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Robust Management Programs to Minimize Losses due to FHB and DON: A Multi-state Coordinated Project

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OBJECTIVE

Evaluate the integrated effects of fungicide and genetic resistance on FHB and DON in all major grain classes, with emphasis on different application timings and new genotypes to develop more robust “*best-management practices*” for FHB and DON.

INTRODUCTION

FHB Management programs that integrate multiple in-field, harvesting and post-harvesting strategies have been shown to be the most effective for minimizing FHB-associated grain yield and quality losses in wheat and barley (Wegulo et al., 2011; Willyerd et al., 2012; McMullen et al., 2012; Salgado et al., 2014). For instance, Willyerd et al (2012) demonstrated that the application of the DMI fungicide Prosaro at anthesis combined with a moderately resistant cultivar resulted in more than 70% control of both FHB index and DON. However, weather and field conditions often prevent fungicides from being sprayed at the recommended anthesis growth stage. For instance, wet, soggy field conditions may prevent ground applications, and even if such applications are made, research shows the rainfall during or shortly after treatment may reduce fungicide efficacy (Andersen et al., 2014). Moreover, several other factors such as uneven crop development and variable anthesis window affect the ability of producers and crop advisors to correctly determine the anthesis growth stage when making a fungicide application to manage FHB and DON. To address these limitations, one of the primary goals of the USWBSI management action plan is to develop integrated management strategies for FHB and mycotoxins that are robust to conditions experienced in production fields.

MATERIALS AND METHODS

Field experiments were established in 12 US wheat-growing states (AR, DE, IL, IN, MD, MI, MN, ND, NE, NY, OH and SD) to investigate the effects of cultivar resistance and fungicide application timing on FHB and DON. Plots were established following host or non-host crops of *F. graminearum*, according to standard agronomic practices for each location. At least three commercial wheat cultivars, classified as susceptible (S), moderately susceptible (MS), or moderately resistant (MR), were planted in most trials. However, some trials only included one or two of these resistance categories. Plots were planted

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in four to six replicate blocks. The standard experimental design was a randomized complete block, with a split-plot arrangement of cultivar as whole-plot and fungicide (Prosaro, 6.5 fl.oz./A + NIS) application timing as sub-plot (untreated or treated at anthesis [A] or 2 to 7 days post-anthesis [A+2 ... A+7, respectively]). All plots were artificially inoculated with either *F. graminearum*-colonized corn kernels spread on the soil surface or spray-inoculated with a spore suspension of the fungus approximately 24-36 hours following the anthesis fungicide treatment. FHB index (plot severity) was assessed during the soft dough stage of grain development. Milled grain samples were sent to a USWBSI-supported laboratory for toxin analysis. For the purpose of this report, percent control of FHB index and DON was estimated for each cultivar x fungicide application timing combination relative to the untreated susceptible or very susceptible check (the reference treatment) for each trial/environment. However, in NY the untreated MS cultivar was used as the reference when estimating percent control.

RESULTS AND DISCUSSION

FHB index and DON results from 27 environments, representing 15 soft red winter, two soft white winter, three hard red winter, and seven hard red spring wheat classes were summarized. Estimated means and percent controls for FHB index and DON for S/Vs, MS and MR cultivars treated with Prosaro at or after anthesis are shown in Table 1, 2 and 3, respectively. In some environments, FHB did not develop due to unfavorable weather conditions. In addition, DON data were not available for some trials at the time of this report, therefore trials with missing data or nominal disease and mycotoxin levels (< 3% index and < 1 ppm DON) in the untreated susceptible reference (S/Vs/MS) were not used. Overall, mean FHB index and DON in the untreated susceptible check ranged from 3 to 54% and from 1.9 to 33 ppm, respectively. Relative to the untreated susceptible or very susceptible check, fungicide alone reduced FHB index by 1 to 97% and DON by 5 to 54% (Table 1). However, combinations of the fungicide treatment with a moderately susceptible (Table 2) or a moderately resistant (Table 3) cultivar were consistently more effective than fungicide alone at reducing FHB and DON in most trials, with percent control ranging from 4 to 99% for index and 11 to 89% for DON on the MS cultivars and from 42 to 99% for Index and 32 to 93% for DON on MR cultivars. Post-anthesis treatments were as effective as or more effective than anthesis treatments, particularly on MR cultivars. Based on these results, there is evidence suggesting that applying fungicides post-anthesis may be as efficacious against FHB and DON as treatments applied at anthesis in all wheat classes and environments.

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Table 1. Mean FHB index, DON, and percent control for different fungicide programs on FHB susceptible cultivars in 20 environments (ENV) representing different wheat classes (TYPE = SRW, SWW, HRW and HRS). Results are organized by fungicide treatment (untreated [UT] or treated at anthesis [A] or 2, 4, 5, 6 or 7 days post-anthesis [A+2...A+7, respectively]). Percent controls were estimated relative to the untreated susceptible or very susceptible (S_UT).

STATE	TYPE	ENV	Fungicide timing of application ^a							% Control Compared to Susceptible reference (S/VS ^b)						
			S_UT	A	A+2	A+4	A+5	A+6	A+7	A	A+2	A+4	A+5	A+6	A+7	
FHB Index (%)= mean proportion of disease spikelets per spike																
IL	SRW	1	7.3	8.5	3.8	0.7	--	1.1	--	-17.2	48.3	91.0	--	84.4	--	
IL	SRW	2	12.5	7.0	3.0	8.3	--	7.5	--	44.0	76.0	34.0	--	40.0	--	
IL	SRW	3 ^b	31.3	17.8	16.8	8.8	--	16.8	--	43.2	46.4	72.0	--	46.4	--	
IL	SRW	4 ^b	22.0	5.4	6.1	7.6	--	2.4	--	75.5	72.1	65.3	--	89.2	--	
IN	SRW	5	4.4	2.3	1.8	2.8	--	1.7	--	48.3	58.1	36.4	--	62.2	--	
IN	SRW	6	29.5	16.8	8.2	22.1	--	18.4	--	42.9	72.3	25.0	--	37.4	--	
OH	SRW	7	12.6	10.3	4.1	7.2	--	12.2	--	18.3	67.5	42.9	--	3.2	--	
OH	SRW	8	40.6	22.1	23.5	30.2	--	26.2	--	45.6	42.1	25.6	--	35.5	--	
MI	SWW	11 ^b	8.7	2.3	1.3	1.5	--	2.9	--	74.0	85.6	83.3	--	67.1	--	
DE	SRW	14	7.0	4.9	--	4.1	--	3.3	--	30.3	--	40.9	--	53.2	--	
MD	SRW	15	13.2	12.4	--	12.0	--	10.5	--	5.9	--	8.5	--	20.2	--	
DE	SRW	16	3.2	1.1	--	0.3	--	1.3	--	65.8	--	89.3	--	58.6	--	
NE	HRW	17	3.6	6.0	--	--	2.4	--	2.0	-69.6	--	--	31.6	--	43.4	
NE	HRW	18	27.5	11.6	--	--	--	--	16.9	57.9	--	--	--	--	38.7	
SD	HRW	19	19.0	8.5	10.9	14.9	--	15.4	--	55.5	42.7	21.6	--	18.9	--	
SD	HRS	20	48.8	37.8	38.4	33.3	--	50.6	--	22.5	21.2	31.7	--	-3.8	--	
SD	HRS	21	21.1	13.2	13.0	12.3	--	15.6	--	37.6	38.5	41.9	--	26.2	--	
SD	HRS	22	53.6	29.5	34.0	32.9	--	35.9	--	44.9	36.5	38.5	--	32.9	--	
ND	HRS	25	10.1	4.5	--	--	2.1	--	--	54.9	--	--	79.1	--	--	
ND	HRS	27	21.4	4.2	--	0.6	--	--	--	80.5	--	97.0	--	--	--	
DON = Deoxynivalenol content of harvested grain in ppm																
IL	SRW	1	4.0	7.9	3.0	2.4	--	3.0	--	-97.2	25.1	38.9	--	25.1	--	
IL	SRW	2	7.6	5.7	5.1	4.4	--	4.5	--	24.8	33.1	42.4	--	40.4	--	
IN	SRW	5	7.1	7.3	4.5	4.1	--	4.1	--	-2.8	36.7	42.1	--	42.8	--	
IN	SRW	6	7.2	4.9	4.9	4.7	--	4.5	--	31.5	32.2	35.0	--	36.6	--	
OH	SRW	7	15.6	9.0	7.3	9.1	--	9.2	--	42.3	53.2	41.7	--	41.0	--	
MI	SW/SR	10	2.4	1.6	1.1	1.5	--	1.4	--	35.4	54.2	37.5	--	43.8	--	
DE	SRW	14	2.0	1.2	--	1.2	--	1.2	--	41.5	--	40.5	--	42.0	--	
MD	SRW	15	1.9	1.6	--	1.1	--	0.9	--	13.7	--	42.6	--	51.6	--	
NE	HRW	18	33.3	26.7	--	--	--	--	24.9	19.7	--	--	--	--	25.3	
SD	HRW	19	6.9	5.4	5.4	5.0	--	5.3	--	21.9	21.2	27.0	--	23.7	--	
SD	HRS	20	9.3	8.8	8.0	6.2	--	6.6	--	5.4	14.2	33.5	--	29.0	--	
SD	HRS	21	9.6	7.7	7.2	6.3	--	7.6	--	20.3	25.3	35.2	--	21.2	--	
ND	HRS	25	7.4	5.6	--	--	4.0	--	--	24.5	--	--	45.2	--	--	

^a Fungicide application = Prosaro applied at 6.5 fl. oz./A + NIS at or after anthesis

^b Environments (ENV) where very susceptible cultivars (VS) were planted

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Table 2. Mean FHB index, DON, and percent control for different fungicide programs on moderately susceptible cultivars in 15 environments (ENV) representing different wheat classes (TYPE = SRW, SWW, HRW and HRS). Results are organized by fungicide treatment (untreated [UT] or treated at anthesis [A] or 2, 4, 5, 6 or 7 days post-anthesis [A+2...A+7, respectively]). Percent controls were estimated relative to the untreated susceptible or moderately susceptible (S_UT or MS_UT).

STATE	TYPE	ENV	Fungicide timing of application ^a							% Control Compared to Susceptible reference (S/VS ^b /MS ^c)						
			MS_UT	A	A+2	A+4	A+5	A+6	A+7	MS_UT	A	A+2	A+4	A+5	A+6	A+7
FHB Index (%)= mean proportion of disease spikelets per spike																
IL	SRW	3 ^b	6.5	2.8	5.8	3.3	--	5.3	--	79.2	91.2	81.6	89.6	--	83.2	--
IL	SRW	4 ^b	8.3	3.5	2.1	2.8	--	1.8	--	62.5	84.1	90.3	87.5	--	92.0	--
IN	SRW	5	0.5	0.4	0.4	0.4	--	0.2	--	88.4	90.4	90.7	90.0	--	95.4	--
IN	SRW	6	14.4	7.1	6.4	9.2	--	15.2	--	51.2	75.9	78.3	68.6	--	48.4	--
OH	SRW	7	8.4	6.5	3.3	4.6	--	7.8	--	33.3	48.4	73.8	63.5	--	38.1	--
OH	SRW	8	16.7	8.8	8.8	9.7	--	8.1	--	58.9	78.3	78.3	76.1	--	80.0	--
MI	SWW	11 ^b	3.1	1.6	1.0	0.9	--	0.6	--	64.6	81.5	88.8	89.6	--	93.1	--
NY	SRW	12 ^c	4.2	1.8	--	--	--	--	0.5	N/A	57.4	--	--	--	--	87.9
NY	SRW	13 ^c	8.5	2.0	--	--	2.7	--	--	N/A	76.3	--	--	68.4	--	--
SD	HRW	19	30.6	11.3	10.4	15.9	--	18.3	--	-60.8	40.8	45.3	16.6	--	3.9	--
SD	HRS	20	11.3	9.8	13.5	9.2	--	14.1	--	76.9	79.9	72.3	81.2	--	71.0	--
SD	HRS	21	3.7	2.3	1.6	3.0	--	1.4	--	82.7	89.2	92.5	86.0	--	93.2	--
SD	HRS	22	31.4	22.3	16.7	19.3	--	24.5	--	41.5	58.3	68.9	64.0	--	54.3	--
ND	HRS	25	0.5	0.2	--	--	0.1	--	--	95.1	97.9	--	--	98.6	--	--
ND	HRS	27	1.3	0.4	--	0.1	--	--	--	93.9	97.9	--	99.4	--	--	--
DON = Deoxynivalenol content of harvested grain in ppm																
IN	SRW	5	2.4	2.3	2.1	2.0	--	1.8	--	65.7	67.5	70.3	71.3	--	74.9	--
IN	SRW	6	3.8	2.9	2.8	2.6	--	3.0	--	47.1	59.4	61.1	63.6	--	58.3	--
OH	SRW	7	6.1	5.3	4.6	4.4	--	5.0	--	60.9	66.0	70.5	71.8	--	67.9	--
MI	SW/SR	10	0.6	0.4	0.3	0.4	--	0.3	--	75.8	83.3	86.3	84.2	--	86.3	--
NY	SRW	12	3.2	1.3	--	--	--	--	0.7	N/A	59.1	--	--	--	--	76.7
NY	SRW	13	2.3	1.3	--	--	1.3	--	--	N/A	44.5	--	--	43.2	--	--
SD	HRW	19	7.4	5.9	5.9	6.1	--	4.5	--	-7.6	14.5	14.7	11.0	--	34.3	--
SD	HRS	20	3.6	2.6	2.5	2.6	--	3.2	--	61.5	71.7	73.7	72.0	--	65.8	--
SD	HRS	21	2.4	1.6	1.7	1.5	--	1.9	--	75.2	83.6	82.6	84.4	--	80.0	--
ND	HRS	25	1.0	0.8	--	--	1.0	--	--	86.4	88.7	--	--	87.1	--	--

^a Fungicide application = Prosaro applied at 6.5 fl. oz./A + NIS at or after anthesis

^b Environments (ENV) where very susceptible cultivars (VS) were planted

^c Percent Control was estimated relative to moderately susceptible.

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Table 3. Mean FHB index, DON, and percent control for different fungicide programs on moderately resistant cultivars from 22 environments (ENV) representing different wheat classes (TYPE = SRW, SWW, HRW and HRS). Results are organized by fungicide treatment (untreated [UT] or treated at anthesis [A] or 2, 4, 5, 6 or 7 days post-anthesis [A+2...A+7, respectively]). Percent controls were estimated relative to the untreated susceptible or moderately susceptible (S_UT or MS_UT).

STATE	TYPE	ENV	Fungicide timing of application ^a							% Control Compared to Susceptible reference (S/VS ^b /MS ^c)						
			MR_UT	A	A+2	A+4	A+5	A+6	A+7	MR_UT	A	A+2	A+4	A+5	A+6	A+7
FHB Index (%)= mean proportion of disease spikelets per spike																
IL	SRW	1	1.8	2.4	1.5	1.1	--	0.8	--	74.8	67.2	79.3	84.4	--	88.6	--
IL	SRW	2	4.7	2.1	2.8	2.8	--	3.7	--	62.6	83.4	78.0	77.4	--	70.6	--
IL	SRW	3 ^b	5.4	1.4	2.0	0.4	--	1.1	--	82.8	95.6	93.6	98.8	--	96.4	--
IL	SRW	4 ^b	1.3	1.3	0.8	1.0	--	0.8	--	94.3	94.0	96.6	95.5	--	96.6	--
IN	SRW	5	0.4	0.2	0.2	0.2	--	0.5	--	90.0	94.5	96.6	96.1	--	87.9	--
IN	SRW	6	4.8	1.6	1.6	1.0	--	1.8	--	83.6	94.6	94.6	96.6	--	93.9	--
OH	SRW	7	4.1	3.2	1.3	2.5	--	3.4	--	67.5	74.6	89.7	80.2	--	73.0	--
OH	SRW	8	10.6	4.6	3.7	7.0	--	4.5	--	73.9	88.7	90.9	82.8	--	88.9	--
MI	SWW	11 ^b	0.6	0.4	0.2	0.3	--	0.4	--	92.7	96.0	97.7	97.0	--	95.5	--
NY	SRW	12 ^c	1.0	0.8	--	--	--	--	0.3	76.0	81.9	--	--	--	--	94.0
NY	SRW	13 ^c	8.8	2.9	--	--	1.5	--	--	-3.9	66.2	--	--	82.6	--	--
DE	SRW	14	0.4	0.2	--	0.7	--	0.3	--	94.3	97.9	--	90.4	--	96.1	--
MD	SRW	15	5.2	0.8	--	3.7	--	2.4	--	60.8	93.6	--	71.6	--	81.5	--
DE	SRW	16	0.8	0.4	--	0.2	--	0.6	--	74.6	89.0	--	94.0	--	80.3	--
NE	HRW	17	1.8	1.2	--	--	1.5	--	0.8	49.4	65.3	--	--	57.3	--	78.7
NE	HRW	18	9.9	4.9	--	--	--	--	12.2	64.1	82.1	--	--	--	--	55.6
SD	HRW	19	7.2	1.8	3.0	4.2	--	3.9	--	62.4	90.4	84.1	78.2	--	79.5	--
SD	HRS	20	28.9	27.7	19.8	22.4	--	28.4	--	40.7	43.2	59.3	54.1	--	41.8	--
SD	HRS	21	2.9	1.4	1.9	2.0	--	1.6	--	86.5	93.6	91.1	90.6	--	92.3	--
SD	HRS	22	15.5	12.2	9.8	7.9	--	13.1	--	71.0	77.3	81.8	85.2	--	75.6	--
ND	HRS	25	2.8	0.9	--	--	3.1	--	--	71.9	91.3	--	--	69.7	--	--
ND	HRS	27	1.5	0.2	--	0.0	--	--	--	93.2	99.1	--	99.9	--	--	--
DON = Deoxynivalenol content of harvested grain in ppm																
IL	SRW	1	1.1	2.5	1.1	0.8	--	1.5	--	73.6	37.4	71.9	79.4	--	63.1	--
IL	SRW	2	2.2	2.4	2.1	2.5	--	2.1	--	70.3	68.5	71.9	66.6	--	72.7	--
IN	SRW	5	3.9	2.6	3.0	2.5	--	2.1	--	44.4	63.7	57.9	64.7	--	69.8	--
IN	SRW	6	3.9	3.0	3.3	2.8	--	2.8	--	45.0	57.5	54.0	61.0	--	60.4	--
OH	SRW	7	4.2	3.5	2.1	2.5	--	2.4	--	73.1	77.6	86.5	84.0	--	84.6	--
MI	SW/SR	10	0.4	0.3	0.2	0.2	--	0.2	--	85.4	89.2	92.1	91.3	--	91.3	--
NY	SRW	12	1.3	0.5	--	--	--	--	0.2	59.4	83.3	--	--	--	--	93.4
NY	SRW	13	1.5	1.2	--	--	0.7	--	--	34.9	47.2	--	--	68.6	--	--
DE	SRW	14	0.3	0.3	--	0.2	--	0.2	--	83.5	86.0	--	90.5	--	88.0	--
MD	SRW	15	0.6	0.5	--	0.4	--	0.4	--	67.4	73.7	--	77.9	--	81.6	--
NE	HRW	18	13.3	12.9	--	--	--	--	10.1	60.1	61.2	--	--	--	--	69.6
SD	HRW	19	4.8	4.7	3.6	3.8	--	2.6	--	30.2	31.7	48.4	44.3	--	62.2	--
SD	HRS	20	3.1	2.4	2.6	2.4	--	2.6	--	67.2	74.4	72.0	74.4	--	71.7	--
SD	HRS	21	2.3	1.4	1.4	1.2	--	1.5	--	76.7	86.0	86.0	87.2	--	84.6	--
ND	HRS	25	2.1	1.6	--	--	1.4	--	--	71.4	78.2	--	--	80.5	--	--

^a Fungicide application = Prosaro applied at 6.5 fl. oz./A + NIS at or after anthesis

^b Environments (ENV) where very susceptible cultivars (VS) were planted

^c Percent Control was estimated relative to moderately susceptible.