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Reducing the Wheat Yield Gap Through Variety-Specific Management

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Reducing the Wheat Yield Gap Through Variety-Specific Management

Abstract

In Kansas, wheat yields have been nearly stagnant at approximately 40 bu/a for the past 30 years, which corresponds to a yield gap (the difference between average producer yield and yield potential) of approximately 35 bu/a relative to the state average yield potential of ~75 bu/a. Our objective was to continue investigation on the influence of varieties with different genetic and agronomic characteristics and management practices on grain yield to demonstrate that appropriate variety-specific management can help producers to achieve long-term profitability in a sustainable manner. The Kansas State University wheat variety performance tests (VPT) evaluate 35–50 varieties in more than 20 locations every year. We have expanded the test to a paired-plot design in three VPT locations (Ellsworth, Conway Springs, and McPherson, KS) in the 2016–2017 growing season, where one plot is managed under standard management practice (SM) based on current farmer's practice of each region with no fungicide application and the adjacent plot with the same variety is enhanced with additional 40 lb of N/a and two fungicide applications hereafter referred to as intensive management (IM). Yield gap between the IM and SM ranged from 7 bu/a in Conway to 10 bu/a in Ellsworth on average of all varieties, mainly due to stripe rust (*Puccinia striiformis* Westend) occurrence in the growing season. Varieties more susceptible to stripe rust had 50% cumulative probability yield gain of 9 bu/a across all locations studied by switching from SM to IM, while resistant varieties gained 7 bu/a. The probability of breakeven was 22% greater in susceptible varieties as compared to resistant varieties. Our results indicate that selecting varieties with resistance to major fungal diseases can narrow the wheat yield gap in most years, reducing the need for additional fungicide. By comparing yield responses of currently-grown and new wheat varieties under farmer's management and intensive management practices, this on-farm research provides science-based information for farmers to maximize profit while protecting natural resources and reducing the wheat yield gap in Kansas.

Keywords

wheat yield gain, foliar fungal diseases, profitability, yield gap

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Summary

In Kansas, wheat yields have been nearly stagnant at approximately 40 bu/a for the past 30 years, which corresponds to a yield gap (the difference between average producer yield and yield potential) of approximately 35 bu/a relative to the state average yield potential of ~75 bu/a. Our objective was to continue investigation on the influence of varieties with different genetic and agronomic characteristics and management practices on grain yield to demonstrate that appropriate variety-specific management can help producers to achieve long-term profitability in a sustainable manner. The Kansas State University wheat variety performance tests (VPT) evaluate 35–50 varieties in more than 20 locations every year. We have expanded the test to a paired-plot design in three VPT locations (Ellsworth, Conway Springs, and McPherson, KS) in the 2016–2017 growing season, where one plot is managed under standard management practice (SM) based on current farmer's practice of each region with no fungicide application and the adjacent plot with the same variety is enhanced with additional 40 lb of N/a and two fungicide applications hereafter referred to as intensive management (IM). Yield gap between the IM and SM ranged from 7 bu/a in Conway to 10 bu/a in Ellsworth on average of all varieties, mainly due to stripe rust (*Puccinia striiformis* Westend) occurrence in the growing season. Varieties more susceptible to stripe rust had 50% cumulative probability yield gain of 9 bu/a across all locations studied by switching from SM to IM, while resistant varieties gained 7 bu/a. The probability of breakeven was 22% greater in susceptible varieties as compared to resistant varieties. Our results indicate that selecting varieties with resistance to major fungal diseases can narrow the wheat yield gap in most years, reducing the need for additional fungicide. By comparing yield responses of currently-grown and new wheat varieties under farmer's management and intensive management practices, this on-farm research provides science-based information for farmers to maximize profit while protecting natural resources and reducing the wheat yield gap in Kansas.

Introduction

In Kansas, wheat yields have been nearly stagnant at approximately 40 bu/a for the past 30 years, which corresponds to a yield gap (i.e. difference between average producer yield and economical yield potential of the region) of approximately 35 bu/a relative to state average yield potential of ~75 bu/a. A few studies and yield contests have reported average yields of ~110 bu/a, suggesting even larger opportunities for yield improvements in this region during particular growing seasons. It is proposed that the yield gap in the southern Great Plains is possibly due to low-input management practices rather than lack of genetic potential of current varieties. Yield gain from fungicide applications has been inconsistent across production systems as its effectiveness depends on variety resistance, disease pressure, and growing season weather, while split-N application has increased yield, grain protein concentration and N use-efficiency in wheat. Thus, studies evaluating variety-specific crop management are crucial to sustainably improve yield in different farming systems. Our preliminary data show that the development of variety-based agronomic recommendations can economically enhance yields, but long-term analyses including multiple site-years are needed to understand ways to reduce the environmental footprint in wheat production while increasing producers' profitability. Furthermore, a comprehensive characterization of varieties under a wide range of cropping systems will assist producers to select varieties best suited to their area, and consequently, narrow the yield gap in wheat production through variety selection and variety-specific agronomic management.

Procedures

We conducted rainfed research studies in three production fields in Kansas during the 2016–2017 growing season: Conway Springs (CO), Ellsworth (ELL), and McPherson (MP) (Table 1). Weather data were collected on a daily basis from sowing to harvesting from the Kansas Mesonet Network, which had stations located at the vicinity of the experiment sites (Table 1). The predominant soil type was Bethany silt loam in CO, and Crete silt loam in ELL and MP. At all site-years, the seeding rate was 60 lb/a. We adopted conventional tillage practices at ELL and MP locations, and no-till practices in CO. Wheat field trials were sown with a 6-row Hege small plot cone planter with row spacing of 10 in. and plot length of 15 ft (Table 1). Insect and weed occurrence was minimal, and controlled with commercially available pesticides as needed.

A total of 38 to 48 wheat varieties (both commercially available and experimental lines) were tested at each location as part of the official Kansas State University Wheat Performance tests (Table 2). Varieties differed in year of release, maturity range, disease resistance, responsiveness to nitrogen (N), and yield potential. The experimental design was a strip plot design with variety as the main factor and management practice as the subfactor. The varieties were arranged in a randomized complete block design with three replications, while the two treatments were non-randomized and applied as strips. The management treatments tested were (i) standard management (SM), with the N rate calculated based on K-State fertilizer recommendations for approximately 70 bu/a yield goal and no fungicide application; and (ii) intensive management (IM), comprising the SM treatment, an additional N rate of 40 lb of N/a applied as urea (46-0-0) at Feekes GS 3 (spring tillering), and two fungicide applications at Feekes GS 6 (jointing) and 10.5 (heading) (Table 2). For the SM treatment, the N rate, source and timing of application slightly varied across locations depending on soil N profile and each farmer's practice (Table 2). Plots were harvested with a small plot combine Wintersteiger Delta and grain yield was adjusted to 12% moisture (Table 1). The average yield recorded by farmers for the past 3–5 years prior the establishment of the field trials in these regions, were 49, 60, 62 bu/a for ELL, CO, and MP, respectively.

Statistical analysis was executed using the R software. The yield differences between management treatments (hereafter referred to as yield gap) were estimated prior to analysis, and used as dependent variable. At each location, the yield gap was estimated as the difference between the yield from the intensive management (IM) and standard management (SM) for each plot. Varieties were grouped into three categories of resistance levels to stripe rust based on K-State wheat variety disease ratings (De Wolf et al., 2017): [i.e., resistant (RES) with ratings score of 1 to 3; intermediate (INT) with ratings score between 4 and 6; and susceptible (SUS) with ratings score of 7 and 9] for the yield gap, cumulative probability of yield gain, and probability of breakeven analyses.

Results

The weather variability during the 2016–2017 growing season led to highly variable yields across the three studied locations. Adequate fall precipitation and temperature increased early vegetative growth of the crop. Dry conditions, few freezing events, and above average temperature (+6 to 10°F) were observed during the winter, which was followed by above average rainfall and cooler temperatures from March to May, which benefited grain development and yield. However, the latter conditions also favored lodging in high yielding environments (e.g. McPherson), and the incidence of the fungal diseases stripe rust (*Puccinia striiformis* Westend) and leaf rust (*Puccinia triticina*).

The average yield across all varieties for each management treatment at each location was 97 bu/a for the IM and 87 bu/a for the SM treatments in ELL, 71 bu/a for the IM and 64 bu/a for the SM in CO, and 77 bu/a for the IM and 68 bu/a for the SM managements in MP (Table 2). The minimum and maximum yield observed when averaged across all varieties and management treatments at each location were 51 and 125 bu/a in ELL, 34 and 92 bu/a in CO, and 40 and 101 bu/a in MP. Grain protein concentration was not nearly as variable as grain yield, with average protein of 10% across management practices and locations (Table 2). The additional N supplied in the intensive management increased protein levels from 9.5–10% in the SM to 10–10.5% in the IM (Table 2).

The large yield variability observed was possibly due to differences in disease pressure across locations, and to variety differences in resistance levels to stripe and leaf rust, consequently affecting the response to the fungicide applications. Additionally, yield differences might also have occurred due to differences in responses to N fertilizer applied (data not shown). Although a trend was observed, yield gap was not statistically different between varieties SUS to stripe rust as compared to the other groups in any of the locations during the 2016–2017 growing season (Figure 1). The lack of difference could be explained by the unbalanced number of varieties tested within each resistance level group, and the consequent lower number of SUS varieties (n = 12) relative to RES (n = 35) and INT (n = 45) varieties across locations.

For each location, the greatest yield gap (i.e., 28 bu/a) was measured in ELL for the SY Flint and WB4269 varieties and average yield for both varieties was ~100 bu/a under the IM (Figure 2). This yield gap was followed by a yield gap of 23 bu/a for the varieties Tatanka in CO and WB4303 in MP, with average yields of 85 and 94 bu/a for the IM, respectively (data not shown). The variety Everest showed a consistent yield gain of approximately 15 bu/a resulting from switching from SM to IM across the three studied locations with average yield of 88 bu/a at IM. Meanwhile, the variety

T158 showed a larger yield gap as a result of the yield gain of ~19 bu/a in MP and CO locations, likely due to its susceptibility to stripe rust. Additionally, T158 was severely lodged at harvesting in MP, and showed inconsistent lodging scores in CO and ELL.

Probability of yield gain resulting from the IM treatment was slightly larger for susceptible than for resistant varieties (Figure 3). Susceptible varieties had 50% cumulative probability of yield gain of 9 bu/a across all studied locations in KS by switching from SM to IM, while resistant varieties gained 7 bu/a. On average of the three locations, the probability of breakeven was 22% greater in susceptible varieties as compared to resistant varieties (42 vs. 20%) (Figure 4). Probability of breakeven (%) was estimated using $4/bu for the wheat price, $32/a for fungicide costs and total nitrogen costs of $20/a.

Preliminary Conclusions

Our results indicate that selecting varieties with resistance to major fungal diseases may narrow the wheat yield gap in Kansas, potentially reducing the need for additional fungicide. Intensive management may be a viable alternative for varieties that lack the aforementioned genetic resistance, but long-term analyses including multiple site-years are needed to quantify the most typical response per level of disease resistance. Wheat variety response to N fertilizer rate was related to straw strength, and avoiding over-fertilization in varieties with below-average straw strength can help reduce the environmental footprint in wheat production. This study provides science-based information to farmers on how to maximize profit while protecting natural resources and reducing the wheat yield gap in Kansas.

References

De Wolf, E., R.P. Lollato, and R.J. Whitworth. 2017. Wheat variety disease and insect ratings 2017. Kansas State University Agricultural Experiment Station and Cooperative Extension Service MF991.

Table 1. Site information: plot coordinates, planting and harvesting dates, previous crop, cumulative precipitation (Cum PPT) in inches, and cumulative evapotranspiration (Cum ET) in inches and cumulative growing degree days (Cum GDD) at each location during the 2016–2017 growing season in Kansas

Location	Coordinates	Planting date	Harvesting date	Previous crop	Cum PPT	Cum ET	Cum GDD
					----------- in. -----------		°F
Ellsworth	38°35’37.99” N 98°19’58.18” W	10/7/2016	6/27/2017	wheat	16	554	5380
Conway Springs	37°27’36.7” N 97°37’48.3” W	10/11/2016	6/22/2017	corn	22	837	4159
McPherson	38°15’50.83” N 97°35’33.36” W	10/11/2016	6/20/2017	wheat	15	772	3724

There were no solar radiation data available for the fall period in Ellsworth, therefore cumulative evapotranspiration in this location represents values from January to June (harvesting).

Table 2. Number of varieties tested, total nitrogen (N) rate (lb/a), average grain yield (bu/a) and grain protein concentration at 12% moisture adjustment for standard management (SM) and intensive management (IM) at each location in the 2016–2017 growing season in Kansas

	Varieties	N rate		Grain yield		Grain protein	
Location	#	IM	SM	IM	SM	IM	SM
		---------- lb/a ----------		---------- bu/a ----------		---------- % ----------	
Ellsworth	38	130	95	97 a	87 b	10.6 a	10.0 b
Conway Springs	48	130	90	71 a	64 b	10.4 a	9.9 b
McPherson	48	100	60	77 a	68 b	10.0 a	9.5 b

Within location, different letters mean statistical significant difference between intensive (IM) and standard (SM) management at $P < 0.05$ (LSD).

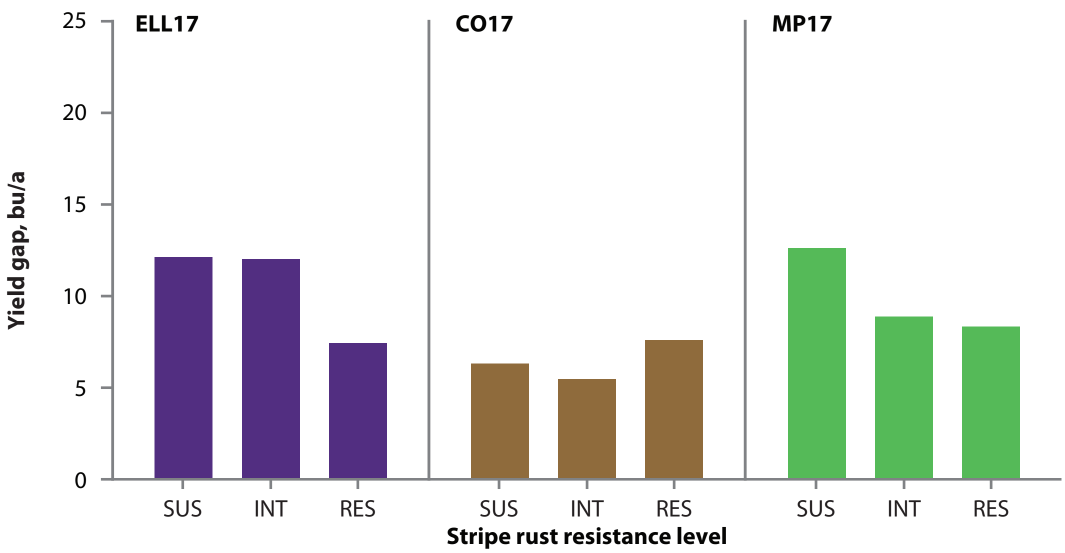

Figure 1. Yield gap between standard (SM) and intensive management (IM) for different variety resistance levels to stripe rust disease at the three locations of Ellsworth, Conway Springs, and McPherson, KS, 2017. SUS = susceptible, INT = intermediate, RES = resistant. Within location, yield gap means for each resistance level were not significantly different at *P* < 0.05 (LSD).

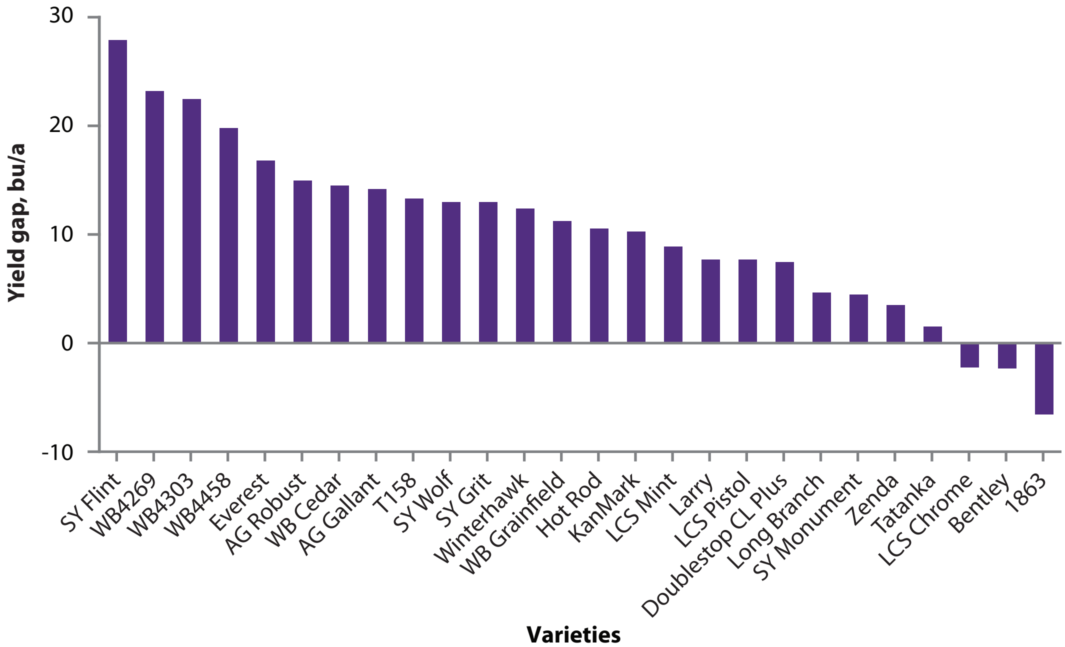

Figure 2. Yield gap between standard intensive management for varieties with different resistance levels to stripe rust disease for the location in Ellsworth, KS, 2017. Yield gap means were only statistically different between the varieties with the highest (28 bu/a) and lowest yield gap (-7 bu/a) *P* < 0.05 (LSD). The other varieties were not significantly different from each other.

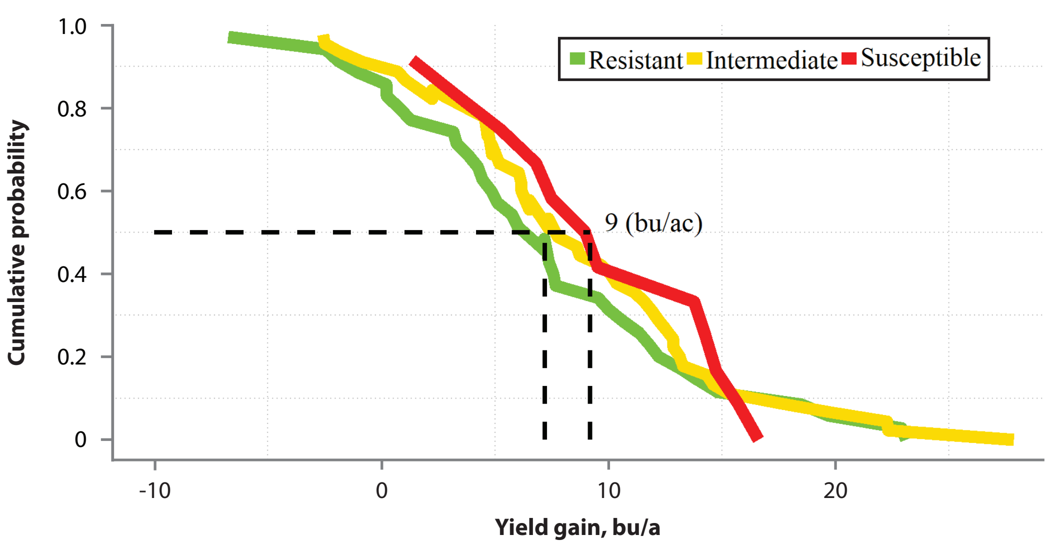

Figure 3. Cumulative probability of yield gain from standard (SM) to intensive management (IM) for different variety resistance levels to stripe rust disease at the three locations of Ellsworth, Conway Springs, and McPherson, KS, 2017.

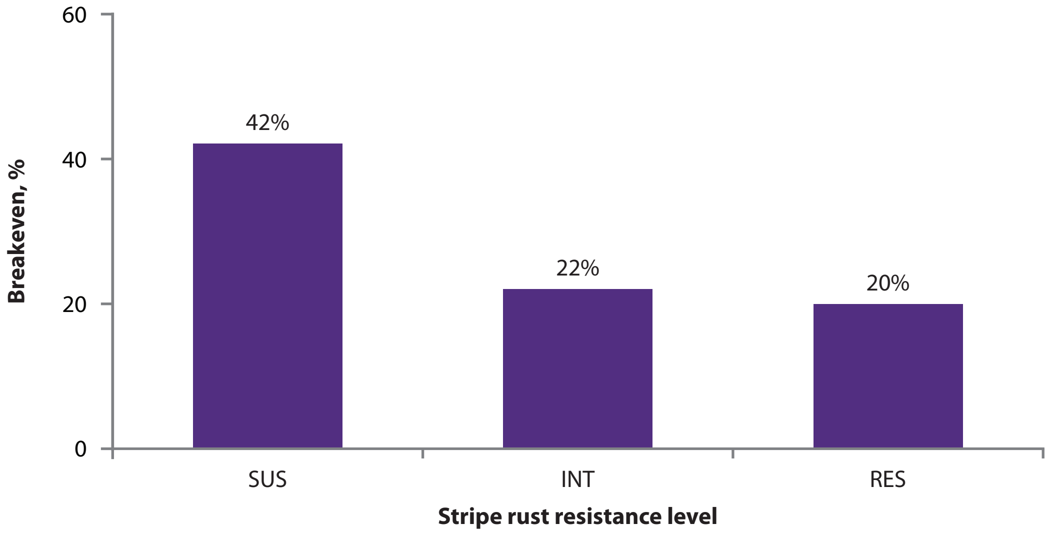

Figure 4. Probability of breakeven (%) for the additional N rate (40 lb/a) and two fungicide applications at Feekes GS 6 and 10.5. Means at the three locations of Ellsworth, Conway Springs, and McPherson, KS, 2017. SUS = susceptible, INT = intermediate, RES = resistant.