Kansas Agricultural Experiment Station Research Reports

Volume 11
Issue 3 *Kansas Field Research*

Article 14

2025

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Recommended Citation

Mota, Mariana; Pradella, Luiz O.; Gastaldi, Jazmin; Romero Soler, Jorge; Giordano, Nicolas; and Lollato, Romulo P. (2025) "Do Wheat Grain Yield and Grain Protein Concentration Responses to Nitrogen Rate Depend on Variety-Specific Agronomic Traits?," *Kansas Agricultural Experiment Station Research Reports*: Vol. 11: Iss. 3. https://doi.org/10.4148/2378-5977.8706

Do Wheat Grain Yield and Grain Protein Concentration Responses to Nitrogen Rate Depend on Variety-Specific Agronomic Traits?

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Abstract

Nitrogen (N) management and genotype selection play crucial roles in optimizing winter wheat (*Triticum aestivum* L.) yield in Kansas. This study evaluated whether wheat cultivars with different agronomic traits would require differential nitrogen management. Eight cultivars were selected to represent high- and low-grain yield stability, above- and below-grain protein deviation for a given yield level, and early and late maturity. These cultivars were exposed to seven nitrogen rates ranging from 0 to 180 pounds of N per acre in seven rainfed locations in Kansas during the 2023–2024 growing season. Results suggested significant N rate by environment interactions and cultivar agronomic trait by environment interactions for grain yield and grain protein concentration. Still, there were no agronomic trait by N rate interactions. Overall, in specific environments, less stable cultivars outyielded more stable cultivars, and early maturity cultivars outyielded late maturity cultivars. These yield advantages were often associated with lower protein concentration. The agronomic trait of grain protein deviation did not result in yield advantages but had higher protein concentrations at all locations. These results emphasize the importance of understanding cultivar traits and their interaction with the environment when making variety selection, and the crop's overall response to N management as a function of environmental conditions. Still, results suggested no differences in how N should be managed according to a cultivar's specific agronomic traits.

Introduction

Nitrogen is a key limiting factor for winter wheat (*Triticum aestivum* L.) yield in Kansas (Lollato et al., 2019a, 2021; Jaenisch et al., 2021). Accurately managing this macronutrient is essential to maximize yields while avoiding over- and under-application, which can lead to waste and environmental pollution, or result in larger yield gaps and below-optimal grain quality (Cruppe et al., 2017; Lollato et al., 2019b; Giordano et al., 2023). Since wheat in this region is already characterized by large yield gaps, in other words, current yields are well below their potential (Couedel et al., 2025; Lollato et al., 2017; Jaenisch et al., 2021), management practices to narrow yield gaps are warranted since they can be profitable.

At question here is whether wheat variety selection should be considered when making N recommendations since the interaction between genotype and environment (G × E) can be significant (Beres et al., 2020), nitrogen rate can change the yield-environment (Giordano et al., 2024), and varieties may interact with management to drive wheat yield (Jaenisch et al., 2022; Raj et al., 2023). Giordano et al. (2024) provided some initial evidence highlighting the interaction between genotype and nitrogen (G × N) on wheat yield in Kansas. The authors suggested that more stable (or less plastic) varieties had similar grain yield to those less stable in environments with low yield, but stable varieties failed to capture the higher yield potential of higher-yielding environments — specifically when N was not limiting. This behavior — a more conservative yield of stable cultivars under high-yielding conditions — had previously been reported in eastern Kansas (Lollato et al., 2020). Consequently, cultivar grain yield stability may influence a wheat cultivar's response to nitrogen. Likewise, traits such as protein concentration and maturity can affect the crop's nitrogen use efficiency (Lollato et al., 2021). Thus, our aim was to quantify how varieties with more or less stable grain yield, below- or above-average protein for a given yield level, and early- or late-maturity, respond to nitrogen rates across a range of locations and environmental conditions in Kansas.

Procedures

Treatments, experimental design, and management

Rainfed field experiments were conducted during the 2023-2024 winter wheat season in seven locations across Kansas: Ashland Bottoms, Belleville, Hays, Hoisington, McPherson, Manhattan, and Phillipsburg. A split-plot design was used to evaluate a combination of seven nitrogen rates (whole plot) and eight winter wheat varieties (sub-plot) with three or four repetitions.

The N rates (0, 30, 60, 90, 120, 150, and 180 lb N/a) were applied as granulated urea (46-0-0) at spring green up or around the Feekes 3-4 growth stage. At the N application time, all the experiments received 15 pounds per acre of sulfur (S) as gypsum to avoid S deficiency and interaction with N availability (Jaenisch et al., 2019, 2020, 2021). The eight varieties were selected based on three traits: grain yield stability based on long-term trials (Munaro et al., 2020), grain protein deviation (GPD, the deviation in grain protein for a given yield level), and maturity. All combinations of traits occurred so that direct comparisons of a given trait could be made while other traits were constant, resulting in a balanced presence/absence of traits. The varieties selected for this study and their classification in terms of stability, GPD, and maturity are shown in Table 1.

Wheat was sown from late September through October 2023 with a Great Plains 606 no-till drill with a row spacing of 7.5 inches. Plots were seven rows wide and about 30 ft long. At sowing, soil samples were collected at each location from 0 to 6 and 6 to 24 inches deep (Table 1). Foliar fungicide was applied once in each trial between flag leaf and anthesis (Feekes 9-10.5) to avoid the confounding effects of variety-specific disease resistances (Cruppe et al., 2021, de Oliveira Silva et al., 2020). Grain weight and moisture were measured with a Massey Ferguson 8XP small plot combine. A moisture basis of 13% was used to adjust grain yield. Grain protein concentration was adjusted to a dry basis measured by NIR spectroscopy.

Statistical Analysis

Statistical analysis was performed with R Studio. Linear mixed-effects models were used to assess the impact of the different agronomic traits of the studied cultivars across different environments, as well as the effect of N rates on grain yield and grain protein concentration. The model structure included fixed effects for cultivar groups (either high- and low-stability, protein deviation, or maturity), environment, N rate, and their interactions. Random effects included cultivars nested within the agronomic trait group, N rate nested with repetition, and repetition nested within the environment. The groups of cultivars used in the analyses always consisted of four cultivars contrasting for the trait of interest and balanced for the other two traits.

Results

There was a wide range in grain yields across the experiments. The highest yield was measured in Phillipsburg (72.9 bushels per acre) followed by Ashland Bottoms (67.5 bushels per acre), sites that received more in-season precipitation (Figure 1). Hays (8.3 bushels per acre) and Hoisington (15.3 bushels per acre) had the lowest yields, which may be due to a dry soil profile at sowing coupled with low precipitation during the growing season, resulting in severe water stress. Across sources of variation, grain protein concentration ranged from 8.7% to 22.5%, averaging 13.8%.

Statistical analysis of grain yield and grain protein concentration across E, N rates, and agronomic traits suggested that there were significant N × E interactions and, for most cases, agronomic trait × E interactions, except for grain yield as a function of the trait GPD (Table 2). Overall, there were no agronomic trait × N interactions or three-way interactions (Table 2), suggesting that the response of the different varieties to N rate were similar, irrespective of the agronomic trait considered.

The interaction between N rate and E on wheat grain yield is shown in Figure 1. There were significant responses to N in four out of seven environments (i.e., Ashland Bottoms, Belleville, Manhattan, and Phillipsburg). The remaining sites were unresponsive, either due to extreme drought (Hays, Hoisington), or due to high soil NO_3-N at sowing (McPherson) (Table 1). Additionally, the interaction between N and E significantly affected grain protein concentration (Table 2). This interaction resulted from Hoisington showing no response in grain protein concentration to N rate, two sites showing a linear increase in protein as a function of N rate, three sites portraying a quadratic protein response to N rate, and Phillipsburg portraying a cubic response of protein to N rate (Figure 2), which is biologically explained (Giordano et al., 2024).

The interactions between agronomic trait and environment on grain yields are shown in Table 3. Varieties with lower yield stability were higher yielding than their stable counterparts in Ashland Bottoms, Belleville, Manhattan, and Phillipsburg, yielding similarly in the remaining environments. The trait GPD did not interact with environment on grain yield. Finally, earlier maturing varieties yielded more than their later counterparts in Ashland Bottoms, Belleville, Hoisington, McPherson, and Phillipsburg, yielding similarly in the other environments.

Regarding the interactions between agronomic trait and environment on grain protein concentration (Table 4), more yield-stable varieties had greater protein concentration than their less stable counterparts in five out of seven locations. Varieties with the trait high GPD had greater protein than their counterparts in all environments, and late maturing varieties had greater grain protein concentration than early maturing varieties in three out of seven environments. Greater protein concentration as a function of later variety maturity may relate to these varieties being more exposed to the harsher environmental conditions that are typical later in the calendar year as the crop progresses into the summer (Zhao et al., 2022).

Preliminary Conclusions

The interaction between N rates and the environment influenced grain yield and grain protein, highlighting the complex nature of crop response to nitrogen availability and its management. The interaction between cultivars with contrasting agronomic traits and environment also highlighted the need for cultivar-specific and environment-specific knowledge when selecting wheat varieties for a given farm. However, the lack of interaction between agronomic trait and N rate suggests that cultivar-specific N management recommendations may not be warranted for the cultivars and traits evaluated.

References

Beres, B.L., Hatfield, J.L., Kirkegaard, J.A., Eigenbrode, S.D., Pan, W.L., Lollato, R.P., Hunt, J.R., Strydhorst, S., Porker, K., Ransom, J. and Wiersma, J., 2020. Toward a better understanding of genotype× environment× management interactions—a global wheat initiative agronomic research strategy. Frontiers in Plant Science, 11, p.515450.

Couëdel, A., Lollato, R.P., Archontoulis, S.V., Tenorio, F.A., Aramburu-Merlos, F., Rattalino Edreira, J.I. and Grassini, P., 2025. Statistical approaches are inadequate for accurate estimation of yield potential and gaps at regional level. Nature Food, pp.1-10.

Cruppe, G., Edwards, J.T. and Lollato, R.P., 2017. In-season canopy reflectance can aid fungicide and late-season nitrogen decisions on winter wheat. Agronomy Journal, 109(5), pp.2072-2086.

Cruppe, G., DeWolf, E., Jaenisch, B.R., Onofre, K.A., Valent, B., Fritz, A.K. and Lollato, R.P., 2021. Experimental and producer-reported data quantify the value of foliar fungicide to winter wheat and its dependency on genotype and environment in the US central Great Plains. Field Crops Research, 273, p.108300.

de Oliveira Silva, A., Slafer, G.A., Fritz, A.K. and Lollato, R.P., 2020. Physiological basis of genotypic response to management in dryland wheat. Frontiers in plant science, 10, p.1644.

Giordano, N., Sadras, V. O., Correndo, A. A., & Lollato, R. P. (2024). Cultivar-specific phenotypic plasticity of yield and grain protein concentration in response to nitrogen in winter wheat. Field Crops Research, 306, 109202. doi: 10.1016/j.fcr.2023.109202.

Jaenisch, B.R., L.B. Munaro, L.M. Bastos, M. Moraes, X. Lin, et al. 2021. On-farm data-rich analysis explains yield and quantifies yield gaps of winter wheat in the U.S. central Great Plains. Field Crops Research 272: 108287. doi: 10.1016/j.fcr.2021.108287.

Jaenisch, B.R., Munaro, L.B., Jagadish, S.K. and Lollato, R.P., 2022. Modulation of wheat yield components in response to management intensification to reduce yield gaps. Frontiers in plant science, 13, p.772232.

Lollato, R.P., Edwards, J.T. and Ochsner, T.E., 2017. Meteorological limits to winter wheat productivity in the US southern Great Plains. Field Crops Research, 203, pp.212-226.

Lollato, R.P., Ruiz Diaz, D.A., DeWolf, E., Knapp, M., Peterson, D.E. and Fritz, A.K., 2019a. Agronomic practices for reducing wheat yield gaps: a quantitative appraisal of progressive producers. Crop Science, 59(1), pp.333-350.

Lollato, R.P., Figueiredo, B.M., Dhillon, J.S., Arnall, D.B. and Raun, W.R., 2019b. Wheat grain yield and grain-nitrogen relationships as affected by N, P, and K fertilization: A synthesis of long-term experiments. Field Crops Research, 236, pp.42-57.

Lollato, R.P., Roozeboom, K., Lingenfelser, J.F., da Silva, C.L. and Sassenrath, G., 2020. Soft winter wheat outyields hard winter wheat in a subhumid environment: Weather drivers, yield plasticity, and rates of yield gain. Crop Science, 60(3), pp.1617-1633.

Lollato, R.P., Jaenisch, B.R. and Silva, S.R., 2021. Genotype-specific nitrogen uptake dynamics and fertilizer management explain contrasting wheat protein concentration. Crop Science, 61(3), pp.2048-2066.

Raj, A.S., Siliveru, K., McLean, R., Prasad, P.V.V. and Lollato, R.P., 2023. Intensive management simultaneously reduces yield gaps and improves milling and baking properties of bread wheat. Crop Science, 63(2), pp.936-955.

Zhao, H., Zhang, L., Kirkham, M.B., Welch, S.M., Nielsen-Gammon, J.W., Bai, G., Luo, J., Andresen, D.A., Rice, C.W., Wan, N. and Lollato, R.P., 2022. US winter wheat yield loss attributed to compound hot-dry-windy events. Nature communications, 13(1), p.7233.

Table 1. Agronomic traits of the different winter wheat varieties evaluated in this study.

Variety	Yield stability	GPD	Maturity
Bob Dole	Stable	High	Early
LCS Chrome	Stable	High	Late
LCS Julep	Not stable	High	Late
SY Monument	Stable	Low	Late
SY Wolverine	Not stable	High	Early
WB4269	Stable	Low	Early
WB4401	Not stable	Low	Early
WB4699	Not stable	Low	Late

Table 2. Soil characteristics for the 0 to 6 and for the 6 to 18-inch or 6 to 24-inch depth layers at each study location during 2023-2024 growing season

Location	Depth	OM	pH	NO_3-N	P	K	CEC	Cl	Sand	Silt	Clay
	in.	%	---------------- ppm ----------------				meq/100 g	ppm	------------ % ------------		
Ashland Bottoms	0 to 6	1.7	6.1	24.4	65	198	8	5.6	35	53	12
Ashland Bottoms	6 to 24	1.4	7.7	5.4	34	154	11.8	2.8	35	53	12
Belleville	0 to 6	3.2	5	14.7	54	478	21.5	4.6	16	61	23
Belleville	6 to 24	2.9	5.7	5.3	35	435	26.2	5.1	17	48	35
Hays	0 to 6	2.4	5.2	53.2	39	441	18.2	12.3	9	70	21
Hays	6 to 24	2.1	6.6	33.5	17	298	19.4	6.1	16	67	17
Hoisington	0 to 6	2.1	7.2	43	28	177	23.8	5.6	31	46	23
Hoisington	6 to 24	1.9	8	31	17	147	30	4.7	32	40	28
McPherson	0 to 6	2.9	6.5	9.4	36	330	25.5	21.6	16	49	35
McPherson	6 to 18	2.4	6.8	10.7	19	319	29.3	9.6	15	45	40
Manhattan	0 to 6	4.6	6.8	9.4	27	234	29.3	6.1	16	56	28
Manhattan	6 to 12	3.7	7.2	6.2	13	218	30.5	6.4	14	53	33
Phillipsburg	0 to 6	2.5	6.1	40.6	97	651	17.7	4.6	20	56	24
Phillipsburg	6 to 24	2	6.9	31.4	110.0	702.0	18.30	5.2	18	53	29

Abbreviations: OM, organic matter; pH, soil pH; NO_3-N, soil nitrate nitrogen; P, phosphorus; K, potassium; CEC, cation exchange capacity, Cl, chloride.

Table 3. Analyses of variance of wheat grain yield and grain protein concentration (GPC) as affected by agronomic traits (yield stability, grain protein deviation [GPD], and maturity) and N rates at seven locations during the 2023–2024 growing season

		Yield stability		GPD		Maturity	
Source of variance	df	Grain yield	GPC	Grain yield	GPC	Grain yield	GPC
Environment (E)	6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nitrogen rate (N)	6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Agron. trait (AT)	1	<0.001	<0.001	0.17	<0.001	<0.001	0.06
E × N	36	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
E × AT	6	0.001	<0.001	0.67	<0.001	0.06	0.05
N × AT	6	0.73	0.16	0.96	0.41	0.77	0.99
E × N × AT	36	0.99	0.99	0.99	0.77	0.98	0.99

Abbreviation: df, degrees of freedom.

Table 4. Grain yield (bushels per acre) as a function of the interaction between environment and the agronomic traits yield stability, GPD, and maturity, across seven Kansas locations during the 2023-2024 growing season

	Grain yield (bushels per acre)					
	Yield stability		GPD		Maturity	
Environment	**Low**	**High**	**Low**	**High**	**Early**	**Late**
Ashland Bottoms	**59.5**	57.5	35.6	35.5	**59.3**	57.6
Belleville	**51.3**	46.6	40.7	40.5	**50.7**	47.3
Hays	7.6	6.8	41.3	40.1	8.3	6.1
Hoisington	13.2	13.2	42.5	42.6	**15.2**	11.2
McPherson	52.5	52.9	44.6	44.0	**54.2**	51.3
Manhattan	**49.7**	47.7	44.4	43.0	48.4	49.0
Phillipsburg	**65.2**	60.9	45.2	44.7	**64.3**	61.8

Values in bold indicate that means of the two agronomic trait groups are significantly different within environment. ($\alpha = 0.05$). Abbreviation: GPD, grain protein deviation.

Table 5. Grain protein concentration (percent) as function of the interaction between environment and the agronomic traits yield stability, GPD, and maturity, across seven Kansas locations during the 2023-2024 growing season

	Protein (%)					
	Yield stability		GPD		Maturity	
Environment	**Low**	**High**	**Low**	**High**	**Early**	**Late**
Ashland Bottoms	12.2	**12.8**	12.2	**12.8**	**12.6**	12.4
Belleville	12.6	**13.3**	12.7	**13.2**	13.0	12.9
Hays	12.8	**13.1**	12.4	**13.6**	12.9	13.0
Hoisington	18.7	18.3	17.8	**19.1**	18.4	**18.6**
McPherson	14.2	14.9	13.8	**15.3**	14.2	**14.8**
Manhattan	11.7	**12.3**	11.6	**12.4**	11.9	**12.1**
Phillipsburg	12.2	**12.8**	12.2	**12.7**	12.5	12.5

Values in bold indicate that means of the two agronomic trait groups are significantly different within environment. ($\alpha = 0.05$). Abbreviation: GPD, grain protein deviation.

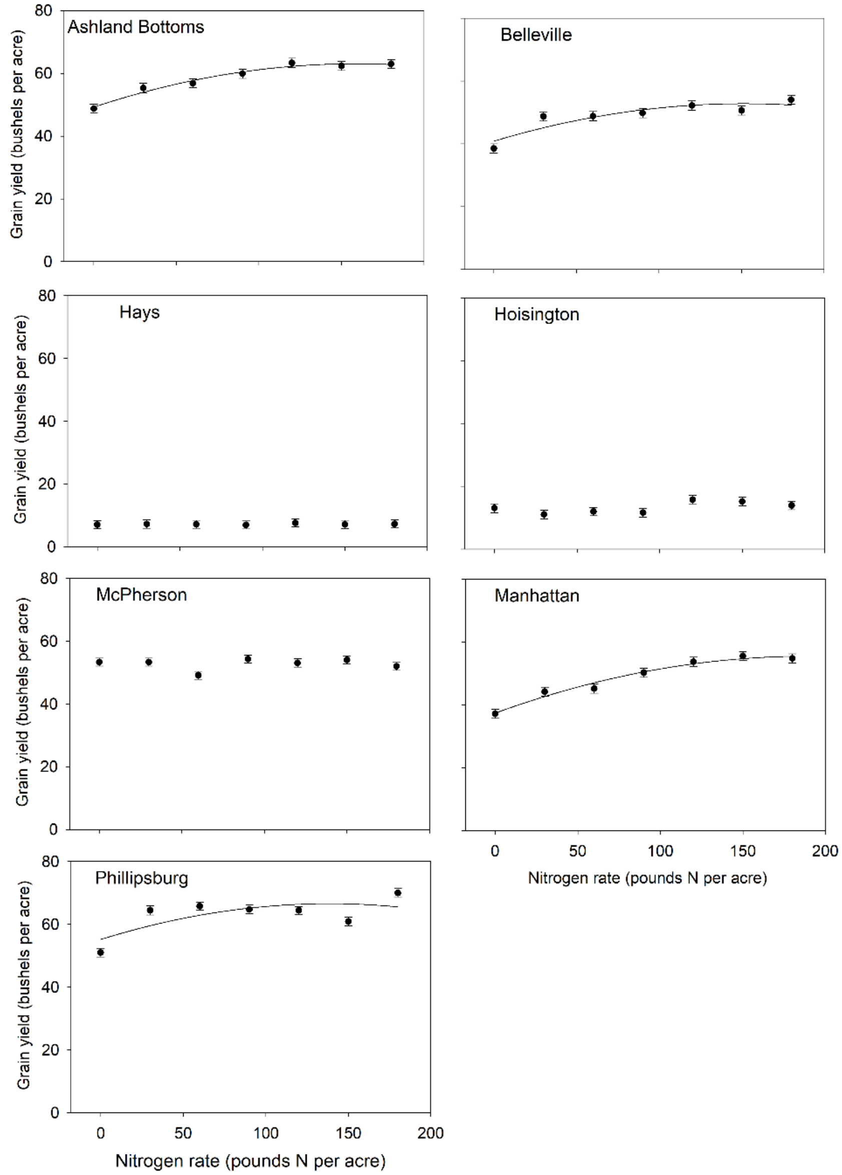

Figure 1. Winter wheat grain yield as a function of the interaction between nitrogen rate and environment at seven Kansas locations during the 2023-2024 growing season. Lines portray statistically significant quadratic regressions.

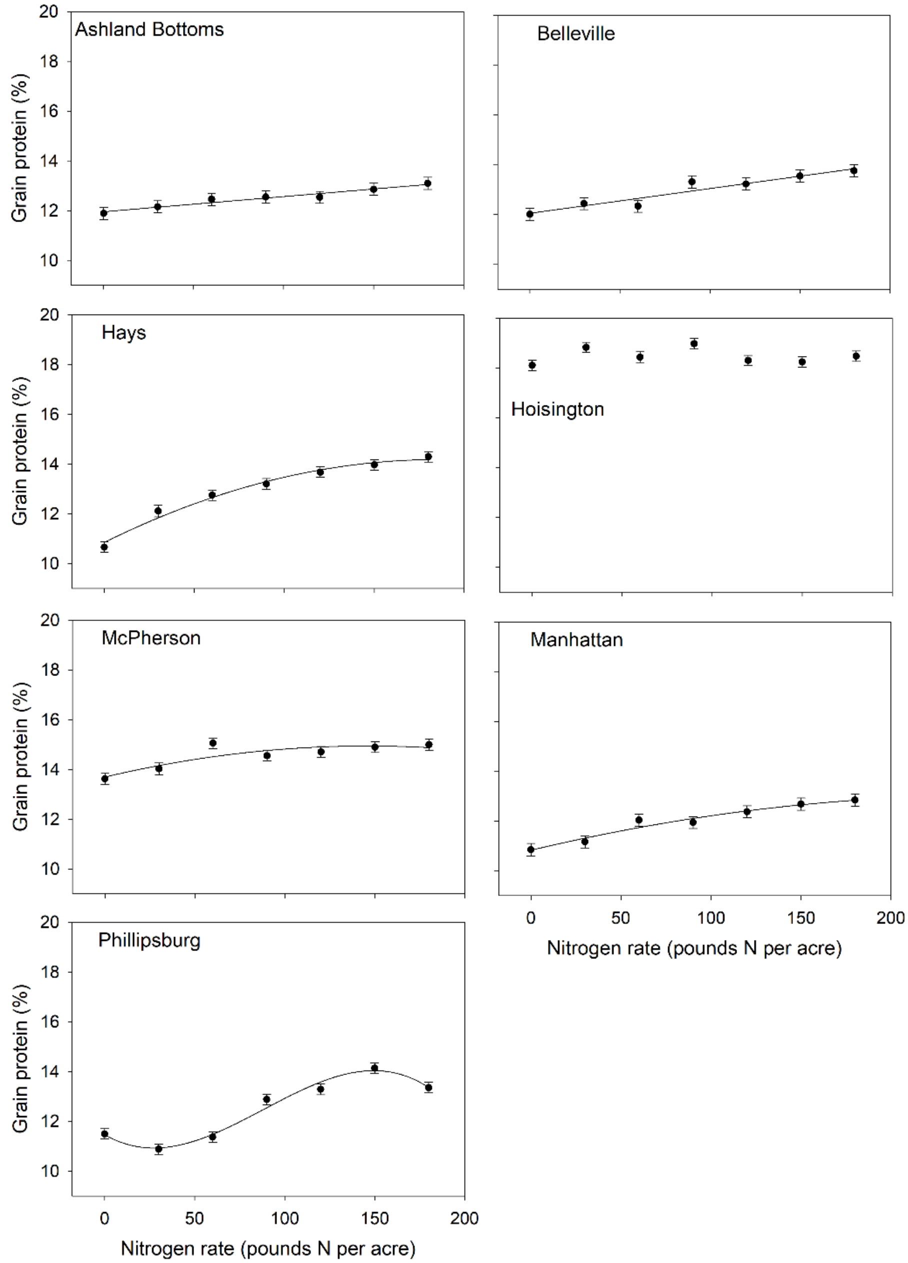

Figure 2. Winter wheat grain protein concentration as a function of the interaction between nitrogen rate and environment at seven Kansas locations during the 2023-2024 growing season. Lines portray statistically significant polynomial regressions.