location near Leoti, KS, during the 2021–2022 growing season.