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Intensive Wheat Management for Yield and Quality: The Role of Variety, Environment, and Management Practices

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Intensive Wheat Management for Yield and Quality: The Role of Variety, Environment, and Management Practices

Abstract

Management (M), variety (V), and environment (E) greatly influence wheat yield and quality. With the objective of determining the partial influence of V, E, and M, we conducted a field experiment where we imposed four management intensities to five wheat varieties during six site-years in Kansas and Oklahoma. Management intensities were 1) low-input (N fertility for a yield goal of 60 bu/a); 2) high-input (foliar fungicide, sulfur and chloride fertilizers, growth regulator, and nitrogen (N) fertility for a yield goal of 100 bu/a); 3) high-input minus fungicide; and 4) high-input minus additional N. We selected commonly grown wheat varieties with contrasting yield potential and quality characteristics. We used a split-plot design with M as whole-plots (established in randomized complete block design), and V as sub-plot (completely randomized within whole-plot). Variance component analyses suggested that E accounted for 63% of the variability in wheat yield and 55% of the variability in grain test weight; G accounted for 1 and 23% of the variability in yield and test weight, and M accounted for 1% of the variability of both. The interactions V × G and E × M accounted for 4 and 9% of the variability in yield, and 10 and 1% of the variability in test weight, respectively. Analysis of variance pooled across the entire dataset considering V and M fixed and E random suggested a significant G × M interaction on yield, which ranged from 49–61 bu/a. Meanwhile, both V and M affected test weight, which ranged from 52–58 lb/bu for the different V and from 55–57 lb/bu for the different M. These results suggest that E has the greatest impact in yield and quality, but there is room for yield improvement through V-specific M, and for quality improvement through V and M separately.

Keywords

wheat, intensive management, fungicide, nitrogen, variety

Cover Page Footnote

We thank Andrew Esser, Keith Thompson, Dustan Ridder, and Robert Calhoun for helping us with project establishment, management, and harvest at the experiment fields. We also thank the Kansas Wheat Commission for partial funding for this research. Finally, we thank Grain Craft for analyzing all the samples collected from this research for milling and baking quality (data not shown in this report).

Intensive Wheat Management for Yield and Quality: The Role of Variety, Environment, and Management Practices

R.P. Lollato, B.R. Jaenisch, and D. Marburger

Summary

Management (M), variety (V), and environment (E) greatly influence wheat yield and quality. With the objective of determining the partial influence of V, E, and M, we conducted a field experiment where we imposed four management intensities to five wheat varieties during six site-years in Kansas and Oklahoma. Management intensities were 1) low-input (N fertility for a yield goal of 60 bu/a); 2) high-input (foliar fungicide, sulfur and chloride fertilizers, growth regulator, and nitrogen (N) fertility for a yield goal of 100 bu/a); 3) high-input minus fungicide; and 4) high-input minus additional N. We selected commonly grown wheat varieties with contrasting yield potential and quality characteristics. We used a split-plot design with M as whole-plots (established in randomized complete block design), and V as sub-plot (completely randomized within whole-plot). Variance component analyses suggested that E accounted for 63% of the variability in wheat yield and 55% of the variability in grain test weight; G accounted for 1 and 23% of the variability in yield and test weight, and M accounted for 1% of the variability of both. The interactions V × G and E × M accounted for 4 and 9% of the variability in yield, and 10 and 1% of the variability in test weight, respectively. Analysis of variance pooled across the entire dataset considering V and M fixed and E random suggested a significant G × M interaction on yield, which ranged from 49–61 bu/a. Meanwhile, both V and M affected test weight, which ranged from 52–58 lb/bu for the different V and from 55–57 lb/bu for the different M. These results suggest that E has the greatest impact in yield and quality, but there is room for yield improvement through V-specific M, and for quality improvement through V and M separately.

Introduction

Wheat yields in Kansas average about 40 bu/a, which corresponds to about 52% of their potential that is estimated at 77 bu/a (Lollato et al., 2017; Lollato et al., 2019). While managing the crop for the yield potential is typically not economical, this large gap between actual and potential yield suggests that yields could be economically improved to ~54 bu/a, or 70% of the potential (Lobell et al., 2009). Increases in wheat yield will result from improving management of high-yielding cultivars, and will ultimately be dictated by the interaction with environment. Beyond yield, wheat quality attributes are also important for the end user. The effects of G and M combined can account for as much as 46% of the variability in wheat quality, while the effects of environment range from 3–76%, depending on growing season and quality parameter (Rozbicki et al., 2015). Given the large yield gap in Kansas and the importance of yield and quality to maximize producers' profitability, our objectives were to estimate the partial influence of G, E, and M on winter wheat yield and quality, and to explore opportunities to better manage both attributes.

Procedures

Field trials were conducted during two winter wheat growing seasons, including the 2016–17 (Manhattan and Hutchinson, KS) and the 2017–18 (Manhattan and Belleville, KS; and Stillwater and Perkins, OK). The treatments evaluated here were selected as a follow-up study to that conducted by Jaenisch et al. (2019). We used a split-plot design with main plots arranged as randomized complete block design and sub-plots completely randomized within main plots with four replications. Main plots were four management strategies: 1) low-input (N fertility for a yield goal of 60 bu/a); 2) high-input (two foliar fungicide applications, sulfur and chloride fertilizers, plant growth regulator, and additional N fertilizer for a yield goal of 100 bu/a); 3) high-input minus foliar fungicide; and 4) high-input minus additional N fertilizer. Sub-plots were five commonly grown hard red winter wheat varieties with contrasting yield potential and quality characteristics: WB4458, WB-Grainfield, WB4269, WB4303, and WB4515. Grain yield and grain test weight were measured at harvest maturity and corrected to 13.5% moisture content.

We performed a two-way analysis of variance (ANOVA) using PROC GLIMMIX in SAS v. 9.4 (SAS Inst. Inc., Cary, NC) for the data combined across environments. Fixed effects were variety, management, and their interaction. Random effects were environment, block nested within environment, and the interaction of management and block nested within environment. An analysis of adaptability was performed in which yield gain (the difference between high-input and low-input) was regressed against mean environment yield for each variety. The slope of this relationship was assessed to understand variety-specific yield adaptability.

Results

Environment accounted for the largest proportion in both yield and test weight variability (63 and 55%, respectively) (Table 1). For grain yield, the next largest factors accounting for the variability were the interactions E × M (9%) and E × G (4%). The largest manageable factor accounting for grain test weight variability was G (23%) and E × G (10%).

The varieties WB-Grainfield, WB4303, WB4458, and WB4515 followed the same trend, in that the low input and the high input minus fungicide treatments had the lowest yield, while the high-input had the highest yield (Figure 1). Removing N from the high-input did not decrease yields to the same extent as removing foliar fungicide. On the other hand, the variety WB4269 did not respond significantly to improved management (Figure 1).

The most responsive variety was WB4303, with a yield gain of 0.59 bu/a in response to the high-input treatment for each bu/a increase in mean environment yield (Figure 2).

The varieties WB4269, WB4515, and WB-Grainfield all responded similarly to increases in yield environment, at about 0.35-0.38 bu/a for every bu/a environment yield increase (Figure 2). The yield gain from the variety WB4458 was about 7 bu/a and was independent of environment yield.

Differences in grain test weight between varieties were as large as 6 lb/bu, with WB4303 resulting in the lowest test weights among the studied varieties (Figure 3). Meanwhile, WB-Grainfield and WB4458 had a lower test weight than WB4269, which had lower test weight than WB4515. Regarding management, removing foliar fungicide from the high-input treatment reduced grain test weight by 2 lb/bu.

Preliminary Conclusions

These data confirm that the environment is the major player for both yield and test weight. However, it also suggests that there is room to optimize management for grain yield according to environment and variety. For grain test weight, there was also room to select varieties with higher test weight and, to a lower extent, apply foliar fungicide.

Acknowledgments

We thank Andrew Esser, Keith Thompson, Dustan Ridder, and Robert Calhoun for helping us with project establishment, management, and harvest at the experiment fields. We also thank the Kansas Wheat Commission for partial funding for this research. Finally, we thank Grain Craft for analyzing all the samples collected from this research for milling and baking quality (data not shown in this report).

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Table 1. Variance component analysis of the individual effects of variety (V), management (M), environment (E), and their interactions on wheat grain yield and grain test weight variability

	Yield		Test weight	
Source of variation	Variance	% Variance	Variance	% Variance
V	3	1	5	23
M	2	1	0	1
V × M	1	0	0	0
E	150	63	12	55
E × V	10	4	2	10
E × M	21	9	0	1
V × E × M	0	0	0	2
Block (E)	21	9	0	1
Error	30	13	1	6
Total	238	100	22	100

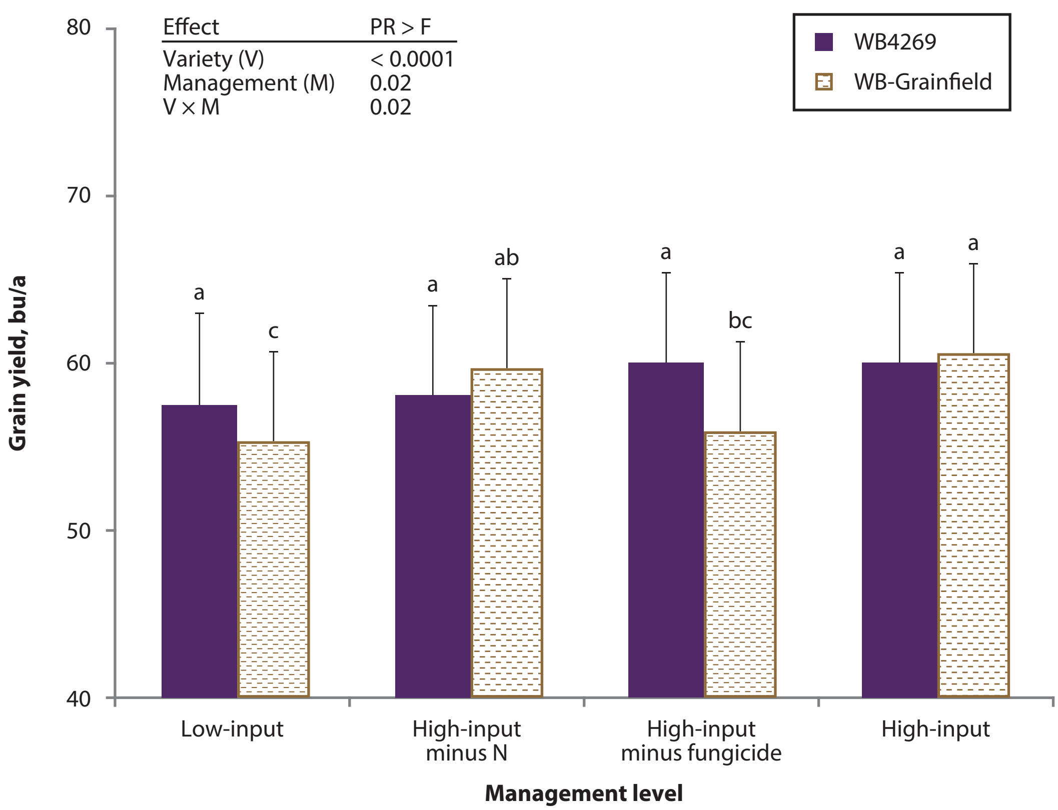

Figure 1. Wheat grain yield as affected by variety and management level. Significance of effects from analysis of variance is shown in the inset table. Bars followed by the same letter indicate lack of statistical difference between management practices within variety.

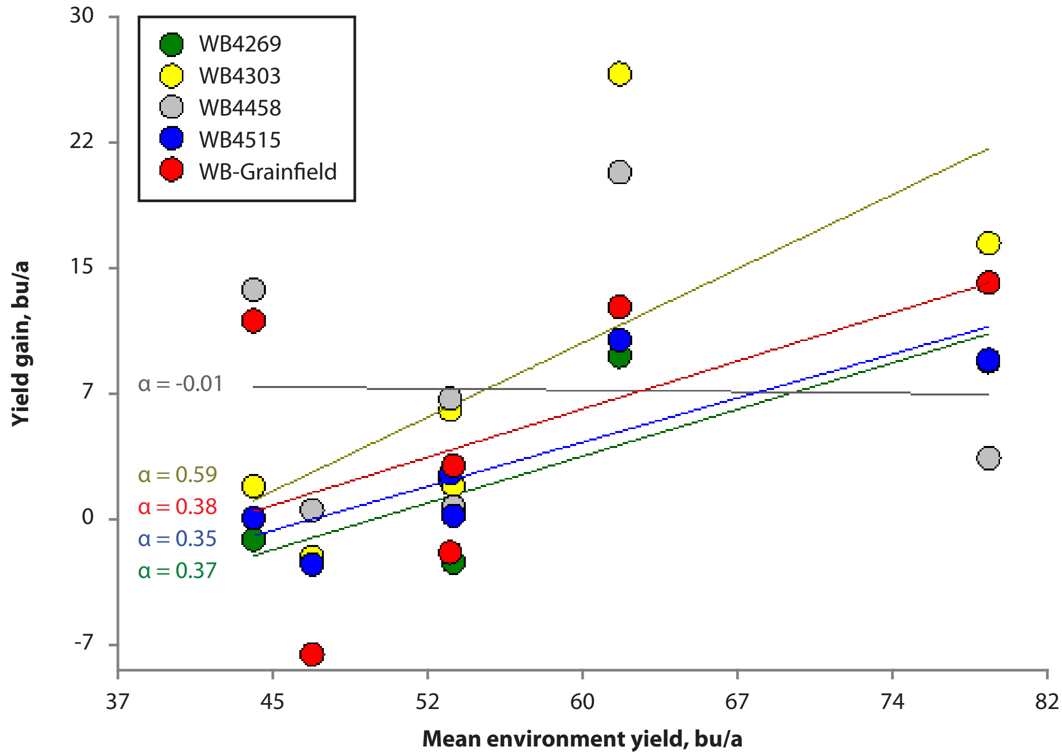

Figure 2. Variety-specific yield gain in response to intensive management according to the mean environment yield. Yield gain was calculated as the mean yield in the high-input management minus the mean yield in the low-input management at each environment. The slopes of the linear regression (α) are also shown, representing each variety's responsiveness to increases in environmental yield potential.

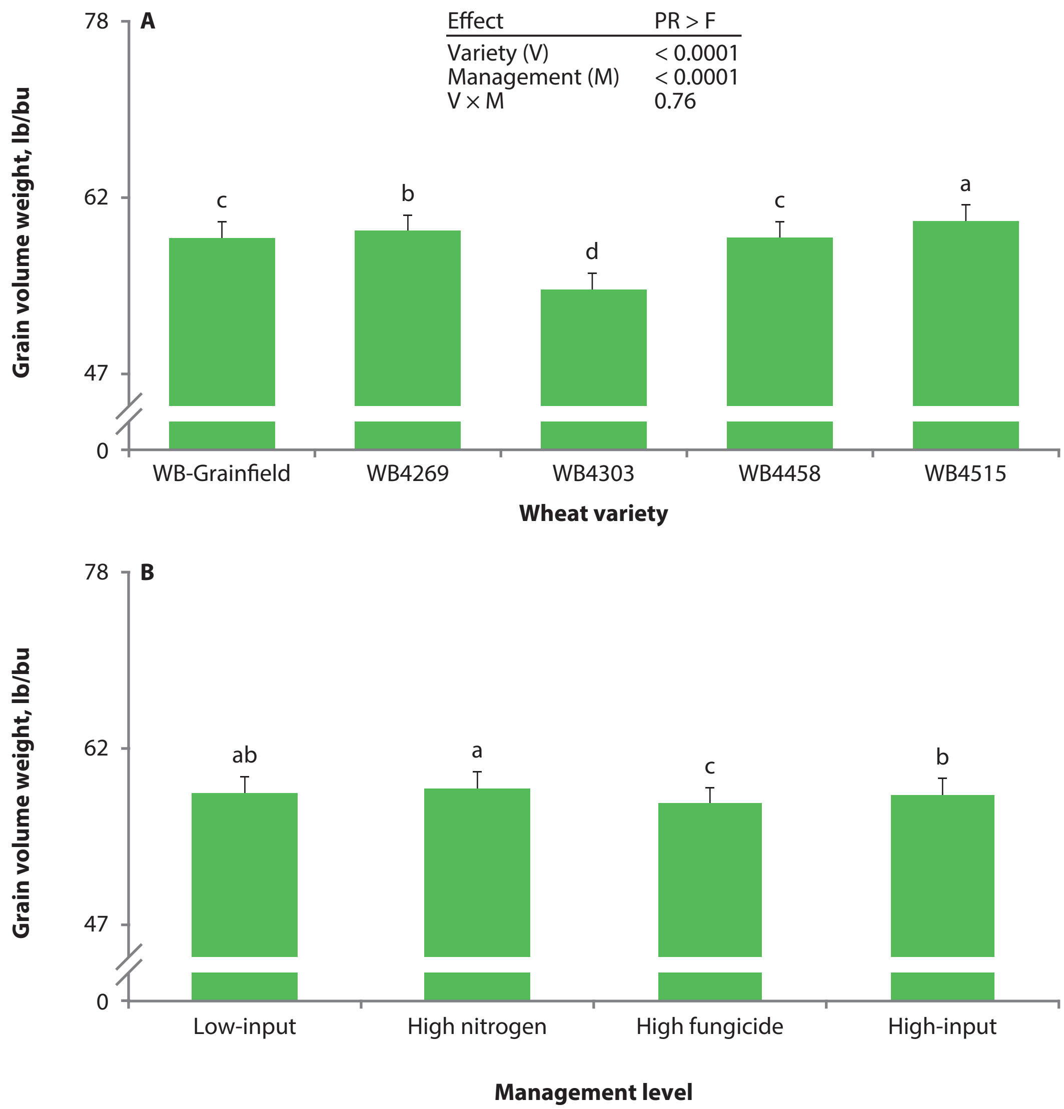

Figure 3. Wheat grain test weight response to (a) variety and (b) management level. Significance of effects from analysis of variance (ANOVA) is shown in the inset table.