FHB MANAGEMENT

TRIAZOLE SENSITIVITY IN POPULATIONS OF *FUSARIUM GRAMINEARUM*: PRELIMINARY FINDINGS, NEEDED RESEARCH, AND IMPLICATIONS FOR MANAGEMENT

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ABSTRACT

As part of a wider survey effort to assess genetic and phenotypic diversity among contemporary isolates of *Fusarium graminearum* in New York, we screened 50 isolates for sensitivity to two triazole fungicides, tebuconazole and metconazole. Our objective was to establish a baseline of sensitivity against which future and more extensive surveys could be referenced. One of the 50 isolates was found to be highly resistant to tebuconazole based on a laboratory determination of EC_{50} (effective concentration leading to a 50% reduction of mycelial growth) at 8.09 mg/l. This was not just a laboratory phenomenon; suppression of FHB and DON was significantly reduced when a commercial rate of tebuconazole was applied to wheat plants inoculated with the resistant isolate as compared to plants inoculated with a sensitive isolate. Following treatment with tebuconazole, more individuals of the resistant isolate were recovered from wheat plants inoculated with an equal mixture of the resistant and sensitive isolate; in the absence of tebuconazole application, equal numbers of the resistant and sensitive isolates were recovered from co-inoculated plants. The tebuconazole-resistant isolate was an outlier among the 50 isolates though a wide range of sensitivity, EC_{50} of 0.28 to 2.5 mg tebuconazole per l, was found among the other 49 isolates. None of the 50 isolates was resistant to metconazole and the range of EC_{50} was narrower, from 0.05 to 0.86 mg/l. Putting these findings into some perspective, there has been no documented failure of control of Fusarium head blight with tebuconazole or any other triazole fungicides in North America; a partial reduction in control due to fungicide resistance build-up would be very hard to discern. It is not uncommon to find low frequencies of fungicide resistance in native fungal populations even before exposure to a particular fungicide. Natural variation in fungicide resistance should be expected in this fungus that is well know for its high degree of genetic variability. We suggest that more isolates with resistance at various levels will be found as larger surveys are conducted. We will share our perspectives on needed future research and on what implications that triazole resistance may have on the management of Fusarium head blight.

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EFFECT OF GLYPHOSATE ON FUSARIUM HEAD BLIGHT IN WHEAT AND BARLEY UNDER DIFFERENT SOIL TILLAGES IN EASTERN CANADA

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ABSTRACT

Fusarium head blight (FHB) is an important disease of wheat and barley, particularly in the wet conditions of eastern Canada. The principal pathogen associated with FHB, *Fusarium graminearum*, produces deoxynivalenol (DON), a mycotoxin that makes the grain unfit for food or feed. Surveys conducted in eastern Saskatchewan in 2005 and 2007 revealed that glyphosate application in the previous 18 months within minimum-till system was significantly associated with higher FHB levels in wheat and barley. This study aimed to determine the effect of glyphosate on FHB development in wheat and barley and on *F. graminearum* inoculum production under different soil tillages in eastern Canada. The experiment was performed during two years (2007-2008) at two different sites in Quebec, Canada (Saint-Augustin-de-Desmaures and Saint-Mathieu-de-Beloeil). Six trials were set in both sites, combining two cereal species, wheat and barley, and three soil tillages: moldboard plough, spring tillage (minimum-till) and direct drilling. For each trial, glyphosate or other herbicides chosen according to weed species were applied as main plot treatments on Roundup Ready™ soybean the year preceding cereal crops. The next year, three wheat and three barley cultivars with a distinct FHB resistance level were sown in the main herbicide plots, constituting the subplots. In each main plot, two Petri plates containing a *Fusarium*-selective medium were placed facing the ground in order to capture spores coming from the soybean residues. FHB index, *Fusarium*-damaged kernels (FDK), deoxynivalenol (DON) content and *F. graminearum* inoculum production were measured. Glyphosate had no significant effect on FHB index, FDK or DON content, whatever the trial and the site. *F. graminearum* inoculum production was enhanced by glyphosate in only one trial out of twelve. The relationship between *F. graminearum* inoculum from soybean residues and DON content was weak. Therefore, it seems that glyphosate used on soybean the year preceding wheat or barley crop has no or low impact on FHB development and *F. graminearum* inoculum production under Quebec cropping conditions, whatever the tillage practices used.

ACCUMULATION OF *FUSARIUM GRAMINEARUM* MYCOTOXINS IN WHEAT STRAW AT VARIOUS INTERVALS AFTER ANTHESIS FOR WHEAT CULTIVARS RANGING IN SUSCEPTIBILITY TO FUSARIUM HEAD BIGHT

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ABSTRACT

Mycotoxins are known to be present in grains from plants affected by Fusarium head blight (FHB), but little is known about their presence in wheat straw. Wheat straw is commonly used as bedding material for livestock. Non-ruminants, such as swine, are especially sensitive to mycotoxins and may eat up to 4 kg of wheat straw bedding per day. When straw from fields affected by FHB is used as bedding, livestock are at risk of exposure to FHB-associated mycotoxins.

A field trial was conducted in Urbana, Illinois in 2013 and 2014 to test for the accumulation of mycotoxins in different parts of straw tissue. The trial was mist-irrigated, and *Fusarium graminearum*-infested corn kernels were spread throughout the trial to serve as an inoculum source. Twelve soft red winter wheat cultivars ranging in susceptibility to FHB were planted. Whole plants were sampled from each plot in 15 cm linear row sections at four different times during the growing season: 7 days after anthesis (daa), 14 daa, 21 daa, and 28 daa. These plants were split equally into lower and upper sections of the plant with all head and root tissue removed. The samples were then dried under forced air and ground into smaller particles. After harvest, stubble (consisting of only stem tissue) also was collected, dried, and ground. All grain and straw samples were sent to the University of Minnesota for mycotoxin analysis.

Five mycotoxins were tested for in this study, which were deoxynivalenol (DON), 3-acetyl-deoxynivalenol (3ADON), 15-acetyl-deoxynivalenol (15ADON), nivalenol (NIV), and zearalenone (ZEA). Due to low levels of NIV and ZEA, only DON, 3ADON, and 15ADON are reported.

DON concentrations in the top portion of the stems ranged from 0 to 3.8 ppm at 14 daa, 0 to 28.2 ppm at 21 daa, and 0 to 39.6 ppm at 28 daa. DON concentrations in the lower portion of the stem ranged from 0 to 1.3 ppm at 14 daa, 0 to 4.5 ppm at 21 daa, and 0 to 21.8 ppm at 28 daa. Post-harvest DON concentrations in the straw tissue ranged from 0.7 to 31.9 ppm, and concentrations of DON in harvested grain ranged from 0.2 to 14.2 ppm.

3ADON concentrations in the top portion of the stems ranged from 0 to 0.4 ppm at 14 daa, 0 to 0.7 ppm at 21 daa, and 0 to 1.2 ppm at 28 daa. 3ADON concentrations in the lower portion of the stem ranged from 0 ppm at 14 daa, 0 to 0.2 ppm at 21 daa, and 0 to 0.8 ppm at 28 daa. Post-harvest 3ADON concentrations in the straw tissue ranged from 0 to 3.8 ppm, and concentrations of 3ADON in harvested grain ranged from 0 to 0.1 ppm.

15ADON concentrations in the top portion of the stems ranged from 0 to 0.9 ppm at 14 daa, 0 to 2.1 ppm at 21 daa, and 0 to 8.0 ppm at 28 daa. 15ADON concentrations in the lower portion of the stem

ranged from 0 to 0.4 ppm at 14 daa, 0 to 0.8 ppm at 21 daa, and 0 to1.7 ppm at 28 daa. Post-harvest 15ADON concentrations in the straw tissue ranged from 0 to 16.3 ppm, and concentrations of 15ADON in harvested grain ranged from 0 to 0.3 ppm.

At the 14 and 21 daa sampling timings, differences in DON concentration between upper and lower stem tissue did not differ within each cultivar. At 28 daa, significantly ($P \leq 0.05$) greater levels of DON were observed in the upper stem tissue compared to the lower stem tissue for 'Pioneer 25R47', 'Kaskaska', and 'Sisson', but no differences in DON concentration between upper and lower stem tissue were observed for any other cultivar.

Spearman's correlation analysis was conducted to determine relationships between mycotoxin concentrations in grain and stems collected post-harvest. This analysis revealed that positive, significant correlations were present for DON in grain and stems ($P = 0.0001$; $R = 0.80$), for 3ADON in grain and stems ($P = 0.0007$; $R = 0.34$), and for 15ADON in grain and stems ($P = 0.0001$; $R = 0.70$). These results indicate that cultivars with resistance to mycotoxin accumulation in the grain may also have a low risk of mycotoxin accumulating in the straw tissue.

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PRELIMINARY ANALYSIS OF NATIONAL SURVEY OF WHEAT & BARLEY PRODUCERS ON SCAB MANAGEMENT

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ABSTRACT

In late 2012, the USWBSI commissioned the National Agricultural Statistics Service (NASS) of the USDA to survey wheat and barley producers in 17 states that have experienced epidemics of Fusarium head blight in small grains. The purpose of the survey was to gather information from grain producers that would help us better assist them in managing the damaging disease.

A four-page questionnaire was mailed to more than 16,000 producers in March 2014. The survey asked questions about which practices are used to manage scab. Such practices include planting moderately resistant varieties, staggering planting dates, using scab risk forecasts, and applying fungicides. The survey probed both the degree of adoption of management techniques, and also barriers to adoption. It also asked how producers obtain information about scab management.

Survey responses were collected both in writing and over the phone. State-by-state response rates ranged from 43% to 68%. Within each state, counties with similar production practices were grouped together in one to nine districts. Responses are being analyzed at the district, state, and national levels.

EVALUATION OF INTEGRATED METHODS FOR MANAGING FHB AND DON IN WINTER WHEAT IN NEW YORK IN 2014

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OBJECTIVE

To evaluate the individual and interactive effects of moderately resistant cultivars and application timings of the fungicide Prosaro® on wheat yield and the integrated management of Fusarium head blight (FHB) and deoxynivalenol (DON) in New York.

INTRODUCTION

In response to the USWBSI goal to validate integrated management strategies for FHB and DON, the Disease Management RAC of USWBSI initiated a multi-state, multi-year, coordinated field study. In New York during 2014, we observed the disease and yield impact of cultivar susceptibility, inoculation with *Fusarium graminearum*, and treatment with Prosaro fungicide at two timings.

MATERIALS AND METHODS

The trial was conducted at the Musgrave Research Farm in Aurora, NY in a Lima silt loam soil planted with four soft red winter wheat varieties, 'Pioneer Brand 25R40' (susceptible to Fusarium head blight (FHB), 'Emmit' (moderately susceptible to FHB), 'Otsego' (moderately susceptible to FHB), and 'Pioneer Brand 25R46' (moderately resistant to FHB), following soybean harvest on 25 Sep 2013. The experiment was set up as a completely randomized block design with a split-plot arrangement, with cultivar as the main plot and the treatments as subplots, randomized in six replicated blocks. Main plots were sown with wheat at 118.8 lb/A with a 10 ft wide commercial grain drill. Subplots were 20 x 10 ft including 15 rows with 7-in. row spacing. The plots were fertilized at planting (200 lb/A of 10-20-20) and topdressed on 10 Apr (170 lb/A of a 50/50 mix of ammonium sulfate and urea, providing ca. 57 lb/A of nitrogen) and again on 21 Apr (30 lb/A of urea, providing an additional 13.8 lb/A of nitrogen). The first Prosaro application was at anthesis (Feekes growth stage, FGS 10.51) on 2 Jun including the surfactant Induce at 0.125% V/V, and inoculated with a conidial suspension of *F. graminearum* (40,000 conidia/ml) after the fungicide had dried to augment the development of FHB. The second Prosaro application occurred seven days after anthesis on 9 Jun including the surfactant Induce at 0.125% V/V, and inoculated with a conidial suspension of *F. graminearum* (40,000 conidia/ml) after the fungicide had dried. Fungicide and *F. graminearum* treatments were applied with a tractor-mounted sprayer with paired TJ-60 8003vs nozzles mounted at an angle (30^{o} from horizontal) forward and backward, 20-in. apart, pressurized at 30 psi, and calibrated to deliver 20 gal/A. Incidence and severity (percent of symptomatic spikelets on symptomatic heads) of FHB in each plot were rated on 23 Jun and used to calculate FHB Index, where FHB index = (FHB severity * FHB incidence)/100. Foliar diseases were rated on 23 Jun as percent severity on flag leaves (average rating for whole plot). Grain was harvested from a 20 x 4 ft area in each subplot using an Almaco plot combine on 25 Jul. Grain moistures, plot yields, and test weights were recorded. Yields and test weights were adjusted to bu/A at 13.5% moisture. *Fusarium* damaged kernels (FDK) were evaluated post-harvest as a percentage of kernels visibly affected by FHB out of a 100 kernel subsample from each plot. Analysis of deoxynivalenol (DON) content in grain was conducted in the US Wheat and Barley Scab Initiative-supported mycotoxin analysis laboratory at the University of Minnesota, St. Paul, MN. Treatment means were calculated, subjected to analysis of variance, and separated by Fisher's protected LSD test (*P* = 0.05).

RESULTS AND DISCUSSION

The incidence of FHB over all plots ranged from 0.7 to 16%. The impact of supplemental inoculation with *F. graminearum* was determined by comparing the non-inoculated and inoculum only treatment. Overall, inoculation resulted in significantly reduced yield and increased FHB and DON as compared with the non-inoculated plots. FHB and DON development in 2014 were attributed primarily to supplemental rather than background inoculum.

Significant cultivar responses to inoculation were observed for yield, FHB and DON for the susceptible variety Pioneer 25R40, but only for FHB and DON, for the moderately susceptible varieties Emmit and Otsego and for the moderately resistant variety Pioneer 25R46. These data support the current qualitative designations of varieties as susceptible (Pioneer 25R40), moderately susceptible (Emmit and Otsego), and moderately resistant (Pioneer 25R46).

Under moderately low disease pressure, significant differences were detected in yield among the varieties with both Pioneer varieties yielding highest and Otsego yielding lowest, regardless of treatment. Pioneer 25R40 had significantly higher FHB index and DON than all the other varieties, regardless of treatment, and was the only variety to have an overall DON level above the 2.0 ppm threshold observed by grain buyers. Despite its high yield potential, planting of the susceptible variety carries an increased risk of docked or rejected grain even under moderate disease pressure. Prosaro fungicide application at either FGS 10.51 or 7 days later reduced DON risk in the susceptible variety by more than 50%. With excellent choice of high yielding varieties in the moderately susceptible and moderately resistant categories, we counsel New York growers to no longer plant susceptible soft red winter wheats.

Environmental conditions encountered in our plots in 2014 were more favorable for *Fusarium* infection at 7 days after FGS 10.51 than they were at 10.51 and, therefore, the spores applied later served as the more important inoculum for infection. When results of all the cultivars were combined, the overall impact of each of the two Prosaro application timings was to significantly decrease FHB incidence, index, DON, and foliar diseases, as compared with the inoculum only treatment. The Prosaro application at 7 days after the initiation of flowering resulted in the lowest FHB and DON, i.e., the fungicide applied later did the best job of suppressing FHB and DON resulting from fungal spores that arrived at the later timing. FHB and DON applied at 7 days after FGS 10.51 were significantly lower than for the Prosaro application at FGS 10.51, and did not differ from the non-inoculated, no-fungicide control treatment. But it is also worth noting that sufficient fungicide remained on spikes from the FGS 10.51 application to give significant suppression of FHB and DON resulting from fungal spores deposited on plants at 7 days after 10.51. It is unlikely that we would have seen any advantage of the late fungicide application over the earlier if spores had only been applied at the early timing. This underscores the necessity to apply supplemental inoculum corresponding to all timings that fungicides are applied in an unbiased experiment to assess comparative efficacy of fungicide timings.

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Table 1. Main effect of treatment on Fusarium head blight incidence, index, *Fusarium* damaged kernels, deoxynivalenol contamination and grain yield at Aurora, NY.

Treatment	FHB Incidence (%)	FHB Index	FDK (%)	DON (ppm)	Yield (bu/A)
No-fungicide, non-inoculated control..........	1.9 c	0.2 c	1.5 b	0.33 c	110.9 a
No-fungicide, inoculated FGS 10.51, and again 7 days later......................................	11.4 a	2.6 a	10.3 a	2.19 a	104.7 b
Prosaro SC (6.5 fl oz) at FGS 10.51, inoculated FGS 10.51, and again 7 days later..	7.7 b	1.3 b	4.2 b	0.91 b	110.1 ab
Prosaro SC (6.5 fl oz) at 7 days after FGS 10.51, inoculated FGS 10.51, and again 7 days later..	3.8 c	0.4 c	2.8 b	0.47 bc	110.1 ab
LSD (*P*=0.05)	2.31	0.70	3.66	0.59	5.99

Table 2. Main effect of cultivar on Fusarium head blight incidence, index, *Fusarium* damaged kernels, deoxynivalenol contamination and grain yield at Aurora, NY.

Cultivar	FHB Incidence (%)	FHB Index	FDK (%)	DON (ppm)	Yield (bu/A)
Pioneer 25R40	8.3 a	1.6 a	9.9 a	2.01 a	115.2 a
Otsego.....................	8.2 a	1.7 a	4.8 b	0.79 b	97.4 c
Emmit.	6.8 a	1.0 a	2.7 b	0.78 b	104.6 b
Pioneer 25R46	1.5 b	0.1 b	1.2 b	0.33 b	118.6 a
LSD (*P*=0.05)	2.72	0.83	3.68	0.63	3.53

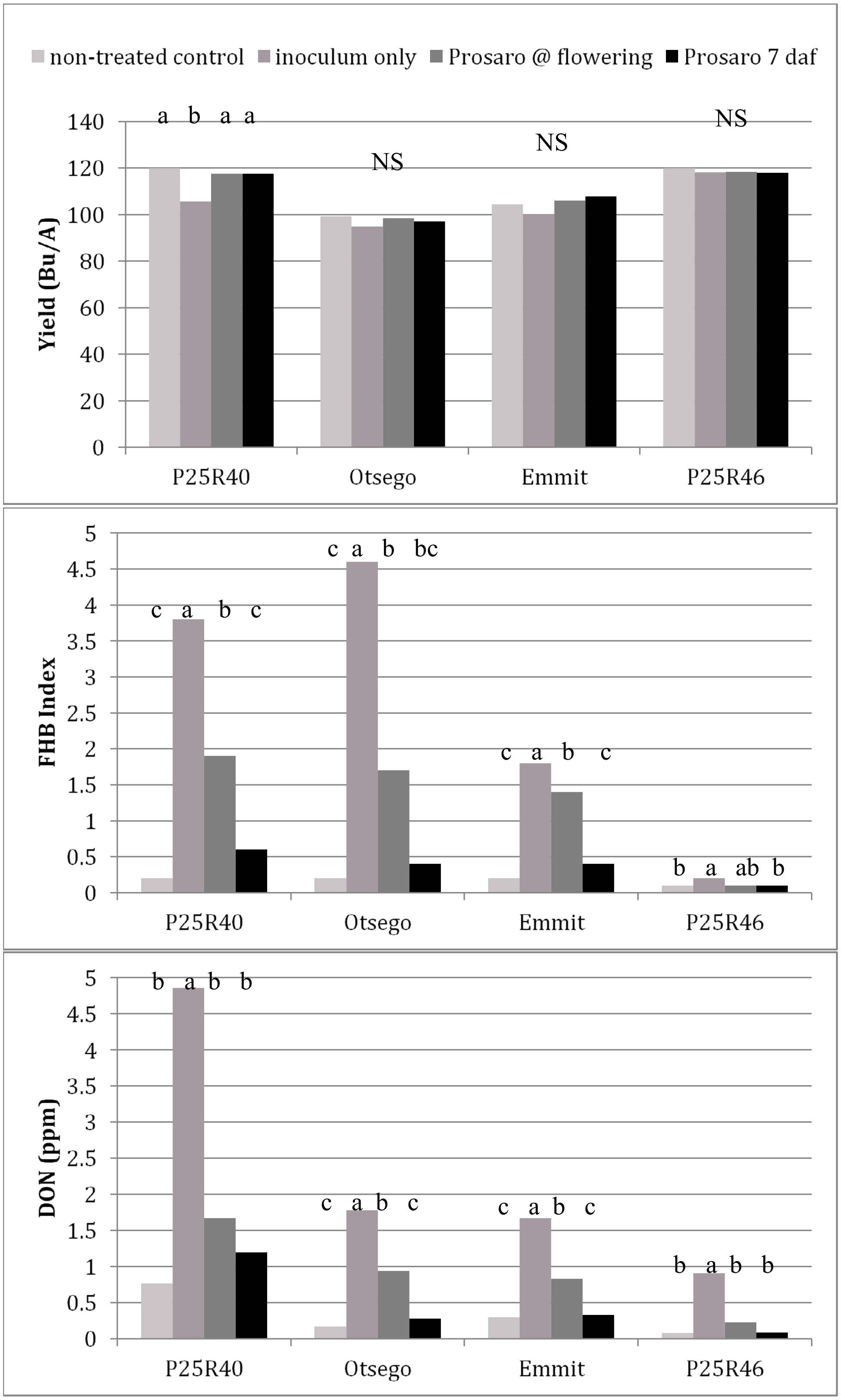

Figure 1. Effect of Prosaro fungicide application and *F. graminearum* inoculation on yield, FHB index and DON contamination of four winter wheat cultivars in Aurora, NY.

CORRELATION AND CAUSALITY ANALYSES OF METEOROLOGICAL VARIABLES TO EXAMINE PREDICTORS OF *FUSARIUM GRAMINEARUM* ASCOSPORE RELEASE

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ABSTRACT

Fusarium graminearum is spread via macroconidia (asexual spores) and ascospores (sexual spores). Ascospores have been shown to travel long distances (>100 m) from sources of inoculum. We are investigating the meteorological variables and conditions associated with ascospore release to improve our understanding of temporal variation and spore emission rates. We aim to produce a useful model that includes source and at-risk wheat fields, spore emission rates, and built-in functionality capable of analyzing for favorable conditions for ascospore release. Our goal is to produce a model that provides stakeholders with an accurate representation of potential pathways of disease spread that may assist in making better informed management decisions, such as the application of fungicides.

Field trials were conducted in 2011 and 2012 at Virginia Tech's Kentland Farm, and statistical analyses were performed to examine potential relationships between spore release and a variety of meteorological variables. Our objective was to determine the correlation and causality relationships between environmental variables and spore release based on data obtained from a series of field experiments conducted over two growing seasons. In each of these growing seasons, a wheat field was artificially inoculated with *F. graminearum*, an active sampler was used to capture atmospheric spores, and meteorological conditions including air temperature, relative humidity, rainfall, and solar radiation were gathered from a nearby weather station. The spore concentration data obtained was assumed to be representative of release events within the inoculated field. Statistical analyses revealed significant relationships between ascospore release and time, solar radiation, wind speed, and relative humidity. Causality analyses were performed to determine if any of the environmental variables appeared to be causal agents for ascospore release events. The results indicated that solar radiation and relative humidity were the most important external driving factors in this system.

Based on the information gained from our correlation and causality analyses, we have designed a series of controlled laboratory experiments to assess ascospore release as a function of environmental variables. Our objective is to define the relationship between spore release and temperature, relative humidity, and light under controlled conditions. We have configured an embedded dual chamber using a growth chamber to maintain temperature and light and an acrylic chamber containing perithecia and a saturated salt solution to maintain relative humidity. We are testing combinations of temperature (15^{o}C and 25^{o}C), relative humidity (75%, 85%, and 95%), and light (light or complete darkness) and obtaining

temporal particle (ascospore) counts using an aerodynamic particle sizer. We aim to incorporate the knowledge gained about the environmental variables associated with spore release into a model to more accurately represent the atmospheric transport of ascospores from their source to their final destination. The results will further inform farmers and growers on the timing of potential ascospore release events, allowing them to make timely field management decisions.

EXAMINATION OF COMMERCIAL GRAIN SAMPLES TO ASCERTAIN HOW DEOXYNIVALENOL CONTAMINATION EXCEEDED ANTICIPATED LEVELS IN SOME 2014 WHEAT CROPS FROM WESTERN KENTUCKY

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ABSTRACT

Fusarium head blight (FHB or scab) re-emerged in the USA over two decades ago, first appearing in the Upper Midwest states of Minnesota and North Dakota in 1993. Since that time, FHB epidemics and associated mycotoxin contamination, especially by deoxynivalenol (DON), have been reported in all classes of wheat and in all production regions except the Pacific Northwest. The principal strategy to manage FHB has been the development of wheat varieties with moderate resistance and varieties with improved resistance to FHB are now deployed in all FHB-prone production regions in the USA. Effective fungicides are also available following a national effort to test the efficacy of fungicides to control FHB. In addition to the multi-state uniform fungicide testing program, effective technologies for the application of fungicides to the wheat head have been developed and deployed. Thus, growers do now have viable options for chemical control. A national forecasting system, The Fusarium Risk Assessment Tool, was developed, and has been deployed in many states for over a decade, to aid growers in deciding if conditions are favorable for FHB development and thus if fungicide applications are warranted. Best management practices recommend that growers combine the best available genetic resistance with a fungicide when conditions are favorable for FHB development. In some instances however, it seems that despite using best management practices, grain is still occasionally contaminated with *Fusarium*-mycotoxins. In 2014, a number of soft red winter wheat crops in western Kentucky were rejected because of DON contamination. This appeared to have occurred when the forecasting model had suggested that the risk of FHB development was moderate or low and/or where fungicides had been used and were anticipated to be effective. To better understand the level of mycotoxin contamination of crops in this region, samples from 21 commercial fields, representative of crops in this region, were collected and examined. These samples were evaluated for visual damage to the grain and subsequently tested for the presence of Fusarium-mycotoxins. The percent of visually scabby kernels (VSK), determined by visually matching the 21 grain samples to check samples, ranged from one to thirty percent. The percent of symptomatic kernels, in the samples by weight, ranged from three to thirty three percent. In addition to visual inspections of the grain, 100 seeds from each sample (50 symptomatic and 50 non-symptomatic seeds) were plated on a semi-selective growth media to assess the level of *F. graminearum* infestation. In one sample *F. graminearum* was isolated from 86% of the seeds identified as symptomatic and from 70% of the seeds that appeared to be sound. By contrast in another grain sample, *F. graminearum* was only isolated from 18% of the seeds identified as symptomatic and from 6% of the seeds that appeared sound. The deoxynivalenol content of the 21 samples ranged from 0.13 ppm to 16.4 ppm. Our examination of the grain samples confirm that *Fusarium* infection

was generally sufficient to cause some visual damage to grain and that contamination by *Fusarium* mycotoxins appeared closely correlated to visual symptoms. It appear that the crops examined had flowered in mid-May and at least some of the crops had a fungicide, generally Prosaro or Caramba, applied at flowering, with applications reported to have been applied between May 5 and May 20. In the earlier part of this period (May 5-11) the FHB risk assessment tool for this part of Kentucky indicated a low risk of FHB though medium risk was evident in parts of western Kentucky from May 12-20 and an area of high risk was evident within that medium risk area from May 13-18. The prediction of FHB in this region was likely hindered by uneven crop development that followed unusually cool conditions in winter and spring and we speculate that a lag time in the response of the model to the changing in environmental conditions may have resulted in the model underestimating risk. The winter wheat model is considered more prone to this type of inaccuracy than the spring wheat model used in the Fusarium Risk Assessment Tool. Challenging weather conditions may also have hindered the timely application of fungicides to some crops. Unfortunately there was insufficient information available to determine the risk predicted for the individual crops for which grain samples were provided. It would appear however that visual inspection of the grain for *Fusarium* damage at the buying point may have allowed for the segregation of the most heavily contaminated grain from other crops that were less damaged.

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THE EFFECTIVENESS OF AN INTEGRATED STRATEGY TO MANAGE FUSARIUM HEAD BLIGHT IN BARLEY PRODUCTION USING A META-ANALYSIS APPROACH

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ABSTRACT

An integrated management strategy combining host resistance, a timely fungicide application and crop rotation is recommended to help reduce the risk of Fusarium head blight (FHB) in barley production. As part of a research collaboration within the United States Wheat and Barley Scab Initiative, 19 barley field trials were conducted from 2008 to 2014 across North Dakota, Minnesota and South Dakota. The objective of these trials was to determine the efficacy of an integrated FHB management strategy in reducing scab index and deoxynivalenol (DON) levels. The experimental design used was a randomized complete block with either a split-split plot or split plot arrangement, with the treatment factors being previous crop residue, variety, and fungicide application. Three to eight two-row and/or six-row barley varieties, varying in FHB resistance, were included at each location. Fungicide applications using prothioconazole + tebuconazole (Prosaro 421C, Bayer CropScience, Research Triangle Park, NC) were made at 50% heading or 4 to 5 days after 50% heading, and a non-treated check was included at each trial. Previous crop residue was classified as either a host or non-host for *Fusarium graminearum*. As a way to summarize the findings, the data from the trials will be subjected to a multivariate meta-analysis. Data sets will be organized into six host resistance-fungicide combinations; susceptible treated, susceptible non-treated, moderately susceptible treated, moderately susceptible non-treated, moderately resistant treated, and moderately resistant non-treated. The results of the meta-analysis will be used to assess the stability and relative effectiveness of implementing an integrated management strategy for FHB in barley production.

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THE USE OF INTEGRATED MANAGEMENT STRATEGIES TO LOWER FHB DON IN BARLEY

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ABSTRACT

Fusarium Head Blight (FHB) has reduced the quality of barley grown in the Midwest for the last two decades due to discolored kernels, and more importantly the presence of the toxin, deoxynivalenol (DON). Six-rowed and two-rowed barley cultivars with different levels of DON resistance and timing of fungicide applications showed lower DON levels. The first year of these Integrated Pest Management studies were performed at two locations, Fargo and Hope, ND. The Fargo trial investigated the effects of two different application times of a single fungicide application in an artificially inoculated FHB nursery and the experiment at Hope, ND only had one fungicide treatment and was under natural infection. Disease incidence, severity and DON were evaluated along with test weight and yield at both locations. Both treatments at the Fargo location showed significantly lower FHB incidence, severity and DON accumulation when Prosaro® fungicide was applied at Feekes 10.4-10.5 (50%-75% head emergence) and five days later compared to the untreated checks. The study at Hope, ND also showed significantly lower DON accumulation when a single treatment of Prosaro was applied at the Feekes 10.5 stage (0.26 ppm) compared to the untreated control (0.47 ppm). There were significant differences among cultivars at both locations for test weight and yield compared to the untreated checks.

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META-ANALYSIS OF 19 YEARS IF FUNGICIDE TRIALS FOR THE CONTROL OF FUSARIUM HEAD BLIGHT OF WHEAT

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ABSTRACT

Twenty years ago many were skeptical that Fusarium head blight (FHB) could be managed with fungicides (McMullen et al. 2012). Early work by Marcia McMullen and colleagues from 1995-1997 showed that a single application of a triazole (DMI) fungicide had the potential to reduce FHB index. This led to the establishment of the Uniform Fungicide Trials (UFT) by the USWBSI, with the first field studies being conducted in 1998. Initially, the studies focused on the use of propiconazole (Tilt) or tebuconazole (Folicur) for reducing index and DON. In the 2000s, other DMI-active ingredients such as prothioconazole, metconazole, and mixtures of actives such as tebuconazole + prothioconazole were added to the collection of fungicides being tested. Some of these were initially tested as experimental products before being registered and given trade names such as Proline®, Caramba® and Prosaro®, respectively. Other treatments were considered in a small number of trials, but were not of sufficient number for analytical purposes. Preliminary analyses were based on qualitative or ad hoc syntheses of the conducted trials. Paul, Madden, and colleagues then performed quantitative research syntheses of the trials using univariate and multivariate meta-analyses to estimate the expected treatment effects for FHB index, DON, yield, and test weight (Madden & Paul 2011, Paul et al. 2007, 2008, 2010). These meta-analyses were based on trials conducted up through 2005 for index and DON, and through 2007 for yield and test weight. Overall, Proline, Caramba, and Prosaro applied at anthesis performed much better than the other tested fungicides, and there were only minor differences in efficacy among these three.

Nevertheless, mean percent control (percent reduction relative to the untreated control) was typically only 50% for index and 40% for DON for the best treatments (averaged across environments and wheat market classes). Therefore, the UFTs have been continued to: determine the stability of efficacy and economics of these fungicides under a wide range of environments; explore alternative fungicide treatments that may result in higher percent control, especially for DON; and allow greater flexibility in terms of timing of applications. New treatments included: other mixtures of triazole fungicides applied at anthesis (typically as tank mixes); different timings of the best triazoles (before, at, or after anthesis); strobilurin fungicides (especially pyraclostrobin [Headline]) applied at different times; or combinations of Headline early and a triazole at anthesis.

The full data set analyzed consisted of 309 trials, from 1995 through 2013; 27 separate treatments were included as having been tested in a sufficient number of trials for the meta-analysis. Trials were conducted in up to 12 states per year. A multivariate meta-analysis showed large variability in percent control for the different treatments, and none of the new treatments provided significantly better control of index and DON than the original three best treatments, i.e., prothioconazole (Proline), metconazole (Caramba), and tebuconazole + prothioconazole (Prosaro) applied at anthesis. Percent control for these three treatments remained generally stable over time, although treatment efficacy for FHB index declined somewhat for spring wheat relative to winter wheat. For index and DON, a tank mix of tebuconazole

+ metconazole applied at anthesis, and metconzole applied 5 days after anthesis, resulted in percent control about the same as the original best treatments, the latter suggesting that there is some flexibility in applying the single DMI fungicide. A strobilurin application at a single time led to moderate or low percent control of index relative to the original best treatments; however, as hypothesized, a strobilurin application led to significantly *higher* DON in the grain relative to the untreated control. For instance, applying pyraclostrobin at heading produced an average 22% decrease in index and an 18% increase in DON relative to no treatment at all. Applying pyraclostrobin at boot (useful for controlling foliar diseases) and tebuconazole + prothioconazole at anthesis achieved a percent control of index similar to the triazole-only application at anthesis; however, the percent control of DON was considerably lower than for the triazole alone. That is, an anthesis application of a triazole could not counteract the negative effects of an earlier application of a strobilurin.

In conclusion, the best triazole fungicides applied at anthesis, or shortly thereafter, either alone or as a mixture, provide significant levels of control of index and DON. There is no evidence that substantially higher levels of control can be achieved with a single fungicide application without coupling this with other integrated control tactics. Additional analysis is needed to characterize the impact of all the fungicide treatments, especially for yield and test weight.

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SCREENING FOR FHB SUSCEPTIBILITY IN BARLEY AND WHEAT CULTIVARS IN THE WESTERN US

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ABSTRACT

Ten years ago, the incidence of FHB in the irrigated west was regarded as a minor and relatively rare occurrence. With the substantial increase in corn acreage directly due to the increase in the dairy industry, and with changes in irrigation practices, FHB has become a regularly occurring problem with economically significant impacts on small grain producers. The objective of this study was to determine host resistance levels in wheat and barley varieties released for the arid irrigated production areas of the PNW that have been selected without screening for FHB disease reaction. Varieties and advanced breeding lines from public and private breeding programs in the PNW and Intermountain West included in extension variety trials were tested for FHB susceptibility. Small plots were planted April 8, 2014 with two replicates per variety. Inoculum was developed from local isolates of *Fusarium graminearum*. The field nursery was sprayed twice (heading and flowering) with conidial suspension at 5 x 10^4 spores per ml (Chen et al., 2006). Plots were rated for disease incidence and severity three weeks after inoculation. Significant differences in spring wheat varieties for FHB index were recorded, but no significant differences in yield were found. The hard white spring wheat 'Klasic' was very susceptible, but varieties showing significantly lower levels of infection included the soft white spring wheat varieties Alpowa, Babe, UI Stone, UI Pettit, and advanced line WA 8162. However, there was very little infection that occurred in the barley trials.

OBJECTIVE

The objective of this study was to determine host resistance levels in wheat and barley varieties released for the arid irrigated production areas of the PNW.

INTRODUCTION

Ten years ago, the incidence of FHB in the irrigated west was regarded as a minor and relatively rare occurrence. With the substantial increase in corn acreage directly due to the increase in the dairy industry, and with substantial changes in irrigation practices, FHB has become a regularly occurring problem with economically significant impacts on small grain producers. Unacceptable levels of DON toxin have been found consistently in irrigated wheat and barley in areas of the PNW and intermountain West in the past five years. Corn debris, where high levels of *Fusarium graminearum* reside, takes up to three or four years to degrade in arid west environments. Changes in crop rotation have shifted the predominant species of *Fusarium* to *F. graminearum*, which produce airborne ascospores that can disperse many miles in the wind. Disease management approaches have changed depending on level of susceptibility of the varieties being grown. Control strategies must incorporate varieties that are less susceptible to FHB.

MATERIAL AND METHODS

Varieties and advanced breeding lines from public and private breeding programs in the PNW and Intermountain West were tested for degree of susceptibility. An irrigated FHB disease nursery was established at the University of Idaho's Aberdeen Research and Extension Center. The spring wheat and spring barley nurseries were planted separately. Eight-foot plots consisting of two rows were planted April 8, 2014 in a randomized complete block with two replicates per variety. Inoculum was developed from local isolates of *Fusarium graminearum*. The field nursery was sprayed twice (at heading and flowering) based on heading and flowering dates with conidial suspension at 5 x 10^4 spores per ml (Chen et al., 2006). A CO_2 backpack sprayer with 8003 VS nozzle tips calibrated at 40 psi was used to apply inoculum at a rate of 1 sec/ft. Plots were irrigated two hours daily to maintain irrigation requirements and humid conditions. Thirty heads per plot were assessed for disease incidence and severity three weeks after inoculation and the percentage of FHB-colonized seeds and DON will be tested after harvest. A FHB index was calculated as (% severity x % incidence)/100. Plots were harvested 8 September with a small plot combine. Yield was determined with the HarvestMaster® system on the combine. Data were analyzed using GLIMMIX in SAS. Fisher's protected LSD was used for mean comparisons.

RESULTS AND DISCUSSION

Disease developed quicker in the durum wheat, then in the other spring wheat varieties. Disease did not develop in the barley trials. The spring was cooler than average with very cool nights, likely contributing to low disease pressure. Recommendations for 2015 will be to postpone planting for 2 to 4 weeks, in order to increase the likelihood of warmer weather occurring during anthesis and inoculation to facilitate infection and disease development. There were significant differences in varieties for the FHB index (alpha = 0.01), which varied from 1.6 in the advanced line WA 8162, the most resistant variety, to 57.2 in Klasic, a very susceptible hard white spring wheat (Table 1). The three lines showing the highest level of resistance included the soft white spring wheat UI Stone, UI Pettit and WA 8162. UI Stone was selected prior to release based on FHB resistance and carries two known molecular makers; *UMN10* associated with resistance gene *Fhb1* and *Xbarc117,* a QTL on chromosome 5AS. WA 8162 is an advanced soft white line from Washington State University's spring wheat breeding program.

There was a high degree of variability between reps for FHB index and yield. Yield varied from 61 bu/A to 143 bu/A, but there were no significant differences at alpha = 0.05. FDK and DON levels will be measured and reported at a later date.

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Table 1. Yield and FHB index ratings of spring wheat varieties, 2014 trial, Aberdeen R&E Center, Aberdeen, ID.

Variety	Class[z]	Yield bu/A		FHB Index	
Bullseye	hrs	143.4	a	15.5	e-l
SY Basalt	hrs	118.7	ab	20.7	c-j
WB 6121	sws	116.5	abc	23.1	c-h
Alturas	sws	115.4	a-d	31.1	bc
LCS Star	hws	111.4	a-e	16.2	e-l
Dayn	hws	111.1	a-f	19.0	c-j
WB 6430	sws	108.9	a-g	16.0	e-l
Kelse	hrs	108.2	a-g	26.7	cde
UI Pettit	sws	106.7	b-g	3.6	m
Alpowa	sws	106.7	b-g	12.9	f-m
SY-40292	hrs	103.1	b-g	19.1	c-j
Penawawa	sws	101.6	b-g	24.9	c-g
WA 8162	sws	101.6	b-g	1.6	m
11SB0096	sws	100.9	b-g	10.3	i-m
IDO851	sws	100.2	b-g	14.8	e-l
Babe	sws	99.8	b-g	12.4	g-m
IDO852	sws	98.4	b-h	17.9	d-j
LL3419	hrs	94.7	b-i	39.9	b
WA 8166	hrs	94.7	b-i	15.6	e-l
LL 3361	hrs	94.0	b-i	14.9	e-l
Cabernet	hrs	94.0	b-i	28.9	b-e
BZ908-41	hrs	92.6	b-i	10.1	j-m
LL 3378	hrs	91.1	b-i	9.2	j-m
SY-10136	hrs	89.7	b-i	11.5	h-m
LCS Atomo	hws	89.3	b-i	26.5	cde
Alzada	durum	87.5	b-i	23.3	c-h
Snow Crest	hws	86.8	b-i	31.0	bc
IDO862E	hrs	86.0	b-i	22.1	c-j
WB 9229	hrs	84.2	b-i	23.3	c-h
IDO862T	hrs	83.1	b-i	23.0	c-j
WA 8189	sws	82.8	b-i	16.7	e-k
Utopia	durum	82.4	b-i	30.2	b-e
Jefferson	hrs	82.0	c-i	21.9	c-j
IDO1202S	hrs	80.6	c-i	9.0	j-m
WB 9668	hrs	80.6	c-i	23.0	c-i
UI Stone	sws	79.9	d-i	3.9	klm
Westbred 936	hrs	79.1	d-i	25.5	c-f
Klasic	hws	75.5	e-i	57.2	a
Buck Pronto	hrs	74.8	f-i	22.6	c-j
UI Winchester	hrs	73.7	ghi	19.0	c-j
UI Platinum	hws	63.2	hi	30.6	bcd
WB-Paloma	hws	61.3	i	22.6	c-j
	Num DF	41			
	F Value	1.54			
	Pr > F	0.0894			

[Z]Class definitions of wheat varieties: hrs = hard red spring, hws = hard white spring, sws = soft white spring.

RAINFASTNESS OF CARAMBA® AND PROTECTION AGAINST FUSARIUM HEAD BLIGHT AND DEOXYNIVALENOL IN SOFT RED WINTER WHEAT

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ABSTRACT

Fusarium head blight (FHB), caused by the fungal pathogen *Fusarium graminearum*, is a common and devastating disease of wheat and other small grain crops in the United States and other parts of the world. FHB damages and contaminates grain with harmful mycotoxins such as deoxynivalenol (DON). Fungicide application is critical to controlling FHB, conferring 48-52% reduction in disease and 42-45% reduction in DON in the absence of cultivar resistance. Research has shown that the efficacy of fungicides may be reduced if rainfall occurs during or shortly after application. The goal of this study was to quantify the protection that the commonly-recommended Caramba® fungicide confers if it rains within the first few hours after application. Seven-row plots (5 x 10 ft) of FHB susceptible soft red winter wheat cultivar Pioneer 25R45 were planted at a seeding rate of 1.6 x 10^6 seeds/acre and a row spacing of 7.5 in. The experimental design was a randomized complete block, with seven experimental units (plots) per block. Caramba was applied at anthesis at a rate of 14 fl oz/A to all but one plot in each block. Simulated rain was applied at 79 to 112 mm h^{-1} (for a total volume of 4.1 mm across the plot) to five randomly selected plots in each block. The rainfall applications were made at 0, 60, 105, 150, or 195 min after Caramba application. The untreated plot (Check 1) and one fungicide-treated plot (Check 2) within each block were not subjected to simulated rain. All plots were spray-inoculated with a spore suspension of *F. graminearum* approximately 36 hours after fungicide application, and FHB index (IND) and incidence (INC) as well as *Fusarium* damaged kernels (FDK) and DON were quantified for each plot. Mean IND, INC, FDK, and DON in Check 1 were 16%, 41%, 23%, and 10 ppm, compared to 8%, 25%, 14%, 6 ppm in Check 2. All fungicide-treated plots had significantly lower mean INC than Check 1, regardless of whether or when rainfall treatments were applied. Plots subjected to rainfall at least 105 minutes after Caramba application had significantly lower mean IND and FDK than Check 1 (untreated). Mean IND, INC, DON, and FDK were not significantly different among plots exposed to rain between 105 and 195 min after Caramba application and Check 2 (fungicide treated, without rain). Mean IND and FDK in plots that received rain at 0 and 60 min after Caramba application were not significantly different from Check 1. Percent control of IND and DON relative to Check 1 ranged from 45 to 50% for plots exposed to rain at least 105 min after Caramba application, 25 to 40% for those that received rain at 0 or 60 min, and 46 to 52% for treated plots that were not subjected to rain (Check 2). Determining a minimum length of time between application of Caramba and subsequent rainfall that results in significant disease and toxin control (the rainfast time) can advise application recommendations that account for weather. The results of this study suggest that growers should apply Caramba at least 105 minutes before it rains.

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INFLUENCE OF PRE-ANTHESIS RAINFALL PATTERNS AND INOCULUM SOURCES ON FUSARIUM HEAD BLIGHT AND DEOXYNIVALENOL IN WHEAT

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OBJECTIVES

To investigate the effects of intermittent moisture during the 8-day pre-anthesis window and of inoculum sources on Fusarium head blight (FHB) and deoxynivalenol (DON) in wheat.

INTRODUCTION

The effect of variable pre-anthesis high-moisture or rainfall patterns on FHB and DON constitutes a major knowledge gap in the epidemiology of FHB. This has led to uncertainty in the assessment of the risk of this disease and toxin. Producers and researchers alike have questioned the "low-risk" prediction of the FHB risk tool in some seasons when pre-anthesis rainfall is intermittent (spotty). Empirical observations and results from controlled-environment studies show that infection cycle events critical for FHB development may occur under (or even require) conditions of intermittent moisture. For instance, ascospore release was associated with cyclic wet and dry periods under both laboratory and field conditions (4,7). Rossi et al. (6) found that the number of *F. graminearum* macroconidia sampled in wheat fields often spiked during the day following a rain event, rather than on the day of the rain event.

FHB development and DON accumulation are strongly influenced by environmental conditions before and during anthesis and early grain-fill. It is well known that pre-anthesis temperature and moisture are critical for both processes. However, very few studies have investigated the effects of moisture or rainfall patterns during the pre-anthesis window on FHB and DON (1,2). In particular, the effect of frequency and timing of rainfall within the 7- to 10-day immediately prior to anthesis is still poorly understood. Thus, research is needed to better characterize how the number of days and distribution of pre-anthesis moisture affect FHB development and DON contamination.

MATERIALS AND METHODS

Field plots were planted on 10 October 2013 at the Ohio Agricultural Research and Development Center in Wooster, OH. Plots of Hopewell, an awnless, susceptible soft red winter wheat cultivar, were planted into a field previously cultivated with oats, and managed according to standard agronomic practices for Ohio. Each experimental unit (plot) consisted of seven 6-m-length rows, spaced 19 cm apart, and planted at a seeding rate of 4×10^6 seeds ha^{-1}. The experimental design was a randomized complete block, with a split-plot arrangement of pre-anthesis simulated rainfall patterns (five levels) as whole-plot and inoculum sources (three levels) as sub-plot. There were 2 replicate blocks. Beginning 8 days prior to anthesis and ending at 50% anthesis, the rainfall patterns (treatments) were: 1) rainfall every day; 2) rainfall on the first and last two days, separated by a four-day period without rainfall; 3) no rainfall on the first and last two days, separated by four days with rainfall; 4) rainfall every other day, and 5) check (no supplemental rainfall/irrigation; ambient rainfall). Irrigation risers were mounted in each whole plot, with separate timers programmed to run 4 minutes every 12 minutes between 5:00 and 9:00 h and 17:00 and 22:00 h on the scheduled day of rainfall. On average, 16 mm of "rain" was delivered by the irrigation system on each designated "rainy day".

The inoculum sources were corn spawn (colonized corn kernels) and naturally-infected corn residue, spread between the rows at jointing (Feekes GS 6), and without in-field inoculum (check).

Twenty spikes were harvested daily from each plot and assayed for spores of *F. graminearum* as previously described (5). FHB index (field- or plot-level disease severity, defined as mean proportion of diseased spikelets per spike) was evaluated at soft dough (Feekes GS 11.2) on 20 spikes at 5 arbitrarily selected locations within each sub-plot. A sample of grain from each plot was used to estimate percent *Fusarium* damaged kernels (FDK, the percentage of small, shriveled, whitish-pink kernels) with the aid of a diagrammatic rating scale (3), and then sent to the U.S. Wheat and Barley Scab Initiative-funded laboratory at the University of Minnesota for DON quantification.

RESULTS AND DISCUSSION

We observed that mean FHB index, FDK, and DON were numerically higher for plots that received simulated rain compared to the check, and for plots that received rain, the means were higher for those with corn spawn than those with naturally-infected corn residue or without in-field inoculum (Fig. 1). Pre-anthesis rainfall patterns tended to influence FHB development and DON contamination in plots with corn spawn, but appeared to have little discernable effect on disease and toxin in plots with corn residue or without inoculum. This was likely because plots with corn spawn had more spores on the infection court (Fig. 2A and B). In plots with corn spawn, the every-day rainfall treatment (Rain_1) resulted in numerically higher mean FHB index than treatments with intermittent rainfall (Rain_2, Rain_3 and Rain_4) (Fig. 1). Interestingly, however, although mean FHB index was highest for Rain_1, plots that received rainfall on the first and last two days (Rain_2) or every other day (Rain_4) during the 8-day pre-anthesis window had higher or comparable mean FDK and DON. Rain_1 and Rain_2 also resulted in more spores reaching the spikes than Rain_3 and Rain_4 during the week before anthesis (Fig. 2C and D). Disease and toxin responses were lowest and most variable for Rain_3. These results are probably a reflection of the effects of dry-wet moisture cycles on spore production and release, and stimulation of mycotoxin production. This is consistent with findings from previous field and greenhouse experiments (1,2), suggesting that the pattern and distribution of rainfall may affect FHB and grain quality.

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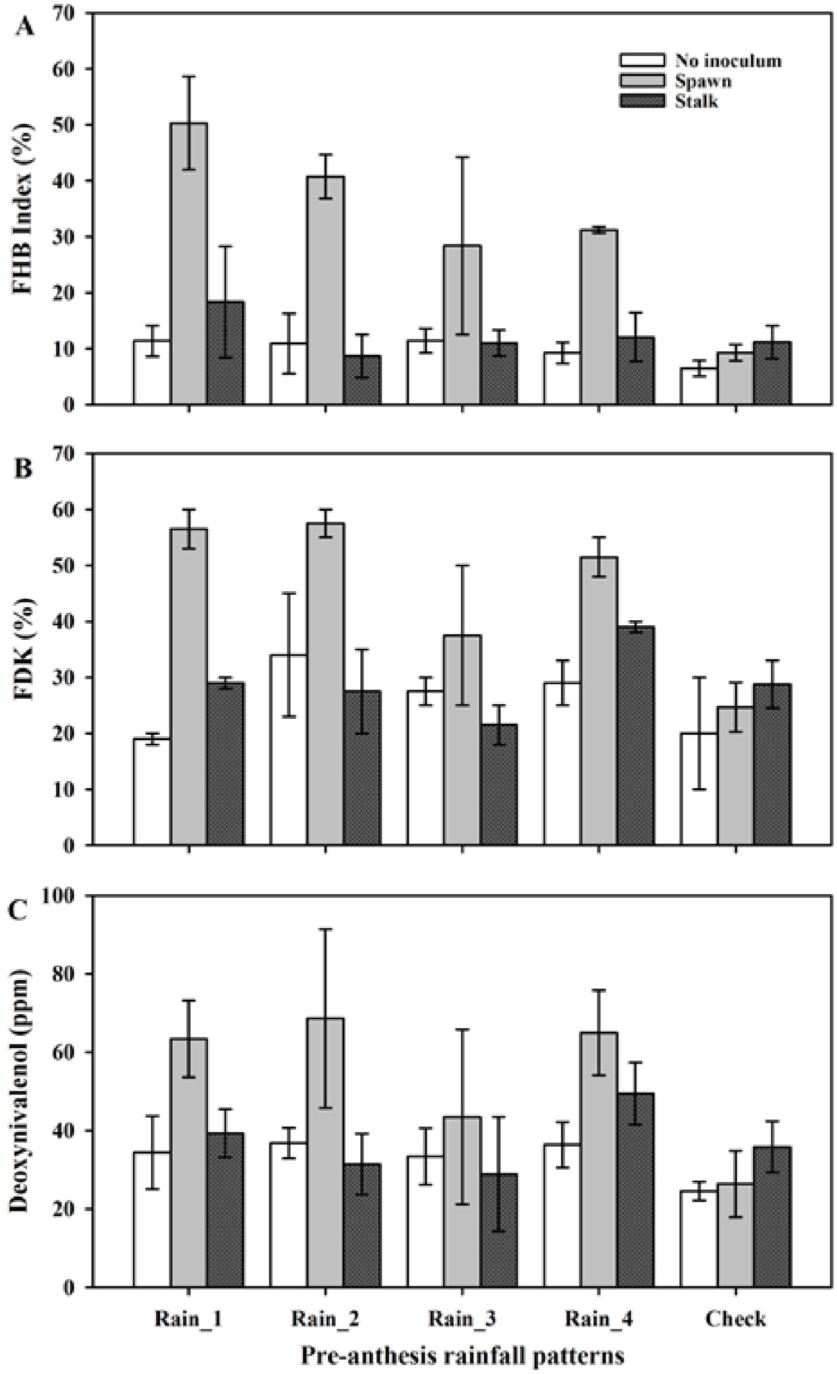

Figure 1. Mean Fusarium head blight (FHB) index (A), *Fusarium* damaged kernels (FDK) (B), and deoxynivalenol (C) content of harvested grain (ppm) under different pre-anthesis rainfall patterns and inoculum sources. Rain_1 = rain every day for 8 days, Rain_2 = rain only on the first and last two days of the window, Rain_3 = rain only on the middle four days of the window, Rain_4 = rain every other day, Check = ambient rainfall. No inoculum = without in-field inoculum, Spawn = *F. graminearum* colonized corn kernels, Stalk = naturally-infected corn crop residue. Each bar represents the treatment arithmetic mean from two replicate plots, and error bars are standard error of the mean.

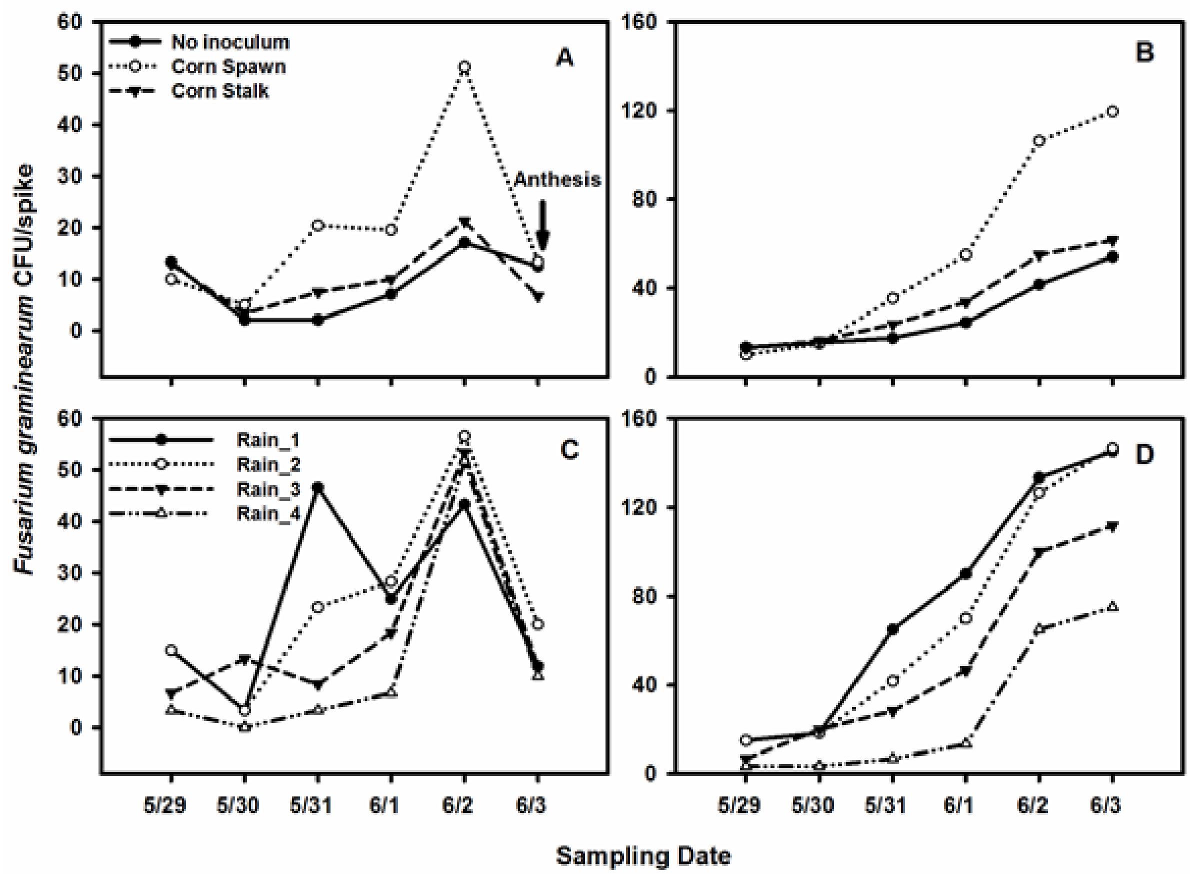

Figure 2. Mean (**A** and **C**) and cumulative number of (**B** and D) CFU/spike for different inoculum sources, averaged across rainfall patterns (**A** and **B**), and for different rainfall patterns applied to plots with corn spawn inoculum (**C** and **D**). Rain_1 = rain on every day for 8 days immediately prior to anthesis, Rain_2 = rain only on the first and last two days of the 8-day window, Rain_3 = rain only on the middle four days of the window, Rain_4 = rain on every other day. No inoculum = no in-field inoculum, and Corn Spawn and Corn Stalk = *F. graminearum* colonized corn kernels and naturally-infected corn residue, respectively, spread between the rows of the plot. *Note: an outlier (1,236 CFU/spike on June 2 for Rain_1 plus corn spawn in block 2) was removed.*

2013 AND 2014 FIELD PLOT TRIALS FOR BIOLOGICAL CONTROL OF FUSARIUM HEAD BLIGHT IN SOUTH DAKOTA USING *BACILLUS AMYLOLIQUEFACIENS* STRAINS

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ABSTRACT

Fusarium Head Blight (FHB) or Wheat Scab, caused by *Fusarium graminearium* is an economically important disease of wheat and barley. Yield losses can be controlled or reduced through the use of fungicides alone or in combination with biological control agents (BCAs). Field plot trials were conducted in Brookings, South Dakota to analyze the efficacy of *Bacillus amyloliquefaciens* strains 1BA and 1D3 in biological control of FHB. Spray applications of *Bacillus* BCAs alone or in combination with Prosaro® (fungicide) and/or Induce NIS (non-ionic surfactants) and/ or colloidal chitin were done on Briggs spring wheat heads at Feekes 10.51. In the 2013 Field Plot trials, multiple treatments exhibited statistically significant reduced levels of DON in comparison to the untreated control. *Bacillus* strain 1BA amended with colloidal chitin, Prosaro and plant oil reduced DON levels significantly (P=0.10), in comparison to treatment with Prosaro alone. Only the DON results from 2013 plots are presented in this abstract, as the other results were presented for the 2013 FHB Forum.

For 2014, no statistically significant treatment differences were observed for FHB incidence, severity, index and yield. The combination of *Bacillus* 1BA, plant oil, colloidal chitin and Prosaro reduced the FHB incidence to 35.5%, which was less than the FHB incidence observed for Prosaro alone (42.5%) or for the untreated control (48.5%). The treatment combination of *Bacillus* strains 1BA, plant oil, and Induce NIS reduced the FHB severity to 51.52%, which was less than the FHB severity observed for Prosaro alone (51.81%) or the untreated control (67.64%). The treatment of *Bacillus* strain 1BA and 1D3 with plant oil, colloidal chitin and Prosaro reduced the disease index to 21.24%, while the treatment of Prosaro alone reduced the disease index to 22.16%. The FHB index of untreated control was 31.57%; further, the treatment of *Bacillus* strain 1D3 with plant oil, colloidal chitin and Prosaro increased the yield to 56.68 bu/acre, while the treatment of Prosaro alone increased the yield to 54.8 bu/acre. The yield for the untreated control was 49.43 bu/acre. Several treatments with the BCAs showed significant differences (P=0.10) for grain test weight in comparison to the untreated control. The Disease Protein, FDK and DON data are not yet available as of November 2014.

These trials demonstrated that *Bacillus* strains 1BA or 1D3 in combination with Prosaro and/or colloidal chitin with plant oil can reduce FHB in wheat, more than a single application of Prosaro.

ACKNOWLEDGEMENT AND DISCLAIMER

This material is based upon work supported by the U.S. Department of Agriculture, under Agreement No. 59-0206-9-050. This is a cooperative project with the U.S. Wheat & Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

INTEGRATING CULTIVAR RESISTANCE AND FUNGICIDE APPLICATION TO MANAGE FUSARIUM HEAD BLIGHT OF WHEAT

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ABSTACT

Fusarium head blight (FHB) is a devastating disease of wheat in the southern cone of South America. FHB represents one of the main constraints for wheat production in Uruguay, where moderate to severe outbreaks have occurred in one of every four years over the past two decades. In order to optimize disease control measures, cultivar resistance and fungicides were investigated and their interaction was evaluated. Commercial cultivars and advanced lines were characterized under intermediate to high disease pressure in nurseries and field trials during 2011 to 2013. Few commonly grown cultivars had high levels of resistance and comprised 7, 10, and 15% of the area planted to wheat in 2011, 2012, and 2013, respectively. Metconazole alone or in combination with epoxiconazole were the most effective fungicides in controlling FHB, by reducing FHB index (FHBI), *Fusarium* damaged kernels (FDK) and deoxynivalenol (DON) content and increasing grain yield. Although some mixtures of triazoles + strobilurins and triazoles + carboxamides + strobilurins reduced FHBI and FDK, they increased DON content. Fungicide efficacy in reducing FHB and DON and in increasing grain yield was greater in a moderately resistant cultivar (INIA-Genesis 2375) that in a susceptible one (INIA Don Alberto).These results suggest that it may be possible to manage FHB by cultivar resistance and timely fungicide applications with recommended triazoles.

CONTROL OF FHB WITH RESISTANT GENOTYPES AND FUNGICIDES: 2014 RESULTS

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ABSTRACT

A series of variety by fungicide trials were conducted in 2014 in the three classes of wheat that are grown in North Dakota: hard red spring, hard red winter and durum. Experiments consisted of a factorial combination of variety and fungicide at Feekes 10.51 stage. The number of varieties varied by class and location and included those varieties that had been released and were likely to be grown in the state. Treatments were replicated three times. The fungicide used was a commercial combination of tebuconazole + prothioconazole (Prosaro™, Bayer CropScience) at a rate of 6.5 fl oz per acre with NIS. Winter wheat was planted no-till after spring wheat. Durum and spring wheat followed various other crops depending on the location and were planted after tillage at some locations and no-till at others. All locations were subject to natural FHB infestation and rainfall. Yield, disease severity and DON levels were recorded and data were analyzed using standard statistical techniques. Fairly high levels of FHB occurred especially in the winter wheat and the durum at Minot. In winter wheat, fungicide reduced DON levels from 5.9 ppm to 3.5 ppm at Prosper and from 12.1 to 9.1 ppm at Forman. Within the treatments that received no fungicide, varieties had DON levels of 13.8 to 1.2 ppm and 32.5 to 2.8 ppm at Prosper and Forman, respectively. The cultivar Emerson which was developed in Canada showed excellent resistance to FHB. With fungicide treatment, yields increased by 10 bu/a at Prosper and 18 bu/a at Forman. In spring wheat, there was little FHB development at Forman. DON levels were reduced from 0.4 to 0.1 ppm and yield increased from 49.0 to 51.9 bu/a with the fungicide treatment. At Hope, where there was slightly more FHB pressure, fungicide reduced DON from 1.0 to 0.1 ppm averaged across varieties. Within the no fungicide treatment, varieties ranged from 0.0 to 3.2 ppm DON. Yield increased by 5 bu/a on average with fungicide treatment. In the durum experiment at Minot, DON levels were reduced from 16 to 12 ppm with the fungicide treatment, and varied from 23 to 10 ppm between varieties. These data show the importance of varietal resistance relative to fungicide in the control of FHB. Fungicide can play and important role in reducing DON levels to an acceptable level when resistant cultivars are used or when disease pressure is not excessive.

ACKNOWLEDGEMENT AND DISCLAIMER

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EVALUATION OF HRWW AND HRSW CULTIVARS FOR FHB MANAGEMENT IN SOUTH DAKOTA

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ABSTRACT

Fusarium head blight (FHB – scab) remains a serious concern for wheat and barley producers in South Dakota. One of the sustainable and affordable means of FHB management is through host resistance. The objective of this study was to evaluate the different commercial hard red winter and spring wheat cultivars for FHB management in South Dakota. Fourteen winter wheat cultivars and nineteen spring wheat cultivars were evaluated. The winter wheat cultivars were planted at two locations, Volga and South Shore; whereas the spring wheat cultivars were planted only at Volga. Experimental design used was complete randomized block with four replications. The spring wheat cultivars were under ambient conditions until anthesis, after which mist irrigation was applied. Winter wheat was left under ambient conditions at both locations. Twenty-one days following anthesis, plots were evaluated for leaf diseases, FHB incidence, FHB head severity, FHB field severity, and FHB disease index (FHB incidence x severity). At harvest, grain yield and test weight were determined. Grain samples were collected for assessing *Fusarium* damaged kernels (FDK) and deoxynivalenol (DON).

The Volga location generally had high FHB pressure (highest FHB index of 38.6) while the South Shore location had low FHB pressure (highest FHB index of 11.5) At the Volga Research Farm location, the winter wheat cultivars that had the lowest FHB disease index were Arapahoe (4.51%), Lyman (6.54%) Ideal (7.31%), and Matlock (9.65%) whereas at South Shore, the cultivars that had the lowest FHB Disease Index were Matlock (0.91%), Redfield (1.05%), Arapahoe (1.06%), Everest (1.51%), Expedition (2.29%), and Ideal (3.20%), . The winter wheat cultivars that had the highest yield were Matlock and Arapahoe at Volga and Matlock and Redfield at South Shore. For the spring wheat cultivars that were tested at the Volga Research Farm, the cultivars that had the lowest FHB Disease Index were LCS Iguacu (1.09%), LCS Albany (1.99%), and WB9507 (3.15%). Forefront (3.25%), Sabin (3.72%), SY Ingmar (3.93%), and SY Soren (4.24%) The highest yielding spring wheat cultivars at Volga were Forefront and Prevail.

These results indicate FHB moderate resistance for both winter and spring commercial wheat cultivars in South Dakota for the management of FHB.

ACKNOWLEDGEMENT AND DISCLAIMER

This material is based upon work supported by the U.S. Department of Agriculture, under Agreement No. 59-0206-9-050. This is a cooperative project with the U.S. Wheat & Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

BEST FHB MANAGEMENT PRACTICES: A 2014 MULTI-STATE PROJECT UPDATE

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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

Over the last 15 years, considerable progress has been made to develop management strategies to minimize FHB-associated grain yield and quality losses in wheat and barley. Several new resistant cultivars have been developed, efficacious fungicides registered, accurate disease forecasting models deployed to help guide fungicide applications, and the value of integrating multiple in-field and grain harvesting strategies to manage this disease-toxin complex has been demonstrated (Salgado et al., 2014; Willyerd et al., 2012; McMullen et al., 2012). For instance, results from several years of coordinated integrated management trials showed that relative to the untreated susceptible check, the combination of moderately resistant cultivar and Prosaro application at anthesis resulted in more than 70% control of both FHB index and DON (Willyerd et al., 2012). However, weather conditions, fungicide and spray associated costs, cultivar yield potential and other factors often prevent the adoption of current management recommendations. For instance, wet, soggy field conditions may make it impossible for ground applications of fungicides at the recommended anthesis growth stage. Moreover, even if such applications are made, research shows the rainfall during or shortly after treatment may reduce fungicide efficacy (Andersen et al., 2014). Other limitations to adequate timing of fungicide applications include uneven crop development and variable anthesis window within a field, and the inability to correctly determine the anthesis growth stage. These limitations have led to questions being asked about the efficacy of applying fungicides before or after anthesis.

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 in four to six replicate blocks. The standard experimental design was a randomized complete block, with a split-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 stages 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 check, and the best management practice, based on percent control, was highlighted for each trial/environment.

RESULTS AND DISCUSSION

For this report, data from 14 trials, representing seven soft red winter wheat, two hard red winter wheat, four hard red spring wheat, and one soft white winter wheat classes were summarized (Table 1). Means for each cultivar resistance class x fungicide application timing combination are shown in Table 1. Mean FHB index in the untreated susceptible check ranged from 0 to 49%, and mean DON from 0.5 to 15.6 ppm. In some locations, 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 toxin levels (< 4% index and < 2 ppm DON, Table 1) were not used to estimate percent control. Percent control of FHB index and DON, relative to the untreated susceptible check is shown in Figs. 1 and 2 for trials with the highest levels of mean index and DON in the check (and where possible, representative of each market class). The best management combinations, based on the highest percent control of index, for trials/environment with index > 4% are presented in Fig. 3.

Fungicide alone reduced FHB index and DON in each resistance category and wheat market class, however, the combination of cultivar resistance and fungicide application was most effective at reducing FHB and DON in most trials (Table 1 and Figs. 1-3, in 8 out of 11 trials reporting FHB index > 4%). In some cases (ENV = 3, 8 and 9) fungicide-treated MS cultivars had the highest percent control of both FHB and DON, and post-anthesis treatments in ENV 3, 8, 9, 10, and 13 were as effective as or more effective than anthesis treatments (Figs. 1-3). 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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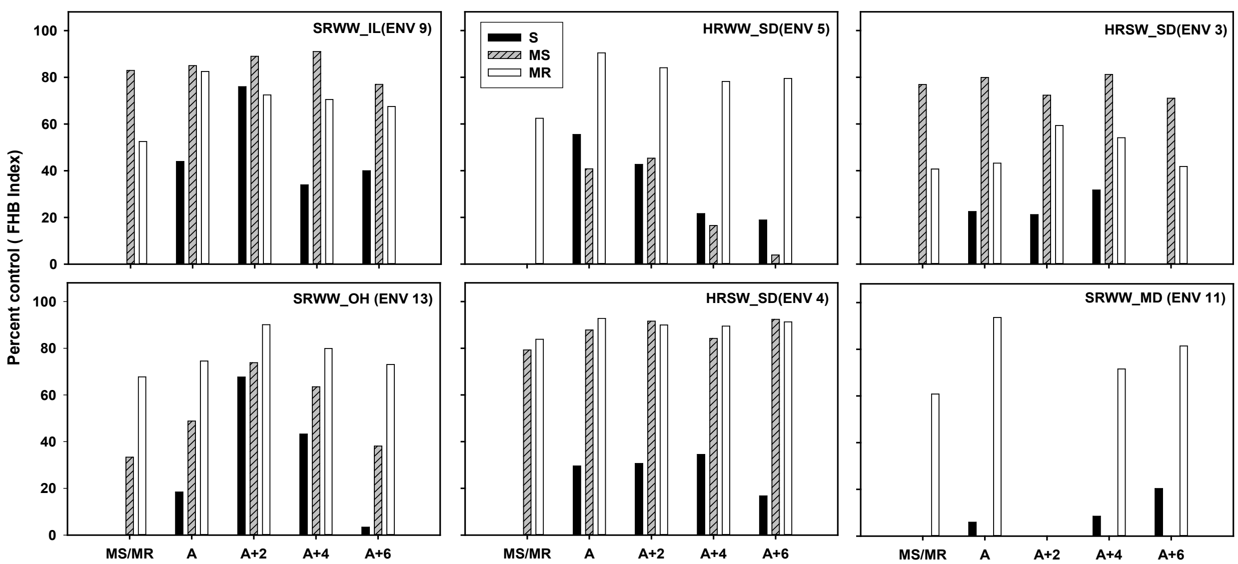

Figure 1. Percent control of FHB index relative to the untreated susceptible check (Table 1) for different FHB management combinations in three different wheat classes (HRWW, HRSW, and SRWW). Cultivar resistance (susceptible, S; moderately susceptible, MS; and moderately resistant, MR). MS/MR, represents the effect of cultivar resistance alone (untreated MR or MS cultivar). Prosaro (6.5 fl oz/A) was applied either at anthesis (A), or 2, 4, or 6 days post-anthesis (A+2, A+4 or A+6, respectively.

Table 1. Mean FHB index and DON for different cultivar x fungicide timing management combinations from 14 coordinated integrated management trials (ENV, environments) representing different wheat classes (TYPE = HRWW, HRSW, SRWW and SWWW). Results are organized by cultivar FHB resistance reaction (susceptible, S; moderately susceptible, MS; and moderately resistant, MR) and fungicide treatment (untreated [No] or treated [TR] at anthesis [Yes] or 2, 4, 5, 6 or 7 days post-anthesis.

				Susceptible (S)							Moderately Susceptible (MS)							Moderately Resistant (MR)						
				[c]Anthesis TR		Post anthesis TR (days)					Anthesis TR		Post anthesis TR (days)					Anthesis TR		Post anthesis TR (days)				
Response	**ENV**	**LOCATION**	**TYPE**	**No**	**Yes**	**2**	**3**	**4**	**5**	**6**	**No**	**Yes**	**2**	**4**	**5**	**6**	**7**	**No**	**Yes**	**2**	**4**	**5**	**6**	**7**
FHB Index [a]	1	Langdon, ND	HRSW	10.1	4.6	…	…	…	2.1	…	…	…	…	…	…	…	…	1.7	0.6	…	…	1.6	…	…
(%)	2	Fargo, ND	HRSW	0.0	0.1	…	…	…	0.0	…	0.0	0.0	…	…	0.0	…	…	0.0	0.0	…	…	0.5	…	…
	3	Volga, SD	HRSW	48.8	37.8	38.4	…	33.3	…	50.6	11.3	9.8	13.5	9.2	…	14.1	…	28.9	27.7	19.8	22.4	…	28.4	…
	4	South Shore, SD	HRSW	18.8	13.2	13.0	…	12.3	…	15.6	3.9	2.3	1.6	3.0	…	1.4	…	3.0	1.4	1.9	2.0	…	1.6	…
	5	Volga, SD	HRWW	19.0	8.5	10.9	…	14.9	…	15.4	30.6	11.3	10.4	15.9	…	18.3	…	7.2	1.8	3.0	4.2	…	3.9	…
	6	Mead, NE	HRWW	3.1	3.1	2.4	…	2.4	…	2.7	…	…	…	…	…	…	…	1.5	1.6	1.7	1.8	…	1.8	…
	7	Georgetown, DE	SRWW	7.0	4.9	…	…	4.1	…	3.3	…	…	…	…	…	…	…	0.4	0.1	…	0.7	…	0.3	…
	8	Dixon Springs, IL	SRWW	7.3	8.5	3.8	…	0.7	…	1.1	1.6	1.1	0.6	0.0	…	0.7	…	1.9	3.0	1.9	1.7	…	0.8	…
	9	Urbana, IL	SRWW	12.5	7.0	3.0	…	8.3	…	7.5	2.1	1.9	1.4	1.1	…	2.9	…	5.9	2.2	3.4	3.7	…	4.1	…
	10	West Lafayette, IN	SRWW	4.4	2.3	1.8	…	2.8	…	1.7	0.5	0.4	0.4	0.5	…	0.2	…	0.4	0.2	0.2	0.2	…	0.5	…
	11	Wye, MD	SRWW	13.2	12.4	…	…	12.0	…	10.5	…	…	…	…	…	…	…	5.2	0.8	…	3.7	…	2.4	…
	12	Aurora, NY	SRWW	…	…	…	…	…	…	…	4.2	1.8	…	…	…	…	0.5	1.0	0.8	…	…	…	…	0.3
	13	Wooster, OH	SRWW	12.6	10.3	4.1	…	7.2	…	12.2	8.4	6.5	3.3	4.6	…	7.8	…	4.1	3.2	1.3	2.5	…	3.4	…
	14	Deckerville, MI	SWWW	0.6	0.3	…	0.1	…	…	0.2	…	…	…	…	…	…	…	…	…	…	…	…	…	…
DON [b] (ppm)	6	Mead, NE	HRWW	0.6	1.2	0.8	…	1.1	…	0.7	…	…	…	…	…	…	…	0.6	0.6	1.3	0.9	…	0.9	…
	7	Georgetown, DE	SRWW	2.0	1.2	…	…	1.2	…	1.2	…	…	…	…	…	…	…	0.3	0.3	…	0.2	…	0.2	…
	8	Dixon Springs, IL	SRWW	4.0	7.9	3.0	…	2.4	…	3.0	0.8	0.9	0.8	0.3	…	1.0	…	1.2	3.3	1.3	1.1	…	1.7	…
	9	Urbana, IL	SRWW	7.6	5.7	5.1	…	4.4	…	4.5	1.2	1.9	1.8	2.1	…	1.9	…	2.8	2.6	2.3	2.7	…	2.1	…
	10	West Lafayette, IN	SRWW	7.1	7.3	4.5	…	4.1	…	4.1	2.4	2.3	2.1	2.0	…	1.8	…	3.9	2.6	3.0	2.5	…	2.1	…
	11	Wye, MD	SRWW	1.9	1.6	…	…	1.1	…	0.9	…	…	…	…	…	…	…	0.6	0.5	…	…	0.4	…	0.3
	12	Aurora, NY	SRWW	…	…	…	…	…	…	…	3.2	1.3	…	…	…	…	0.8	1.3	0.5	…	…	…	…	0.2
	13	Wooster, OH	SRWW	15.6	9.0	7.3	…	9.1	…	9.2	6.1	5.3	4.6	4.4	…	5.0	…	4.2	3.5	2.1	2.5	…	2.4	…
	14	Deckerville, MI	SWWW	0.5	0.5	…	0.1	…	…	0.1	…	…	…	…	…	…	…	…	…	…	…	…	…	…

[a]FHB index = mean proportion of disease spikelets per spike.

[b]DON = deoxynivalenol content of harvested grain in ppm.

[c]Fungicide application = Prosaro applied at 6.5 fl. oz./A + NIS at or after anthesis.

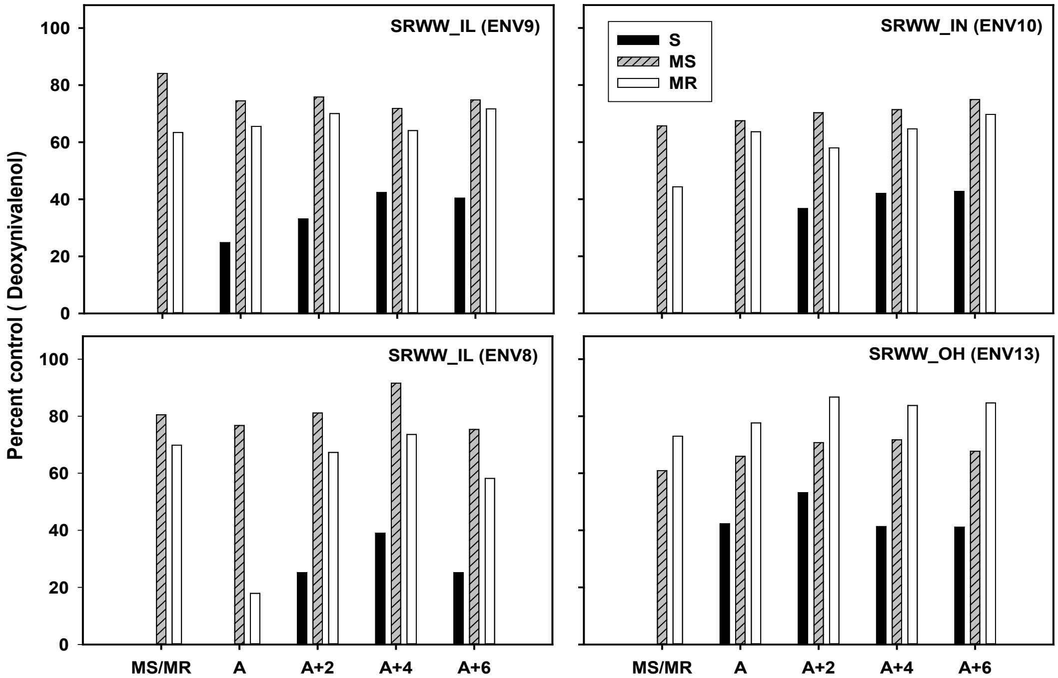

Figure 2. Percent control of DON relative to the untreated susceptible check (Table1) for different FHB management combinations in trials with mean DON check > 2 ppm. Cultivar resistance (susceptible, S; moderately susceptible, MS; and moderately resistant, MR). MS/MR, represents the effect of cultivar resistance alone (untreated MR or MS cultivar). Prosaro (6.5 fl oz/A) was applied either at anthesis (A), or 2, 4, or 6 days post-anthesis (A+2, A+4 or A+6, respectively).

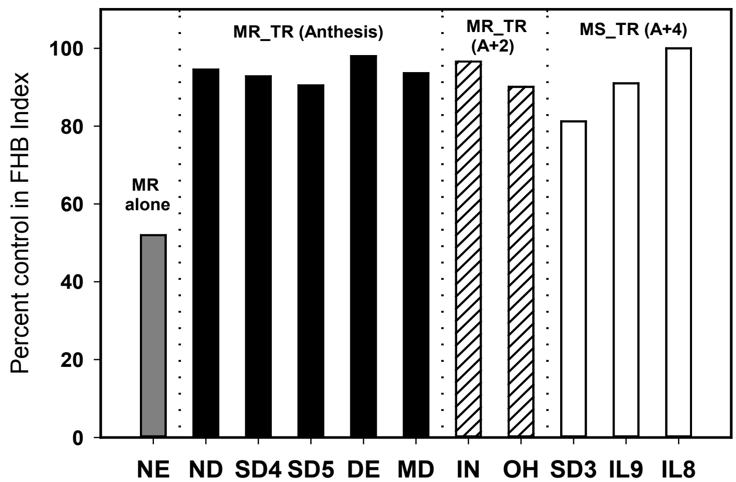

Figure 3. Percent control of FHB index relative to the untreated susceptible check for the best management combinations in environments that reported FHB index levels in the susceptible untreated check above 4% (Table 1). Environments are grouped based on the cultivar x fungicide application timing combination with the highest percent control. Cultivar FHB resistance reaction (susceptible, S; moderately susceptible, MS; and moderately resistant, MR). Plots were treated (TR) with Prosaro (6.5 fl oz/A) either at anthesis (A), or 2, 4, or 6 days post-anthesis (A+2, A+4 or A+6, respectively). MR alone = the effect of moderate resistance in the absence of fungicide.

INTEGRATING CULTIVAR RESISTANCE AND FUNGICIDE APPLICATION RATE AND TIMING FOR FHB MANAGEMENT IN OHIO

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OBJECTIVES

The objective of this study was to develop more robust strategies for FHB management in soft red winter wheat in Ohio, by reevaluating the efficacy of post-anthesis fungicide treatments as influenced by cultivar resistance, fungicide chemistry, and application rate.

INTRODUCTION

Best-management practices for Fusarium head blight (FHB) and deoxynivalenol (DON) in wheat include the use of moderately resistant cultivars, crop rotation, tillage, and fungicide application at anthesis. However, weather and other farm-related factors may prevent the adoption of these strategies or reduce their efficiency. For instance, rainfall during anthesis may reduce the efficacy of fungicides or even prevent them from being applied at the recommended time. Previous research has shown that Prosaro applications made after anthesis may be just as effective as or sometime more effective than applications made at anthesis (D'Angelo et al 2014). However, it is unclear whether the efficacy of post-anthesis applications will be influenced by active ingredient, application rate, or resistance of the cultivar being treated.

MATERIALS AND METHODS

Two field experiments were established in Wooster, Ohio during the 2014 season, using a split-plot arrangement as the experimental design. In the first study, Prosaro (6.5 fl. oz./A) was applied to four cultivars with different levels of resistance to FHB (Hopewell, susceptible; Bromfield, moderately susceptible; and Truman and Malabar, both moderately resistant), and in the second, Prosaro and Caramba were applied to Hopewell at low and high rates (6.5 and 8.2 fl. oz./A for Prosaro and 13.5 and 17 fl. oz./A, for Caramba). In both studies, treatments were either applied at 50% anthesis or between 2 and 7 days after anthesis. All plots were spray-inoculated at anthesis with a spore suspension of *F. graminearum*, and FHB intensity and *Fusarium* damaged kernel (FDK) were rated, grain yield estimated, and grain samples tested for DON. FHB intensity and DON data were arcsine-square root- and log-transformed, respectively, and analyzed using a linear mixed modeling approach.

RESULTS AND DISCUSSION

Mean FHB index (IND) ranged from 1.5 to 21% and 0.7 to 16% in untreated and fungicide-treated plots, respectively. The corresponding ranges for mean DON were 3.3 to 16.7 and 0.9 to 15 ppm. The effects of cultivar and fungicide x rate combination on IND, FDK, DON, and grain yield did not depend on application time (the interactions were not significant, $P > 0.05$) (**Table 1 and 2**). Differences in mean IND and DON among cultivars and fungicide treatments ($P < 0.05$) were statistically significant (**Table 3 and 4**). Averaged across application time, Truman and Malabar had significantly lower mean IND, FDK, and DON than Hopewell and Bromfield (**Table 3** and **Fig.1**), and Prosaro at the high rate had significantly lower mean IND, and numerically, but not always statistically, lower mean FDK and DON than the other tested fungicide x rate combinations (**Table**

4 and **Fig.2**). Fungicide-treated plots generally had significantly lower mean IND, FDK, DON, and higher mean grain yield than the untreated check. Averaged across cultivars (experiment 1) or fungicide x rate combinations (experiment 2), treatments applied between two and five days post-anthesis had significantly lower mean IND and DON ($P < 0.05$) than those applied at anthesis, and comparable or significantly lower mean FDK (**Table 3**, **Table 4**, **Fig. 1 and Fig. 2**). The effects of treatments made more than five days after anthesis varied between the two experiments (**Table 3** and **Table 4**). Cultivar and fungicide x rate combination did not have a significant effect on grain yield (**Table 1** and **Table 2**); however, for all application times, treated plots had significantly higher mean yield (between 307 and 644 kg/ha) than the untreated check (**Table 3** and **Table 4**). In general, mean yields were comparable among anthesis and post-anthesis treatments. The only exception was for the treatment applied two days after anthesis in experiment 1, which had significantly higher mean yield than the anthesis treatment.

Our results showed that using a moderately resistant cultivar reduced mean IND by 59 to 76% and DON by 72 to 74% when compared to untreated-susceptible check, and fungicide alone reduced IND by 3 to 84% and DON by 41 to 68%, relative to the check. However, combinations of moderate resistance and fungicide, particularly treatments made between at 2 and 4 days after anthesis, were the most efficacious, with mean percent control relative to the susceptible-untreated ranging from 68 to 96% for IND and 81 to 88% for DON, and percent yield increase ranging from 8 to 12%.

ACKNOWLEDGEMENT AND DISCLAIMER

This material is based upon work supported by the U.S. Department of Agriculture, under Agreement No. 59-0206-9-071. This is a cooperative project with the U.S. Wheat & Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

REFERENCE

D'Angelo, D. L., Bradley, C. A., Ames, K. A., Willyerd, K. T., Madden, L. V., and Paul, P. A. 2014. Efficacy of fungicide applications during and after anthesis against Fusarium head blight and deoxynivalenol in soft red winter wheat. Plant Dis. 98:1387-1397.

Table 1. Summary statistics from linear mixed model analyses of the effect of cultivar and fungicide timing on arcsine-transformed FHB incidence (INC), index (IND), *Fusarium* damaged kernels (FDK) and log-transformed deoxynivalenol (DON) grain contamination and grain yield (YLD) in soft red winter wheat in Ohio.

Factor	IND	FDK	DON	YLD
Cultivar	<0.001	<0.001	<0.001	0.086
TIME	<0.001	<0.001	<0.001	<0.001
Cultivar*TIME	0.397	0.050	0.499	0.219

Cultivar = Hopewell, susceptible; Bromfield, moderately susceptible; and Truman and Malabar, both moderately resistant.
Time = Time of Prosaro application - anthesis or 2, 4 or 6 days after anthesis

Table 2. Summary statistics from linear mixed model analyses of the effect of fungicide and application timing on arcsine-transformed FHB incidence (INC), index (IND), *Fusarium* damaged kernels (FDK) and log-transformed deoxynivalenol (DON) grain contamination and grain yield (YLD) in soft red winter wheat in Ohio.

Factor	IND	FDK	DON	YLD
Fungicide	0.001	0.080	0.019	0.314
TIME	<0.001	0.001	<0.001	0.220
Fungicide*TIME	0.054	0.922	0.250	0.807

Fungicide = Prosaro and Caramba applied at low and high rates (6.5 and 8.2 fl. oz./A for Prosaro and 13.5 and 17 fl. oz./A, for Caramba).
Time: Time of fungicide application - anthesis or 2, 5 or 7 days after anthesis

Table 3. Probability values for pairwise differences of least square means from linear mixed model analyses of the effect of cultivar and fungicide timing on arcsine-transformed FHB incidence (INC), index (IND), *Fusarium* damaged kernels (FDK) and log-transformed deoxynivalenol (DON) grain contamination and grain yield (YLD) in soft red winter wheat in Ohio.

Contrast	IND	FDK	DON	YLD
Check vs A	0.013	<0.001	0.002	0.001
Check vs A+2	<0.001	<0.001	<0.001	<0.001
Check vs A+4	<0.001	<0.001	<0.001	0.001
Check vs A+6	0.319	0.001	<0.001	0.001
A vs A2	<0.001	0.087	0.001	0.001
A vs A4	0.002	0.844	0.026	0.927
A vs A6	0.120	0.449	0.063	0.977
Hopewell vs Bromfield	0.010	<0.001	0.001	0.362
Hopewell vs Malabar	<0.001	<0.001	<0.001	0.016
Hopewell vs Truman	<0.001	<0.001	<0.001	0.195
Truman vs Bromfield	<0.001	<0.001	0.002	0.670
Truman vs Malabar	0.003	0.016	0.569	0.153
Bromfield vs Malabar	0.015	0.001	0.005	0.077

Check = untreated and A = fungicide application at anthesis or 2 (A+2), 4 (A+4) or 6 (A+6) days after anthesis. Hopewell, susceptible; Bromfield, moderately susceptible; and Truman and Malabar, both moderately resistant.

Table 4. Probability values for pairwise differences of least square means from linear mixed model analyses of the effect of fungicide and application timing on arcsine-transformed FHB incidence (INC), index (IND), *Fusarium* damaged kernels (FDK) and log-transformed deoxynivalenol (DON) grain contamination and grain yield (YLD) in soft red winter wheat in Ohio

Contrast	IND	FDK	DON	YLD
Check vs A	<0.001	<0.001	<0.001	<0.001
Check vs A+2	<0.001	<0.001	<0.001	<0.001
Check vs A+5	<0.001	<0.001	<0.001	<0.001
Check vs A+7	<0.001	<0.001	<0.001	<0.001
A vs A2	<0.001	0.047	0.003	0.379
A vs A5	<0.001	<0.001	<0.001	0.164
A vs A7	0.001	0.063	0.002	0.595
Prosaro low vs Prosaro high	0.049	0.550	0.019	0.128
Prosaro low vs Caramba low	0.003	0.048	0.297	0.730
Prosaro low vs Caramba high	0.449	0.487	0.436	0.172
Prosaro high vs Caramba low	<0.001	0.017	0.003	0.219
Prosaro high vs Caramba high	0.014	0.211	0.072	0.851
Caramba low vs Caramba high	0.009	0.153	0.087	0.288

Check = untreated and A = fungicide application at anthesis or 2 (A+2), 4 (A+5) or 6 (A+7) days after anthesis. Prosaro and Caramba applied at low and high rates (6.5 and 8.2 fl. oz./A for Prosaro and 13.5 and 17 fl. oz./A, for Caramba).

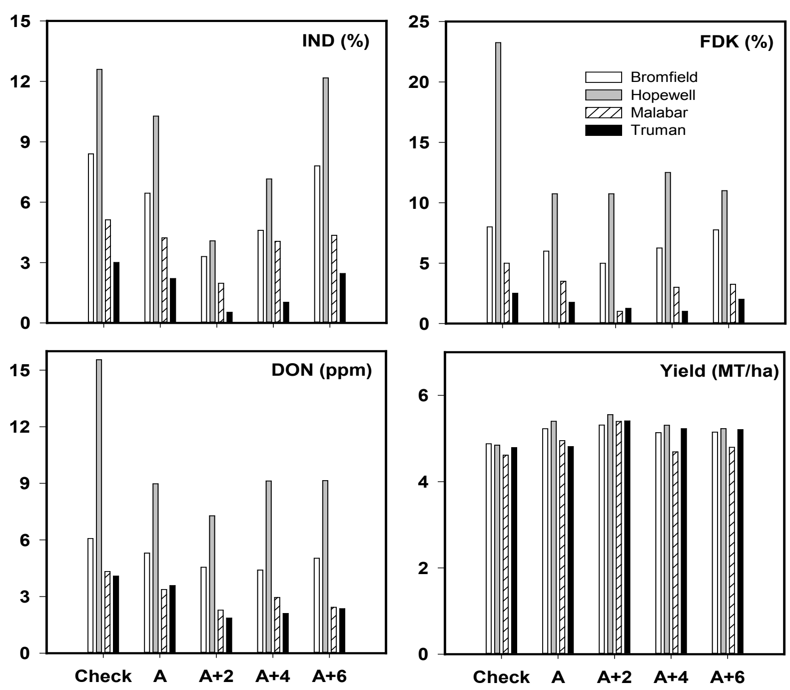

Fig. 1. Mean FHB index (IND), FDK, DON and grain yield from untreated (Check) and Prosaro-treated (6.5 fl oz/A) plots of soft red winter wheat cultivars Bromfield (moderately resistant), Hopewell (susceptible), and Malabar and Truman (moderately resistant). Treatments were made at anthesis (A), or 2, 4, or 6 days post-anthesis (A+2, A+4 or A+6, respectively).

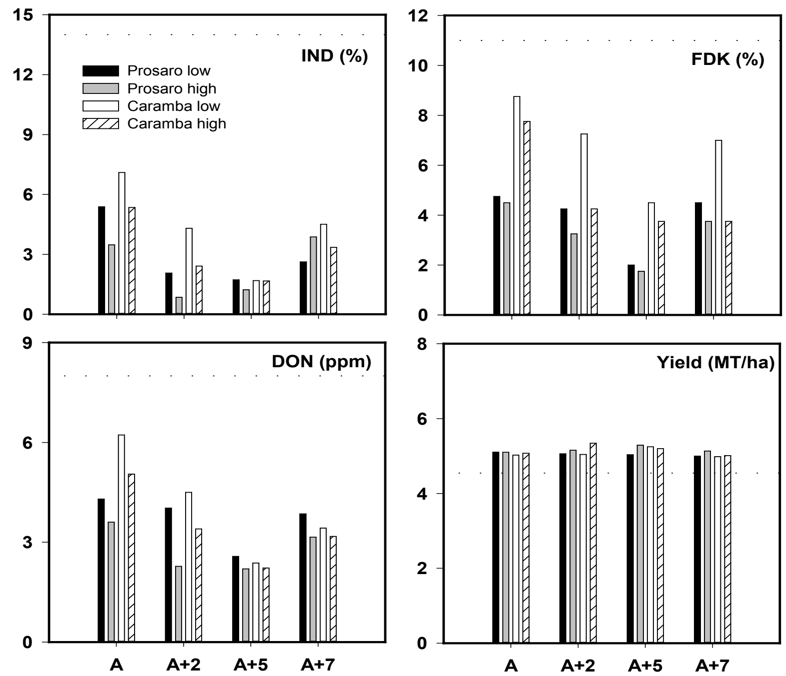

Fig. 2. Mean FHB index (IND), FDK, DON and grain yield from plots of susceptible cultivar Hopewell treated with four fungicide-rate combinations: Prosaro at low and high rates (6.5 and 8.2 fl. oz./A) and Caramba at high and low rates (13.5 and 17 fl. oz./A, respectively). Treatments were applied at anthesis (A) or 2, 5, or 7 days post-anthesis (A+2, A+5 and A+7, respectively). Dashed line indicates untreated check values.

WEATHER TIME SERIES CURVES IN RELATION TO FUSARIUM HEAD BLIGHT EPIDEMICS

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ABSTRACT

Our long term goal is to develop and deliver predictive models for Fusarium head blight (FHB) epidemics in the U.S. The current FHB observational data matrix was updated to include data from 2010 onwards sent by collaborators participating in U.S. Wheat & Barley Scab Initiative (USWBSI) FHB coordinated integrated management projects. The new data expanded the data matrix from 527 to 865 observations, a 64% increase. Sixteen states are now represented, with 74% of the observations coming from winter wheat and the remainder from spring wheat. FHB epidemics, defined as FHB index ≥ 10% (this threshold having been determined by observing the most susceptible varieties), had occurred in 236 of the observations. No FHB (i.e. FHB index = 0) was recorded in 184 of the remaining 629 observations. Latitude and longitude coordinates associated with each location-year were used to identify the closest reporting weather station with air temperature, dew point and pressure data. Weather data, from September 01 of the year preceding anthesis to 30 days post-anthesis, were downloaded via Mathematica scripts, and summarized to hourly data after data integrity checks and cleaning. Missing values were imputed by interpolation or by an algorithm designed specifically for multivariate time series. Relative humidity and vapor pressure deficit were calculated from temperature and dew point. The hourly weather data were summarized to daily values. Mean curves for epidemics and non-epidemics were then plotted for the period beginning 120 days before anthesis and ending 20 days post-anthesis. During this period, mean daily temperature and dew point increased approximately linearly, with some apparent separation between the temperature curves a few days on either side of anthesis. Pressure showed a decreasing trend during this period, with multiple crossing-overs between the epidemic and non-epidemic curves. With relative humidity, there was a clear and consistent separation between the mean epidemic and non-epidemic curves, beginning around 35 days pre-anthesis and continuing into the post-anthesis period, with the epidemic relative humidity curve being above the non-epidemic curve. Similarly, for vapor pressure deficit, the mean epidemic curve was consistently below the non-epidemic curve from about 17 days pre-anthesis through 20 days post-anthesis. These exploratory time series analyses suggest that the signal capturing the difference between FHB epidemics and non-epidemics is strongest in moisture-related variables, beginning about 3 to 4 weeks pre-anthesis and extending as far as 3 weeks into the post-anthesis period.

ACKNOWLEDGEMENT AND DISCLAIMER

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UNIFORM FUNGICIDE TRIAL RESULTS FOR MANAGEMENT OF FHB AND DON, 2014

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ABSTRACT

Data from prior USWBSI-funded uniform fungicide trials have shown that DMI fungicides Caramba® 90 SL, Prosaro® 421 SC were two of the most effective products against FHB and DON. However, for the grower these products can be relatively expensive. Tebuconazole fungicide is now off-patent, and several “generic” formulations are available at relatively low costs (some reports of less than $3 per acre). In years where the risk of scab is predicted as low, and growers have fields planted to moderately FHB resistant varieties, many are making the economic decision to use generic tebuconazole products. The aim of this project was to compare generic formulations of tebuconzole products to evaluate any differences in efficacy and to examine bio control formulations for the suppression of FHB. Trials were conducted at multiple locations across six states (Arkansas, Illinois, North Dakota, South Dakota, Minnesota and New York) in 2014. All sites were inoculated with *Fusarium graminearum* infested corn spawn, infested residue, or spray inoculation with spores at flowering. In several locations, mist irrigation was used to promote disease development. Eleven common treatments were evaluated across locations; Prosaro, Caramba, Monsoon, Muscle, Onset, Orius, Tebustar, Toledo, Aproach, Aproach Prima and the biological control Taegro in combination with Prosaro. Additional rates of Caramba and/or Prosaro were tested. All treatments were applied at Feekes 10.5.1 (early anthesis). Preliminary analysis of the data revealed that all treatments helped reduce the incidence of FHB in comparison with plots that received no fungicide application. The fungicides Caramba and Prosaro appeared to provide the best control of FHB, yield increase and reduction in DON for those locations which reported DON levels. Not all generic tebuconazole products (Monsoon, Muscle, Onset, Orius, Tebustar and Toledo) performed equally across all locations.

ACKNOWLEDGEMENT AND DISCLAIMER

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