SESSION 5:

FHB MANAGEMENT

Co-Chairpersons: Larry Madden and
Stephen Wegulo

NON-CHEMICAL APPROACH FOR CONTROL OF FUSARIUM HEAD BLIGHT OF WHEAT

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ABSTRACT

Fusarium head blight (FHB) is a serious disease worldwide, of economic importance. FHB of wheat and other cereals in Kazakhstan is mainly caused by *Fusarium graminearum* and/or *F.culmorum*. Both pathogens are of moderate virulence. Nevertheless, they can cause yield decrease and grain quality. Traditionally applied synthetic fungicides are of high cost and not ecologically safe. Thus, effective, low cost and environmentally friendly control agents are of significant importance. Several species of *Brassicaceae* are known as suppressive agent of plant pathogenic fungi, especially of soil-borne ones. This study provides a novel approach to manage FHB based on alternative non-chemical strategy of biofungicide search. A laboratory bioassays and a field experiment were conducted over 3 years to evaluate efficacy of ground horseradish (*Armoraceae lapathifolia*) tuber tissue atmosphere and squeezed juice as a biocontrol agent. Three variants in vitro bioassays were made with *F. graminearum*, *F. culmorum* and *Bipolaris sorokiniana* strains: i) on PDA medium amended with ground horseradish tuber mass; ii) on PDA plates with two 0,5 cm diameter wells filled with squeezed juice mixed with water 1:1 (v/v); iii) PDA plates with fungal cultures exposed to horseradish tuber tissue atmosphere. Control constitutes plates with fungal strains only. Radial growth of cultures incubated at 23ºC after 7 d was 3 (i), 2,5 (ii), and 1,5 (iii) cm, respectively. Surface of control plates by 7th d was fully covered with mycelium mat. Light microscope observation revealed deformed hyphae, swollen tips and weakly germinating conidial aggregates compared to profuse sporulating culture and actively germinating conidia in control plates. Results made in collaboration with wheat growers have shown that seeds treated with squeezed juice mixed with water and seed lot placed for 7 hrs under the atmosphere of ground horseradish tuber tissue germinated in field condition up to 100%, plants were healthy. Seed treatment reduced FHB (up to 75%), and yield increased over 60-65%, grain were high in weight. Together our results suggest the potential for *Brassicaceae* species to use as ecologically safe and effective antifungal agents.

EFFECT OF *FUSARIUM GRAMINEARUM* CHEMOTYPES 3ADON AND 15ADON AND FUNGICIDE APPLICATION ON FUSARIUM HEAD BLIGHT (FHB) DEVELOPMENT AND DON PRODUCTION IN SPRING WHEAT UNDER NORTH DAKOTA FIELD CONDITIONS IN 2011

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ABSTRACT

Two wheat cultivars, Alsen (with the *Fhb1* gene for FHB resistance) and Briggs (FHB susceptible), were planted in randomly complete block design with a split plot arrangement and three replications at the NDSU Research Station at Fargo on May 18. The plot size was 10×10 feet and each plot was separated with a 20 feet strip of Alsen to minimize the chances of inoculum interferences among the treatments. Three plots of each cultivar treated with or without fungicide were spray inoculated with a spore suspension of 100K spores/ml containing a mixture of 10 isolates of 3ADON chemotype or 15ADON chemotype or a mixture of both chemotypes at the mid-flowering stage (Feekes GS 10.52). For the fungicide treated plots, Prosaro™ (prothioconazole + tebuconazole, 6.5fl oz/acre) was sprayed four hours prior to inoculations at 8:30 pm. FHB disease parameters were recorded at late milk to early dough stage (Feekes GS 11.1-11.2). One hundred heads within each plot were randomly rated for disease. Fifty diseased heads in each plot of all treatments were tagged at the time of disease rating, and then harvested at the crop maturity. These samples were thrashed, ground and submitted to the Veterinary Diagnostic Lab at NDSU for DON analysis. In plots not treated with fungicide, the FHB severity of Alsen and Briggs were significantly higher in the treatments inoculated with the mixture of 3ADON isolates (mean disease severity = 12.8% and 42.5%, respectively) and with the mixture of the two chemotypes isolates (mean disease severity = 9.6% and 36.3%, respectively) than those with the mixture of the 15ADON isolates (mean disease severity = 8.6% and 30.4%, respectively). For untreated, inoculated plots, the DON levels were higher in inoculation with the 3ADON isolates (29.7 ppm in Alsen, 39.7 ppm in Briggs), as compared to inoculations with the 15ADON isolates (9.0 ppm in Alsen, 15.9 ppm in Briggs). In the plots treated with the fungicide, the disease incidence, severity, and DON were significantly lower as compared to non-fungicide treated plots, regardless of which chemotype was used as the source of inoculum. Our study indicates that the 3ADON population is more aggressive than 15ADON population in FHB development and should be considered in screening for resistance, and that fungicides are effective against both chemotypes.

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INFLUENCE OF VARIABLE MISTING PATTERNS ON FUSARIUM HEAD BLIGHT AND DON IN SOFT RED WINTER WHEAT

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ABSTRACT

FHB intensity and DON contamination of wheat are dependent on environmental conditions, most notably moisture. Pre-anthesis moisture drives inoculum production, while moisture during anthesis promotes spore germination and infection of wheat spikes. Post-anthesis moisture affects DON accumulation and may also contribute to secondary infections. The majority of research to date, including research on FHB risk prediction, has focused on the effects of continuous moisture on FHB and DON. There is circumstantial evidence suggesting that discontinuous moisture also affects the development of FHB and accumulation of DON. However, there is very little quantitative, research-based information on the effects of different intermittent moisture patterns on FHB and DON. A field trial was established during the 2010/11 wheat-growing season to examine the effects of intermittent moisture before, during, and after anthesis on FHB and DON in soft red winter wheat (SRWW). A moderately susceptible SRWW variety (Hopewell) was planted on three different dates to stagger anthesis (PD1, PD2 and PD3) and four 7-day supplemental misting treatments were employed in the spring (Mist_1: mist every day; Mist_2: 2 days of mist, 3 days off, 2 days of mist; Mist_3: 2 days off, 3 days of mist, 2 days off; Mist_4: mist every other day). Misting treatments occurred before, during, and after anthesis for PD3, PD2 and PD1, respectively. In addition to a control (ambient inoculum), colonized corn kernels or corn stalks were spread in plots as an inoculum source. Head washes were used to estimate inoculum levels as a result of each PD x Mist x Inoculum combination at the end of the 7-day mist treatment period. FHB incidence and index were estimated approximately 3 weeks post-anthesis for PD3 and DON was quantified post-harvest. Anthesis occurred on May 28, 30 and June 2 for PD1, PD2 and PD3, respectively; while misting treatments were assigned from May 26 to June 1. Ambient rainfall totaled approximately 80 mm from May 23 to 26. In addition to ambient rainfall, Mist_1-4 delivered approximately 286, 145, 83 and 144 mm of total precipitation during the 7 days. In general, spike inoculum density, incidence, index and DON decreased with planting date, suggesting precipitation immediately following anthesis also has a positive effect on FHB development and DON contamination, in addition to pre-anthesis moisture. Considering PD1, in which treatments primarily occurred post-anthesis, incidence, index and DON were all greatest as a result of Mist_1 and similar for the other mist treatments. Regardless of treatment and inoculum source, DON was > 2 ppm in all plots of PD1. Considering PD2, in which anthesis occurred during intermittent misting treatments, MIST_1 also had the highest mean levels of incidence, index and DON. For both PD1 and PD2, FHB incidence and index as a result of Mist_2, 3 and 4 were not considerably different from that observed under ambient conditions. For PD3, in which intermittent misting treatments concluded immediately prior to anthesis, plots receiving corn stalk inoculum generally had the highest levels of incidence, index and DON, within each misting treatment. Of those corn stalk plots, Mist_1 and 4 consistently had the highest levels of incidence (> 30%), index (> 8%) and DON (> 5 ppm). Although Mist_2 and 3 had relatively low FHB symptoms (< 3% index), these treatments resulted in > 5 and > 2 ppm DON, respectively. This work suggests that the pattern of intermittent moisture before and after anthesis may differentially affect FHB development and DON accumulation, and as a result should be considered when developing FHB/DON risk prediction models.

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EFFECTS OF LOCAL CORN DEBRIS MANAGEMENT ON FHB AND DON LEVELS IN SEVEN U.S. WHEAT ENVIRONMENTS IN 2011

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ABSTRACT

Reduction or elimination of within-field sources of inoculum of *Gibberella zeae* is the basis for cultural control measures such as crop rotation sequences in which cereals follow non-cereal crops. In USWBSI-supported microplot experiments conducted in twenty-one winter wheat fields over five states in 2009 and 2010, DON level differed significantly between corn debris and no debris microplots in only one location, strongly suggesting that regional atmospheric inoculum is the strongest contributor to infection even when corn debris is present in a wheat field. Small area sources of debris, however, may result in an underestimation of the contribution of spores from a larger field of corn debris to FHB and DON. The goal of the current USWBSI research project is to provide realistic estimates of 'DON reduction' that can be expected from cultural controls that reduce within-field inoculum sources. We utilized moldboard plowing of corn debris as a proxy for planting after a non-cereal crop to compare directly with wheat planted no-till into corn debris in commercial-scale wheat fields planted following grain corn harvest in Illinois, Kentucky, Michigan, Missouri, Nebraska, New York, and Vermont. Following corn harvest in 2010, replicated wide (60 ft) strips were moldboard plowed or left non-plowed prior to sowing wheat over the entire field with a no-till drill. Wheat in each strip was monitored for FHB and sampled for laboratory quantification of head infection by *Gibberella zeae* and contamination of grain by DON in 2011. Results from year one of this research project with winter wheat in six states (IL, KY, MI, MO, NE, and NY) and spring wheat in one state (VT) are shown in Fig. 1. FHB symptoms at soft dough stage were low to moderate at every location except Missouri. Yet, at crop maturity, a high percentage of wheat heads was found to be infected by *G. zeae* in all locations except Nebraska and Vermont. Measurable DON was found in grain from every environment and the levels were lowest in Vermont and highest in Kentucky and Nebraska. It is interesting that the Nebraska site showed the lowest disease index and lowest incidence of head infection, but the highest average toxin level. Moldboard plowing resulted in a significant decrease in FHB index in four environments (IL, MO, NY, MI), though the magnitude of the difference was large only in Missouri. In Nebraska, FHB index was significantly higher in the moldboard-plowed treatment in which the wheat crop matured earlier than in the no-till corn debris treatment. Moldboard plowing was associated with a small but significant decrease in recovery of *G. zeae* from mature heads in three environments (IL, MI, NY). There was no significant effect of plowing on DON level in five environments (IL, KY, MO, NY, VT) and there were small, but significant decreases in toxin in moldboard-plowed compared to no-till strips in two environments (MI and NE). An additional treatment of minimum tillage (chisel plow) was added in the Michigan experiment; DON levels in the minimum-till plots were intermediate between moldboard and no-till but not significantly different from no-till. There is a strong trend in year one data suggesting that inoculum from area atmospheric sources exerts a far greater effect than inoculum from in-field corn

residue on the level of DON contamination. A second year of experimentation in seven additional wheat environments in 2012 will provide increased evidence of the magnitude of the effect of corn residue management on DON reduction.

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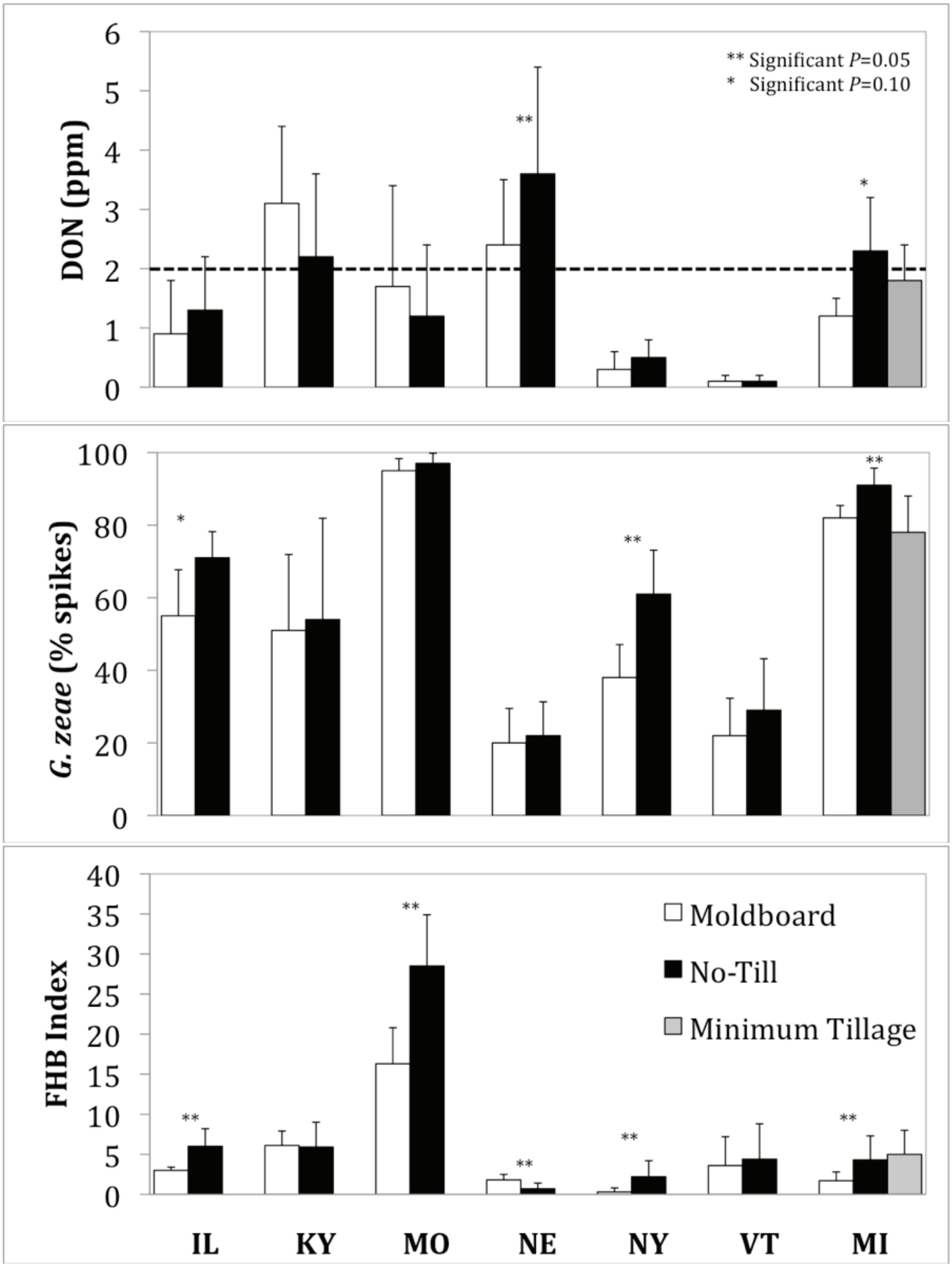

Figure 1. Effects of corn debris management by plowing on FHB parameters in wheat (FHB index at soft dough stage; incidence of infection by *G. zeae* in mature heads; and deoxynivalenol contamination in harvested grain) in experiments in seven states in 2011.

2011 TRIAL OF THE PERFORMANCE OF SELECTED BIOLOGICAL CONTROL AGENTS FOR THE SUPPRESSION OF FUSARIUM HEAD BLIGHT IN SOUTH DAKOTA AND NORTH DAKOTA

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ABSTRACT

Fusarium Head Blight (FHB, or scab) remains a potential problem for wheat and barley producers in South Dakota and North Dakota. The objective of this study was to continue evaluating the efficacy of selected biological control agents (BCAs), alone or in combination with fungicide, that can suppress different measures of FHB under field conditions in the Dakotas. Briggs hard red spring wheat was planted at Brookings, SD. Trial treatments included an untreated check; the fungicide premix Prosaro®; *Bacillus* strain 1BA; *Bacillus* strain 1D3; a combination of *Bacillus* strain 1BA and *Bacillus* strain 1D3; and combinations of Prosaro with one or more of the *Bacillus* BCAs. Chelated manganese was added to the spray mix for some treatments. All treatments were applied at anthesis. Plots were treated with pathogen by spreading *Fusarium graminearum* (isolate Fg4) inoculated corn (*Zea mays*) grain throughout the field, and applying overhead mist irrigation each day for 10 days following anthesis. Following the treatments, plots were evaluated for FHB incidence, FHB head severity, and FHB field severity. Plots were harvested for yield and test weight and samples were collected for *Fusarium* damaged kernels (FDK) and deoxynivalenol (DON). Similar treatments and analyses were conducted in Langdon, ND.

In Brookings, SD, grain yield was about 20 bushel/acre or less, much less than for average years, probably due in large part to high moisture, as well as other diseases than FHB being present. Damage due to Bacterial Blight and Black Chaff was widespread, and may have caused excessive damage to the vascular and photosynthetic apparatus of the wheat. Readings of FHB effects in the wheat were difficult to make due to the excessive bacterial disease. No DON was detected in the grain. Grain yield and measures of FHB from our BCA treatments at Langdon, ND were more normal and/or evident, and will be reported.

EFFECT OF SEED TREATMENT OF SCABBY SEED ON PLANT STANDS AND GRAIN YIELDS OF WINTER WHEAT

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ABSTRACT

Fusarium head blight (FHB) is a serious disease of small grains such as wheat. Significant losses can occur due to the blighting of many heads in the field. Besides limiting production in the head, harvested grain can contain *Fusarium*-damaged ("scabby") kernels that can display white or pink discoloration. Kernels from a field that has been affected by FHB may be alive and healthy, dead, or infected by the fungal pathogen although alive. If a seed lot is sown that has viable, infected kernels, the fungus can become active in the moist soil and rot the seed or kill the young seedling resulting in reduced or weak stands. The goal of this research was to determine if fungicide seed treatment of scabby wheat seed could increase plant stands and grain yields. Seven winter wheat field experiments were established near Manhattan, Kansas during 2008-2011; two experiments each year except 2011 which had only one experiment. Scabby seed was obtained from inoculated FHB phenotyping nurseries established by the authors. The amounts of *Fusarium*-damaged kernels in the seed were relatively high (10-40%). Besides the non-treated check, each experiment had three to nine seed treatments, most with currently-labeled chemicals. Experimental design was a randomized complete block with plots 5' by 15' and five replications. Plots were sown around the first week of October which is the optimum planting date for Riley County in Kansas. Plant stands were determined after full emergence by counting all emerged plants in the center row of each plot. Upon maturity, grain yields were determined with a small-plot combine. In five of the seven experiments, there were significant ($P<0.10$) increases in plant stands with seed treatment. In two experiments, increases averaged over 50%. The average stand increase over all experiments was about 26%. Despite significant increases in stand, there were no significant increases in yield for any experiment. However, the average (non-significant) yield increase was 1.0 bu/A which, if real, would more than offset the cost of the treatment. In conclusion, fungicide seed treatments can significantly increase stands with scabby seed but do not consistently result in a grain yield increase.

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ASSESSING THE BEST FUNGICIDE APPLICATION TIMING FOR FUSARIUM HEAD BLIGHT AND MYCOTOXIN MANAGEMENT

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ABSTRACT

Previously conducted research has identified the demethylation inhibitor (DMI) fungicide products Caramba® (metconazole; BASF Corp.) and Prosaro® (prothioconazole + tebuconazole; Bayer CropScience) as being the most efficacious products for management of Fusarium head blight (FHB) and the associated mycotoxin deoxynivalenol (DON) of all the fungicide products currently registered for use on wheat in the United States. Current recommendations for use of these fungicide products for FHB and DON management are that they be applied at the beginning of anthesis (Feekes growth stage – FGS – 10.5.1). In a "real-world" setting, wheat producers may not be able to time a fungicide application according to the "perfect" growth stage due to several constraints that include unfavorable weather, lack of flexibility in reserving a professional applicator, and variability in wheat growth and development within a field. Multi-state research funded by the USWBSI evaluated Caramba and Prosaro fungicides for their effect on FHB and DON when applied at three different growth stages (FGS 10.5, 10.5.1, and 5 days following 10.5.1) in 2010. Across all locations combined, the mean control of FHB with Caramba was 43%, 54%, and 41% for FGS 10.5, 10.5.1, and 5 days following 10.5.1, respectively. Across all locations combined, the mean control of DON with Caramba was 15%, 45%, and 41% for FGS 10.5, 10.5.1, and 5 days following 10.5.1, respectively. For Prosaro, the mean control of FHB was 28%, 53%, and 42% for FGS 10.5, 10.5.1, and 5 days following 10.5.1, respectively. The mean control of DON with Prosaro was 34%, 25%, and 45% for FGS 10.5, 10.5.1, and 5 days following 10.5.1, respectively. An additional study was conducted at the University of Illinois in 2011, where Prosaro or Caramba was applied to wheat at FGS 10.5.1, 3 days following 10.5.1, or 6 days following 10.5.1. In this study, wheat heads in all plots were inoculated with a *Fusarium graminearum* conidial suspension at FGS 10.5.1 (approximately 6 hours after FGS 10.5.1 fungicide applications were made). Results from this research indicated that FHB was significantly reduced ($P \leq 0.05$) by all fungicide treatments when compared to the non-treated control; however Caramba and Prosaro applied at FGS 10.5.1 provided the greatest control of FHB (93.7% and 93.4%, respectively). None of the treatments significantly reduced DON compared to the non-treated control in this study. In general, FGS 10.5.1 appears to be the most effective timing for control of FHB and DON, but applications made a few days after FGS 10.5.1 may also provide a benefit in reducing FHB and DON levels.

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EFFECTS OF TRIAZOLE, STROBILURIN, AND TRIAZOLE + STROBILURIN FUNGICIDES ON FUSARIUM HEAD BLIGHT AND ASSOCIATED MYCOTOXINS

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ABSTRACT

A multi-state research project was conducted across nine states (Arkansas, Illinois, Indiana, Maryland, Michigan, Minnesota, North Dakota, South Dakota, and New York) encompassing five wheat market classes (durum, hard red spring, hard red winter, soft red winter, and soft white winter) to evaluate the effects of triazole, strobilurin, and triazole + strobilurin fungicides on Fusarium head blight (FHB) and associated mycotoxins. Previously conducted research has indicated that the strobilurin fungicide pyraclostrobin (Headline) can increase FHB-associated mycotoxins such as deoxynivalenol (DON) and nivalenol (NIV). Because of this, strobilurin fungicides are not recommended for FHB control, but they still are valuable tools for controlling leaf diseases. One component of our research was to evaluate other strobilurin fungicides, such as azoxystrobin (Quadris) and fluoxastrobin (Evito), to determine if they also can increase FHB-associated mycotoxins. In addition, strobilurin + triazole mixtures (trifloxystrobin + prothioconazole, Stratego YLD; azoxystrobin + propiconazole, Quilt Xcel; and pyraclostrobin + metconazole, Twinline) as well as a sequential treatment of pyraclostrobin followed by the triazole fungicide metconazole (Caramba®) were evaluated to determine if triazole fungicides would negate any increases in mycotoxin levels due to the strobilurin fungicides. Headline applied at Feekes' growth stage (FGS) 9 or 10.5 significantly ($P \leq 0.05$) increased DON levels when compared to the non-treated control in 2 out of 12 locations and 2 out of 9 locations tested, respectively. When Caramba was applied (FGS 10.5.1) following a FGS 9 application of Headline, neither DON or NIV (NIV was evaluated only in Arkansas) levels were significantly greater than the non-treated control at any of the locations, but DON levels were significantly less than the non-treated control with this combination treatment at 5 out of 12 locations. Quadris and Evito (FGS 10.5) significantly increased DON levels over the non-treated control at 1 out of 9 and 2 out of 9 locations, respectively. When the strobilurin + triazole fungicide products, Stratego YLD, Quilt Xcel, and Twinline, were evaluated (FGS 10.5), they increased DON levels over the non-treated control at 1 out of 12, 2 out of 12, and 2 out of 11 locations, respectively. In light of our results, there is a risk of increasing DON levels when solo strobilurin products or strobilurin + triazole products are applied to wheat. However, it does appear that if a strobilurin fungicide was applied at FGS 9 and followed with an effective triazole application at FGS 10.5.1, that the strobilurin effect on DON was negated.

Previously conducted research has shown that Caramba and Prosaro® fungicides are the most effective in reducing FHB and associated mycotoxins. Another objective of our research was to evaluate the experimental fungicide A9232D (Syngenta Crop Protection) for control of FHB and mycotoxins and compare

its performance with the industry standards, Caramba and Prosaro (all applied at FGS 10.5.1). A9232D significantly decreased DON levels compared to the non-treated control at 4 out of 13 locations, whereas Caramba and Prosaro both significantly decreased DON at 6 out of 13 locations. A9232D, Caramba, and Prosaro significantly reduced FHB index compared to the non-treated control at 9 out of 21 locations; however, the level of control achieved with A9232D was equal to the level of control with either Caramba or Prosaro at only 7 of these locations. In general, our research indicates that A9232D at the rate used in these trials does have efficacy for control of FHB and DON, but it may not be quite at the same level as the industry standards, Caramba and Prosaro.

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INFLUENCE OF FUSARIUM HEAD BLIGHT MANAGEMENT PRACTICES ON MYCOTOXINS IN WHEAT STRAW

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ABSTRACT

The effect of crop rotation, foliar fungicides, and resistant cultivars have been evaluated for their effects on mycotoxins in grain associated with Fusarium head blight (FHB) of wheat; however, little is known about how these FHB management practices affect mycotoxins in wheat straw. The occurrence of high mycotoxin levels in grain is considered a major problem for wheat producers and millers, but high mycotoxin levels in wheat straw also could be a serious problem for livestock producers who use wheat straw for bedding in their livestock facilities. This could be most detrimental to non-ruminant animals such as swine sows, which can eat 2 to 4 kg of wheat straw bedding per day. Research trials were conducted in Illinois to determine mycotoxin levels present in wheat straw (stems only) and if typical FHB management practices had an effect on mycotoxin levels. To determine the mycotoxin levels, stem samples were collected immediately after harvest, were ground into small particles, and then sent to the University of Minnesota mycotoxin testing lab.

Fungicide trials were conducted at four locations in Illinois (Brownstown, Dixon Springs, Monmouth, and Urbana) to determine the effects of Headline® (pyraclostrobin; BASF Corp.), Caramba® (metconazole; BASF Corp.), Prosaro® (prothioconazole + tebuconazole; Bayer CropSciences), and Folicur® (tebuconazole; Bayer CropSciences) on mycotoxins in wheat straw. All locations were planted into corn stubble and were mist-irrigated. Headline was applied at Feekes growth stage (FGS) 9, while all other fungicides were applied at FGS 10.5.1. Ranges of DON, 3ADON, 15ADON, NIV, and ZEA at these locations were 0.6-104.6 ppm, 0.01-5.7 ppm, 0.1-17.8 ppm, 0-1.6 ppm, and 0-1.3 ppm, respectively. When averaged over all locations, none of the fungicides decreased mycotoxin levels compared to the non-treated control, but Headline fungicide significantly ($P \leq 0.10$) increased 3ADON and 15ADON compared to the non-treated control.

Non-irrigated FHB integrated management trials designed to evaluate cultivar (susceptible vs. moderately-resistant) × fungicide (Prosaro vs. non-treated) effects (Dixon Springs and Monmouth) and cultivar × fungicide × previous crop (corn vs. soybean) effects (Urbana) were conducted. Ranges of DON, 3ADON, 15ADON, NIV, and ZEA at these locations were 0.1-5.1 ppm, 0-0.19 ppm, 0-0.82 ppm, 0-0.5 ppm, and 0-1.5 ppm, respectively. Foliar fungicides did not affect mycotoxin levels, but the susceptible cultivar (Pioneer 25R47) generally had higher DON levels compared to the moderately resistant cultivar (BW5228). At the Urbana trial, the susceptible cultivar planted into corn stubble had a significantly greater DON level than when planted into soybean stubble.

A mist-irrigated fungicide (non-treated, Prosaro, Caramba) × cultivar (susceptible vs. moderately resistant) trial was conducted at Urbana. Ranges of DON, 3ADON, 15ADON, NIV, and ZEA in this trial were 6.8-33.5 ppm, 0.3-1.3 ppm, 0.9-10.1 ppm, 0-0.3 ppm, and 0-0.06 ppm, respectively. The moderately resistant cultivar (BW5228) had significantly lower levels of DON and 15ADON than the susceptible cultivar

(Pioneer 25R47). Foliar fungicides significantly reduced DON levels compared to the non-treated controls for both cultivars, but fungicides significantly reduced 15ADON levels only in the susceptible cultivar.

A mist-irrigated cultivar evaluation trial was conducted at Urbana. Ranges of DON, 3ADON, 15ADON, and ZEA at these locations were 8.9-54.1 ppm, 0.6-3.1 ppm, 4.9-16.6 ppm, and 0-0.5 ppm, respectively. No NIV was detected in this trial. Significant differences in levels of DON, 3ADON, and 15ADON were observed among the cultivars. A significant, positive Spearman correlation ($P = 0.0001$; $R = 0.50$) was detected between DON levels observed in straw and DON levels observed in grain, indicating that a cultivar's FHB resistance level may play a role in the level of DON observed in the straw.

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EVALUATION OF HOST PLANT RESISTANCE AND FUNGICIDE TREATMENT FOR SUPPRESSION OF FUSARIUM HEAD BLIGHT

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ABSTRACT

Researchers and breeders have been challenged by the U.S. Wheat and Barley Scab Initiative to find a solution for managing Fusarium head blight (FHB; caused by *F. graminearum*) in the United States. Especially important is keeping the mycotoxin, deoxynivalenol (DON), level below the threshold of 2 ppm in the grain, so that it may be used for human consumption. Fungicide technology is improving and fungicides in the demethylation inhibitor (DMI) class have proven to be the most effective in managing FHB, although results are variable. Caramba® (metconazole; BASF) and Prosaro® (tebuconazole + prothioconazole; Bayer CropScience) are currently the most effective fungicides available for reducing FHB and deoxynivalenol (DON) in the U.S. Planting a FHB-resistant cultivar is another management tool for producers; however, neither fungicide nor resistant cultivar can provide complete control. Our objective was to evaluate the effectiveness of two foliar applied fungicides and host plant resistance on suppression of FHB, DON accumulation, yield, and test weight. The experiment was a split-plot design with fungicide treatment as the main plot and cultivar as the sub-plot, blocked into four replications and repeated in two years. An inoculated, mist-irrigated disease nursery was used to evaluate Caramba and Prosaro fungicides, and twelve wheat cultivars ranging from susceptible to resistant to FHB. Data were collected on FHB incidence, severity, *Fusarium* damaged kernels (FDK), DON, yield, and test weight. FHB index and incidence/severity/kernel quality index (ISK index) were also calculated. In individual non-treated plots, FHB incidence ranged from 23% to 100% thereby confirming high disease pressure and varying cultivar FHB resistance levels. Averaged over all cultivars, both Caramba and Prosaro resulted in significantly ($P < 0.001$) greater yield and test weight, and significantly lower FHB incidence, severity, FHB index, FDK, ISK index, and DON compared to the non-treated control. No significant difference was found between Caramba and Prosaro for any variable measured. When the cultivars were split into a resistant and a susceptible group, FHB-resistant cultivars significantly ($P < 0.0001$) outperformed the FHB-susceptible cultivars, regardless of the fungicide treatment, for all parameters. In the non-treated plots, FHB–resistant cultivars had higher yield (15.4 bu/A) and test weight (5.6 lbs/bu.), and FHB index was reduced by 51%, FDK by 78%, and DON by 59% when compared to the FHB-susceptible cultivars. Notably, IL06-13708 and IL01-11934 yielded significantly ($P < 0.05$) more in the non-treated plots than Sisson when treated with either fungicide. Also, the most FHB-resistant cultivar, IL02-18228, was the only cultivar to not realize a significant yield increase from the addition of fungicides. No single cultivar or fungicide individually reduced DON below 1ppm; however, the combination of the most FHB-resistant cultivars, IL01-16170 and IL02-18228, and the fungicide Caramba reduced DON, on average, below 1 ppm. Based on our results from this test and a similar, previous test, we can conclude that under severe FHB pressure, wheat producers can produce high yields of sound grain by using cultivars with high FHB resistance levels in combination with either Caramba or Prosaro fungicide.

A TIME COURSE OF SCAB IN DEVELOPING FIELD-GROWN WHEAT SPIKES

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ABSTRACT

Although the relationship of visual FHB symptoms (e.g., index) to levels of deoxynivalenol (DON) and *Fusarium*-damaged kernels (FDK) in mature grain has been well studied, little is known about the time course of DON levels in wheat spikes over the period from infection to harvest. This is of interest because whole small-grain plants may be harvested at the milk, soft-dough, or medium-dough stages for silage production. Also, wheat and barley straw is used as litter for turkey and swine production, and swine may consume their bedding. In addition, cereal straw and chaff is used as a source of roughage in dairy and beef cattle rations. A field experiment was conducted in Kinston, North Carolina, in 2006 and 2007 to investigate the progress of FHB in wheat spikes following infection. In the first year, eight soft red winter wheat cultivars with varying degrees of FHB resistance were grown in 3.1-m plots. At mid-anthesis for each cultivar, plots were sprayed with a suspension of 10^5 macroconidia/ml of *Fusarium graminearum*. Plots received daily misting for either 0, 10, 20, or 30 days after anthesis (daa). *Fusarium* index (incidence x severity / 100) was determined in each plot at soft-dough. From each plot, 30 spikes were blindly chosen at 10-day intervals from medium-milk (10 daa) to kernel-loosening (64 daa), and bulked by plot. The samples were separated into three fractions: grain, glumes, and rachises. Weight and DON were assayed in all fractions, and FDK and percent *Fusarium*-infected kernels (PIK) were also determined in the grain. In the second year, the experiment was repeated with four of the eight cultivars.

The first year was naturally wetter and more scab-conducive than the second year. In both years, when averaging across mist durations, PIK increased during the sampling period; FDK increased between early kernel-hard and harvest-ripe; and grain DON dropped following the first or second sample. Increasing durations of mist were generally associated with increasing levels of PIK, FDK, and grain DON in the first year, but mist made less difference in the second year. As has been previously reported, peak DON in glumes and rachises, and also those at harvest-ripe, was significantly higher than DON in grain of the same samples. DON in glumes and rachises varied greatly over time. Maximum DON concentrations were attained in rachises at kernel-hard, and in glumes at kernel-hard (2006) or early kernel-hard (2007) stage. The results suggest that in a scab epidemic, total spike DON may increase between infection and the later timepoints for silage harvest. Combining the data from both years, DON in grain was significantly correlated with DON in both glumes and rachises ($P \leq 0.003$), but DON in glumes was only marginally correlated with DON in rachises ($P = 0.089$). Correlation of index to grain, glume, and rachis DON at silage harvest and harvest-ripeness will be reported. The question whether cultivar grain resistance level is a good predictor of relative DON levels in other spike fractions will also be addressed.

ECOLOGY OF *BACILLUS AMYLOLIQUEFACIENS* ON WHEAT FLORETS IN RELATION TO BIOLOGICAL CONTROL OF FHB/DON

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ABSTRACT

The TrigoCor strain of *Bacillus amyloliquefaciens* is one of a handful of biological control agents (BCAs) that shows potential in the integrated management of FHB/DON. We are using TrigoCor as a model to understand why it, like many promising BCAs tested through the USWBSI, provides excellent and consistent FHB control in the greenhouse but not in the field. Using dilution plating, we quantified *Bacillus* populations on wheat heads at 0h, 24h, 72h, 7d, and 14d post- *Bacillus* application in the greenhouse and in two field locations in 2009. Although *Bacillus* populations were fairly stable on heads in both the greenhouse and the field, the population level in the greenhouse (10^8CFUs/head) was significantly higher than in the field (10^6-10^7CFUs/head). In addition to these hand-sprayed field trials, we also quantified population levels from field plots sprayed with *Bacillus* using a commercial sprayer (20 gal/A, paired Twinjet nozzles facing front and back and aimed 30° from horizontal), and found that *Bacillus* population levels on heads in these fields were even lower (10^4-10^6 CFUs/head at 0h and 24h after *Bacillus* application from fields in New York, North Dakota, and Missouri in 2008, as well as throughout a 14d sampling period from a field trial in New York in 2009). Treatment with TrigoCor did not provide significant reductions in FHB in any of the hand-sprayed or commercially sprayed trials. In 2010 field trials, we increased the amount of *Bacillus* applied per head, resulting in levels initially comparable to those recovered from the greenhouse (10^8 CFUs/mL at 0 and 1d post-application). Despite these high *Bacillus* levels, there was still insufficient FHB control, suggesting that population levels alone do not explain biocontrol.

We used high performance liquid chromatography to monitor the persistence of a key *Bacillus*-produced antifungal compound on wheat heads from the greenhouse and from a spring wheat field in 2010. Although levels of the compound on heads decreased rapidly by 3d post-application in both environments, the quantity per head was significantly higher in the greenhouse than in the field over critical infection periods. Greenhouse experiments with diluted TrigoCor inoculum indicate that the difference in metabolite levels observed between the greenhouse and the field is significant for FHB disease control. It is likely that the inadequate persistence of antifungal metabolites on wheat heads in the field is an important factor limiting disease control.

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EFFECT OF POST-ANTHESIS FUNGICIDE APPLICATION ON FUSARIUM HEAD BLIGHT AND DON IN SOFT RED WHEAT

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ABSTRACT

High relative humidity and frequent rainfall during anthesis (Feekes 10.5.1) and early grain fill are considered environmental risk factors for FHB development and DON accumulation in small grain crops. For best efficacy and FHB control it is recommended that fungicides be applied at early anthesis (Feekes 10.5.1), as this is when small grain crops are most susceptible to *F. graminearum*, especially when anthesis coincides with wet weather. Despite these recommendations, producers often find it difficult to adhere to these best management guidelines due to the physical limitations of spraying fungicides in the rain and driving equipment in soggy fields. Field studies in Wooster and South Charleston, OH were established to evaluate the effectiveness of fungicide applications made post-anthesis. At Wooster, one moderately resistant and one susceptible SRWW cultivar were planted as whole plots in a randomized complete block design, with three replicate blocks. Fungicide treatment served as the sub-plot: untreated check, Prosaro® (6.5 fl oz/acre + NIS) at anthesis, 2, 4 and 6 days post-anthesis (dpa) and inoculum density as the sub-sub plot: 1, 3, 5 and 7 x 10^4 macroconidia/mL applied at anthesis. At South Charleston a susceptible cultivar was used, and seven fungicide treatments were assigned to plots in a randomized complete block design, with 4 blocks. The treatments were: untreated check, Prosaro (6.5 fl oz/acre + NIS) at anthesis, 2 and 5 dpa and Caramba® (13.5 fl oz/acre + NIS) at anthesis, 2 and 5 dpa. Plots were naturally infected at South Charleston. FHB incidence and index were estimated approximately 3 weeks post-anthesis; while percent *Fusarium* damaged kernels (FDK) and DON concentration were assessed post-harvest. Proc GLIMMIX in SAS was used to evaluate the effects of variety, inoculum density, treatment and their interactions on FHB, DON, FDK, and yield. In Wooster, variety had a marginal effect on index ($P = 0.087$) and a significant effect ($P < 0.05$) on FDK, DON and yield. Inoculum density did not have a significant effect on any of the measured responses. At both locations, fungicide treatment had significant effects on FHB incidence, index, FDK, DON and yield. All fungicide treatments, regardless of timing, resulted in significantly higher yield and significantly lower index, incidence, FDK and DON than the untreated check. In Wooster, the levels of index, incidence, FDK and DON as a result of Prosaro treatment at anthesis were not significantly different from the values resulting from applications made 2, 4 or 6 dpa. However, Prosaro at anthesis resulted in significantly higher grain yield than later applications. Results from South Charleston, where it rained on the day treatments were applied (at 50% anthesis) and the day after, suggested that post-anthesis applications of fungicide provided better disease and DON control than applications made at anthesis itself. Under the conditions of this study, these results suggest that relative to applications made at anthesis, the efficacy of Prosaro and Caramba, in terms of FHB and DON control, is not greatly reduced when these products are applied at label-recommended rates within a week of anthesis. While producers should continue to identify anthesis timing and actively monitor risk prediction tools, this preliminary research suggests that applications of foliar fungicide may still provide effective FHB and DON control when applied up to 5-6 days post-anthesis. These "delayed" applications may provide adequate protection of upper- and lower-most wheat spikelets and secondary tillers which may continue to flower for a period beyond the main spike.

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EVALUATING THE IMPACT OF THE FHB PREDICTION MODELS AND FHB ALERTS, 2009-2011

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ABSTRACT

The cooperative effort to deploy the prediction models for FHB and DON currently affects 30 states. This effort includes the support of commentary tools for each state, and partnerships with the USWBSI-NFO to implement the FHB Alert System. The FHB Alert System sends the commentary developed by the state specialists via email to subscribers and automatically posts the information on the USWBSI blog (http://scabusa.org/modules/wordpress/). Subscribers can also request that the FHB Alert System send text messages to their mobile devices each time a new commentary is submitted for their region. Users of the prediction models and the FHB Alert System were surveyed in 2009-2010. The survey results included input from 1016 respondents, and indicated that 66% of these users were either farm advisors or farmers. Other users of the system included university extension personnel (16%), university educators (4%) and members of the grain marketing (2.5%) and milling industries (4%). The results also indicated that 73% of the users applied the information provided by the prediction system directly on their farm, or to make recommendations about disease management to others. In the two years covered by this survey, 94% of the users considered the information to be of high or moderate value for their farm operations or organization. The 2010 survey included a subset of questions that further documented the impact of the information. The responses to these questions indicated that 86% of the users experienced a moderate or great improvement in their awareness of the disease risk in their area. The results also showed that the information influenced the decision about the need for management action directly for 37% of the respondents, and motivated another 24% to seek advice from others. In 2011, the prediction tools received over 13,000 visits during the growing season in the U.S. (April – August), representing 6,579 visitors. Nearly all of the wheat disease specialists in the 30 states covered by the disease prediction system contributed commentary to the disease prediction effort. A total of 132 commentaries were submitted in 2011 (similar levels to 2010), with specialists in AR, IN, KS, KY, MD, MN, NC, ND, OH, OK, PA and WI each contributing more than 5 commentary updates to the prediction system. The FHB Alerts sent commentary to over 800 subscribers in 2011, nearly doubling the number of participants from 2010. A survey evaluating the impact of the disease prediction system and the FHB Alerts during the 2011-growing season is currently underway.

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THE RISK OF FHB EPIDEMICS BASED ON WEATHER, HOST RESISTANCE AND CORN RESIDUE

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ABSTRACT

Severe epidemics of Fusarium head blight (FHB) are often associated with environmental and cultural practices. Many historical accounts of FHB epidemics suggest that above normal rainfall during anthesis, when the crop is most vulnerable to infection by *Fusarium*, is often associated with epidemics. Some practitioners have also observed that planting wheat into fields containing large amounts of corn or other host crop residues also increases the risk of severe FHB. When such observations are cited repeatedly in the literature, they begin to transition from a generalized theory, based on limited observation, to scientifically accepted common knowledge. The objective of this study was to evaluate the influence of weather factors, host resistance, and the presence of corn residue on the risk of FHB epidemics. The data available for modeling included 527 location-years, from 15 states collected between 1982 and 2009, and consisted of observations from the hard red spring, hard red winter, and soft red winter wheat market classes. All data sets were subjected to extensive quality control, checking for missing data, out-of-range values, or other errors. Missing weather observations were estimated by multiple imputation. The disease intensity was coded as a binary variable where a given location-year was considered an epidemic if the FHB index was >10%. Logistic regression was used to model the probability of a location experiencing an FHB epidemic, given input predictors such as the genetic resistance to FHB of a variety, the presence of residue from a previous corn crop, and different representations of hourly temperature, relative humidity and rainfall. Variable selection procedures identified that relative humidity and temperature variables were frequently associated FHB epidemics. Variables summarizing either the total rainfall or the duration of rainfall were identified far less frequently. These results suggest that precipitation may be indirectly related to FHB epidemics and that other measures of atmospheric moisture are more strongly associated with epidemics of FHB. The analysis supports evidence that planting cultivars with moderate levels of genetic resistance reduces the risk of severe FHB; however, planting wheat in fields containing large amounts of corn residue increases the risk of disease. This analysis verifies the role of risk factors associated with FHB and establishes a framework for the development of prediction models that can be used in disease management. The accuracy of prediction models developed in this analysis is similar to the benchmarks established in previous modeling efforts, and we are now positioned to explore more advanced approaches to modeling FHB epidemics.

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This material is based upon work supported by the U.S. Department of Agriculture, under Agreement Nos. 59-0790-7-072 and 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 author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

BARLEY SCAB: FORECASTING TO MANAGEMENT

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ABSTRACT

Fusarium head blight (FHB), caused by the fungus *Gibberella zeae* (Schwein) Petch (anamorph: *Fusarium graminearum* Schwabe), continues to be a serious problem for barley producers in the U.S. Northern Great Plains and elsewhere. Economic losses associated with FHB occur due to contamination of grain with trichothecene mycotoxins, primarily deoxynivalenol (DON). Predictive models were developed to predict economic level of DON (DON$\geq$ 0.5 mg/kg) using the weather conditions prior to full head emergence. Three commonly grown cultivars were planted throughout the region over six growing seasons (2005-10) and FHB disease and DON concentration were recorded. Nine predictor variables were calculated using hourly temperature and relative humidity during the 10-days preceding the full head emergence day and nine simple logistic regression models were developed using these predictor variables. Four of the nine models had sensitivity greater than 80% (n=150). The results of this study confirm that weather conditions prior to full head emergence could be used to accurately predict the risk of economically significant DON accumulation for spring malting barley.

An experiment, split-split plot with five replications, was established at SDSU research station, Brookings, SD, during summer 2011 to study the relationship between Fusarium head blight (FHB) symptoms and DON concentration by examining the contribution of main stem and secondary tillers as it relates to the final DON concentration. Main plots were resistance levels of cultivars [Quest, a moderately resistant (MR) and Robust, a moderately susceptible (MS) cultivar], inoculation timing (at Feekes 10.5 and 11.2) as sub-plots, and sub-sub plots included *Fusarium graminearum* or mock inoculation.

FHB severity was not statistically different between main heads and tillers. Robust had significantly higher FHB severity than Quest only in main heads. Levels of DON were statistically higher in main heads in each cultivar compared to its tillers. Robust had significantly higher DON levels at each inoculation compared to that of Quest. Our results suggest that main heads has larger contribution towards total DON levels at harvest than tillers. However, it should be noted that this year, environmental condition was not suitable for optimum growth of barley. During the growing season, especially at pre-booting to anthesis there was a strong heat wave in the mid west region, resulting into stunted plants and very small heads, especially tillers, with abrupt anthesis. This might have resulted in anthesis of main heads and tillers at around same time leading to the similar duration of time frame available for infection from inoculation. Thus we suggest further study on wheat and barley with normal growth, which might provide us more accurate information.

CONTRIBUTION OF SECONDARY TILLERS TO TOTAL DEOXYNIVALENOL CONCENTRATION IN HARVEST GRAIN

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ABSTRACT

Studies in the past have reported that late infection of wheat and barley results in low disease development but high deoxynivalenol (DON) concentration. Formation of higher number of tillers is desirable as it has positive impact on final grain yield. Lateral tillers of wheat and barley, however, have delayed physiological development, which might correlate with the late infection findings. The objective of this study was to improve our understanding of the relationship between Fusarium head blight (FHB) symptoms and DON concentration by examining the contribution of main stem and secondary tillers as it relates to the final DON concentration.

Experiments, split-split plot with five replications, were established at SDSU research station, Brookings, SD, during summer 2011. Main plots were resistance levels of cultivars [moderately resistant (MR) and moderately susceptible (MS)], inoculation timing (at Feekes 10.5 and 11.2) as sub-plots, and sub-sub plots included *Fusarium graminearum* or mock inoculation. Two cultivars each of barley; 'Robust' (MS to FHB) and 'Quest' (MR); hard red spring wheat (HRSW); SD3851 (cv 'Brick' MR, possesses *Fhb1* QTL) and SD3854 (MS, lacks *Fhb1* QTL) and hard red winter wheat (HRWW); WesleyBC6 (MR, possesses *Fhb1* QTL) and WesleyBC70 (MS, lacks *Fhb1* QTL) were planted in mid-May. Individual plot was of 5 x 15 square ft. in size. Twenty-five main heads and secondary tillers were tagged in plot that was inoculated at Feekes 10.5 (at anthesis of main heads) and Feekes 11.2 (~ at anthesis of secondary tillers), respectively. Plots were inoculated using backpack sprayer with a mixture of 15 isolates of *F. graminearum* inoculum at the concentration at 80,000 spores ml^{-1}. Mist-irrigation system was run for 10 min immediately following inoculation to avoid drying of inoculum. Mist-irrigation was run until 14 days after inoculation (DAI) for 10 minutes per hour from 5 p.m. to 7 a.m. to create conducive environment for FHB development. FHB severity was assessed on 18 DAI by counting total and symptomatic spikelets in tagged 25 heads. At maturity, tagged heads were hand harvested, and threshed. Heads from individual plot were bulked and analyzed for *Fusarium* damaged kernel (FDK) by counting scabby kernels in 100 seeds (3 reps), ground and analyzed for DON at mycotoxin laboratory at North Dakota State University. The rest of the plots were harvested mechanically, threshed, analyzed for FDK following Jones and Mirocha (1999), and analyzed for DON. Arcsine transformed data of barley severity and HRWW FDK, log transformed barley DON data, and square root transformed HRSW FDK and DON data were used for analyses. Data on HRSW severity, and HRWW severity and DON were analyzed without transformation. Data were analyzed using proc mixed procedure in SAS.

Though FHB severity in mock inoculated was high up to 50%, it was significantly low compared to the *F. graminearum* inoculated plots. In barley, FHB severity was not statistically different between main heads and tillers. Robust had significantly higher FHB severity than Quest only in main heads. In HRSW, there was no statistical difference between FHB severity in main heads and tillers. SD3854 had significantly higher

FHB severity than Brick in both inoculations. In HRWW, while WesleyBC6 had significantly higher main head FHB severity than tillers, there was no difference in Wesley BC70.

Percentage of FDK was significantly high in main heads of SD3854 compared to its tillers and main heads and tillers of Brick. In Brick there was no statistical difference between FDK observed in main heads and tillers. In HRWW, none of the variables were significant.

Levels of DON were statistically higher in main heads of barley in each cultivar compared to its tillers. Robust had significantly higher DON levels at each inoculation of compared to that of Quest. In HRSW, DON levels were significantly higher in main heads than tillers in each cultivar. SD3854 had statistically higher DON than Brick for main tillers or early inoculation but Brick had higher DON than SD3854 in tillers or late inoculation. In HRWW, though there was higher DON level in tillers than main heads in each cultivar, it was not statistically different.

Our results suggest that main heads has larger contribution towards total DON levels at harvest than tillers. However, it should be noted that this year, environmental condition was not suitable for optimum growth of wheat. During the growing season, especially at pre-booting to anthesis there was a strong heat wave in the mid west region, resulting into stunted plants and very small heads, especially tillers, with abrupt anthesis. This might have resulted in anthesis of main heads and tillers at around same time leading to the similar duration of time frame available for infection from inoculation. Thus we suggest further study on wheat and barley with normal growth, which might provide us more accurate information.

MANAGING FUSARIUM HEAD BLIGHT IN BARLEY WITH CULTIVAR RESISTANCE, FUNGICIDE CHEMISTRY AND SEQUENTIAL APPLICATIONS

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ABSTRACT

Fungicide application to control Fusarium head blight (FHB) can affect wheat and barley yield and substantially reduce deoxynivalenol accumulation (DON) in both barley and wheat seed. Studies conducted in 2007-2009 at Langdon and Osnabrock North Dakota on 6-row spring barley showed that sequential fungicide applications at Feekes growth stage (GS) 10.51 and 10.53 reduced DON on the main stem and boot GS tillers and subsequently the whole plot compared to the untreated. Sequential fungicide treatments were applied to improve on the approximately 60% DON reduction previously reported from single fungicide applications at GS 10.51. In some locations single treatment with prothioconazole was more effective in reducing DON than tebuconazole. Tebuconazole applied as the first sequential treatment was usually but not always as effective in reducing DON as prothioconazole as at the first sequential timing. The studies show that the boot growth stage tillers can contribute large concentrations of DON to the overall plot and will warrant treatment in some environments. Sequential treatments of prothioconazole increased yield. Both sequential treatments increased 1000 seed weight. Untreated North Dakota State University experimental barley line 'ND20448' had less DON accumulation than untreated 'Tradition'. 'ND20448' had greater plump than 'Tradition'. Tebuconazole is desired by growers because it costs significantly less to apply than prothioconazole.

UNIFORM BIOLOGICAL FUNGICIDE EVALUATIONS FOR CONTROL OF FUSARIUM HEAD BLIGHT AND DEOXYNIVALENOL IN WHEAT

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ABSTRACT

A multi-location research project was conducted on various wheat market classes at six locations; North Dakota (hard red spring-HRSW), Nebraska (2 locations hard red winter), South Dakota (HRSW), New York (soft red winter-SRWW) and Missouri [2 cultivars-SRWW with different susceptibility to Fusarium head blight (FHB)]. Treatments applied as a single application at Feeke's Growth Stage (FGS) 10.51 included i) Taegro™; ii)Taegro + Prosaro™ iii) Taegro + Prosaro + chelated manganese (Mn) (Pro-manganese 5 chelated manganese solution; Tetra Micronutrients; Woodlands, TX); and iv) Prosaro. Treatments applied sequentially at FGS 10.51 and 5 to 7 days later included v) Taegro and Taegro; vi) Taegro + Prosaro and Taegro; and viii) Taegro + Prosaro + Mn and Taegro. A vii) nontreated was included as a control. All fungicides and biological fungicides were tank mixed with the adjuvant Induce (Helena Chemical Co.) at 0.125% v/v. Taegro (Novozymes Biologicals, Inc.) is a *Bacillus subtilis var. amyloliquefacians* Strain FZB24 containing 5.0 x 10^{10} colony forming units per gram and was include at 3.5 oz. / acre. Prosaro (Bayer CropScience) is a 50:50 blend of tebuconazole and prothioconazole and was applied at 6.5 fl. oz. /acre. Manganese is known to stimulate antibiotic production by some *Bacillus* species. The Mn was added at a rate of 0.01% v/v. Out of seven trials, significant ($P \leq 0.05$) F-tests for FHB incidence were reported at NY (five of seven treatments less than the nontreated) and MO-Roane (five of seven treatments less than the nontreated), severity at ND (four of seven treatments less than the nontreated), and index at NY (five of seven treatments less than the nontreated), at Mead, NE (three of seven treatments less than the non-treated), and at ND (four of seven treatments less than the nontreated). Significant differences for yield were reported from three of seven reporting locations at NY, ND and MO-Roane (one of seven treatments increased yield over the nontreated). Significant differences for test weight were reported at MO-Elkhart (five of seven treatments different from the untreated). Of four reporting trials significant differences in deoxynivalenol accumulation in the seed (DON) were reported at NY (seven of seven treatments less than the nontreated), Mead, NE (three of seven treatments less than the nontreated) and MO-Elkhart (six of seven treatments less than the nontreated). Significant differences for % *Fusarium* damaged kernels were reported at Mead, NE (two of seven treatments less than the nontreated) and MO-Elkhart (four of seven treatments less than the untreated) from two of four reported trials. Significant differences for foliar disease levels were reported from three of three reporting trials, NY (six of seven treatments less than the nontreated), MO-Elkhart (five of seven treatments less than the nontreated) and MO-Roane (five of seven treatments less than the untreated).

In summary, treatments with significant improvement over the nontreated included ii, iii, iv, vi, and viii for visual symptoms of FHB. Treatments with reduction in DON compared to the nontreated included ii, iii, and vi and in two studies iv, vi and viii. Deoxynivalenol accumulations were low in the reported trials. Treatments that increased yield over the nontreated included iii, vii, and viii. Prosaro was effective in

reducing the visual symptoms of FHB at NY and Mead, NE but not ND. However, there were examples where the addition of a biological in a tank mix or as a sequential treatment reduced FHB symptoms or yield over Prosaro including treatments vi, and viii for severity, iii, vi and viii for index and iii for yield in ND, viii for yield in NY and MO-Roane, and ii, vi and viii for DON in MO-Elkhart. This year's results lend further evidence for combining a biological with a fungicide to maximize control of FHB and DON.

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INTEGRATED MANAGEMENT OF FHB IN HARD RED SPRING WHEAT, FARGO, ND 2011

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ABSTRACT

Integrated management trials for FHB have been supported by the USWBSI in ND for multiple locations and grain classes. In 2011, a hard red spring wheat study was conducted at Fargo in which previous crop and fungicide treatment effects on FHB, DON, and yield and quality were examined on four hard red spring wheat cultivars. Cultivars of varying FHB resistance levels were seeded on May 16 in ground previously planted to either spring wheat or dry beans in 2010. Individual plots were 5 feet by 20 feet, with four replications of each fungicide treatment x cultivar treatment. The previous crop components were in side by side fields. Because of the previous crop component, plots were not inoculated with *Fusarium graminearum*; all infections were from natural inoculum. Spring wheat cultivars tested and their FHB resistance level included: Glenn (MR), Samson (S), Steele ND (MS) and Briggs (MS). Plots were either not fungicide treated or treated at the flowering stage with 6.5 fl oz of Prosaro® (prothioconazole + tebuconazole) fungicide. Dates of fungicide application for each cultivar varied because of stage of maturity: July 6 for Briggs, July 8 for Briggs and July 11 for Samson and Steele ND. Fungicide applications were made with a CO_2 backpack sprayer delivering 18 gpa with 40 psi. The average July temperature was 75^0 F, four degrees above the 30 year normal, and night-time temperatures in July averaged five degrees above normal, with some nighttime temperatures not dropping below 73^0 F. June rainfall totaled 4 inches, which was 0.5 inches above the 30 year normal. July rainfall total was 4.1 inches, which was 1.2 inches above the 30 year normal. FHB ratings were taken at soft dough stage of kernel development. Harvest was on August 22. DON levels were determined by the NDSU Veterinary Toxicology Lab using gas chromatography and electron capture techniques. Disease and yield and quality parameters were analyzed using ANOVA at P = 0.05. FHB field severities ranged from 0.6 to 9.4 % across varieties and treatments. DON levels ranged from 0.3 to 2.13 ppm across all treatments and cultivars. These levels of disease were relatively low considering moisture levels during June and July. The highest level of DON (2.13 ppm) was observed in untreated Samson (Susceptible to FHB) grown on wheat ground. Untreated Samson on dry bean ground had 1.43 ppm DON. Significant reductions of DON were achieved with fungicide treatment in Samson on wheat ground, and in Samson, Briggs and Steele ND on bean ground. The FHB field severity values and the DON levels in Glenn (Mod. Resistant to FHB) were consistently low and not significantly impacted by previous crop or fungicide treatment. The highest average yield across all cultivars was with fungicide treatment on dry bean ground.

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IMPACT OF INFORMATION SOURCES ON FHB CONTROL STRATEGIES ADOPTED BY SPRING WHEAT GROWERS

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ABSTRACT

A survey of the adoption of Fusarium Head Blight (FHB) control practices in the FHB-prone spring wheat region of North Dakota and Minnesota was conducted in 2010. Data on current use of five management practices known to be beneficial in controlling FHB as well as socio-economic factors were obtained from more than 1000 wheat growers, using questionnaires mailed by the USDA-NASS office in Fargo. The rate of adoption of the three practices considered to be the most effective in controlling FHB was very high, with 81% of the growers using a resistant variety, 76% rotating crops so that wheat does not follow another small grain or corn crop, and 68% applying a fungicide at flowering. Just over half of the growers used all three of these methods. The two practices that have potential in reducing the risk of FHB infection at the whole farm level, growing varieties with differing flowering dates and staggering the planting date so that not all fields flower on the same date, were each used by only 22% of the respondents. More farmers ranked extension information sources as being most valuable (72%), than professional sources (20%) and media sources (7%). Farmers using resistant varieties that valued extension sources highest were most likely to use fungicides only when the weather seemed conducive to FHB development, while farmers using resistant varieties that valued professional sources highest were more likely to apply fungicides on all varieties every year. Use of resistant varieties tended to be greatest by farmers that valued extension sources the highest. Education level did not seem to impact level of adoption, although younger farmers using fungicides tended to be better educated than older farmers in the sample. A significant correlation existed between the number of FHB control practices used and having a computer. Other factors found to be correlated with the number of FHB control practices used were: computers used for searches for information about farming practices, visiting extension and product websites for information on varieties and pesticide, visiting extension sites to obtain copies of extension bulletins, and viewing the FHB forecasting website during the critical period of the growing season. These data suggest a general relationship between computer use and higher levels of FHB management. Extension meeting attendance, including field days, was considered low (about half attended meetings once in three years or less frequently) even by those that valued extension information sources highly, suggesting that extension publications and web-based information is a preferred way of obtaining extension information. Most farmers (86%) have a computer with internet access but only 18% used their computer for viewing the FHB forecasting website. Furthermore, less than 50% indicated an interest in obtaining information on the risk and management of FHB through any new electronic technology (Internet blogs, Twitter, Facebook, YouTube, message sent to a cell phone). This survey suggests a very high level of adoption of currently available FHB control practices. The availability of multiple sources of information has been vital in promoting the high level of adoption of the multiple control practices that are currently available.

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2011 UNIFORM FUNGICIDE PERFORMANCE TRIALS FOR THE SUPPRESSION OF FUSARIUM HEAD BLIGHT IN SOUTH DAKOTA

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ABSTRACT

Fusarium head blight (FHB – scab) has been a serious concern for wheat and barley producers in South Dakota for over fifteen years. The objective of this study was to continue to evaluate the effects of various fungicides and fungicide combinations along with different application timings for the suppression of Fusarium head blight and other wheat diseases. Two hard red spring wheat cultivars, 'Select' and 'Reeder', were planted at three South Dakota locations (Brookings, Groton, and South Shore/Watertown). 'Wesley' winter wheat study sites were also established at South Shore/Watertown and Brookings. Studies at both of these sites were conducted under ambient conditions. Due to the overwhelming presence and damage from bacterial diseases at Brookings, only the spring wheat data from the Groton and South Shore/Watertown trials are presented in this report. Trial treatments from the Uniform Fungicide Trial treatments list for the suppression of FHB included an untreated check and the following fungicides: Applied at Feekes growth stage 10.51: A9232D (7.0 fl oz/A), Caramba® (14 fl oz/A), Prosaro® (6.5 fl oz/A); Applied at Feekes growth stage 9: Headline SC (6 fl oz/A); Applied at Feekes growth stage 9: Headline SC (6 fl oz/A) followed by Caramba (14 fl oz/A) at Feekes growth stage 10.51; Applied at Feekes growth stage 10.5: Headline SC (6 fl oz/A), Quadris (6.2 fl oz/A), Evito (4 fl oz/A), Stratego YLD (4 fl oz/A), Quilt (10.5 fl oz/A) and TwinLine (9 fl oz/A). All treatments except the A9232D treatment included Induce, a non-ionic surfactant, applied at 0.125% v/v. Spring wheat trials were planted in a factorial randomized complete block design with six replications. Winter wheat locations had four replications. Plots at the Brookings location were inoculated by spreading *Fusarium graminearum* (isolate Fg4) inoculated corn (*Zea mays*) grain throughout the field and providing overhead mist irrigation applied from 5:00 pm until 10:00 pm each day for two weeks following anthesis. Other sites had natural inoculum from corn stalk residue and natural moisture conditions. Twenty-one days following treatment, plots were evaluated for leaf diseases, FHB incidence, FHB head severity, and FHB field severity. Samples were collected for *Fusarium* damaged kernels (FDK), deoxynivalenol (DON), grain yield and test weight. Even though the Groton location had low levels of Fusarium head blight this year, there were some significant results seen. On the resistant variety 'Select' at Groton, the following products significantly reduced FDK: Prosaro, Headline SC applied at Feekes 9 followed by Caramba at Feekes 10.51, Headline SC applied at Feekes 10.5, Evito and TwinLine. On the susceptible variety 'Reeder' at Groton, the following fungicides significantly reduced FHB Incidence: Caramba, Prosaro and Headline SC applied at Feekes 9 followed by Caramba at Feekes 10.51 while only Caramba reduced the FHB Disease Index. At the South Shore/Watertown location for spring wheat, the following products significantly reduced DON on the resistant variety, 'Select': Caramba, Prosaro, Headline SC, Stratego YLD and TwinLine. On the susceptible variety, 'Reeder', the following fungicides: A9232D, Caramba, Prosaro, Stratego YLD and TwinLine significantly reduced DON. In 'Reeder', Stratego YLD and TwinLine reduced FHB Disease Index. In the more resistant variety 'Select': A9232D, Caramba, Headline SC applied at Feekes 10.5, Quadris, Evito, Stratego YLD, Quilt and TwinLine all significantly reduced FHB Disease Index. At this location and this growing season, it appears that an early application of fungicide, prior to flowering, had a positive impact on *Fusarium* control. The improvement in control

seen with early applications vs. "standard" at-flowering applications is unique to this location this season, and was not seen at other locations in SD. A possible explanation is related to the rapid loss of leaf tissue around wheat flowering from severe bacterial disease infection, reducing leaf and head uptake of the later fungicide applications. It also appears that, at this location, effective triazole fungicides on *Fusarium*, such as prothioconazole and metconazole, can partially mask the known negative impact of a strobilurin fungicide on components of *Fusarium* epidemics, such as DON level, when applied in a combination triazole/strobilurin fungicide. These effects from some of the strobilurins and the strobilurins + triazole fungicides which were only seen in the spring wheat trial at the South Shore/Watertown location may be unique to the environmental conditions and hastened plant development at this location in 2011. No change in current recommendations for Fusarium head blight management can be construed from this data set.

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COMBINED EFFECTS OF STAGONOSPORA LEAF BLOTCH AND FUSARIUM HEAD BLIGHT ON GRAIN YIELD AND QUALITY OF SOFT RED WINTER WHEAT

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ABSTRCT

Stagonospora nodorum Berk [teleomorph: *Phaeosphaeria nodorum* (Müll.) Hedjar] and *Fusarium graminearum* Schwabe (teleomorph: *Gibberella zeae*) are major necrotrophic pathogens of wheat (*Triticum aestivum* L.) and related cereals. *S. nodorum* affects wheat leaves and spikes, causing Stagonospora leaf and glume blotch (SLB and SGB, respectively), while *F. graminearum* is the primary causal agent of Fusarium head blight (FHB). Both pathogens are favored by wet, humid conditions, thus, it is quite common for SLB, SGB, and FHB to occur simultaneously in naturally infected fields, with similar effects on grain yield and quality. A previous model of the relationship between FHB and grain yield reported that wheat class affected the intercept but not the slope of this relationship. However, this relationship may also vary among cultivars with different levels of resistance to FHB and could be influenced by the presence and severity of foliar diseases. Field experiments were conducted at the Ohio Agricultural Research and Development Center, near Wooster, OH to characterize the relationships between FHB and grain yield and quality as influenced by cultivar FHB resistance and SLB severity. The experimental design was a split-split-plot with cultivar (Cooper, Hopewell and Truman) as whole plot, *S. nodorum* inoculum density (0 to 1 x 10^6 spore/ml) as sub-plot, and *F. graminearum* inoculum density (0 to 1.5 x 10^4 spores/ml) as sub-sub-plot. *S. nodorum* and *F. graminearum* inoculations were done at full flag leaf emergence (Feekes 9.0) and early anthesis (Feekes 10.5.1), respectively. SLB severity was rated on the flag leaf at the milky ripe stage (Feekes 11.1), and FHB index was rated at soft dough (Feekes 11.2). Results from the 2010 growing season showed that there were significant differences in SLB and FHB intensity among inoculation treatments, with the severity of both diseases increasing as the inoculum density of their respective causal agent increased. The effect of cultivar on both SLB severity and FHB index was also significant ($P \leq 0.001$). Hopewell had the highest level of mean SLB (34.6%) and FHB (23.2%), followed by Cooper (SLB, 19.5% and FHB, 18.3%), and Truman (SLB, 12.2%, and FHB 7.83%). The interaction between cultivar and inoculum density was significant for FHB, but not for SLB. Grain yield and test weight were also evaluated at different levels of FHB index and SLB severity and among cultivars. Both responses were affected by FHB index, with mean yield and test weight decreasing with increasing index. However, the interaction between cultivar and FHB index was not significant (P = 0.711 for yield and 0.218 for TW), suggesting that the rates of yield and test weight reduction with increasing FHB index were similar among the cultivars. The effect of SLB severity on yield and test weight was no statistically significant. However, when both SLB severity and FHB index were used as predictors in a mixed model multiple regression analysis, both were significant predictors (P= 0.031 and <0.0001, respectively) of yield response. Our results also indicated that the interaction effect of cultivar and FHB index on DON accumulation was statistically significant (P = 0.018), thus the rate of toxin accumulation as index increased varied among cultivars. A more comprehensive analysis of the effects of SLB, FHB, and wheat cultivars on grain yield and quality will be conducted using results from the 2011 and 2012 seasons. Models will be developed for the combined effects of SLB and FHB on wheat yield and test weight.

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MANAGEMENT OF MYCOTOXINS IN GRAIN: THE ONTARIO EXPERIENCE

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ABSTRACT

The severe Fusarium head blight epidemic of wheat in the great lakes region of 1996 stimulated an incredible response by stakeholders along the value chain in a very unusual display of solidarity in a normally competitive environment, resulting in several significant and integrated steps forward in how mycotoxins are managed. Similar to many groups around North America and Europe our group developed and adapted an integrated strategy to manage the occurrence of deoxynivalenol in wheat based products, tailored to the market, regulatory, economic, and production environments of the region. Early on, it was clear to most that weather played the most significant role in epidemics, with genetics placing a close second, and agronomic practices other than variety selection placing an important but more distant third. Over the ensuing years a management strategy emerged combining a significant effort in plant breeding, with best agronomic practices, with a weather-based mycotoxin forecast (DONcast), and prescriptive fungicide applications. With these tools available, if the weather of 1996 was duplicated today an estimated 50-75% reduction in mycotoxin can be expected. The tools as currently used for wheat in Ontario will be described. By comparison, the same great lakes region also happens to be the most frequently infected corn growing region by the same pathogen manifested as Gibberella ear rot. In contrast against the success achieved in wheat in only 10 years after 1996, no progress was apparent in corn in 2006, 20 years after a severe epidemic in corn in 1986, of similar magnitude to the one in wheat in 1996. Some explanations for this marked contrast will be proffered, as well as some recent progress in managing mycotoxins in corn discussed.

REDUCTION OF FUSARIUM HEAD SCAB INCIDENCE AND SEVERITY, AND DON LEVELS, AND YIELD INCREASES USING PROSARO™ FUNGICIDE

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ABSTRACT

Prosaro™ is a broad spectrum head and leaf disease foliar fungicide that was introduced in 2009 by Bayer CropScience. Prosaro is registered for use in spring wheat, durum wheat, winter wheat, and barley. Prosaro is a mixture of prothioconazole and tebuconazole; these two active ingredients provide control of Fusarium head blight (FHB) as well as several important cereal leaf diseases. Prosaro is formulated as a soluble concentrate for ease of handling. It is applied at 6.5 to 8.2 fl oz/ac with a non-ionic surfactant to wheat or barley up to 30 days prior to harvest.

Replicated trials were completed in 2008, 2009, 2010, and 2011 at multiple locations in the soft red winter wheat growing region of Illinois, Indiana, Kentucky, Michigan, Ohio, and Tennessee. Prosaro was applied once at 6.5 fl oz/ac with a non-ionic surfactant when the winter wheat initiated flag leaf emergence (Feekes 8) to flowering (Feekes 10.51). The objective of these trials was to evaluate the effect of Prosaro on grain yield (bushels/acre) and test weight (lbs/bushel) in winter wheat. FHB incidence and severity were recorded where applicable. DON levels (ppm) were evaluated at some sites where FHB was present.

Test results from 2008 to 2010 (237 trials) showed Prosaro applied at Feekes 8.0 to 10.51 increased the grain yield of soft red winter wheat by an average of 10.4 bu/ac, independent of FHB, over non-treated plots. Test weight was also increased by an average of more than 1.5 lb/bu by using Prosaro. DON levels were reduced from an average of 3.57 ppm in non-treated plots to 1.18 ppm in Prosaro-treated plots (40 sites). In a trial conducted on two varieties in 2011 in Illinois, FHB incidence and severity were controlled by Prosaro an average of 82% and 81%, respectively, using Prosaro applied at Feekes 10.51 and compared to the non-treated check.

LIPASE ACTIVITY OF BACILLUS STRAINS USED FOR BIOLOGICAL CONTROL OF FUSARIUM HEAD BLIGHT

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ABSTRACT

The growth medium used for producing microorganisms used as biological control agents can be critical to optimizing their effectiveness in controlling plant disease. Including vegetable oil in the broth medium might promote biosurfactant production in some bacterial strains. If oil has a positive effect on biosurfactant production, then the microorganism should have mechanisms to utilize the oil present in the broth medium. Most organisms utilize the oil or lipid sources through the production of extracellular lipases. We hypothesize that including plant oil in the broth medium used to grow several *Bacillus* strains promotes biosurfactant production via production of extracellular lipase(s). The *Bacillus* biological control agents (*Bacillus amyloliquefaciens* strains 1-BA, 1-BC, 1-BE and 1-D3) were inoculated into a broth medium containing Tryptic soy broth + yeast extract + manganese with or without plant oil. Later, the broth culture medium was subjected to biosurfactant analysis through three assays (droplet collapse, oil spreading, and turbidometric analysis). Also, assays were done to examine the strains for extracellular lipase production. Oil amendment and shaking of broth cultures had a significant impact on biosurfactant production. All the strains experienced increased biosurfactant production, with differences observed among the strains. Strain 1D3 showed the best biosurfactant production, in comparison to all other strains. Lipase production was observed for all the strains. Further work will examine the effect of different oils on the production of extracellular lipase and its influence on biosurfactant production.

INTEGRATED MANAGEMENT STRATEGIES FOR FUSARIUM HEAD BLIGHT OF SOFT RED WINTER WHEAT IN MISSOURI: SUMMARIZATION OF TRIAL DATA FROM FIVE YEARS

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OBJECTIVE

To evaluate the importance of crop sequence, variety selection and fungicide application as components of an integrated management program for Fusarium head blight (FHB) of soft red winter wheat in Missouri.

INTRODUCTION:

The severity of FHB or scab epidemics in the United States has caused enormous yield and quality losses in both wheat and barley over the last decade. The development of this disease is dependent on the genetics of the host, favorable environmental conditions, the prevalence of the causal fungus and the survival and spread of the causal fungus. Control of this disease has been difficult because of the complex nature of the host/pathogen interaction. Management of FHB and the associated mycotoxin DON have not been achieved by any single control measure. An integrated approach is critical to attaining the best possible management of FHB and DON in any given environment.

As a result of a workshop sponsored by the Chemical, Biological and Cultural Control Research Area of the U.S. Wheat & Barley Scab Initiative in 2006, a protocol for a multi-state project focusing on integrated management strategies for FHB was developed. The research portion of the project has been multi-state trials evaluating crop sequence, variety selection and fungicide application as an integrated management program for FHB.

The University of Missouri has participated in the multi-state integrated management project for the past five growing seasons. Results from the five years are summarized in this poster abstract.

MATERIALS AND METHODS

During the fall of 2006 two adjacent fields at the University of Missouri Bradford Research and Extension Center just east of Columbia, MO, were identified for this study. The fields had been in a corn/soybean rotation for at least five years prior to the initiation of the study and were separated by a small drainage ditch. The wheat trials were planted into standing corn residue or soybean residue on the same day. The remainder of each field was planted into the normal rotational crop of corn or soybeans. In subsequent years, the wheat trials were shifted to other areas of the same fields with the remainder of the fields planted to the normal rotational crop.

Five soft red winter wheat varieties with similar heading times and varying reactions to FHB were selected for the trial. The five varieties included the public varieties Bess and Roane which are widely grown in Missouri, the Agri-Pro variety Elkhart and the Pioneer varieties 25R47 and 25R54. The FHB resistance reactions for the five varieties are as follows: Bess is considered as tolerant, Elkhart as susceptible, Pioneer variety 25R37 as moderately susceptible, Pioneer variety 25R54 as moderately tolerant and Roane as moderately tolerant.

In the fall of 2006 the trials were planted no-tillage into either soybean residue or standing corn residue on the same day. Individual plots were 7 rows (~7.5" row spacings) by 30' in length. Each trial was set up as a split plot trial with fungicide application as the main plot and variety as the sub-plot. There were

6 replicates in each trial. Sub-plots were separated by buffer plots. The foliar fungicide treatment Prosaro® (6.5 fl oz/A) was applied at Feekes Growth Stage 10.51. A non-ionic surfactant was added to the fungicide at a rate of 0.125% v/v, and application was made using a CO2 pressurized backpack sprayer with TwinJet XR8002 nozzles mounted at an angle (30 and 60 degrees) forward and backward.

Plots were evaluated for incidence and severity of FHB, yield was taken, grain samples were submitted to North Dakota State University for DON analysis and grain samples were rated for percent of *Fusarium* damaged kernels (FDK). Data has been submitted annually to the regional coordinator for inclusion in the multi-state project report. Analysis of variance was used to determine the effects of variety, fungicide and their interactions on yield, DON levels, FHB index (average of 100 wheat heads per plot) and percent FDK for each residue type.

The trial was repeated following the same protocol during the next four growing seasons.

RESULTS

Weather conditions during the 2006-2007 season were not conducive for the development of FHB at the Columbia, MO location. Conditions as the wheat crop was flowering were too dry for infection to occur and disease to develop. However, the following four seasons were quite conducive for the development of FHB. In 2008, 2009 and 2010 weather conditions were unusually wet and cool as the wheat crop flowered and after flowering so both scab and DON levels were high. The 2011 season was wet during flowering so scab developed but was hot and dry during grain fill so DON levels were lower than in the previous three years.

The results from the five years of this trial demonstrate the importance of crop sequence, variety selection and fungicide application in reducing FHB and DON levels in soft red winter wheat in Missouri. Planting winter wheat after soybean rather than corn showed a reduction in both FHB and DON even in years which were not particularly favorable for the development of FHB. Crop sequence and variety selection appear to valuable preventative measures for reducing FHB and DON levels. The application of the fungicide Prosaro at FGS 10.51 tended to reduce FHB levels and increase yields for most of the varieties on both crop sequences with effects being more pronounced on susceptible and moderately tolerant varieties. The data from the five years of this trial indicate that an integrated management approach employing crop sequence and variety selection as pre-plant preventative management measures and fungicide application during the growing season if weather conditions at flowering warrant application may be beneficial in reducing FHB, reducing DON levels and increasing yield for soft red winter wheat grown in Missouri.

ACKNOWLEDGEMENT AND DISCLAIMER

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EVALUATION OF INTEGRATED METHODS FOR MANAGING FHB AND DON IN WINTER WHEAT IN NEW YORK IN 2011

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OBJECTIVE

To evaluate the individual and interactive effects of moderately resistant cultivars and the foliar fungicide Prosaro® on wheat yield and the integrated management of Fusarium head blight (FHB) and deoxynivalenol (DON) under two environments 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 2011, we observed the disease and yield impact of cultivar susceptibility, inoculation with *Fusarium graminearum*, and treatment with Prosaro in two experimental environments.

MATERIALS AND METHODS

All experiments were performed at the Musgrave Research Farm in Aurora, NY following cultural practices recommended for soft red winter wheat in the region. The four cultivars included were 'Pioneer 25R47' (susceptible to FHB), 'SW 80' (susceptible to FHB), 'Otsego' (classified initially as moderately resistant to FHB), and 'Truman' (established as moderately resistant to FHB). The two experimental environments, both planted on October 13, 2010, were characterized by the planting of winter wheat no-till into 1) soybean residue and 2) corn residue in immediately adjacent parcels of land. Each experimental design was a split-split plot with four wheat cultivars as whole plots, inoculation treatment as subplot, and fungicide treatment as sub-subplot, in four replicate blocks. Main plots were planted with a 10 ft wide commercial grain drill. Spray treatments applied at Feekes GS10.5.1 on 6/3/11 were 1) non-sprayed, non-inoculated 2) Prosaro 6.5 fl oz/A & Induce 0.125%, non-inoculated 3) non-sprayed and inoculated with *F. graminearum*; and 4) Prosaro 6.5 fl oz/A & Induce 0.125% and inoculated with *F. graminearum*. Treatments 3 and 4 were inoculated with a conidial suspension of *F. graminearum* (40,000 conidia/ml) on the same day as the Prosaro application after the fungicide had dried and in early evening to provide a better environment for infection. Prosaro and *F. graminearum* applications were applied with a tractor-mounted sprayer with paired Twinjet nozzles mounted at an angle (30^o from horizontal) forward and backward and calibrated to deliver at 20 gallons per A. FHB and foliar diseases were assessed at soft dough stages. Grain was harvested from a 4 ft wide x 20 ft long area in each subplot using a Hege plot combine. Grain moistures, plot yields, and test weights were recorded and the latter two were adjusted for moisture. Means were calculated and subjected to a split plot Analysis of Variance. Fisher's protected LSD was calculated at P=0.05. Analysis of DON content in grain was conducted in the USWBSI-supported mycotoxin laboratory of Dr. Dong.

RESULTS AND DISCUSSION

Both experimental environments were located in the same field that in the previous year was split, growing corn in one half and soybean in the other. Flowering occurred simultaneously in both environments during a relatively dry period, considered low risk for FHB infection. The average incidence of FHB in the experiment following corn was 7% in non-inoculated plots, 15% in inoculated plots, and 11% overall. The average incidence of FHB in the experiment following soybean was 3% in non-inoculated plots, 11% in inoculated plots, and 7% overall. This suggests that the corn residue provided a slightly more favorable environment and/or higher background inoculum for FHB development. This pattern was observed also for FHB index and DON contamination. The average FHB index and DON contamination in the experiment following corn were 2% and 0.6 ppm in non-inoculated plots, 5% and 1.2 ppm in inoculated plots, and 3% and 0.9 ppm overall. The average incidence of FHB and DON levels in the experiment following soybean were 1% and 0.1 ppm in non-inoculated treatments, 4% and 0.7 ppm in inoculated plots, and 2% and 0.4 ppm overall. The DON contamination exceeded the 2 ppm threshold for sale at flour mills more frequently in the experiment following corn but only in the non-sprayed, inoculated plots. DON concentrations exceeding the threshold occurred in Otsego, Pioneer 25R47, and SW 80 in the environment following corn and in SW 80 in the environment following soybean. Interestingly, while the disease pressure was greater in the experiment following corn, average yields were lower in the experiment following soybean. This is likely to due to greater weed pressure and deer feeding observed in the wheat plots following soybean.

The impact of *F. graminearum* inoculation was determined by comparing the non-inoculated and inoculated treatments (combining non-sprayed and Prosaro treatments). Inoculation did not significantly decrease yield except for Truman in the no-till corn debris environment (but the differences disappeared once fungicide treatment was considered). Inoculation did significantly impact FHB ratings but not for all cultivars in both environments. Inoculation resulted in significantly higher FHB index and DON contamination for Otsego and SW 80 in both environments, and DON contamination for Pioneer 25R47 in the soybean debris environment. FHB index of Truman following soybean was significantly increased due to inoculation, but again, differences were not significant when all four treatments were considered. In general, there were no differences in cultivar response to inoculation between the two environments with the exception of a significantly higher FHB index for Pioneer 25R47 in the corn debris environment.

Significant differences in FHB index between the treatments were observed in two, SW 80 and Otsego, of the four cultivars in both environments. FHB index was significantly greater than all other plots in the non-sprayed, inoculated plots of SW 80 following corn and both cultivars following soybean. For Otsego following corn, FHB index in the two non-sprayed plots were significantly higher than in the two Prosaro plots. When compared to the non-sprayed, inoculated plots, either Prosaro application (with and without inoculation) significantly decreased the FHB index. Due to low levels of natural disease, the Prosaro applications did not always significantly decrease the FHB index compared to the non-sprayed, non-inoculated plots. For Pioneer 25R47 and Truman in both environments and Otsego following corn, there was no significant increase in FHB index due to inoculation.

Significant differences in DON contamination between the treatments were observed with Pioneer 25R47, SW 80 and Otsego. DON contamination was significantly greater than all other plots in the non-sprayed, inoculated plots of SW 80 and Otsego following corn and all three cultivars following soybean. When compared to the non-sprayed, inoculated plots, either Prosaro application (with and without inoculation) significantly decreased DON contamination. In the corn debris environment, there was significantly less DON contamination in the non-inoculated Prosaro plots than the non-sprayed, non-inoculated plots. In contrast, in the soybean debris environment, there were no significant differences observed between the two non-inoculated and the inoculated Prosaro plots, again indicating lower natural disease pressure following soybean. There were no statistically significant differences in DON between any treatments observed for Truman in either environment.

In general, *F. graminearum* inoculation and/or application of Prosaro did not cause significant differences in yield for any of the cultivars in either environment. The one exception was observed in Otsego following soybean where plots with the non-inoculated

Prosaro treatment had a significantly greater average yield than plots with the two non-sprayed treatments.

When results of all the cultivars were combined, the overall impact of the Prosaro applications varied between the two environments and mirrored the patterns observed when considering the cultivars separately. In the corn debris environment, both Prosaro applications (with and without inoculation) resulted in significantly lower FHB indices and DON concentrations compared to the either non-sprayed plots. In the soybean debris environment, both Prosaro applications resulted in significantly lower FHB indexes and DON concentrations only when compared to the inoculated non-sprayed plots. While not statistically significant, plots treated with Prosaro were generally higher yielding.

When results of all the treatments were combined, the four cultivars demonstrated some differences in both disease responses and yield capabilities. Significantly greater FHB indices were observed in the susceptible cultivars (Pioneer 25R47 and SW 80) compared to the moderately resistant cultivars (Otsego and Truman) in the corn debris environment. Only Truman had statistically significantly lower levels of DON contamination in the corn debris environment. In the soybean debris environment, SW 80 was the only cultivar that had significantly higher FHB indices and DON concentrations. In summary, SW 80 demonstrated susceptibility in both environments, Pioneer 25R47 demonstrated susceptibility and Otsego demonstrated moderate resistance in the higher disease pressure environment (following corn), and Truman demonstrated moderate resistance in both environments. Although not always statistically significant, the FHB susceptible cultivars had higher yields than the moderately resistant varieties in both environments.

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

	Adjusted grain yield (bu/A)		
Treatment:	After corn	After soybean	Average
Non-sprayed	71	55	63
Prosaro	73	60	66
Non-sprayed, inoculated	68	53	61
Prosaro, inoculated	72	57	65
LSD (*P*=0.05)	NS	NS	
	Fusarium head blight index (%)		
Treatment:	After corn	After soybean	Average
Non-sprayed	3	1	2
Prosaro	1	0	1
Non-sprayed, inoculated	7	6	7
Prosaro, inoculated	2	2	2
LSD (*P*=0.05)	3	2	
	Contamination of grain by DON (ppm)		
Treatment:	After corn	After soybean	Average
Non-sprayed	1.0	0.1	0.6
Prosaro	0.2	0.1	0.2
Non-sprayed, inoculated	1.9	1.2	1.6
Prosaro, inoculated	0.4	0.2	0.3
LSD (*P*=0.05)	0.6	0.4	

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

	Adjusted grain yield (bu/A)		
Treatment:	After corn	After soybean	Average
Otsego	69	52	61
Pioneer 25R47	76	62	69
SW 80	73	57	65
Truman	65	54	60
LSD (*P*=0.05)	6	6	
	Fusarium head blight index (%)		
Treatment:	After corn	After soybean	Average
Otsego	2	2	2
Pioneer 25R47	6	2	4
SW 80	5	5	5
Truman	0	0	0
LSD (*P*=0.05)	3	3	
	Contamination of grain by DON (ppm)		
Treatment:	After corn	After soybean	Average
Otsego	0.9	0.3	0.6
Pioneer 25R47	1.2	0.3	0.8
SW 80	1.3	0.8	1.1
Truman	0.2	0.1	0.4
LSD (*P*=0.05)	0.7	0.5	

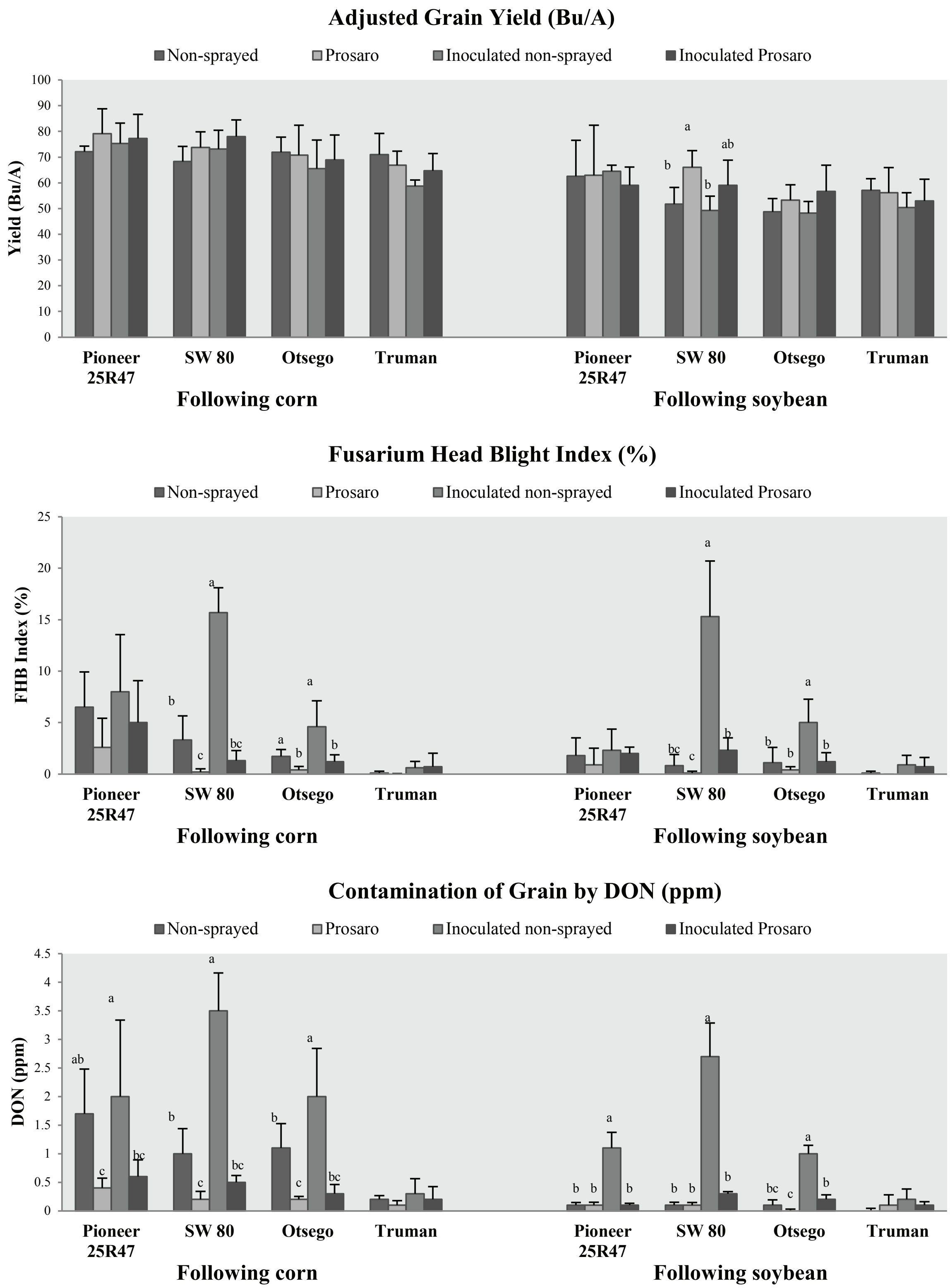

Figure 1. Effect of flowering stage application of Prosaro fungicide and *F. graminearum* inoculation on yield, FHB index and DON contamination of four winter wheat cultivars in Aurora, NY. Letters denote treatment means that differ significantly at *P*=0.05.

EFFECTS OF WINTER WHEAT CULTIVARS AND PROSARO™ FUNGICIDE ON FHB AND DON

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ABSTRACT

Fusarium head blight (FHB), caused by *Fusarium graminearum*, is a destructive disease of wheat. The disease causes premature bleaching of spikelets on the wheat head. Bleached spikelets are sterile or contain discolored and/or shriveled kernels commonly known as *Fusarium*-damaged kernels (FDK). In addition to lowering yield and grain quality, *F. graminearum* also produces the mycotoxin deoxynivalenol (DON) which can be harmful to humans and animals. A management approach for FHB that integrates cultivar resistance and fungicide application is more effective than either strategy. The objective of this study was to determine the effects of cultivar resistance and fungicide application on FHB, DON, FDK, and yield in winter wheat. Four cultivars differing in levels of resistance to FHB were planted following soybean in the fall of 2010 at the University of Nebraska Agricultural Research and Development Center near Mead, NE. The cultivars were 2137 (susceptible), Jagalene (susceptible), Harry (moderately resistant), and Overland (moderately resistant). In the fall of 2010, chopped corn stalks were spread on the soil surface in the wheat plots to serve as a source of inoculum during the following spring. In addition, corn kernels colonized by *F. graminearum* were applied to the soil surface in the wheat plots three weeks before flowering at a rate of 50 g/m^2. At early flowering, plots were spray-inoculated with spores of *F. graminearum* (1 x 10^5 spores/ml). Plots were not irrigated. The experimental design was a split plot in randomized complete blocks with six replications. Cultivars were the main plots and fungicide treatments (check or treated with Prosaro at 6.5 fl. oz/acre + Induce non-ionic surfactant at 0.125% v/v) were the subplots. Plot size was 5 ft x 44 ft. A CO_2-powered backpack sprayer and four Teejet 800-1 VS nozzles spaced 12 in. apart on a boom were used to apply fungicide to heads at early flowering. Disease severity and incidence were assessed on 25 randomly selected heads in each plot on June 21 and used to calculate FHB index. Plots were harvested with a small plot combine. The percentage of *Fusarium*-damaged kernels was visually estimated. A grain sample from each plot was ground and sent to the North Dakota Veterinary Diagnostic Laboratory at North Dakota State University, Fargo, ND for DON analysis. FHB index was generally low; it was significantly higher in Jagalene than in the other three cultivars (Table 1). Prosaro reduced index in three of the four cultivars, but this reduction was not significant at $P = 0.05$. DON was similarly low; it was highest in the check treatments in Jagalene and Harry and lowest in the Prosaro treatment in Overland. Prosaro reduced DON in all four cultivars, but the reduction was not significant at $P = 0.05$ in any of the cultivars. FDK was significantly lower in Overland than in the other three cultivars. Prosaro reduced FDK the greatest in Jagalene; however, this reduction was not significant at $P = 0.05$. Prosaro did not reduce FDK in Overland. Yield in Harry and Overland was significantly higher than yield in Jagalene and 2137. Prosaro significantly increased yield only in Harry.

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Table 1. FHB index, DON, FDK, and yield in four winter wheat cultivars not treated or treated with Prosaro fungicide in a field experiment conducted in Nebraska, USA in 2011.

Cultivar	Fungicide treatment	Index (%)	DON[a] (ppm)	FDK (%)	Yield (bu/A)
Jagalene	Check	3.15 a[b]	1.90 a	28.8 a	44.5 c
Jagalene	Prosaro	2.33 a	1.25 ab	20.8 ab	48.0 c
Harry	Check	0.20 b	1.83 a	30.5 a	57.3 b
Harry	Prosaro	0.05 b	1.03 a-c	28.0 a	62.8 a
2137	Check	0.88 b	1.25 ab	27.3 a	45.5 c
2137	Prosaro	1.03 b	0.68 bc	25.3 a	46.5 c
Overland	Check	0.35 b	0.83 bc	13.0 b	62.3 ab
Overland	Prosaro	0.08 b	0.13 c	14.3 b	62.0 ab

[a]Abbreviations: DON, deoxynivalenol; FDK, *Fusarium*-damaged kernels.
[b]Means within a column followed by the same letter are not significantly different according to the least significant difference test at $P = 0.05$.

UNIFORM FUSARIUM HEAD BLIGHT INTEGRATED MANAGEMENT TRIALS: A 2011 UPDATE

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OBJECTIVE

To evaluate the integrated effects of fungicide and genetic resistance on FHB and DON in all major grain classes in different cropping systems.

INTRODUCTION

FHB and DON management options include genetic resistance, cultural practices, and chemical and biological control. However, when used individually, these control measures are not fully effective under environmental conditions favorable to disease development. Moderately-resistant wheat and barley cultivars may accumulate DON levels above critical thresholds for human and livestock consumption (2). Triazole fungicide efficacy varies among studies, with mean percent control between 40 and 60% for FHB index and 30 to 50% for DON accumulation (3). In general, more effective control is achieved when moderate resistance is combined with appropriate fungicide applications (1, 4). However, this control is variable among grain classes and cropping systems. From 2009 to 2011, coordinated, uniform trials were conducted in multiple states to evaluate the effects of grain class, crop rotation, cultivar resistance, and fungicide application on the reduction of FHB and DON. This report summarizes results from trials conducted during the 2011 season.

MATERIALS AND METHODS

Trials were established in fields following a host or non-host crop of *F. graminearum*. At least two commercial small grain cultivars, classified as susceptible (S), moderately susceptible (MS) or moderately resistant (MR), were planted in four to six replicate blocks in each trial. The standard experimental design was a randomized complete block, with a split-split-plot arrangement of cultivar (whole-plot), inoculation (sub-plot) and fungicide treatment (sub-sub-plot). Some trials used fungicide as whole-plot and cultivar as sub-sub-plot; while others did not include inoculation as a factor. Fungicide (Prosaro®, 6.5 fl. oz/A + NIS) was applied at anthesis, using CO_2 powered sprayers, equipped with Twinjet XR8002 or paired XR8001 nozzles, mounted at a 30 or 60^o angle, forward or backward. For trials with artificial inoculations, either *F. graminearum*-colonized corn kernel were spread on the soil surface of plots prior to anthesis or plots were spray-inoculated with a spore suspension of the fungus approximately 24 hours following fungicide treatments. FHB index (plot severity) was assessed during the dough stages of grain development. Milled grain samples were sent to a USWBSI-supported laboratory for toxin analysis. Analysis of variance (linear mixed model) was used to evaluate the effects of fungicide, cultivar, (and inoculation, when appropriate) and their interactions on index, DON and yield (assuming a significance level $\alpha = 0.05$). Percent control was calculated to compare the effect of control measures to the susceptible, untreated check.

RESULTS AND DISCUSSION

At the time of this summary, data were collected from 29 trials, conducted in 12 states (AR, IL, IN, KY, MD, MN, MO, ND, NE, NY, OH and SD) (Table 1). These included 15 soft red winter wheat (SRWW), 2 hard red winter wheat (HRWW), 4 hard red spring wheat (HRSW), 2 two-row barley, 4 six-row barley and 2 durum wheat trials. FHB intensity and DON accumulation varied among locations and grain classes (Table 1). Trials with < 5% mean index and/or < 1 ppm mean DON in the susceptible, untreated check were not included in this analysis. Means for cultivar resistance class x fungicide treatment combinations and percent control of index and DON, relative to the untreated susceptible check (S_UT), are found in Table 2.

Arkansas. Four SRWW cultivars were planted near Kibler. Index values ranged from 4 to 76%; however, DON values were relatively low and mean DON in the susceptible untreated check was < 1 ppm (Table 1). Yield data were unavailable for this trial. Cultivar, fungicide and their interaction all had significant effects ($P < 0.05$) on index. Inoculation had a marginal effect (P = 0.0541) on index. Approximately 38% control of index was achieved by using a fungicide on the S cultivar and nearly 60% control of index was achieved by using an MR cultivar in combination with fungicide treatment (Table 2).

Illinois. Six SRWW cultivars were planted into host residue near Dixon Springs, Monmouth and Urbana. At Urbana, plots were also planted into non-host residue. Trials at Dixon Springs and Monmouth were inoculated while the trial at Urbana was naturally infected. *Dixon Springs.* Index and yield ranged from 0 to 55.5% and 48.2 and 81.2 bu/A, respectively. Despite substantial index values, mean DON levels in the susceptible untreated check were < 2 ppm (Table 1). Cultivar, fungicide and their 2-way interaction had significant effects on index, while only cultivar had a significant effect on yield. Over 90% control of index was achieved by combining a MS or MR cultivar with fungicide treatment (Table 2). *Monmouth.* Index, DON and yield ranged from 0 to 19.5%, 0.2 to 6 ppm and 78.4 to 106.6 bu/A, respectively. Cultivar, fungicide and inoculation all had significant effects on index, DON and yield. Two-way interactions between cultivar and fungicide and inoculation and fungicide also had significant effects on index. Two-way interactions between cultivar and inoculation and inoculation and fungicide also had significant effects on yield. Combining a MS or MR cultivar with fungicide resulted in > 80% control of index (Table 2). MR combined with fungicide resulted in the greatest reduction (65%) of DON (Table 2) *Urbana.* Index ranged from 0 to 26 and 0 to 32.5% and DON from 0.1 to 3 and 0.1 to 2.1 ppm in the host and non host residue trials, respectively. Cultivar effect was significant for index and DON in both host and non-host residue trials. The effects of fungicide and the cultivar x fungicide interaction were only significant for DON accumulation. Yield data were unavailable for this location. MR and fungicide combination resulted in the greatest reductions in both index (76 and 89%) and DON (82 and 78%) in the host and non-host residue trials, respectively.

Indiana. Four SRWW cultivars were planted into host residue near Tippecanoe. Index and yield values ranged from 4.3 to 35% and 41.7 to 95.5 bu/A, respectively. Cultivar, fungicide and the cultivar x fungicide interaction all had significant ($P < 0.05$) effects on both index and yield. Inoculation did not have a significant effect on index or yield. DON data were not available at publication time. The greatest reduction in index (67.5%), relative to the susceptible, untreated check, was observed as a result of an MR cultivar combined with fungicide treatment. This was followed closely by MR cultivar without fungicide treatment (62%)

Kentucky. Three SRWW cultivars were planted into host residue near Princeton, KY. Cultivar, fungicide and the cultivar x fungicide interaction all had significant effects on index, DON and yield. Inoculation did not have significant effect on index or yield; however, inoculation and the inoculation x fungicide interaction significantly affected DON accumulation. The greatest reductions in index and DON resulted from the use of an MR cultivar in combination with a fungicide treatment, nearly 94 and 88%, respectively (Table 2).

Maryland. Six SRWW cultivars were planted near Wye into both host and non-host residues, and into host residue only near Keedysville. *Wye*. When planted into host residue, index and yield ranged from 1.3 to 48.6% and 56.4 and 92.8 bu/A, respectively. DON data were not available at publication time. Cultivar and fungicide had significant effects on index and yield. Inoculation and the inoculation x cultivar interaction had significant effects on yield. Following non-host residue, index and yield ranged from 0.9 to 61.1% and 51.6 to 96.0 bu/A. Cultivar, fungicide and inoculation all had significant effects on index, while only inoculation had a significant effect on yield. Regardless of the previous crop, the MR and fungicide combination resulted in the greatest reduction of index; however, percent control was higher in the trial planted into host crop residue than in the trial planted into non-host residue (83 and 57%, respectively) (Table 2) *Keedysville*. This location did not receive artificial inoculations. Index, DON and yield ranged from 6.4 to 75.3%, 0.3 to 13.1 ppm and 50.3 to 98.4, respectively. Fungicide had significant effects on index, DON and yield. Cultivar only had a significant effect on index. The greatest control of index and DON was achieved by combining an MS cultivar with fungicide (58 and 79%, respectively) (Table 2).

Minnesota. Four HRSW and four 6-row barley cultivars were used in two separate trials near St. Paul. In the barley trial, mean index and DON in the susceptible untreated check were below 5% and 1 ppm, respectively (Table1). Higher levels of FHB were observed in the HRSW trial, with index and DON ranging from 0 to 23.4% and 0 to 9.4 ppm, respectively. Yield data were not available at publication time. Cultivar, inoculation, fungicide and the cultivar x fungicide and inoculation x fungicide interactions all had significant effects on index. Inoculation, fungicide and their 2-way interaction had significant effects on DON accumulation. Fungicide application reduced index by > 70% and DON by > 55%, regardless of host resistance; however, the highest percent reduction occurring when the MR cultivar was treated (82% for index and 69% for DON) (Table 2).

Missouri. Five SRWW cultivars were planted into host and non-host residue near Columbia. These trials were not inoculated. In the host residue trial, index, DON and yield ranged from 9.9 to 43.1%, 0.5 to 14.7 ppm and 26.6 to 84.8 bu/A, respectively. In the non-host residue trial, index, DON and yield ranged from 6.6 to 35.4%, 0 to 2 ppm and 41.7 to 91.3 bu/A, respectively. Cultivar had significant effects on index, DON and yield in both trials. Fungicide had significant effects on index and yield in the host crop residue trial and on index and DON in the non-host residue trial. The cultivar x fungicide interaction had significant effects on index in the host residue trial and on DON in the non-host residue trial. The greatest reductions in index were observed as a result of combining MR with fungicide in the host and non-host trials (66 and 50%) (Table 2). In the trial planted into non-host crop residue, as DON levels were relatively low, all management combinations resulted in < 1 ppm DON. In the trial planted into host residue, combining MR with fungicide resulted in the highest percent control (80%).

Nebraska. Four hard red winter wheat cultivars were planted into host residue near Mead. Index, DON and yield ranged from 0 to 19.2%, 0 to 2.8 ppm and 41.2 to 68.6, respectively. Cultivar and fungicide were not statistically significant for index in this trial. However, both cultivar and fungicide had significant effects on DON and yield. Additionally, the cultivar x fungicide interaction also had a significant effect on DON. The S cultivar combined with fungicide resulted in the greatest reduction in index (48%), while greatest reduction in DON was observed as a result of the MR and fungicide combination (64%) (Table 2).

New York. Four SRWW cultivars were planted into both host and non-host residue near Aurora. Despite artificial inoculations, mean index and DON levels were relatively low in this trial and mean levels in the susceptible, untreated check were below 5% and 2 ppm, respectively (Table 1).

North Dakota. Fargo. Four cultivars each of HRSW, two-row barley and six-row barley were planted into both host and non-host residue near Fargo. Index values were > 5% only in the HRSW and two-row barley trials planted into host residue (Table 1), with means ranging from 1.1 to 16.8 and 1.1 to 8.8%, respectively. Cultivar was the only factor to have a significant effect on index in these trials. DON levels in the susceptible, untreated check were > 1 ppm only in the HRSW trials (Table 1). DON ranged from 0.3 to 1.6 and 0.2 to 5.7 ppm in non-host and host crop residue HRSW trials, respectively. In HRSW, cultivar, fungicide and their two-way interaction had significant effects on DON in non-host residue only. In HRSW, the combination of MR and fungicide resulted in the highest control of DON, followed by the use of fungicide alone, regardless of residue type. Cultivar had a significant effect on yield in the 2 two-row barley trials only. *Langdon.* Five durum cultivars were also planted into both host and non-host residue near Langdon; however, index and DON data were not available for these trials at publication time. Cultivar had significant effects on yield in both durum trials. In durum planted into host residue, fungicide and cultivar x fungicide interaction also had significant effects on yield.

Ohio. Four SRWW cultivars were planted into non-host residue near Wooster. Index, DON and yield observations ranged from 0.1 to 15.7%, 0.7 to 3.7 ppm and 34.1 to 93.5 bu/A, respectively. The effects of cultivar, fungicide and their interaction had significant effects on index and DON, while only cultivar and fungicide had significant effects on yield. Inoculation did not have a significant effect on FHB, DON or yield in this trial. Fungicide reduced index and DON, regardless of cultivar resistance. Over 90% control of index and DON was observed as a result of the MR and fungicide combination (Table 2).

South Dakota. Three HRWW, three HRSW and three six-row barley cultivars were planted in separate trials. Index data were not available for these trials and DON data were not available for the HRSW trial at the time of publication. DON values for HRWW and barley ranged from 0 to 3 and 0 to 1.6 ppm, respectively. In HRWW, cultivar had a significant effect on DON; however, the effect of fungicide on DON was not significant. In barley, cultivar, fungicide and the cultivar x fungicide interaction all had significant effects on DON. In both HRWW and barley, the use of MS or MR cultivars resulted in DON levels < 1 ppm (Table 2). Yield ranged from 29.8 to 59.1, 9.7 to 24.5 and 31 to 73.7 bu/A for HRWW, HRSW and barley, respectively. Cultivar had significant effects on yield in all three grain classes. Additionally, fungicide and the cultivar x fungicide interaction had significant effects on yield for HRWW only.

CONCLUSIONS

In most trials, the use of a MS or MR cultivar reduced both index and DON, relative to the untreated, susceptible check. The effect of fungicide was slightly more variable across trials, potentially due to interactions between fungicide efficacy and environmental conditions. In general, fungicide application increased percent control of index and DON, within each resistance category. Most frequently the combination of moderate resistance to FHB and an appropriately timed fungicide application resulted in the greatest level of control, across trials. The goal of including artificial inoculum as factor was to increase the number of "useable" trials. It is difficult to assess the efficacy of integrated management strategies in trials with very low FHB intensity, this is index < 5% and DON < 1 ppm. In 2011, 17 out of 24 trials with index data and 14 out of 23 trials with DON data had mean index and DON in the untreated susceptible check above 5% and 1 ppm, respectively.

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Table 1. Study descriptions and trial-wide mean FHB index, DON and yield (averages across all treatments and reps) from twenty-nine coordinated integrated management trials, conducted in twelve states in 2011.

					Trial-wide mean			Susceptible-untreated check	
State	Location	Grain Class	Previous Crop	Trial No.	Index %	DON (ppm)	yield	Index %	DON (ppm)
AR	Kibler	SRWW	.	1	32.78	0.16	.	41.50	0.29
IL	Dixon Springs	SRWW	host	2	12.67	0.25	62.26	34.34	0.52
	Monmouth	SRWW	host	3	4.44	2.16	97.27	9.88	3.26
	Urbana	SRWW	host	4	7.99	0.89	.	12.63	1.82
	Urbana	SRWW	non-host	5	5.99	0.62	.	17.38	1.28
IN	Tippecanoe	SRWW	host	6	11.01	.	87.99	11.98	.
KY	Princeton	SRWW	host	7	13.30	0.74	92.11	31.77	1.56
MD	Keedysville	SRWW	host	8	31.40	4.32	77.41	44.24	6.88
	Wye	SRWW	host	9	15.62	.	75.72	24.96	.
	Wye	SRWW	non-host	10	28.75	.	77.87	38.55	.
MN	StPaul	HRSW	.	28	5.03	1.04	.	9.15	1.70
	StPaul	6ROWB	.	29	1.82	1.13	.	1.02	0.17
MO	Columbia	SRWW	host	15	21.00	2.71	46.33	33.08	5.21
	Columbia	SRWW	non-host	16	17.78	0.37	64.99	24.57	1.14
ND	Fargo	HRSW	non-host	19	2.24	0.76	58.91	3.65	1.04
	Fargo	HRSW	host	20	4.69	0.82	59.39	7.10	1.43
	Fargo	2ROWB	host	21	5.14	0.46	46.18	5.24	0.56
	Fargo	2ROWB	non-host	22	3.47	0.25	46.20	4.85	0.31
	Fargo	6ROWB	host	23	4.20	0.50	43.12	4.28	0.27
	Fargo	6ROWB	non-host	24	4.26	0.84	50.69	3.71	0.47
	Langdon	durum	non-host	25	.	.	46.29	.	.
	Langdon	durum	host	26	.	.	42.70	.	.
NE	Mead	HRWW	host	27	5.51	1.11	45.19	6.98	1.58
NY	Aurora	SRWW	host	17	3.25	0.89	77.06	2.26	0.44
	Aurora	SRWW	non-host	18	2.18	0.38	61.72	1.32	0.12
OH	Wooster	SRWW	host	11	5.78	1.06	53.75	11.71	2.33
SD	Brookings	HRWW	host	12	.	0.95	39.39	.	1.87
	Brookings	HRSW	host	13	.	.	15.29	.	.
	Brookings	6ROWB	host	14	.	0.52	51.98	.	1.05

Table 2. Trial-wide means for index and DON and percent control for each management combination, relative to the untreated, susceptible check.

	Trial No.[1]	Cultivar Resistance Class x Fungicide Means[2]						% Control				
		S_UT	S_FUN	MS_UT	MS_FUN	MR_UT	MR_FUN	S_FUN	MS_UT	MS_FUN	MR_UT	MR_FUN
INDEX	**1**	41.50	25.75	45.25	35.75	30.00	16.75	37.95	-9.04	13.86	27.71	59.64
(%)	**2**	34.34	14.72	15.31	3.13	9.56	2.27	57.14	55.41	90.90	72.15	93.39
	3	9.88	4.34	5.19	1.69	4.29	1.71	56.10	47.49	82.92	56.56	82.71
	4	12.63	12.44	5.88	10.25	6.83	3.04	1.52	53.48	18.84	45.90	75.92
	5	17.38	7.00	4.63	3.25	3.21	1.88	59.72	73.39	81.30	81.54	89.21
	6	20.79	11.98	13.92	11.67	7.94	6.75	42.38	33.06	43.88	61.82	67.53
	7	31.77	12.69	18.37	7.88	7.08	2.00	60.06	42.18	75.21	77.71	93.70
	8	44.24	34.63	25.37	18.43	31.00	21.57	21.73	42.66	58.33	29.93	51.25
	9	24.96	12.60	21.30	9.21	16.56	4.27	49.54	14.65	63.11	33.66	82.91
	10	38.55	31.03	34.52	18.47	30.32	16.50	19.50	10.45	52.10	21.36	57.20
	11	11.71	5.46	11.39	3.27	4.13	1.02	53.34	2.75	72.11	64.77	91.25
	15	33.08	21.76	21.18	14.10	18.52	11.20	34.23	35.99	57.38	44.02	66.14
	16	24.57	16.99	17.04	14.62	19.17	12.23	30.84	30.64	40.51	21.99	50.21
	20	7.10	4.59	5.03	3.43	1.63	4.10	35.39	29.23	51.76	77.11	42.25
	21	5.24	5.43	6.09	4.00	.	.	-3.60	-16.13	23.65	.	.
	27	6.98	3.60	.	.	5.91	5.55	48.42	.	.	15.29	20.49
	28	9.15	2.25	8.84	2.71	4.31	1.63	75.45	3.41	70.43	52.94	82.18
DON	**3**	3.26	2.94	2.85	2.25	1.67	1.14	9.70	12.58	30.98	48.80	65.16
(ppm)	**4**	1.82	1.20	0.87	0.60	0.65	0.40	34.07	52.34	67.03	64.19	78.16
	5	1.28	0.88	0.62	0.51	0.38	0.24	31.05	51.76	60.55	70.51	81.53
	7	1.56	0.44	1.25	0.44	0.54	0.19	71.63	19.63	72.04	65.63	87.58
	8	6.88	3.40	3.36	1.45	7.97	3.38	50.65	51.14	78.88	-15.79	50.92
	11	2.33	0.72	2.23	0.80	0.62	0.20	69.05	4.22	65.72	73.25	91.31
	12	1.87	1.30	0.82	0.52	0.32	0.90	30.48	56.33	72.37	83.07	51.87
	14	1.05	0.45	.	.	0.13	0.00	57.14	.	.	88.10	100.00
	15	5.21	3.63	2.28	1.29	1.27	1.03	30.42	56.33	75.21	75.69	80.17
	16	1.14	0.59	0.09	0.04	0.00	0.00	48.10	91.96	96.35	100.00	100.00
	19	1.04	0.70	0.93	0.63	0.55	0.45	32.69	11.06	39.90	47.12	56.73
	20	1.43	0.50	0.95	0.70	0.65	0.43	65.03	33.57	51.05	54.55	70.28
	27	1.58	0.96	.	.	1.33	0.58	39.08	.	.	16.14	63.61
	28	1.70	0.68	1.39	0.75	0.93	0.54	60.00	18.46	55.66	45.29	68.53

[1] Only trials with > 5% index and >1 ppm DON were included in this analysis.
[2] S_UT = susceptible, untreated check; S_FUN = susceptible, fungicide-treated; MS_UT = moderately susceptible, untreated; MS_FUN = moderately susceptible, fungicide-treated; MR_UT = moderately resistant, untreated; MR_FUN = moderately resistant, fungicide-treated.