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Summary

Foliar fungicides applied at the flag leaf stage can improve wheat grain yield in Kansas, but there is limited information on the impact of earlier or combined applications of fungicide on wheat grain yield. We conducted a field study in six Kansas locations during the 2020–2021 growing season to evaluate the yield and test weight of the winter wheat variety WB-Grainfield in response to different fungicide application timings. The trial was conducted in a randomized complete block design with four replications to evaluate (1) a non-treated control; Topguard applied at 5 ounces per acre at (2) jointing, (3) heading; and (4) jointing plus heading. The study was conducted in two locations with contrasting soil textures near Ashland Bottoms, in two locations with different previous crops resulting in optimum- and late-sowing dates near Belleville, in one location near Hutchinson, and another near Manhattan. Statistical analysis indicated that for both grain yield and grain test weight, there were significant fungicide timing by location interactions, suggesting that the response to fungicide was location-specific. Grain yield ranged from 28 bushels per acre in the no fungicide treatment in Manhattan to 109.9 bu/a with dual-fungicide in the Belleville field sown at the optimum time. Depending on environment, the increase in yield due to the fungicide application as compared to the untreated control ranged from 0.7 to 8.0 bu/a in the jointing application, from -1.8 to 19.3 bu/a in the heading application, and from -1.4 to 17.7 bu/a in the dual application. Grain test weights ranged from 54.1 pounds per bushel without fungicide in one of the trials near Ashland Bottoms, to 62.8 lb/bu near Hutchinson with the dual fungicide application. Test weight benefits due to fungicide depended on location and ranged from -0.1 to 1.7 lb/bu in the jointing application, from -0.9 to 2.6 lb/bu in the heading application, and from -0.3 to 3.9 lb/bu in the dual application. This research is an initial step in determining the benefits of foliar fungicide timing to winter wheat yield and test weight. The results from this study suggest that benefits are substantial, however, the magnitude depended on the environmental conditions experienced during the growing season.

Introduction

The application of foliar fungicides has been associated with increased wheat yields in Kansas (Cruppe et al., 2021; de Oliveira Silva et al., 2020, 2021; Jaenisch et al., 2019, 2021, 2022; Munaro et al., 2020; Lollato et al., 2019; Sassenrath et al., 2019). However,

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most of the existing research has focused on a single fungicide application at flag leaf emergence (e.g., Cruppe et al., 2017, 2021), even though some intensive production systems maximizing wheat yield have used a dual-fungicide system (Lollato and Edwards, 2015). Understanding the potential benefits of dual fungicide application, as well as of application timings, can potentially help narrow the large yield gaps for wheat in this region (Lollato et al., 2017).

The most prevalent diseases causing yield losses to Kansas wheat are leaf and stripe rust (Hollandbeck et al., 2019), perhaps justifying the majority of the research focused on late-season fungicide applications. However, Hollandbeck et al. (2019) also suggested that early-season diseases such as tan spot and septoria might cause significant yield losses if the conditions are favorable for development of such diseases. There is a need to better understand the effects of different timings of fungicide application on winter wheat grain yield in the state. Likewise, different products might offer different levels of protection (DeWolf et al., 2019). Therefore, testing the interaction between fungicide timing and product on wheat yield is warranted.

The objective of this study was to evaluate the response of winter wheat in terms of grain yield and test weight to different fungicide timings in Kansas.

Procedures

A field experiment was conducted in six Kansas locations during the 2020–2021 winter wheat growing season, including two fields with contrasting soil texture characteristics near Ashland Bottoms, two fields with different previous crops resulting in optimum- and late-sowing dates near Belleville, one field near Hutchinson and one field near Manhattan. The experiments were established in a randomized complete block design with four treatments and four replications. Treatments included (1) a non-treated control; Topguard foliar fungicide applied at 5 ounces per acre at (2) jointing, (3) heading, and (4) jointing plus heading. All treatments were applied with non-ionic surfactant and a spray volume of 15 gallons per acre using a backpack sprayer. The winter wheat variety evaluated at all locations was WB-Grainfield. 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 test weight. Statistical analysis was performed using a two-way ANOVA in PROC GLIMMIX procedure in SAS v. 9.4 where treatment, location, and their interactions were considered fixed effects, and replication nested within location was treated as a random effect.

Results

Weather Conditions

The study locations had anywhere from 10.9 to 18.6 inches of precipitation during the growing season, with corresponding crop reference evapotranspiration of 30.4 to 32.7 inches (Table 1). These precipitation and atmospheric water demand values resulted in water supply:water demand ratios of 0.14 to 0.85 depending on location and portion of the season considered, suggesting that water deficit was possibly limiting wheat yields differently according to location. However, water deficit and temperature stresses are common themes of wheat production in Kansas (Couedel et al., 2021;

Lollato et al., 2020; Sciarresi et al., 2019) and therefore represent conditions experienced at growers' fields.

Grain Yield

Grain yield was affected by the interaction of fungicide and location ($P < 0.01$), suggesting that fungicide management ranked differently at each location evaluated. Manhattan was the lowest yielding environment; grain yields ranged between 26.1 and 31.5 bu/a with no effect of fungicide (Table 2). At four locations (the two fields in Ashland Bottoms, Belleville optimum, and Hutchinson), grain yield was greatest in the treatments receiving fungicide at heading as well as in the dual fungicide treatment (Table 2). In Belleville sown late, the treatment receiving a fungicide application at heading resulted in the highest yield (Table 2). Depending on environment, the increase in yield due to the fungicide application as compared to the untreated control ranged from 0.7 to 8.0 bu/a in the jointing application, from -1.8 to 19.3 bu/a in the heading application, and from -1.4 to 17.7 bu/a in the dual application. Grain test weight ranged from 54.1 lb/bu without fungicide in one of the trials near Ashland Bottoms, to 62.8 lb/bu near Hutchinson with the dual fungicide application.

Grain Test Weight

Similar to grain yield, the response of grain test weight to foliar fungicide management also depended on location, as evidenced by the significant interaction between fungicide treatment and location ($P < 0.01$). In Manhattan and Belleville sown late, there was no effect of fungicide treatment on wheat test weight (Table 2). In one field in Ashland Bottoms and in Belleville sown at the optimum time, the greatest test weights occurred in the heading or dual fungicide application treatments (Table 2). In the other Ashland Bottoms field, test weight in the control treatment was lower than that of any treatment receiving fungicides. In Hutchinson, the highest test weight occurred for the dual fungicide treatment. Differences from the untreated control ranged from -0.1 to 1.7 lb/bu in the jointing application, from -0.9 to 2.6 lb/bu in the heading application, and from -0.3 to 3.9 lb/bu in the dual fungicide application, depending on environment.

Preliminary Conclusions

Results suggest that the optimum fungicide management strategy depended on location. In locations with lower yield potential, the application of foliar fungicides did not improve grain yield or grain test weight. In higher yielding locations, application of a foliar fungicide at heading usually produced yields similar to that of a dual fungicide application at jointing plus at heading.

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Table 1. Average maximum (Tmax) and minimum (Tmin) temperatures, cumulative precipitation, grass reference evapotranspiration (ETo), and the ratio of water supply (WS) to water demand (WD) during the growing season at the six study locations during 2020–2021

Location	Season*	Tmax (°F)	Tmin (°F)	Precipitation (inch)	ETo (inch)	WS:WD
Ashland Bottoms*	Fall**	57.7	32.6	4.0	7.8	0.51
	Winter	47.1	25.0	4.5	6.9	0.65
	Spring	75.2	53.4	9.4	16.0	0.59
Belleville*	Fall	56.1	30.0	1.1	8.0	0.14
	Winter	43.7	21.6	4.3	6.5	0.67
	Spring	74.9	50.4	5.5	17.2	0.32
Hutchinson	Fall	59.1	33.3	3.7	8.7	0.43
	Winter	48.2	25.2	6.2	7.3	0.85
	Spring	75.9	52.8	8.1	16.7	0.49
Manhattan	Fall	56.9	32.4	4.0	7.5	0.53
	Winter	47.4	25.5	4.6	7.3	0.63
	Spring	75.7	54.3	10.0	15.6	0.64

*Fall: October 1 - December 31. Winter: January 1 - March 31. Spring: April 1 - June 30.

**There were two fields located near Ashland Bottoms and two fields located near Belleville.

Table 2. Winter wheat grain yield and grain test weight as affected by the interaction of fungicide management and location at the six study sites conducted during the 2020–2021 growing season

Location	Fungicide treatment			
	No	Jointing	Heading	Jointing + Heading
	----- Grain yield (bu/a) -----			
Ashland Bottoms 1	65.8	73.1	80.8*	83.5
Ashland Bottoms 2	64.9	72.9	84.1	81.4
Belleville (late)	56.6	57.4	67.0	55.2
Belleville (optimum)	92.4	96.0	103.7	109.9
Hutchinson	60.1	65.0	76.9	71.9
Manhattan	28.0	31.5	26.1	29.7
	----- Grain test weight (lb/bu) -----			
Ashland Bottoms 1	54.2	55.6	56.8	56.5
Ashland Bottoms 2	54.1	55.8	56.5	57.5
Belleville (late)	61.5	61.5	60.7	61.3
Belleville (optimum)	56.3	57.4	58.6	59.3
Hutchinson	58.9	59.6	61.5	62.8
Manhattan	55.5	55.4	55.6	56.0

Timing of fungicide application is referred to as growth stage in the Feekes scale of cereal development (FK6 = jointing; FK10 = heading).

*Numbers in bold represent those in the highest yielding group based on post-hoc analysis of mean comparison using Tukey's test.