Winter Wheat Variety-Specific Response to the Combination of Nitrogen and Foliar Fungicide in 2018–2019

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

Summary

Yield improvements to wheat can result both from variety selection and adoption of improved management practices. However, the yield response to improved management practices can be variety-specific and can result in decreases in protein concentration. Our objectives were to evaluate the yield and protein responses of different commercial winter wheat varieties to increased nitrogen (N) rates and application of foliar fungicides. We conducted a trial combining 20 winter wheat varieties and two management level intensities. The standard management consisted of N applied for a 75 bushel per acre yield goal and no fungicide; and intensive management consisted of an additional 40 pounds of N per acre and two fungicide applications—the first at jointing and the second at flag leaf emergence. The study was conducted at two Kansas locations (Great Bend, following a terminated cover crop; and Ashland Bottoms, following a previous soybean crop) during the 2018–2019 growing season. Grain yield ranged from 18–103 bushels per acre, with greatest yields recorded in the intensive management treatment in Great Bend and the lowest yields recorded in the standard management treatment in Ashland Bottoms. While there were no statistical differences in the varieties' responses to intensive management, both the ranking of varieties and the yield increase from intensive management depended on location. Grain protein concentration ranged from 10.5–17.7% across all treatments, and the intensive management increased grain protein concentration from 12.7–13.9% in Ashland Bottoms and from 14.1–14.5% in Great Bend. The intensive management concomitantly increased grain yield and grain protein concentration at Ashland Bottoms, and increased grain yield while sustaining grain protein concentration at Great Bend, suggesting that total N removal in the grain increased with intensive management. While we did not investigate the net profits from the intensive management, these results suggest that intensifying management on wheat could add income from additional yield produced and protein premiums, as long as these are available.

Introduction

Wheat yield at the state level in Kansas has rarely surpassed 50 bushels per acre. Nonetheless, recent evidence suggests that the long-term dryland potential yield is about 77 bushels per acre (Lollato and Edwards, 2015; Lollato et al., 2017). While it would not be economical to manage the crop for potential yields every year, Lobell et al. (2009) suggested that attaining about 75–80% of the potential yield is usually

the economic optimum for dryland systems. Thus, there is currently a yield gap of 8–13 bushels per acre in Kansas that could be fulfilled through improved management while maintaining profitability.

Recent analyses of factors contributing to yield gaps in Kansas suggested that both nitrogen management and foliar fungicides are among the most important factors contributing to the regional yield gaps (de Oliveira Silva et al., 2020a; Jaenisch et al., 2019; Lollato et al., 2019a). Specifically, Lollato et al. (2019a) evaluated several years of data from fields entered in the Kansas Wheat Yield Contest and suggested that foliar fungicides were the most important management factor associated with wheat yields. The authors also highlighted differences in nitrogen management between high- and low-yielding growers. Furthermore, Jaenisch et al. (2019) showed that foliar fungicides could contribute as much as 15–20 bushels per acre yield to differences for a variety with high susceptibility to stripe rust in a season when stripe rust is prevalent. De Oliveira Silva et al. (2020a) later suggested that, while the 15 bushels per acre yield difference between fungicide versus non-fungicide was possible, it depended on the variety's susceptibility to major diseases such as leaf rust and stripe rust.

Beyond the variety-specific response to fungicide, de Oliveira Silva et al. (2020a) also suggested that a variety's straw strength can contribute to a variety's response to nitrogen. Nitrogen is the macronutrient needed in greatest amounts by the wheat crop (de Oliveira Silva et al., 2020b), and the crop's yield response to N seems to depend on yield environment (Cruppe et al., 2017; Lollato et al., 2019b). In other words, the agronomic optimum nitrogen rate is greater at higher yield environments as compared to lower yield environments. Thus, maximizing wheat yields in intensively managed, high-yielding crops might require greater amounts of N, though this would depend on the initial N available in the soil profile.

Given the importance of foliar fungicide and nitrogen management to maximize wheat yields, and the dependence of their responses on variety, the objective of this research was to evaluate how different wheat varieties responded in grain yield and grain protein concentration to additional nitrogen and two foliar fungicide applications in Kansas.

Procedures

Field experiments were conducted in two Kansas locations (Ashland Bottoms and Great Bend) during the 2018–2019 winter wheat growing season. The experiment was sown using no-tillage practices after soybeans in Ashland Bottoms, and using conventional tillage practices after a terminated cover crop in Great Bend. A complete two-way factorial treatment structure was arranged in a split-plot design where two levels of management intensities were the main plot (standard versus intensive management), and 20 commercial winter wheat varieties were the sub-plot. Standard management included enough nitrogen fertilizer for a 75 bushel per acre yield goal (considering nitrogen in the soil profile at sowing plus credits from organic matter and one fertilization event with urea during early spring at Feekes 3-4) and no fungicide application. Intensive management included the same N management adopted in the standard management plus an additional 40 pounds of N per acre applied at Feekes 6, and two fungicide applications: 4 ounces per acre of Aproach fungicide at jointing (Feekes 6-7) followed by 6.8 ounces per acre of Aproach Prima fungicide at heading. Dates of field

activities are listed in Table 1. The winter wheat varieties included in this study were: AM Eastwood, Gallagher, Joe, LCS Chrome, LCS Mint, Langin, Larry, Lonerider, Paradise, SY Grit, SY Monument, SY Rugged, Smith's Gold, Spirit Rider, T158, Tatanka, WB4303, WB Grainfield, Whistler, and Zenda. Harvest occurred using a Massey Ferguson XP8 small-plot, self-propelled combine. Plot ends were trimmed at harvest time to avoid border effect. Measurements included grain yield (corrected for 13% moisture content) and grain protein concentration at harvest maturity (dry basis).

Statistical analysis was performed using a three-way ANOVA in PROC GLIMMIX in SAS v. 9.4 (SAS Inst. Inc., Cary, NC) where variety, management, year, and their interactions were considered fixed effects. Replication, replication nested within year, and management nested within replication and year were treated as a random effects in the analysis of variance.

Results
Weather Conditions
Overall, the weather conditions during the 2018–2019 growing season tended towards excessive amounts of precipitation. For instance, at the two studied locations, growing season total rainfall was 34.1 inches in Ashland Bottoms and 29.5 inches in Great Bend (Table 2): both values correspond to greater amounts than the normal annual rainfall at these locations. The majority of the precipitation was accumulated during the spring (16.1 to 20 inches), but the fall was also considerably moist. Temperatures overall were cool, which allowed for the development of stripe rust at both locations (visual observations only) and for a prolonged grain filling period which improved grain yields.

Grain Yield
Across the all locations, varieties, and management intensities, grain yield ranged from 18 to 103 bushels per acre. The highest grain yields were recorded in the intensive management treatment in Great Bend while the lowest grain yields were recorded in the standard management treatment in Ashland Bottoms. The analysis of variance suggested a significant location by management interaction, as well as a significant location by variety interaction, but not variety by management or variety by management by location interaction (Table 3). These results suggest that the ranking of varieties depended on location, and the ranking of management also depended on location; but that there were no statistical differences in how varieties responded to management. Across all varieties, the intensive management increased grain yield from 32 to 41 bushels per acre in Ashland Bottoms, and from 68 to 85 bushels per acre in Great Bend (Table 4). In Ashland Bottoms, the lowest yielding variety was Lonerider (29 bushels per acre) while the highest yielding was LCS Chrome (44 bushels per acre). In Great Bend, the lowest yielding variety was Larry (57 bushels per acre) and the highest yielding variety was Zenda (90 bushels per acre). While there was no variety by management interaction, the magnitude of variety-specific response to management ranged from a yield gain of 0.6 bushels per acre (Paradise) to 19 bushels per acre (AM Eastwood) in Ashland Bottoms, and from 6.6 bushels per acre (Smith's Gold) to 27.6 bushels per acre (Larry) in Great Bend. We suspect that we did not have sufficient observations to detect differences among varieties and their interaction with management.

Grain Protein Concentration

Grain protein concentration on a dry basis ranged from 10.5 to 17.7% across all locations, varieties, and management intensities. Similar to grain yield, grain protein concentration was affected by the interaction of location and management, and by the interaction of location and variety (Table 3). The intensive management increased grain protein concentration from 12.7 to 13.9% in Ashland Bottoms, and from 14.1 to 14.5% in Great Bend (not significant) (Table 5). In Ashland Bottoms, the lowest protein concentration variety was Whistler (11.2%) and the highest were Lonerider and Paradise (14.8%). In Great Bend, the lowest protein concentration variety was Tatanka (13.4%) and the highest testing were Lonerider and Larry (14.8%). Despite no statistical significance in variety by management interaction, the difference in protein concentration between management practices ranged from 0.6% (LCS Chrome) to 1.9% (Larry) in Ashland Bottoms, and from -0.7% (Paradise) to 1.4% (Langin) in Great Bend.

Grain Yield × Grain Protein Relationship

At the same nitrogen levels, there is usually a negative relationship between grain protein concentration and grain yield due to a greater amount of starch accumulated in the grain at greater yield levels (Lollato and Edwards, 2015; Lollato et al., 2019b). In this study, there were weak negative relationships between protein and yield ($r^2 < 0.08$) except for the intensive management in Ashland Bottoms ($r^2 = 0.41$) (Figure 1). Interestingly, the intensive management concomitantly increased both grain yield and grain protein concentration in Ashland Bottoms, and increased grain yield while sustaining grain protein concentration in Great Bend. These results suggest that the amount of N exported in the grain would have been much greater under intensive management as opposed to standard management.

Preliminary Conclusions

These results suggest that both the effects of management and of variety depended on environment, but varieties responded similarly to management. Similar results were reported in previous years of this study (de Oliveira Silva et al., 2019b), though in both cases there were large numerical differences in variety-specific response to management. Thus, we hypothesize that there were not enough observations to build statistical power and detect these differences. During 2018–2019, intensive management increased grain yield at both locations, and grain protein concentration in one location, sustaining protein at similar levels at the second location. While we did not investigate the net profits from the intensive management in this publication, these results suggest that intensifying management on wheat could add income from both additional bushels produced, as well as from protein premiums when these are available.

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Table 1. Date when different field operations were performed in the variety by management intensity trial conducted in Ashland Bottoms and Great Bend during the 2018–2019 winter wheat growing season

Location	Operation	Stage	Date
Ashland Bottoms	Sowing	---	11/1/2018
	Nitrogen	Feekes 4	3/22/2019
	Feekes 6 nitrogen	Feekes 6	4/17/2019
	Fungicide	Feekes 7	5/2/2019
	Fungicide	Feekes 10.5	5/31/2019
Great Bend	Sowing	---	10/2/2018
	Nitrogen	Feekes 4	3/27/2019
	Fungicide	Feekes 6	4/15/2019
	Feekes 6 nitrogen	Feekes 6	4/19/2019
	Fungicide	Feekes 10.5	5/16/2019

Table 2. Average maximum (Tmax) and minimum (Tmin) temperatures, cumulative precipitation, and grass evapotranspiration (ETo) during the fall (October 1 - December 31), winter (January 1 - March 31), and spring (April 1 - June 30) at the study locations during the 2018–2019 growing season

Location	Season	Tmax	Tmin	Precip.	ETo
		°F	°F	inches	inches
Ashland Bottoms	Fall	52.6	30.8	9.1	5.2
	Winter	41.5	23.4	5.0	5.3
	Spring	75.6	53.1	20.0	17.3
Great Bend	Fall	52.3	31.0	10.4	6.6
	Winter	42.2	23.4	3.1	6.0
	Spring	75.4	51.1	16.1	18.4

Table 3. F-test probabilities resulting from the three-way analysis of variance of variety, management, location, and their interaction for the trials conducted in Ashland Bottoms and Great Bend, KS, during the 2018–2019 winter wheat growing season

Effect	Num DF	Yield	Protein	Test wt.
		------------------------ $P > F$ ------------------------		
Variety (V)	19	<.0001	<.0001	<.0001
Management (M)	1	<.0001	0.0001	0.0083
V × M	19	0.6301	0.8115	0.0083
Location (L)	1	0.0007	0.0085	0.0159
L × M	1	0.0117	0.0027	0.105
L × V	19	<.0001	<.0001	<.0001
L × M × V	19	0.9542	0.3791	0.0117

Values less than 0.05 indicate statistical significance.

Table 4. Winter wheat grain yield as affected by variety, management, location, and their interaction for the trials conducted in Ashland Bottoms and Great Bend during the 2018–2019 growing season

Variety	Ashland Bottoms				Great Bend			
	IM	SM	Mean	Diff.	IM	SM	Mean	Diff
	-- bu/a --							
AM Eastwood	46	27	37	20	87	65	76	22
Gallagher	45	39	42	6	84	70	77	14
Joe	43	39	41	5	83	73	78	10
Langin	41	34	37	7	85	70	78	15
Larry	36	27	31	9	71	44	58	28
LCS Chrome	48	40	44	8	84	73	78	11
LCS Mint	40	30	35	10	79	54	66	25
Lonerider	33	25	29	9	86	67	76	19
Paradise	33	32	32	1	86	74	80	12
Smith's Gold	42	33	38	9	87	81	84	7
Spirit Rider	37	28	33	8	96	79	88	17
SY Grit	39	29	34	10	92	68	80	24
SY Monument	45	30	38	15	82	71	77	11
SY Rugged	42	36	39	6	79	71	75	8
T158	41	28	34	13	93	70	81	23
Tatanka	45	30	37	15	71	54	63	17
WB Grainfield	42	35	38	7	82	55	69	27
WB4303	39	33	36	6	98	81	90	17
Whistler	39	31	35	8	71	46	59	25
Zenda	39	31	35	8	97	84	91	12
Mean	41	32			85	68		
LSD	14							

IM = intensive management. SM = standard management.

Table 5. Winter wheat grain protein concentration as affected by variety, management, location, and their interaction for the trials conducted in Ashland Bottoms and Great Bend during the 2018–2019 growing season

Variety	Ashland Bottoms				Great Bend			
	IM	SM	Mean	Diff.	IM	SM	Mean	Diff.
	-- % --							
AM Eastwood	13.9	12.9	13.4	0.9	14.6	14.3	14.5	0.3
Gallagher	14.9	13.1	14.0	1.8	14.9	14.0	14.5	0.9
Joe	13.5	12.7	13.1	0.8	15.0	14.4	14.7	0.6
LCS Chrome	13.2	12.7	12.9	0.6	14.9	14.5	14.7	0.4
LCS Mint	12.8	11.4	12.1	1.4	14.5	13.5	14.0	1.0
Langin	13.6	12.3	12.9	1.3	14.8	13.4	14.1	1.4
Larry	14.8	12.9	13.9	1.9	14.8	14.8	14.8	-0.1
Lonerider	15.6	13.9	14.8	1.7	15.0	14.7	14.8	0.3
Paradise	15.7	13.9	14.8	1.8	14.0	14.7	14.4	-0.7
SY Grit	14.7	13.0	13.8	1.6	14.5	14.2	14.4	0.3
SY Monument	13.4	12.5	12.9	0.9	14.8	14.2	14.5	0.7
SY Rugged	14.1	12.9	13.5	1.3	14.1	13.6	13.9	0.5
Smith's Gold	13.8	12.7	13.2	1.2	14.3	13.6	14.0	0.7
Spirit Rider	14.6	13.6	14.1	1.0	14.4	14.3	14.3	0.1
T158	13.8	12.7	13.2	1.1	14.3	13.8	14.1	0.5
Tatanka	12.5	11.5	12.0	1.0	13.6	13.2	13.4	0.4
WB4303	14.4	13.5	13.9	0.9	14.7	14.2	14.4	0.5
WB Grainfield	13.2	11.8	12.5	1.4	14.2	14.8	14.5	-0.6
Whistler	11.5	10.8	11.2	0.7	14.1	14.0	14.1	0.1
Zenda	14.4	13.3	13.9	1.2	14.3	13.6	14.0	0.7
Mean	13.9	12.7	13.3		14.5	14.1	14.3	
LSD	0.9							

IM = intensive management. SM = standard management.

Ashland Bottoms

$y = -0.0938x + 17.811$
$R^2 = 0.4113$

$y = -0.0439x + 14.084$
$R^2 = 0.0814$

IM
SM
Linear (IM)
Linear (SM)

Grain protein concentration, %

Grain yield, bu/a

Great Bend

$y = -0.0114x + 15.461$
$R^2 = 0.0547$

$y = -0.0111x + 14.843$
$R^2 = 0.0562$

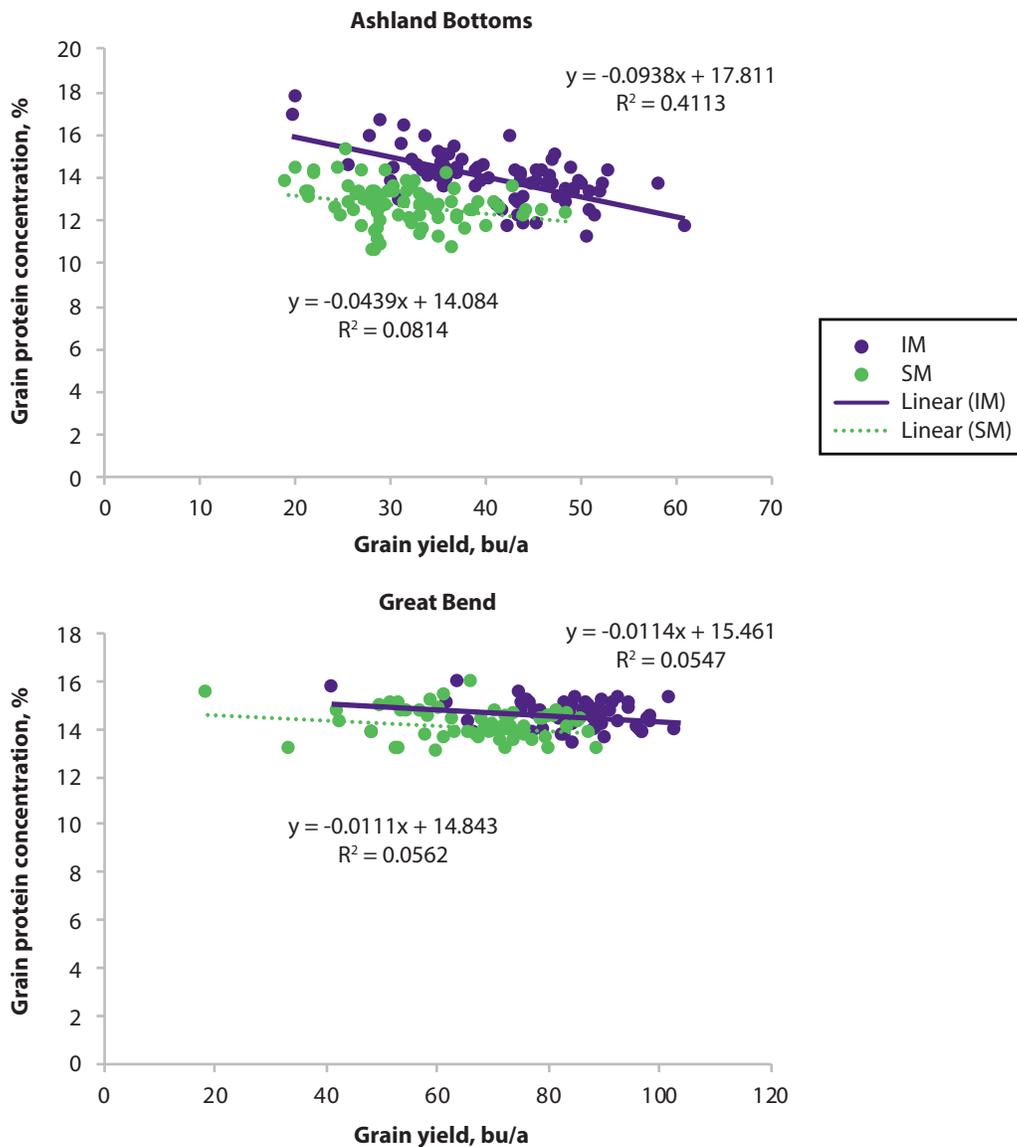Grain protein concentration, %

Grain yield, bu/a

Figure 1. Grain protein concentration as affected by grain yield and management intensity in Ashland Bottoms and Great Bend during the 2018–2019 growing season. IM = intensive management. SM = standard management.