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Wheat Variety-Specific Grain Yield Response to Plant Density Under Intensive Management Conditions in Western Kansas

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Wheat Variety-Specific Grain Yield Response to Plant Density Under Intensive Management Conditions in Western Kansas

Abstract

Seeding rate determines the first yield component of field crops, which is the plant population. However, wheat is less responsive to plant populations than other crops due to the high plasticity in tillering potential, and this responsiveness depends on resource availability. The objective of this project was to evaluate winter wheat population, grain yield, and grain test weight responses to seeding rate and its interaction with variety in a highly managed production system where manageable stresses were limited. Experiments evaluating the response of the wheat varieties 'Joe,' 'WB-Grainfield,' 'Langin,' and 'LCS Revere' to seeding rates ranging from 200,000–1,000,000 seeds per acre were established in a field managed by growers who consistently win state and national wheat yield contests near Leoti, KS. Trials were established at a relatively late date in 2017–2018 (delayed by pre-sowing rainfall), and at the optimal timing during 2018–2019. Growing seasons contrasted in that 2017–2018 was dry (approximately 6 inches in-season precipitation) and had warm grain filling conditions, and 2018–2019 was cool and moist (appx. 13 inches in-season precipitation). Stand count increased with increases in seeding rate both years but final population was closer to the target population during 2017–2018. Grain yield response to seeding rate and to variety depended on year, but all varieties responded similarly to seeding rate. In 2017–2018, grain yield increased linearly from appx. 40–60 bushels per acre with increases in seeding rate from 200,000–400,000 seeds per acre. During 2018–2019, the lowest yield was recorded across varieties in the plots with 200,000 seeds per acre, with the treatments ranging from 400,000–1,000,000 seeds per acre all resulting in the same yield level. Grain yield as affected by emerged plant population (instead of seeding rate) showed similar trends, though quadratic relationships indicated a maximum yield at about 500,000–580,000 plants per acre in 2018–2019. Grain test weight was impacted by the interaction of variety, seeding rate, and year. Greatest test weight values resulted in 2017–2018, when the test weight of all varieties responded in a quadratic way to seeding rates. In 2018–2019, there was no clear trend in varieties' test weight responses to population. These results suggest that wheat grain yield responses to seeding rate (and to plant population) are more dependent on sowing date and weather conditions than on variety, with optimum sowing times and a warm fall allowing for seeding rate as low as 400,000 seeds per acre without yield penalty. Meanwhile, later sowing dates and cooler fall conditions required seeding rates of up to 1,000,000 seeds per acre to maximize grain yield.

Keywords

wheat, seeding rate, population, yield potential

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Cover Page Footnote

We acknowledge Horton Seed Services for providing seed, land, and labor for completion of this project during the two years summarized in this report. This research was initiated following discussions with Mr. Rick Horton about wheat management for high yields.

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Wheat Variety-Specific Grain Yield Response to Plant Density Under Intensive Management Conditions in Western Kansas

R.P. Lollato, K. Mark, and B.R. Jaenisch

Summary

Seeding rate determines the first yield component of field crops, which is the plant population. However, wheat is less responsive to plant populations than other crops due to the high plasticity in tillering potential, and this responsiveness depends on resource availability. The objective of this project was to evaluate winter wheat population, grain yield, and grain test weight responses to seeding rate and its interaction with variety in a highly managed production system where manageable stresses were limited. Experiments evaluating the response of the wheat varieties 'Joe,' 'WB-Grainfield,' 'Langin,' and 'LCS Revere' to seeding rates ranging from 200,000–1,000,000 seeds per acre were established in a field managed by growers who consistently win state and national wheat yield contests near Leoti, KS. Trials were established at a relatively late date in 2017–2018 (delayed by pre-sowing rainfall), and at the optimal timing during 2018–2019. Growing seasons contrasted in that 2017–2018 was dry (approximately 6 inches in-season precipitation) and had warm grain filling conditions, and 2018–2019 was cool and moist (appx. 13 inches in-season precipitation). Stand count increased with increases in seeding rate both years but final population was closer to the target population during 2017–2018. Grain yield response to seeding rate and to variety depended on year, but all varieties responded similarly to seeding rate. In 2017–2018, grain yield increased linearly from appx. 40–60 bushels per acre with increases in seeding rate from 200,000–400,000 seeds per acre. During 2018–2019, the lowest yield was recorded across varieties in the plots with 200,000 seeds per acre, with the treatments ranging from 400,000–1,000,000 seeds per acre all resulting in the same yield level. Grain yield as affected by emerged plant population (instead of seeding rate) showed similar trends, though quadratic relationships indicated a maximum yield at about 500,000–580,000 plants per acre in 2018–2019. Grain test weight was impacted by the interaction of variety, seeding rate, and year. Greatest test weight values resulted in 2017–2018, when the test weight of all varieties responded in a quadratic way to seeding rates. In 2018–2019, there was no clear trend in varieties' test weight responses to population. These results suggest that wheat grain yield responses to seeding rate (and to plant population) are more dependent on sowing date and weather conditions than on variety, with optimum sowing times and a warm fall allowing for seeding rate as low as 400,000 seeds per acre without yield penalty. Meanwhile, later sowing dates and cooler fall conditions required seeding rates of up to 1,000,000 seeds per acre to maximize grain yield.

Introduction

The literature reports inconsistent wheat responses to seeding rate. While the most reported relationship between wheat grain yield and seeding rate is quadratic (Holliday, 1960), some authors suggested that this response might be positive linear, quadratic-plateau, plateau-negative linear, and even inexistent (Whaley et al., 2000; Lloveras et al., 2004; Fischer et al., 2019; Lollato et al., 2019). The quadratic response suggests that there is an optimum population below which the crop is limited by the number of plants and thus, by its yield components (Whaley et al., 2000); and above which other factors such as disease pressure, insects, lodging, or insufficient resources might limit yield (Lloveras et al., 2004). Recently, a comprehensive analysis of winter wheat yield response to plant density suggested that it depends on the level of resource availability of the environment (Bastos et al., 2020). In high-yielding environments (greater than 90 bushels per acre) where the crop is not limited by resources (including fertility levels, temperature, 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 bushels per acre average) and low- (45 bushels per acre average) yielding environments, wheat responded to increases in plant population up until the increase of approximately 25–31 plants per square feet (approximately 1.1–1.35 million plants per acre), leveling out at greater populations (Bastos et al., 2020).

Another important conclusion from the Bastos et al. (2020) study was that the optimum plant population also depended on the variety's tillering potential. Varieties with greater tillering potential usually required less population to maximize yields when compared to varieties with lower tillering potential. Wheat has a very high compensation capacity among its yield components compared to other crops, but this evidence suggests that varieties with high tillering potential have even greater compensation capacity than those with low tillering potential and might offer an opportunity to fine-tune seeding rate recommendations.

With few exceptions, the majority of the studies of wheat yield response to seeding rates were performed under standard management conditions, i.e. not excessively high fertility levels or other management factors (e.g., Whaley et al., 2000; Lloveras et al, 2004; Bastos et al., 2020). Nonetheless, to increase food production to feed an increasing global population without expanding agriculture into current native lands, the large yield gap in Kansas and in the region (Lollato et al., 2017) must be reduced. Thus, more information is needed about wheat yield response to plant population under intensive management systems that have the objective to maximize yield (e.g., Lollato and Edwards, 2015; Jaenisch et al., 2019) is needed. Considering that 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 2017–2018 and the 2018–2019 winter wheat growing seasons in a commercial wheat field near Leoti, KS. The research plots 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 high-yielding commercial wheat varieties (i.e., Joe, Byrd, WB-Grainfield, and LCS Revere) and five seeding rates (200,000, 400,000, 600,000, 800,000 and 1,000,000 seeds per acre). The experiments were planted on October 13, 2017, and September 27, 2018. The crop was planted after a long summer fallow in sorghum (2017–2018) and corn (2018–2019) residue, and in both years it was the second crop after manure application (5 tons per acre, providing approximately 150 pounds of nitrogen (N) and phosphorus (P)). During 2017–2018, management of the field consisted of 80 pounds of N per acre in December; 3.5 ounces per acre of Rave herbicide on February; 6 ounces per acre Azoxystrobinplus 2 ounces per acre Xcite (cytokine) at double ridge stage; and finally 6 ounces per acre generic Azoxystrobin, 4 ounces per acre generic Tebuconazole, 2 ounces per acre Xcite, and 1 pound per acre Harvest More Urea Mate once the flag leaf was fully emerged. During 2018–2019, crop management consisted of 40 pounds of N per acre in September plus 65 pounds of N per acre and 8 lb sulfur (S) in December, 3.5 ounces per acre Rave herbicide in February plus 6 ounces per acre generic Azoxystrobin and 2 ounces per acre Xcite (cytokine) early March, and finally 8 ounces per acre Aproach Prima (Picoxystrobin plus Cyproconazole) plus 2 ounces per acre Xcite and 1 pound per acre Harvest More Urea Mate once the flag leaf was fully emerged. Very likely, all the manageable stresses were reduced. Harvest occurred using a Massey Ferguson XP8 small-plot, self-propelled combine. Plot ends were trimmed at harvest time to avoid border effect.

A total of 15 individual soil cores (0- to 24-in. depth) were collected from each location and divided into 0–6 in. and 6–24 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 approximately 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 as a two-way ANOVA in PROC GLIMMIX procedure in SAS v. 9.4 (SAS Inst. Inc., Cary, NC). Linear and non-linear regression analyses were used to test the grain yield response to plant population. Replication was treated as a random effect in the analysis for individual locations.

Results

Weather Conditions

The two growing seasons included in this study were very contrasting, as shown in Figure 1. The most contrasting aspect was in-season precipitation, which was approximately 6 inches in 2017–2018 versus appx. 13 inches in 2018–2019. Another important difference between seasons was in total temperature accumulated during the fall. Due to precipitation in late September, the trial was not established until October 13 in the 2017–2018 season, which is considerably later than the optimum sowing date for the region (near September 25). Meanwhile, sowing date was much closer to the optimum during 2018–2019. This difference in sowing date allowed for more temperature accumulation during the fall in the second season (982 vs. 884°F), leading to greater fall tillering and canopy development.

Overall Treatment Significance on the Measured Variables

Table 2 shows the results from the analysis of variance for stand establishment, grain yield, and grain test weight as affected by seeding rate, variety, year, and their interaction. For stand establishment, there was a significant year by seeding rate interaction. For grain yield, there were significant year by variety and year by seeding rate interactions. For grain test weight, there was a significant year by variety by seeding rate interaction. Significant interactions with year indicate the response to that specific management practice depended on year.

Stand Establishment

Stand establishment (or emerged plant population) increased with increases in seeding rate both years; however, the final plant population was closer to the target at lower seeding rates and further away from the target at higher seeding rates, and the number of plants emerged per increase in seeding rate depended on year (Figure 2). In 2017–2018, final plant population was closer to the target at all populations, and each increase in 100,000 seeds per acre increased final population establishment in about 85,190 plants. Meanwhile, the attained population was further from the target in 2018–2019 (except for the lowest seeding rate of 200,000 seeds per acre) and increases in 100,000 seeds per acre only resulted in 56,930 additional plants per acre. These differences were likely led by greater pre-sowing precipitation in 2017–2018 as compared to seeding in a dryer topsoil in 2018–2019.

Grain Yield

Grain yield response to seeding rate and variety depended on year, but there was no variety by seeding rate interaction, suggesting that all varieties responded similarly to seeding rates. In the hot and dry season of 2017–2018, when the trial was sown late and grain yield ranged from 40 to 60 bushels per acre, grain yield responded linearly to increases in seeding rate, with the lowest yields achieved at the 200,000 seeds per acre treatment and the highest yields at the 1,000,000 seeds per acre seeding rate (Figure 3). Meanwhile, there was a more quadratic or linear-plateau response to seeding rate in 2018–2019 when the crop was planted earlier and allowed for greater fall tillering and grain yields ranging from 85–110 bushels per acre. In this case, yields were lowest at the 200,000 seeds per acre rate and increased with seeding rate increases until the 400,000 seeds per acre rate, with no increases in grain yield with further increases in seeding rate. These results agree with the report by Bastos et al. (2020) in that grain yield is less responsive to plant population at higher yielding environments. The variety effect also depended on year, as Langin and Joe were the highest yielding varieties in 2018–2019 (53–56 bushels per acre, versus 49–50 bushels per acre for WB-Grainfield and LCS Revere); and Langin and WB-Grainfield were the highest yielding varieties in 2018–2019 (103–104 bushels per acre versus 98–99 bushels per acre for Joe and Langin).

Grain yield as a function of actual plant population (rather than seeding rate) is shown by variety in Figure 4. The trends were similar to those of the seeding rate, in which yields increased linearly with increases in plant population during 2017–2018, and in a quadratic way in 2018–2019. Due to the limited fall tiller potential and dry and hot grain filling period conditions experienced in 2017–2018, we hypothesized that the primary tillers were the main drivers of yield, as the secondary tillers would not have been produced. If produced, the secondary tillers would likely not have survived the harsh environmental conditions. Thus, increasing population increased the number of primary tillers available and therefore increased grain yield. In the quadratic responses experienced during 2018–2019, the peak (maximum grain yield) occurred at plant populations of approximately 500,000 plants per acre for Langin and Joe, and of about 580,000 plants per acre for LCS Revere and WB Grainfield.

Grain Test Weight

The three-way interaction between year, seeding rate, and variety suggested that test weight response of the different varieties depended on seeding rate and on year simultaneously. Overall, test weight was greater during 2017–2018 (59–66 pounds per bushel) as compared to 2018–2019 (57–60 pounds per bushel), likely due to the much more favorable grain filling weather in 2018–2019 which allowed for grains to be produced from secondary and even tertiary heads, which are later in development and usually have low test weight (Figure 5). In 2017–2018, LCS Revere had the greatest test weight across all seeding rates except the highest one, and its advantage over the other varieties was greater at lowest seeding rates. Test weight increased with increases in seeding rate from 200,000 to appx. 600,000 seeds per acre for WB-Grainfield, Langin, and LCS Revere; while for Joe, which had the lowest test weight at the lowest seeding rate, test weight increased until 1,000,000 seeds per acre. In 2018–2019, test weight increased linearly with increases in seeding rate for LCS Revere and Langin in the entire range of 200,000–1,000,000 seeding rate; it followed a quadratic trend for WB-Grainfield, increasing in the 200,000–600,000 range and stabilizing afterwards; and it was irrespective of seeding rate for Joe. Similar trends were observed when grain test weight was plotted as function of emerged plants per acre, with quadratic trends in 2017–2018 and linear (Langin and LCS Revere), quadratic (WB-Grainfield), and absent (Joe) responses of grain test weight to plant population in 2018–2019 (Figure 6).

Preliminary Conclusions

These trials provided information on variety-specific grain yield and grain test weight response to seeding rate under intensive management practices, where resource availability (i.e., nutrients, foliar diseases control, etc.) was not limiting. Findings suggested that yield response to seeding rate was more dependent on growing season conditions than on varieties. When the crop had limited tillering potential in the fall due to a later sowing date, and a lower yield potential due to a drier season, yield responded linearly to increases in seeding rate and plant population. Meanwhile, when the crop had plenty of time to tiller during the fall, seeding rates as low as 400,000 seeds per acre were sufficient to maximize yields under these highly managed conditions.

Acknowledgments

We acknowledge Horton Seed Services for providing seed, land, and labor for completion of this project during the two years summarized in this report. This research was initiated following discussions with Mr. Rick Horton about wheat management for high yields.

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Table 1. Initial soil fertility measured at wheat sowing during the 2017–2018 and 2018–2019 growing seasons for the trial conducted near Leoti, KS

		2017–2018		2018–2019	
Depth	Unit	0–6 in.	6–24 in.	0–6 in.	6–24 in.
Calcium	ppm	2401	4876	2131	5064
Cation exchange capacity	meq/100 g	21	31	23	32
Chlorine	ppm	12	8	5	4
Copper	ppm	3	2	1	1
Iron	ppm	45	13	46	13
Potassium	ppm	826	604	649	577
Magnesium	ppm	399	558	386	629
Manganese	ppm	27	5	30	6
Sodium	ppm	28	24	13	11
NH_4-N	ppm	4	3	4	2
NO_3-N	ppm	36	3	13	13
Organic matter	%	2.4	1.6	2.3	1.7
pH	---	6.2	7.9	6.2	7.6
Phosphorus	ppm	92	18	70	15
Sulfur	ppm	5	4	4	3
Zinc	ppm	2	1	1	1
Clay	%	26	30	26	32
Sand	%	34	24	18	16
Silt	%	40	46	56	52

Table 2. Significance of seeding rate, variety, year, and their interactions on population establishment, grain yield, and grain test weight for the trial conducted near Leoti, KS, during the 2017–2018 and 2018–2019 growing seasons

Effect	Degrees of freedom	Population	Yield	Test weight
		-------------------------- Pr < F		-------------------------
Seeding rate (R)	4	<.0001	<.0001	<.0001
Variety (V)	3	0.7364	0.0003	<.0001
R × V	12	0.7735	0.4573	0.1949
Year (Y)	1	0.0528	0.0014	0.0007
Y × R	4	<.0001	0.0021	<.0001
Y × V	3	0.1757	0.034	<.0001
Y × R × V	12	0.7239	0.388	0.0013

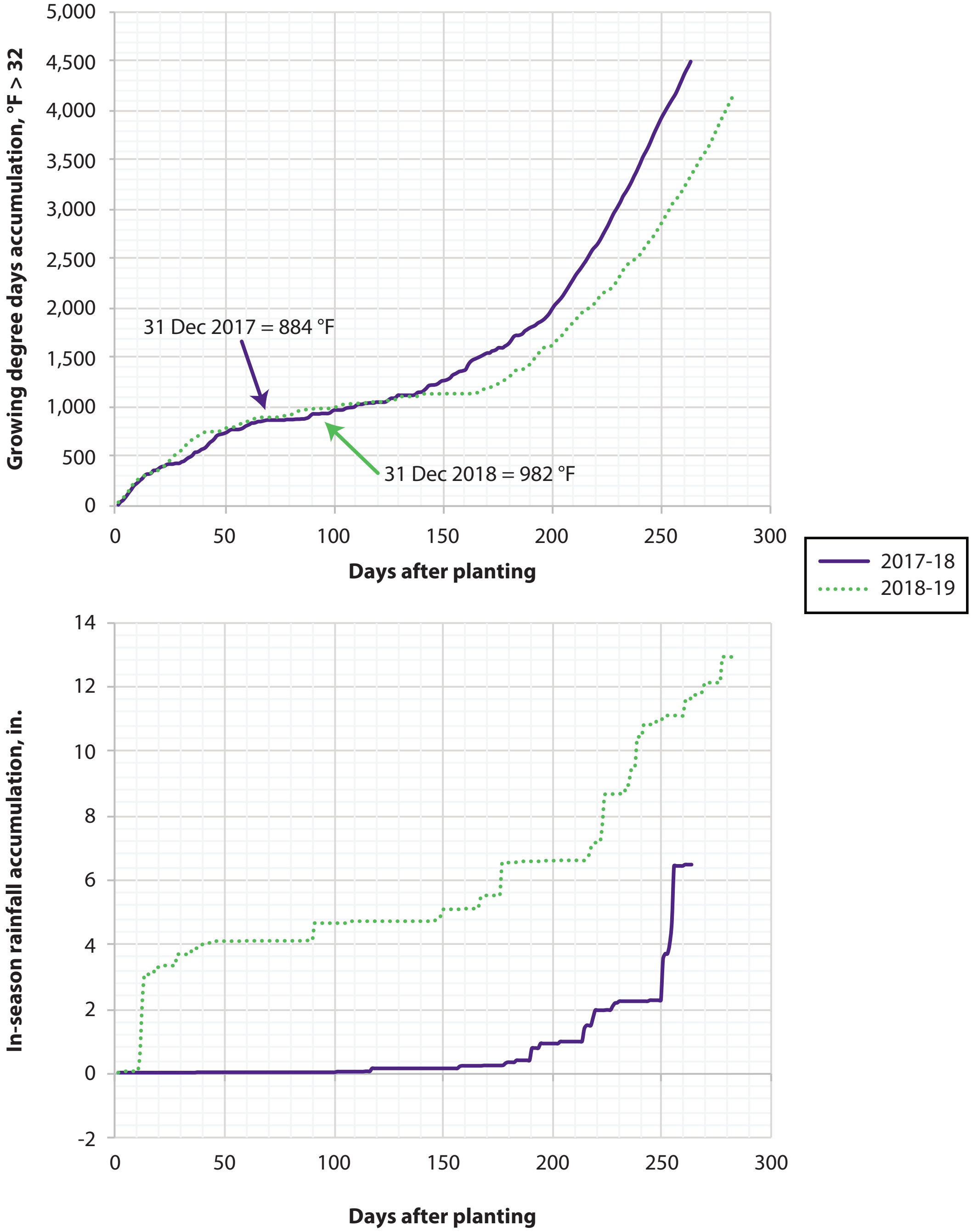

Figure 1. Growing degree-days accumulation (upper panel) and in-season rainfall accumulation (lower panel) during the 2017–2018 and 2018–2019 growing seasons for the trials conducted near Leoti, KS.

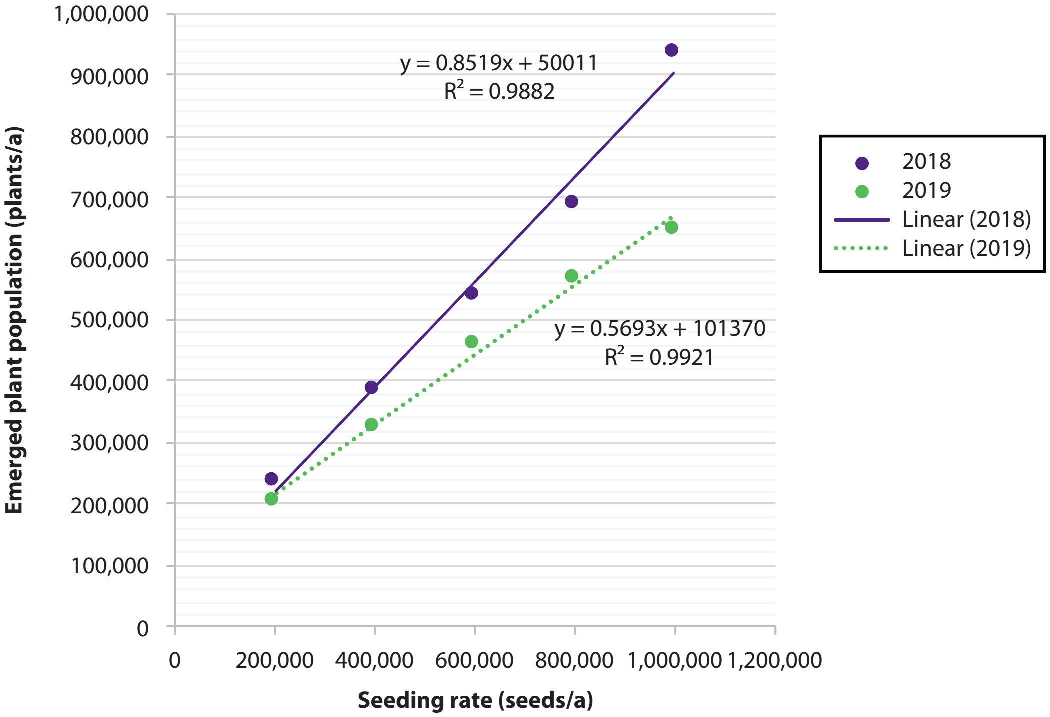

Figure 2. Emerged plant population as affected by seeding rate during the 2017–2018 and 2018–2019 growing seasons for the trials conducted near Leoti, KS.

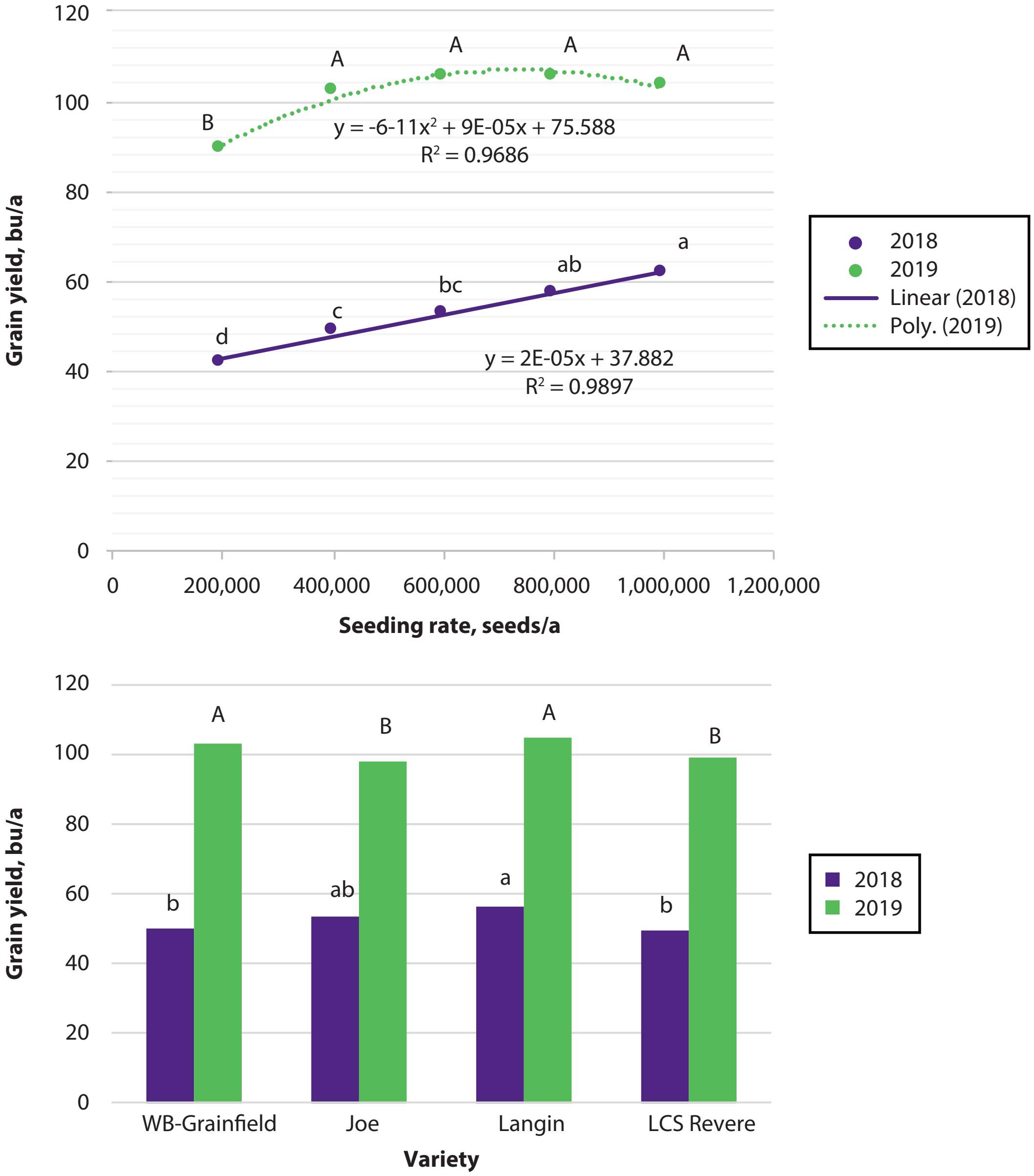

Figure 3. Wheat grain yield response to seeding rate (upper panel) and variety (lower panel) during the 2017–2018 and 2018–2019 growing seasons for the trials conducted near Leoti, KS. Linear and polynomial (Poly.) trends are shown.

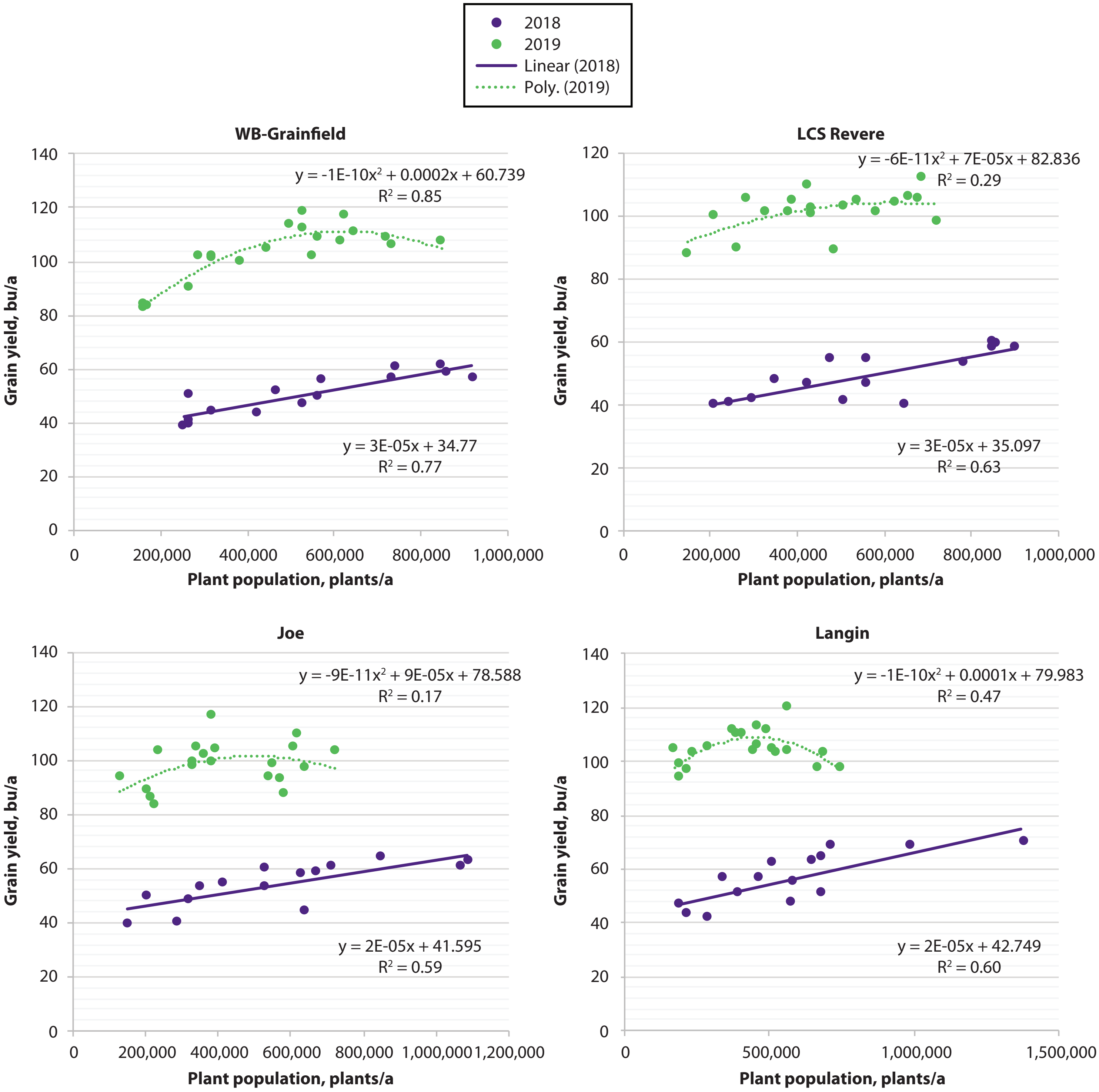

Figure 4. Wheat variety-specific grain yield response to emerged plant population during the 2017–2018 and 2018–2019 growing seasons for the trials conducted near Leoti, KS. Linear and polynomial (Poly.) trends are shown.

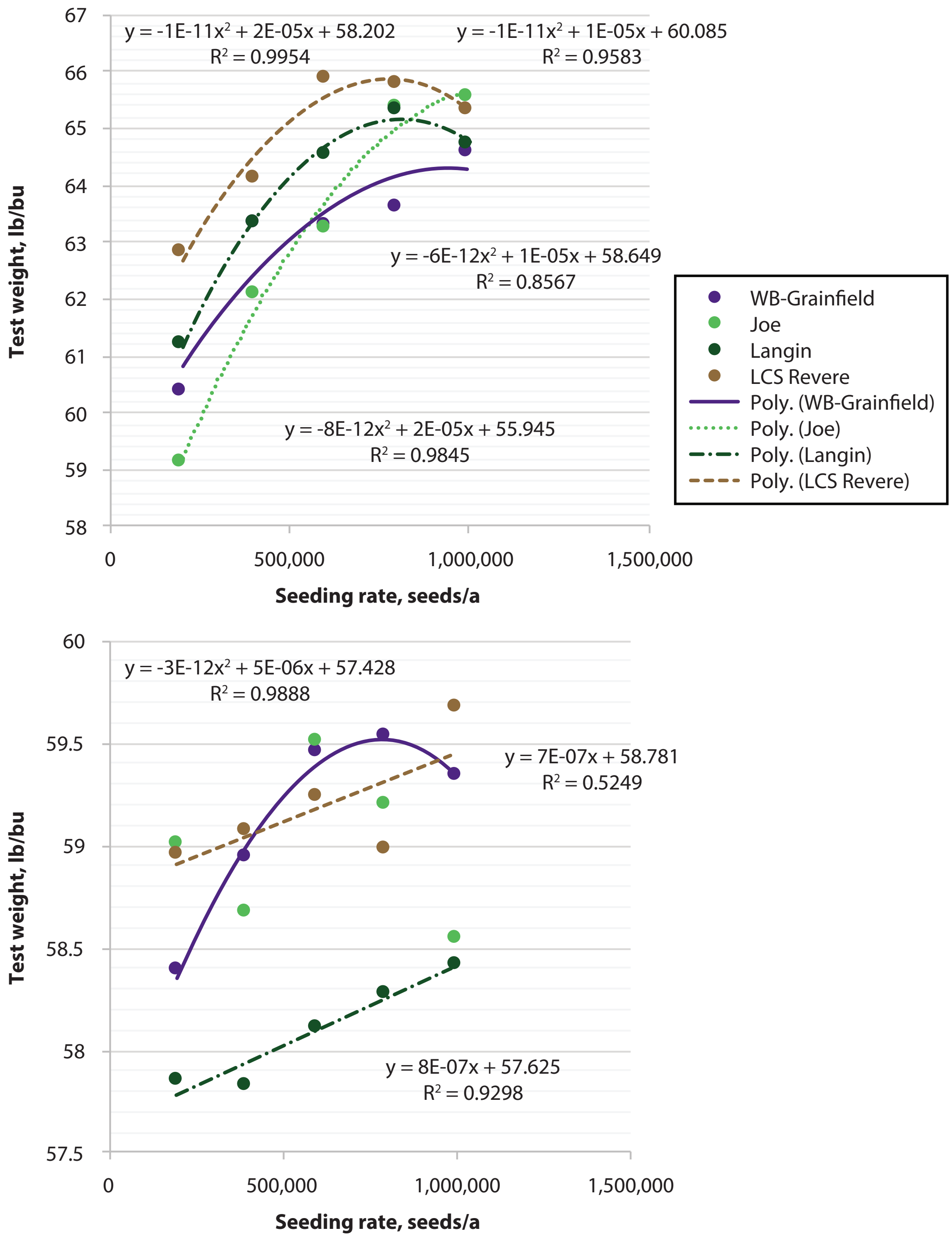

Figure 5. Wheat grain test weight response to the interaction of seeding rate and variety during the 2017–2018 (upper panel) and 2018–2019 (lower panel) growing seasons for the trials conducted near Leoti, KS. Linear and polynomial (Poly.) trends are shown.

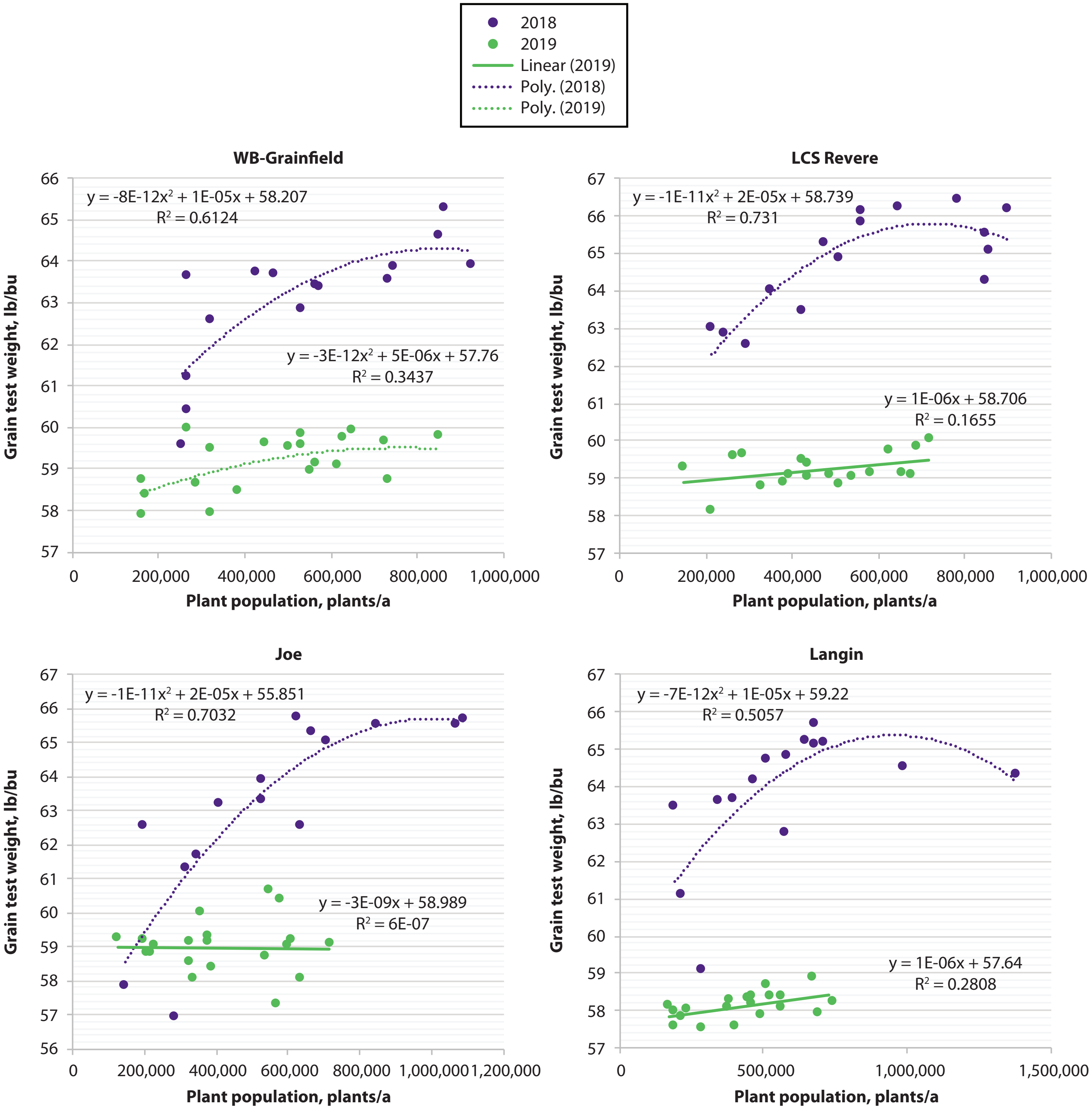

Figure 6. Wheat variety-specific grain test weight response to emerged plant population during the 2017–2018 and 2018–2019 growing seasons for the trials conducted near Leoti, KS. Linear and polynomial (Poly.) trends are shown.