ETIOLOGY, EPIDEMIOLOGY AND DISEASE FORECASTING

Chairperson: Ruth Dill-Macky

EFFECT OF HOST RESISTANCE, FUNGICIDE APPLICATION AND INOCULUM LEVELS ON FUSARIUNM HEAD BLIGHT OF WHEAT IN NORTH DAKOTA

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ABSTRACT

Knowledge of host resistance, inoculum levels, and weather conditions favorable for disease development is necessary to optimize a disease forecaster. A group of plant pathologists from five land-grant universities (North Dakota, Ohio, Pennsylvania, Purdue, and South Dakota) have collaborated to develop and improve performance of a disease forecasting system for Fusarium Head Blight (FHB). The main goal of this study was to determine the effect of host resistance, inoculum levels, and fungicide on FHB development in spring wheat. The experiment was conducted at the NDSU Agricultural Experiment Station, Fargo, ND. The experimental design was a split-split plot with three replications; inoculum levels (n = 2), fungicide treatment (1), and cultivars (3) as main plots, sub-plots, and sub-sub plots, respectively. The previous year crop was soybean. The plots with inoculum were created by distributing corn kernels infested with *F. graminearum* in the plots at the 6-leaf stage. Two FHB susceptible cultivars, Argent (hard white spring wheat and early flowering) and Granite (hard red spring wheat and late flowering), and one FHB resistant cultivar, Alsen (hard red spring wheat), were selected and planted on April 29, 2005. Alsen also was planted between main plots and sub-plots at 20 ft wide to serve as buffers. The buffer strips were free of inoculum. Trizole fungicide “Folicur” (@ 4 fl oz/acre) was applied to one sub-plot of each cultivar in each replicate when cultivars Alsen and Argent were at flowering (Feekes GS 10.51-10.52). The *G. zeae* population from each inoculum treatment was monitored daily from Feekes growth stage 8 (early flag leaf emergence) to Feekes GS 11.2 (soft dough) by collecting spores from air, and from Feekes GS 10 (boot stage) to Feekes 11.2 by head washings. Additionally, 90 wheat heads of each cultivar were monitored daily from Feekes scale GS 10 for growth synchrony. The disease incidence (number of infected head/total number of heads examined) and head severity (% of individual infected head) data were recorded in all treatments. FHB incidence was significantly ($P<0.0001$) different among the inoculum levels. The disease incidence and severity ranged from 21 to 51%, and 10 to 32%, respectively. Fungicide application significantly decreased disease severity and increased the seed test weight. The cultivars exhibited significant differences in FHB severity. The disease severity was significantly ($P< 0.0001$) lower (8 to 11%) in the FHB resistant Alsen than in the susceptible Argent (25 to 33%). Both fungicide application and cultivars had little or no effect on the disease incidence. As expected, air samples collected from high inoculum level and low inoculum level plots resulted in high number (range = 20-134) and low number (7-65) of *G. zeae* colony forming units (CFU) in 20 out 21 days of the samples, respectively. The majority (>97%) of the plants began and ended flowering in 3-4 days in both early and late flowering cultivars. These results indicate that favorable weather conditions for FHB, inoculum levels of *G. zeae*, level of host resistance, and fungicide application may have a significant role in disease development. Also, the fungus has a small window of opportunity to infect wheat heads, as the majority of the plants completed flowering within 3-4 days, a crucial stage for infection.

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EFFECTS OF MOISTURE, WHEAT CULTIVAR, AND INFECTION TIMING ON FHB SEVERITY AND DON IN WHEAT

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ABSTRACT

Deoxynivalenol (DON) levels are important both for their health effects and because DON is a pathogenicity factor in cereals. Our knowledge of the epidemiological and host genetic influences governing DON concentrations is incomplete. While anthesis is thought to be the primary period for Fusarium head blight (FHB) infection in wheat, late infections can also lead to DON production. High levels of DON have sometimes been observed in the absence of abundant disease symptoms. The influences of the timing of moisture and the timing of infection on FHB symptoms, *Fusarium* growth, and DON development are not well understood, particularly in relation to cultivar differences. We are investigating these relationships, which are important to the process of forecasting epidemic severity and economic risk. The goal is to improve our understanding of how the duration of moisture and the timing of infection affect disease development, fungal growth, and DON production.

A multi-year field experiment was undertaken in fall 2004 in a misted nursery at Kinston, NC. The experiment had a split-plot design. Whole-plots were four durations of post-anthesis misting: 0, 10, 20, or 30 days. Sub-plots were seven cultivars, one susceptible to FHB and the others with varying degrees and putative types of moderate resistance. There were two treatments of each cultivar in each irrigation treatment: inoculated and noninoculated. All treatments were replicated three times.

Inoculations of *F. graminearum* spore suspensions were performed either at anthesis with a backpack sprayer on whole plots, or with a spray bottle on individual, funnel-isolated heads that were chosen at random in all noninoculated plots, marked, and protected until inoculation with glassine bags. Late inoculations were performed at 10 or 20 days after anthesis, and late-inoculated heads were compared to those inoculated at anthesis and those never inoculated. Disease incidence and severity were assessed on all plots, omitting the late-inoculated heads. In order to track DON concentrations during grain maturation, heads were selected blindly in all plots in the 30-day-irrigated, backpack-inoculated plots on five occasions starting 2 wks after flowering and continuing at intervals of 7-11 days. Data are being gathered on visual kernel damage, percent infected kernels, and DON concentrations, and also on *F. graminearum* biomass by tissue type (kernel, rachis, or glume) using real-time PCR.

Preliminary Results: In 2004-05, levels of FHB incidence and severity were low, due in part to cool temperatures. Nevertheless, differences in incidence and severity among inoculated cultivars were significant (*P* d•0.05) both within each irrigation regime and across regimes. Across all cultivars, duration of post-anthesis misting had no significant effect on incidence ($P = 0.859$), nor on severity ($P = 0.124$). Misting duration affected disease severity on NKC 9184 and VA01W99 differently from that on other cultivars ($P = 0.0039$); without those two cultivars, misting duration had a positive effect on severity ($P = 0.024$).

The ratio of FHB incidence to severity was significantly higher for NC Neuse than for the other cultivars (P d•0.05). Lower ratios of incidence to severity support the hypothesis of Type I resistance, while higher ratios support the hypothesis of Type II resistance.

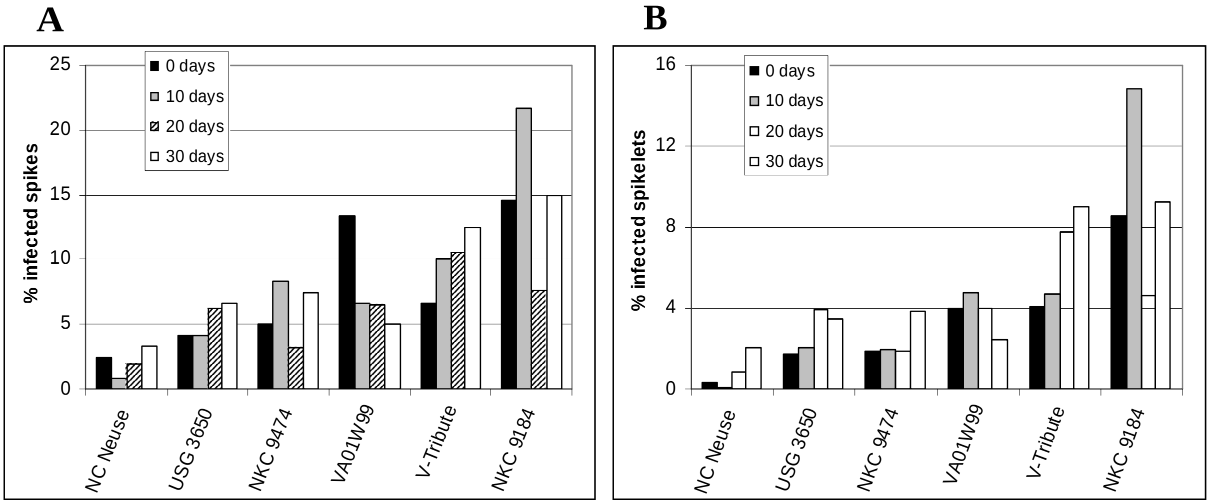

Fig. 1. A. Incidence (% infected spikes) and **B.** severity (% infected spikelets) of FHB in six soft red winter wheat cultivars inoculated with *F. graminearum* spores and subjected to four durations of post-anthesis misting (0, 10, 20 and 30 days). Disease assessments were not available for cultivar Ernie.

FUTURE DIRECTIONS IN THE DEVELOPMENT AND APPLICATION OF RISK ASSESSMENT MODELS FOR FUSARIUM HEAD BLIGHT

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ABSTRACT

A cooperative project to investigate the epidemiology and develop disease forecasting models for Fusarium head blight was established by researchers in IN, ND, OH, PA and SD. This modeling effort is now in its third phase (Phase III) and has demonstrated an iterative progression in model development and deployment. The first generation pre-flowering model used observations of temperature and rainfall from 7-days prior to flowering to predict the probability of a FHB epidemic of greater than 10% field severity. The accuracy of this model was near 70% for data used to develop and validate the model. This experimental model was released for deployment at the state or regional level in 2001-2003. During this period additional information was being collected by members of the cooperative epidemiology effort and used to initiate a second phase (Phase II) of modeling. The resulting model improved accuracy from 70% to near 80% and successfully accounted for potential differences in winter and spring wheat regions. A sub-model for winter wheat also accounted for the presence of corn residue as a local inoculum source. In 2004 the Phase II model was deployed as part of the Fusarium Head Blight Prediction Center (www.wheatscab.psu.edu) that provided daily maps of disease risk for 23 states. We have nearly completed a third phase of model development (Phase III). The Phase III model for spring wheat uses only mean relative humidity for 7 days prior to flowering and a variable describing host resistance to predict epidemics of FHB. This model correctly classified 78% of the cases used to develop and validate the model. The Phase III winter wheat model uses only pre-flowering mean relative humidity and has a prediction accuracy near 70%. The field severity threshold for classifying a case as an epidemic was adjusted from 10 to 2% for this model. These candidate models were evaluated as part of an experimental interface during the 2005 growing season. Additional enhancements to the prediction center including the use of weather forecasts and alternative ways to represent risk over multiple days were also tested as part of the experimental interface. Validation of the Phase III models and other enhancements is ongoing but we anticipate they will be ready for public deployment in 2006. Future goals of the cooperative epidemiology effort include adapting the risk models for use with barley and prediction of the mycotoxin deoxynivalenol.

APPLICATION OF HOTSPOT DETECTION ANALYSIS TO THE PREDICTION OF FUSARIUM HEAD BLIGHT EPIDEMICS

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ABSTRACT

Plant diseases and the pathogens that cause them are distributed spatially at different scales ranging from less than one meter to entire continents. The distribution of disease may result from local pathogen populations or the spread of disease within a geographic region. Locations or regions that have consistently high levels of disease may have characteristics unlike those of the surrounding areas. For example, a particular section of a state may have a climate or cropping practices that are more conducive to pathogen survival, and/or disease development. These highly conducive areas can be called disease hotspots. If patterns in these characteristics can be identified it may provide valuable insights into the factors contributing to disease epidemics and could allow disease prediction models to account for the elevated risk levels in some regions of the country. Hotspot analysis represents a method of searching for consistent spatial patterns in a desired variable. The analysis evaluates three dimensions of patterns: (i) **spatial**, patterns within a landscape; (ii) **temporal**, persistence of high disease levels; and (iii) **spatial-temporal**, addressing the migration of patches of disease or hotspots. FHB is a good candidate for hotspot analysis because of the availability of geo-referenced observations of disease intensity coupled with weather-driven models of disease biology, and information about crop/disease management practices (e.g. tillage, crop rotation). We anticipate that hotspot analysis will allow us to identify areas with consistently higher probability of epidemics given consistent patterns in weather and cultural practices, and determine if these regions have expanded or changed over time. This analysis may also help assess factors that may contribute to the elevated levels of disease within these hotspots and suggest adjustments in crop management practices.

INCORPORATION OF HOST REACTION AND CROP RESIDUE LEVEL INTO PREDICTION MODELS FOR FUSARIUM HEAD BLIGHT

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OBJECTIVES

Develop disease prediction models for Fusarium Head Blight

INTRODUCTION

Fusarium Head Blight is a devastating disease with serious worldwide impacts. Between 1998 and 2000 this disease resulted in more than 800 million dollars in losses for the US wheat and barley industry (Nganje et al., 2004). In the U.S., the disease is primarily caused by the fungus *Fusarium graminearum* (teleomorph: *Gibberella zeae*) (Parry et al, 1995). Several efforts around the world have attempted to forecast the risk for epidemics of FHB, and forecasting models have been proposed for Canada (Hooker et al, 2002), Argentina (Moschini and Fortugno, 1996), China (Zhang and Shang, 1995), USA(De Wolf et al, 2003) and Italy (Rossi et al., 2003). All these models relate the biology of the fungus to environmental conditions using different statistical approaches.

In the US, models developed by our collaborative epidemiology group including researchers in IN, ND, OH, PA, and SD have been deployed on the internet for public use at www.wheatscab.psu.edu. The results of the first phase of this project were published by De Wolf, et al (2003). The following manuscript presents modeling results from phase II and phase III of this development effort.

METHODS

Data collection - Data used to develop the models consisted for observations of disease development and crop phenology from 8 states and multiple wheat production regions in the U.S. The total number of cases available for analysis was 124 and 154 in phase II (2004) and phase III (2005), respectively (Table 1), and comprises a period from 1990-2004. For each of these cases, the observations of disease and crop growth stage were coupled with hourly weather information (hourly temperature, relative humidity, precipitation and dew point temperature), varieties reaction to FHB and the presence of corn residue (a potential local inoculum source).

Variable selection - Hourly observations of temperature, relative humidity, dewpoint temperature and rain fall were used to create candidate variables for use in modeling epidemics. The complexity of the variables ranged from simple summary statistics such as mean temperature to the number of hours of specific weather conditions favorable for certain developmental stages of the pathogen (i.e. perithecia development, or infection) . These variables were calculated to represent 3-, 5-, 7- and 10-day periods prior to flowering. A total of 306 variables were evaluated. Disease was coded as a binary variable (0=no or low disease and 1= severe epidemic). In 2004 (Phase II), cases were considered epidemics if they had a field severity (FHB index) greater than or equal to 10%. In 2005 (Phase III), both 10% and 2% severity threshold were evaluated.

Model development and validation - Variable selection was done by using best subsets. This approach to variable selection helps the modeler identify and eliminated redundant variables, or variables that do not have a strong relationship with the dependent variable. Models describing the relationship between weather variables and FHB epidemics were developed using four modeling approaches: Logistic regression, Classification and Regression Tree (CART), K-Nearest Neighbor discriminant analysis (K-NN), and

Neural Network. In 2005 only the Logistic Regression model approach was used.

In phase II of the analysis (2004), the total data set (n=124) was partitioned into two data sets with one data set (n=86) used for model development. The remaining cases were assigned to a data set used only for model validation. A similar approach was employed in phase III of the analysis (2005), with 108 of the total 154 cases used for model development. However, in phase III we also used a procedure known as 0.632+ Bootstrap. This bootstrap procedure randomly samples the total data set with replacement 200 times and allows for model development and validation on each of the samples. Model fit and accuracy are then based on bootstrap estimates of model parameters, thus minimizing the potential for overfitting the model to a small data set.

Candidate models were selected based on ability to correctly predict epidemics (% accuracy), balance between ability to predict epidemics (% sensitivity) and non-epidemics (% specificity) and measures of model fit. Model errors were evaluated for possible patterns in predictions that might be further explained by additional variables or time periods not currently considered by the models.

RESULTS AND DISCUSSION

Variable selection - The best subsets method of variable selection successfully identified variables related to disease epidemics. In general, temperature variables representing the number of hours that temperature was between 9 and 30°C were selected compared to other representations of temperature, including duration of temperature between 12 and 30°C and 15 and 30°C. Variables summarizing relative humidity were selected over those that used dewpoint temperature to estimate moisture levels. Variables representing the duration of rainfall were selected instead of variables representing summations or frequency of rainfall (number of days with rain). When variables summarizing weather conditions for 3-, 5-, 7- or 10-days periods prior to flowering were considered, only variables from a seven day period were selected by the best subsets analysis. The selected variables (Table 2) are consistent with research results from studies investigating the pathogen reproduction (Dufault et al. 2005). Variables describing crop management types (spring vs winter wheat), or specific production practices (presence of corn residue at a given location or the use of resistant cultivars) were also selected for further model development.

Modeling results Phase II - Among the statistical techniques evaluated, logistic regression and CART had the highest accuracy for all three models (Table 3). A model that used only duration of favorable temperature and humidity for winter wheat without corn residue and additional interaction terms describing interactions between temperature and humidity and hours of rain had the higher prediction accuracy than other models evaluated. For the logistic and CART approaches, this model correctly classified more than 80% of the cases and more than 80% sensitivity and specificity for all pooled cases (training and validation, over both wheat types). Errors of the model appear to be associated with favorable weather conditions during flowering or grain-filling periods of growth that are not considered by the pre-flowering models.

Modeling results Phase III - Logistic regression models were the focus of the phase III analysis, because of their accuracy in the phase II analysis and relative ease of deployment as a simple equation. In this phase of the analysis, we successfully reduced the number of variables used in the models. A candidate model for spring wheat used only mean relative humidity for 7-days prior to flowering and cultivar resistance to FHB as independent variables (Table 4). This model correctly classified 78% of the cases from spring wheat production regions. However, the model has slightly higher sensitivity than specificity indicating that it may overestimate the risk of a FHB epidemic in some years. Bootstrap estimates of model accuracy are similar to the more traditional approach to model validation but have a slightly lower specificity. A model that estimates the risk of a FHB epidemic for winter wheat in fields without corn residue or other local inoculum source was also developed in the phase III analysis. This model uses only mean relative humidity to predict the risk of epidemic of greater than or equal to 2% field severity with 70% accuracy. Sensitivity and specificity was both 70%. The bootstrap method of model development and validation resulted in models with reduced accuracy and poor fit statistics. Models resulting from this analysis were evaluated during the 2005 growing season and we anticipate that these models will be part of the Fusarium Head Blight Prediction Center in 2006

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Table 1. Data collected for use in Phase II and Phase III model development.

State	Locations	2004 Cases	2005 Cases
Indiana	6	10	23
Kentucky	1	0	2
Michigan	1	0	2
Missouri	3	11	11
North Dakota	6	36	48
Ohio	3	28	33
Pennsylvania	2	11	19
South Dakota	1	10	16

Table 2. Selected variables evaluated for model development.

Variable Name	Meaning	Time Frame
W/S	Wheat type w=winter; s=spring	NA
H1	Mean relative humidity	7 days
R2	Hours of rain	7 days
T3	Temperature 9-30 C	7 days
TH2	Temperature 9-30 C and RH >90%	7 days
Corn	Corn residue	NA
Resistance	Cultivar resistance	NA

Table 3. Phase II model results and comparison between modeling methods.

#	Model	Modeling Method	%Correct	Sensitivity	Specificity
1	T3 H1 R2 W Corn	Classification Tree	0.84	0.76	0.89
		K-Nearest Neighbor	0.83	0.74	0.89
		Logistic Regression	0.76	0.78	0.74
		Neural Network	0.67	0.70	0.65
2	S*H1*T3 W*TH2 W*Corn*H1*T3	Classification Tree	0.82	0.94	0.74
		K-Nearest Neighbor	0.67	0.52	0.77
		Logistic Regression	0.72	0.78	0.68
		Neural Network	0.77	0.76	0.77
3	S*R2*T3 S*H1*T3 W*TH2 W*Corn*H1*T3 W*Corn*R2*T3	Classification Tree	0.88	0.90	0.86
		K-Nearest Neighbor	0.83	0.76	0.88
		Logistic Regression	0.82	0.82	0.82
		Neural Network	0.81	0.76	0.84

Table 4. Phase III model results and comparison between validation methods.

Model	Validation Method	%Correct	Sensitivity	Specificity
S S*Resistance S*H1	Training + Cross-Validation	0.78	0.83	0.72
	.632 Bootstrap	0.78	0.86	0.69
W*H1	Training +Cross-validation	0.70	0.70	0.70

IMPACT OF PREHARVEST MANAGEMENT STRATEGIES IN BARLEY ON FHB, SEED COLONIZATION AND DON

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ABSTRACT

Fusarium Head Blight (FHB) substantially affects the barley crop grown in North Dakota and western Minnesota through reductions in yield, lower test weights and inability of farmers to achieve malting quality barley due to contamination with toxins associated with infection by *Fusarium*. To produce barley with low or no FHB symptoms and DON content, will require an integrated approach that includes use of cultural practices, fungicides, and FHB resistant cultivars. As barley is susceptible from flowering through to harvest, preharvest management which alters the susceptibility of the host or changes environmental conditions to favor the pathogen, could significantly reduce the effectiveness of integrated control methods developed for FHB. Weather conditions often experienced in the upper midwest during barley harvest cause slow and non-uniform crop maturity within a field. In most years feed and malt barley producers use windrowing to accelerate crop maturity and drying. In addition, in feed barley pre-harvest herbicides are sometimes used as desiccants. To test the hypothesis that swathing affects disease under normal or high rainfall conditions, preharvest treatments in Fargo in 2004 and 2005 were a factorial combination of irrigated or unirrigated, swathed or straight combined and the cultivars Robust or Stander. In Fargo, barley flowers and ripens in July and in 2004 Fargo experienced a near average mean daily July temperature of 20^0C and total July precipitation of 97mm, but in 2005 it was hotter and drier with a mean daily July temperature of 22^0C and total July precipitation of 40mm. There was no statistical interaction between any combination of irrigation treatment, cultivar or preharvest treatment. In 2004 irrigation significantly increased DON and the percentage of kernels colonized by *Fusarium*, but did not affect visual symptoms on grain. In 2005, a season with lower disease levels, irrigation had no effect on DON, colonized kernels or visual symptoms. In 2004, straight combined barley had more than double the DON of swathed barley and significantly more visual symptoms on the grain. In contrast in 2005, harvest treatment had no effect on DON or visual symptoms on the grain but swathing slightly increased *Fusarium* infected kernels. Instances of iatrogenic disease associated with pesticides are common. Uneven herbicide application, coupled with various effects of an herbicide on the host and/or a pathogen, is likely to be the cause of an increase in disease. To test the hypothesis that preharvest desiccants were affecting disease, treatments in Fargo in 2004 included glyphosate, metsulfuron or 2-4-D at recommended and twice recommended rates on Robust barley applied at the soft dough stage. Treatments in 2005 at Fargo were a factorial combination of the cultivars Robust or Conlon with recommended or twice recommended rates of dicamba, carfentrazone, 2-4-D, metsulfuron, paraquat or glyphosate. Treatments in 2005 at Minot were a factorial combination of the cultivars Stellar, Tradition, Drummond, Excel, Robust, Divide, Eslick or Conlon with recommended rates of dicamba, carfentrazone, 2-4-D, metsulfuron, paraquat or glyphosate. In none of the three preharvest desiccant experiments was DON in harvested grain significantly affected by the application of herbicide and in 2005 at Fargo and Minot, where more than one cultivar was tested in each experiment, there was no significant interaction between cultivar and desiccant herbicide.

EFFECT OF CORN RESIDUE LEVEL ON THE INCIDENCE OF FUSARIUM HEAD BLIGHT

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ABSTRACT

Corn residue is considered to be an important source of inoculum for Fusarium head blight (FHB); however, the quantitative risk of producing wheat in fields with large amounts of corn residue remains undetermined. Experiments were conducted in IN, ND, OH, and PA during the 2003 and 2004 growing seasons to evaluate the effect of corn residue level or other in-field inoculum source on the incidence of FHB. The experiment was a split-split-plot design with three replications at each location. Treatments included three levels of corn residue (approximately 0, 14 and 80% ground cover) as the main plot factor, two planting dates (normal for the location and 14 days after normal planting date) as the sub-plot factor, and three FHB susceptible cultivars (‘Hopewell’, ‘Patterson’ and ‘Elkhart’) as the sub-sub plot factor in IN, OH and PA. The protocol varied at the ND location, where *Gibberella zeae*-colonized corn kernels were used to establish the main plots, and two susceptible cultivars (‘Norm’ and ‘Grandin’) were used as the sub-sub plots; however, the two planting date sub-plot remained consistent. Incidence of FHB varied between years and locations, and current analysis considers each location and year separately. The highest mean incidence was 66.8% for OH-2003, and lowest was 4.0% for OH-2004. Three-way interactions between residue, planting date and cultivar were not significant ($P > 0.05$) in all but one of the locations and years (OH-2003), indicating that cultivars generally responded similarly within planting date and residue levels. Two-way interactions between planting date and cultivar on disease incidence were significant in five out of eight cases. This variation likely resulted from differential effects of planting dates on timing of cultivar flowering, and corresponding weather events conducive to infection around flowering. There was only one case (ND-2004) of an interaction between planting date and residue level on disease incidence. This indicates that the effects of residue levels on disease incidence were similar regardless of planting date in nearly all cases. The interaction between residue and cultivar on disease incidence was not significant in all cases, which suggests that changes in disease incidence in response to the residue level were similar among cultivars. The effect of residue level on FHB incidence was significant ($P < 0.05$) in five out of the eight cases; however the response was not consistent. For example, incidence was significantly lower in plots with no corn residue than plots with either the 14% or 80% residue levels, but disease incidence was not significantly different between the 14% and 80% residue levels in the PA-2003 case. In contrast, incidence was similar at the 0% and 14% residue levels, however, incidence at both of these levels of residue were significantly lower than disease incidence at the 80% residue level for the OH-2004 case. Cases with no significant effect of residue level had disease incidence nearly twice that of the cases where residue was significant. This observation suggests that the effects of local inoculum are variable for disease development and depend on local environment.

EFFECTS OF MOISTURE DURING AND AFTER ANTHESIS ON THE DEVELOPMENT OF FUSARIUM HEAD BLIGHT OF WHEAT AND MYCOTOXIN PRODUCTION

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OBJECTIVES

The objective of this study was to evaluate the potential relationship of moisture during the grain filling growth stages with the development of disease symptoms and DON accumulation

INTRODUCTION

Fusarium damaged grain is commonly contaminated with the mycotoxin deoxynivalenol (DON) (Parry et al. 1995; McMullen et al. 1997). In general, DON contamination is positively correlated with visual ratings of Fusarium head blight (FHB) intensity with the strongest relationship between field severity and Fusarium damaged kernels (Paul et al. 2005). However, lots of asymptomatic grain with greater than 2.0 ppm DON were reported in recent FHB epidemics.

MATERIALS AND METHODS

The role of moisture during and after anthesis was evaluated in a wheat field environment located at the Penn State Plant Pathology Research Farm located near State College, PA. The experimental was a split-plot design with moisture timing as the main plot and cultivar as the sub plot. Treatments included (i) supplemental moisture at anthesis and dry grain filling; (ii) dry during anthesis and supplemental moisture during grain fill; (iii) supplemental moisture during both anthesis and grain fill; and (iv) ambient moisture levels. The sub plots consisted of three soft red winter wheat cultivars. Two of these cultivars were FHB susceptible (‘Hopewell’ and ‘Patterson’) and the third (‘Valor’) was moderately resistant. The different moisture timings were achieved by either excluding with a mobile roof activated by rainfall or by adding moisture with supplemental mist irrigation. All plots were inoculated at the stem elongation stage of growth with corn kernels colonized with *Gibberella zeae*, and subjected to appropriate moisture treatment. The plots were evaluated for disease incidence and severity during the mid-dough growth stage. The harvested grain was evaluated for symptoms of disease and DON levels were assessed by HPLC.

RESULTS AND DISCUSSION

In 2004, disease incidence, disease severity, and DON concentration varied from 16 to 100% (mean 72.3%), 1.5 to 99.8% (mean 43.5%), and 4.9 to 29.4 ppm (mean 14.6 ppm) respectively (Figures 1 and 2). In 2005, development of disease was less than the previous year. Disease incidence ranged from 0 to 28% (mean 8.8%), and disease severity and DON concentration ranged from 0 to 8.6% (mean 2.6%) and 0 to 4.5 ppm (mean 0.9 ppm), respectively (Figures 1 and 2).

In general, treatments that provided misting during the anthesis resulted in significantly higher (*P d”* 0.05) disease intensity (incidence and severity) and DON concentration. An interaction between treatment and cultivar on disease intensity was also observed in 2004. More specifically, for treatments that received supplemental moisture only during the grain-fill, susceptible variety (‘Patterson’) resulted in larger increases of disease intensity compared with the moderately resistant variety (‘Valor’). All varieties resulted in a similar degree of disease intensity with other treatments. No interaction between treatment and cultivar for disease intensity was identified in 2005, and plots that received supplemental moisture only during the grain-fill resulted in low disease intensity (Figure 1) and were not significantly different from the treatment without misting.

In both years, plants that received supplemental moisture only during grain-fill resulted in DON concentration that was relatively low (Figure 2) and not significantly different ($P \leq 0.05$) from the results of the treatment without misting.

In 2005, there were no significant interactions between treatment and cultivar for disease intensity, but a significant ($P \leq 0.05$) interaction between treatment and cultivar on DON production was identified. In this year, the variety 'Hopewell' had significantly higher levels of DON when supplemental moisture was applied only during anthesis than did the other combinations of variety and moisture treatment. Plots that received supplemental moisture during both anthesis and grain-fill produced different responses in disease and DON over two years (Figures 1 and 2). In 2004, both disease intensity and DON concentration were significantly higher than plots that received only ambient moisture, and results were not significantly different from plots that received moisture at either only anthesis or grain-fill stages of growth. In 2005, although disease intensity was significantly higher than plots that received only ambient moisture, it was significantly lower than in plots that received moisture only at anthesis. DON concentration was also low in the grain harvested from plots that had received moisture during both anthesis and grain filling growth stages and were not significantly different DON levels observed in plots that received only ambient moisture.

Plants that did not receive misting (ambient treatment) tended to have low disease development in both years (Figures 1 and 2); however, in some cases, high levels of DON were observed in the presence of low field symptoms. For example, in 2004, a plot of 'Valor' under ambient conditions resulted in low disease intensity (19% incidence and 1.5% severity), while DON concentration was relatively high (16.3 ppm). To investigate further, a separate analysis on DON concentration was conducted by selectively sampling apparently healthy kernels from the harvested grain. It confirmed that samples of asymptomatic kernels could contain high levels of DON (up to 4.9 ppm was detected). However, there was no clear evidence to suggest that the prolonged wetness during milk-development was responsible for the presence of asymptomatic kernels with considerable DON concentration.

ACKNOWLEDGEMENTS

We thank Tim Grove for technical work in the field and Dr. Douglas Archibald, Brian Dombroski and Nik Zitomer for assistance with DON analyses.

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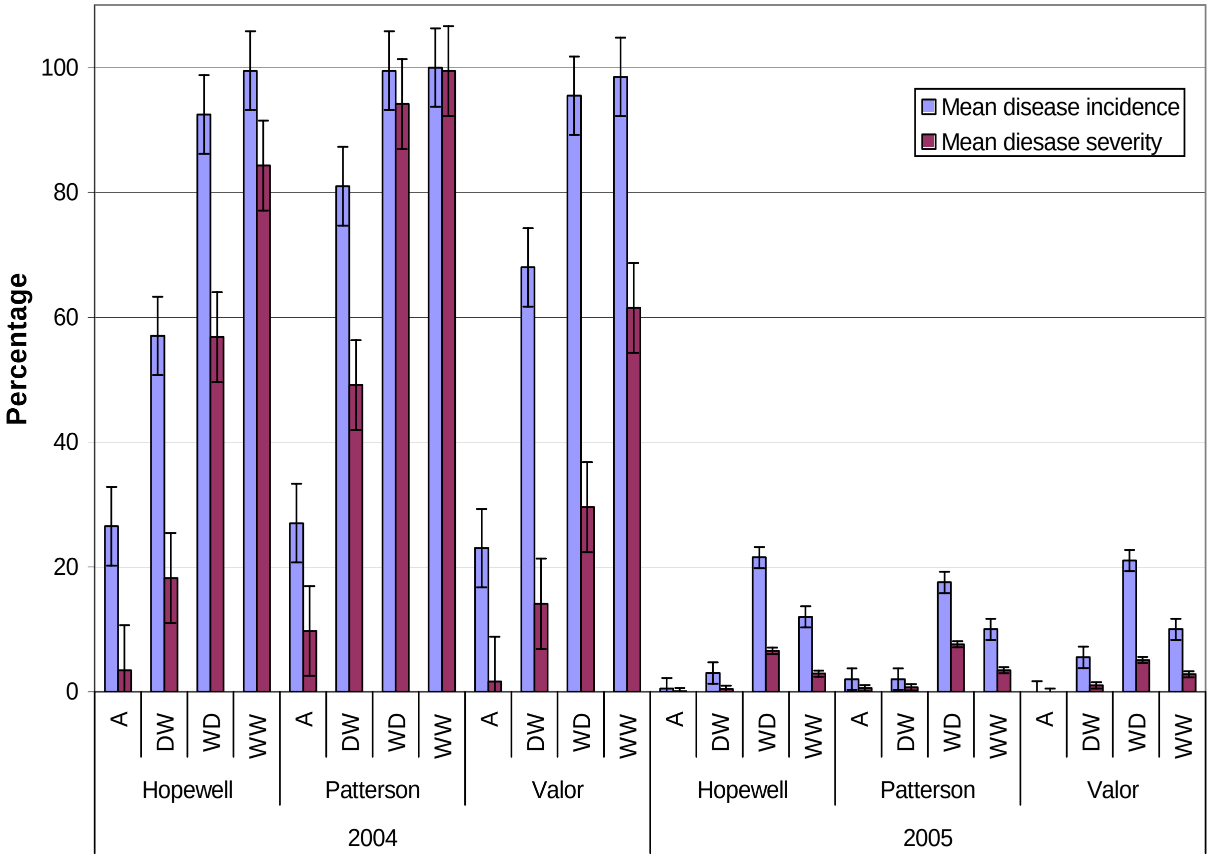

Figure 1. Effects of supplemental moisture during anthesis and grain-fill on disease incidence and severity of Fusarim head blight of wheat on three cultivars, 2004-2005, State College, PA. Treatments are: A=ambient; DW=misted only at grain-fill; WD=misted only at anthesis; and WW=misted at both anthesis and grain-fill. An error bar represents standard error of the mean across all treatments and cultivars per year.

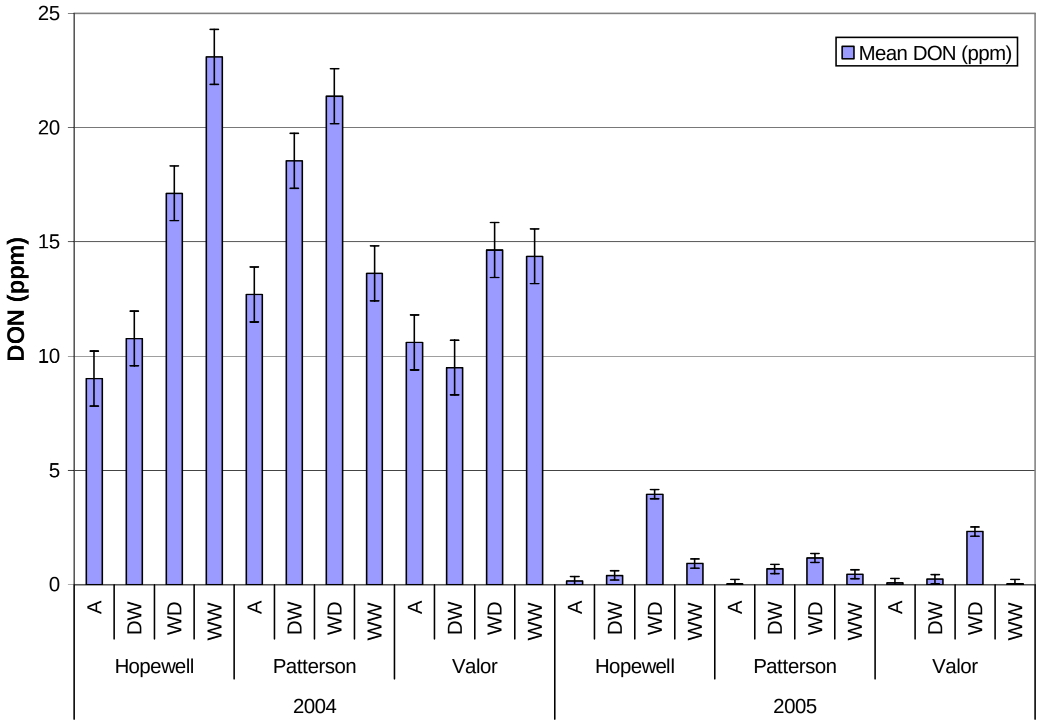

Figure 2. Effects of supplemental moisture during anthesis and grain-fill on DON (deoxynivalenol) production due to Fusarium head blight of wheat on three cultivars, 2004-2005, State College, PA. Treatments are: A=ambient; DW=misted only at grain-fill; WD=misted only at anthesis; and WW=misted at both anthesis and grain-fill. An error bar represents standard error of the mean across all treatments and cultivars per year.

AIRBORNE INOCULUM DYNAMICS FOR SEVEN LOCATION-YEARS IN RELATION TO ENVIRONMENTAL PARAMETERS

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INTRODUCTION

Worldwide, Fusarium head blight (FHB) of wheat, barley and other cereals is caused by a number of related fungi. In the United States, the primary causal agent on wheat is *Fusarium graminearum* (Fg) (teleomorph: *Gibberella zeae*, (Gz)). This fungus is homothallic and readily produces perithecia and ascospores on crop residues at the soil surface. The anamorphic form of the fungus generally produces copious conidia in sporodochial masses on suitable substrates. The fungus is not considered to be pathogenic on otherwise healthy leaf tissues, however evidence suggests there is potential for superficial, or subpathogenic colonization on vegetative tissues such as leaves and stems (Shaukat Ali, Yue Jin, pers. comm.). In the U.S., China and other areas of the world, the accepted etiology of Fusarium head blight begins with pathogen-colonized residues at the soil surface. This biomass could be corn, small grains or soybean residue, or any other tissue capable of harboring the pathogen over the winter months. In the spring, the fungus begins to produce sexual fruiting structures, called perithecia, which contain sacs (asci) of haploid spores (ascospores). Ascospores are forcible ejected from the perithecial masses and are thus able to be carried by air movement and rain splash. The spores are contained in an epiplasmic fluid while in the asci, and they retain some of this material after ejection (Trail et al., 2002), which is believed to allow the spores to adhere to contacted surfaces.

The asexual forms and stages of *Fusarium* spp. are known to be important etiologically to the FHB disease system in wheat as illustrated by those species with no sexual stage (*F. culmorum*, *F. avenaceum*). However, the role of conidial (asexual) inoculum is not well defined for *F. graminearum*. It is known that Fg conidia are fully capable of producing disease under controlled environments (Mesterházy, 1978; Stack and McMullen, 1985; Wang and Miller, 1988). Stack (1989) states that there is no significant difference in the efficacy of Fg conidia or Gz ascospores in producing infections and disease on wheat. There are differences in environmental limits and requirements that have been reported for each form of the fungus, and for spore survival (Doohan et al., 2003, Brennan et al, 2003). The objective of this investigation is to determine the relative abundance of conidia and ascospores of the causal agent for FHB in air samples above wheat canopies in South Dakota. A further objective is to relate quantity of airborne inoculum to environmental parameters including precipitation, temperature, and humidity.

MATERIALS AND METHODS

Several sites in northeast South Dakota were selected for sampling of airborne inoculum for Fusarium head blight in 2003 and 2004. Sites included spring wheat cultivar evaluation areas within wheat fields near Aurora, Watertown, Groton and Redfield, SD. Air was sampled using a Hirst-type spore trap, sampling approximately 5 L/min at the orifice. Airborne particulates were collected by impingement on double-sided adhesive tape affixed to a rotating drum, rotation once each 8 days. Drums were changed weekly and tapes were dissected with a razor into sections representing 24 hours of sampling. Dissection was performed while the tape remained on the drum. Each tape section was carefully lifted taking precaution not to touch the adhesive (outer) surface. Sections were placed with the non-exposed tape surface (drum-side) secured onto slide glass microscope slides. Spores were counted in the field of view of the microscope at 400X magnification. Each field measured 0.50 mm dia., or 0.20 mm^2 area. The length of each tape section was examined twice from end to end in chronological order just above, and then just below the central (horizontal) axis of the tape to yield a continuous estimate of spores per unit time. Each section was 65+/-2 mm in length, therefore each field of view at 400X represented approximately 11 to 12 minutes. In this manner, conidia and ascospores were enumerated in a time course lasting up to three weeks at some locations. Conidia and ascospores were identified to species and differentiated based solely on spore morphology. Hyaline spores with a straight to slightly curved fusiform shape, 4-6 transverse septae, foot-shaped basal cell, and convex-conoid apical cell in a size range of approximately 50 +/- 10μm by 5 +/- 2μm were considered to be conidia belonging to *Fusarium graminearum*. Spores were counted as *Gibberella zeae* ascospores if they were hyaline, slightly crescent shaped, 1-3 septate, with convex-conoid terminal cells, and were approximately 20 to 30μm by 3-5μm in size (approx. one-half the size of *F. graminearum* conidia). For purposes of graphical and analytical comparison to weather data, the sub-hourly data was reduced to spores per hour.

RESULTS AND DISCUSSION

Ascospores and conidia were found in relatively similar abundance in both 2003 and 2004, however there were generally more ascospores for a given time period than conidia. Pearson's correlation coefficient (r) for ascospores and conidia at each location was greater than 0.90. The mean number of ascospores per hour across all locations in 2003 was 2.12 compared to 1.84 conidia per hour. In 2004, ascospores were also slightly more abundant (1.92 per hour) relative to conidia (1.55 per hour). Figures 1 through 7 represent each location-year and contain weather parameters as well as ascospore data. For simplicity, conidial concentrations are not graphed in Figures 1-7, and are not discussed further. Also note that spore concentrations reported in the figures are 'spores per hour', recorded as a 24-hr moving average (to smooth day/night fluctuations) of sub-hourly data. Moving averages, including those for temperature and RH data are reported for each hour as summary of the past 24 hours. Peaks in inoculum occurred at the rate of approximately one for every three days of monitoring, and in some cases were fairly regular. Duration of the peaks varied from less than 24 hours to as much as three days, which corresponds well with the findings of de Luna, et al. (2002). Magnitude of peaks ranged from less than one spore per hour to nearly 14 spores per hour. Peaks in spore abundance were often associated with precipitation events, particularly large events, as describe by de Luna, et al. (2002) and Markell and Francl (2003) though not always. Peaks in inoculum also occurred during long periods (up to 12 days) without recorded rainfall. Inoculum peaks appear to lag increases in mean relative humidity, and their curves appear to have some relationship, graphically. Simple correlation analysis shows that the moving average RH does correlate to moving average ascospore count in some location-years, though the r-values are not high, and for most location-years, the correlation is poor. By shifting the RH data, it was noted that the correlation became stronger. Shifting was accomplished by moving the RH data forward, to correspond with 'future' ascospore counts. For all location-years, increases in correlation coefficient were achieved in this manner. For 2003 locations, shifts of 8, 12, 16, 20, 24, 28, and 32, and 36 hours were evaluated. When the RH data is shifted forward, the correlation coefficients increase for each shift forward, to a point, after which the r-values then decline, though the maximum point varied at all three locations. For example, at Aurora, 2003 a shift forward of 8 and 12 hours maximized correlation coefficient at r = 0.79. At Groton, 2003, r-values increased from 0.44 with no shift, to a maximum of 0.88 with a 20 hour shift forward of the mean RH values. At Watertown, a shift of 32 hours forward was required to maximize r at 0.74. These results suggest the predictive value of RH as little as 8-12 hours before an inoculum release event begins. The variability in the apparent RH 'lag' suggests that temperature, or some other factor or combination of factors may help to strengthen the predictive value of a moving average of the relative humidity data.

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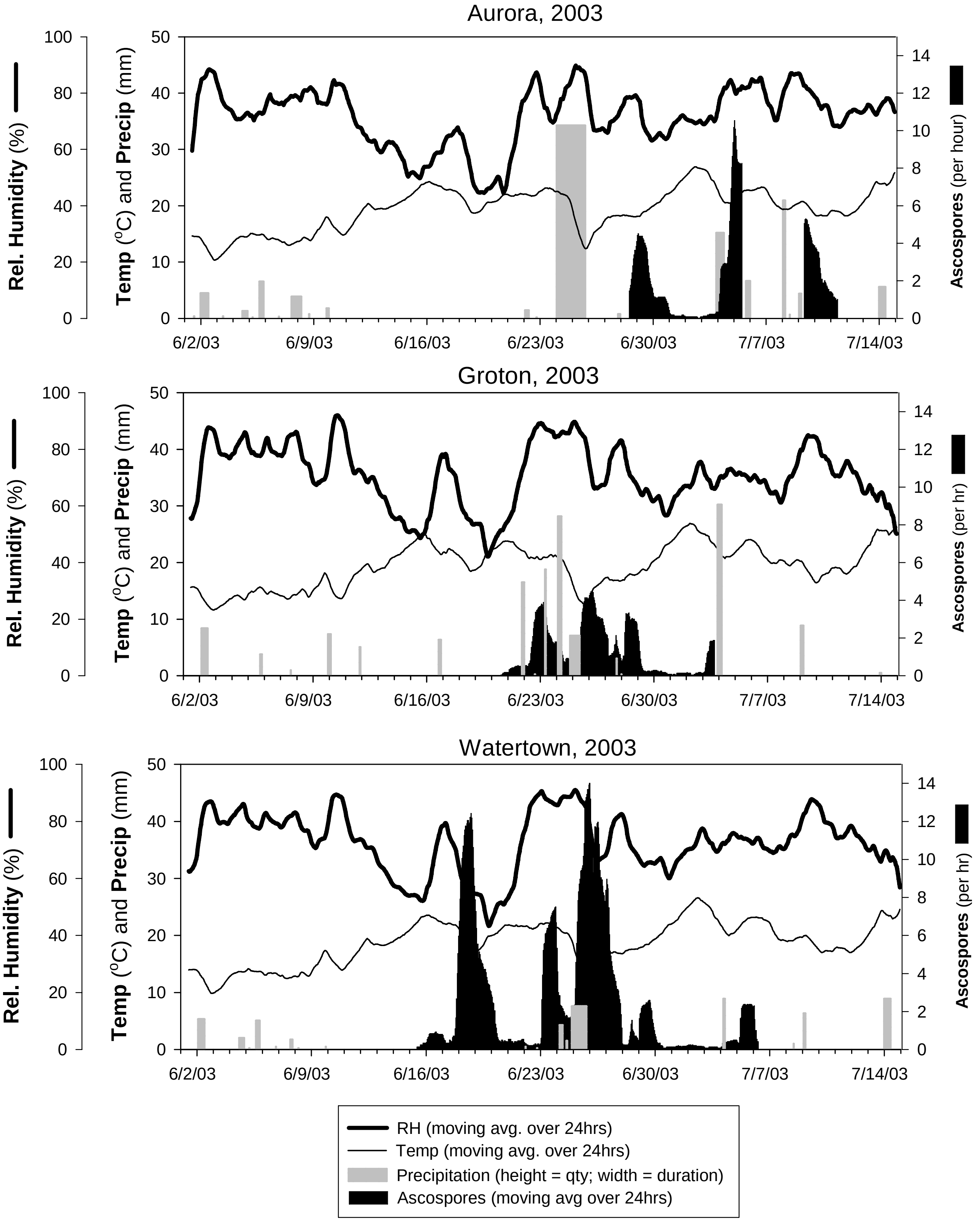
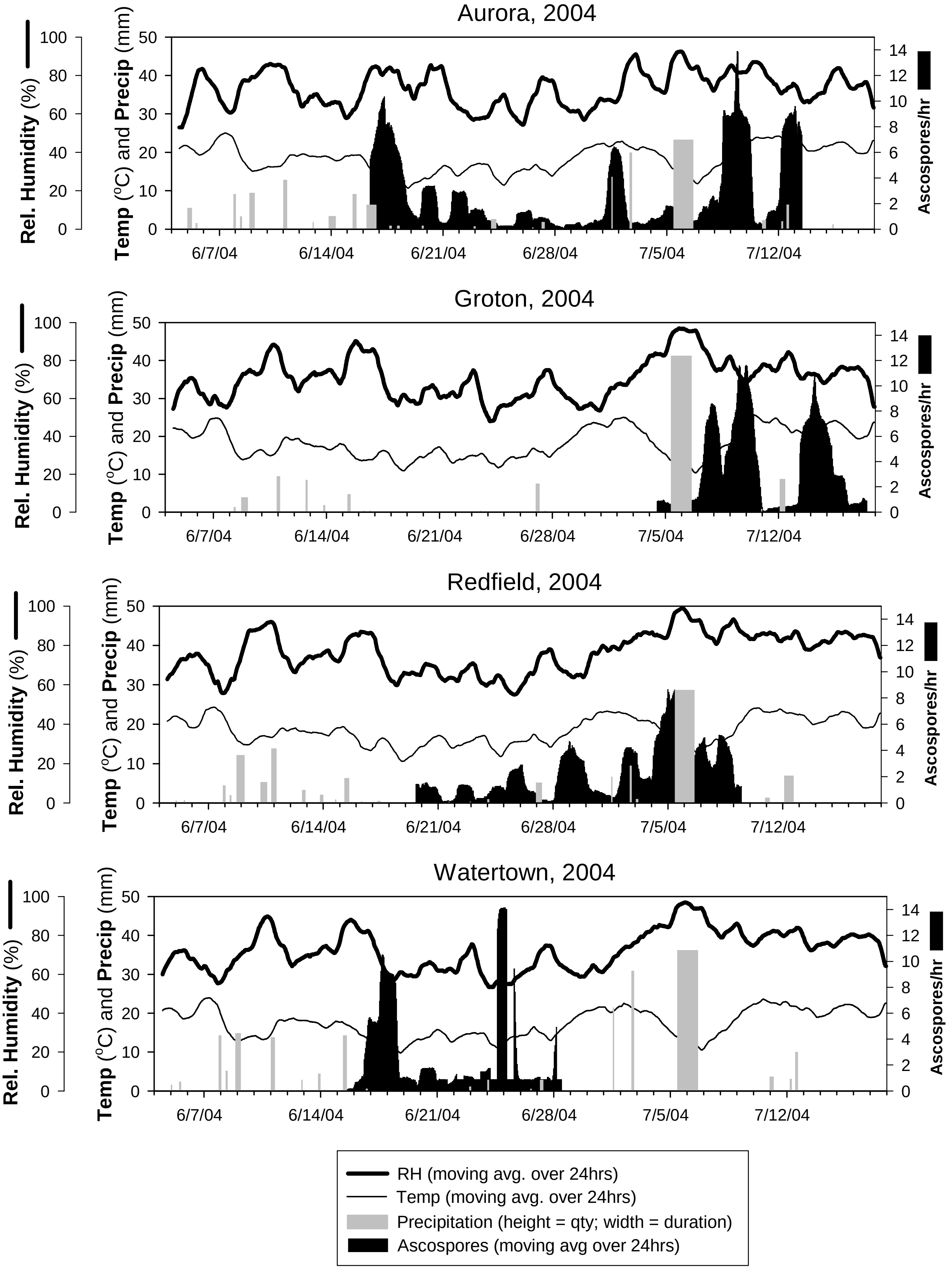
Figures 1-3.


Aurora, 2003
Groton, 2003
Watertown, 2003
Rel. Humidity (%)
Temp (°C) and Precip (mm)
Ascospores (per hour)
Ascospores (per hr)
0
20
40
60
80
100
0
10
20
30
40
50
0
2
4
6
8
10
12
14
6/2/03
6/9/03
6/16/03
6/23/03
6/30/03
7/7/03
7/14/03
RH (moving avg. over 24hrs)
Temp (moving avg. over 24hrs)
Precipitation (height = qty; width = duration)
Ascospores (moving avg over 24hrs)

Figures 4-7.


Aurora, 2004
Rel. Humidity (%)
100
80
60
40
20
0
Temp (°C) and Precip (mm)
50
40
30
20
10
0
Ascospores/hr
14
12
10
8
6
4
2
0
6/7/04
6/14/04
6/21/04
6/28/04
7/5/04
7/12/04
Groton, 2004
Rel. Humidity (%)
Temp (°C) and Precip (mm)
Ascospores/hr
Redfield, 2004
Rel. Humidity (%)
Temp (°C) and Precip (mm)
Ascospores/hr
Watertown, 2004
Rel. Humidity (%)
Temp (°C) and Precip (mm)
Ascospores/hr
RH (moving avg. over 24hrs)
Temp (moving avg. over 24hrs)
Precipitation (height = qty; width = duration)
Ascospores (moving avg over 24hrs)

EFFECTS OF MAIZE RESIDUES AND VARIETY ON FUSARIUM HEAD BLIGHT IN SOUTH DAKOTA

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INTRODUCTION AND OBJECTIVES

Fusarium head blight (FHB) of wheat and barley, caused by numerous *Fusarium* species, but primarily by *Fusarium graminearum* (teleomorph: *Gibberella zeae*) continues to occur at epidemic and at sub-epidemic levels in many regions of the U.S. and Canada including growing areas in the central and eastern U.S. By investigating the relationship of FHB incidence and severity to environmental conditions, a better characterization of the disease can be made. Environmentally-based forecasting systems have been shown to be effective in predicting epidemic levels of FHB in field situations (De Wolf et al, 2003) using temperature, precipitation and relative humidity parameters; however, the accuracy of these modeling systems is considered to be only moderate. Through the course of collecting disease and environmental data over numerous location-years, it has been observed that field disease can be highly variable under environments falling near the prediction threshold for the models mentioned above. It was hypothesized that in those instances when environment is not highly conducive to disease development, inoculum level may be more predictive of final disease than is the environment. Additionally, host resistance is an important factor that should be considered when developing and evaluating prediction systems. Although there are no wheat cultivars available having total resistance to FHB, there is wide variability among commonly planted varieties.

South Dakota State University is part of a multi-state collaborative project studying the epidemiology of Fusarium head blight (FHB) on wheat under different environments throughout the north-central and upper mid-west regions of the U.S. The ultimate goal of this collaborative effort is to refine a disease risk advisory/forecast system, and to elucidate principle components of the FHB disease cycle. In 2003, a project was established to examine the influence of varying inoculum load on field disease measurements. The study was continued for two additional years, with some modification. The primary objectives include: 1) establishment of distinct inoculum (spore) loads by varying the amount of maize stover residue on the soil surface of experimental plots; 2) to determine the effects of high and low inoculum loads and weather on final disease and mycotoxin levels in grain; and 3) to evaluate the effects of varied inoculum levels on two differentially FHB susceptible varieties under identical environments. An additional treatment and fourth objective were added in 2005 by including a fungicide in the design. The objective was to determine if fungicide treatment interacts with variety, inoculum level, and weather parameters to affect final disease estimates.

RESEARCH METHODS

Field plots were established in Brookings, SD in 2003, 2004 and 2005, based on protocols established by collaborators. In general, plots consisted of residue treatment (0, 30, and 80% soil coverage, by line-transect method) to generate corresponding low, medium and high levels of local inoculum. The medium level was discontinued for 2005. Sub-plots consisted of spring wheat varieties (‘Alsen’, a moderately resistant cultivar; and ‘Norm’, a highly susceptible cultivar). In 2005, sub-sub plots were treated with tebuconazole fungicide (trade name: Folicur, Bayer CropScience) or water (control). Plot size varied slightly from year to year due to space restrictions; however, final plot disease measurements were collected from areas no smaller that 3.1m by 4.6m, representing the smallest division of space within the design. In each year, whole-plots (residue treatments) were buffered on all sides by 8m of a tall wheat variety (‘Reeder’ in 2003, and ‘Ingot’ in 2004 and 2005) to mitigate inter-plot interference. For fungicide treated plots in 2005, application of Folicur at 126 g a.i. per hectare (4oz product per acre) was made at Feekes 10.51. Within all sub-plots, a designated area was sampled daily after spike emergence by collecting five spikes per sub-plot for enumeration of spike-borne inoculum. At three weeks post-flowering, disease ratings were made on all plots after Stack and McMullen, (1995) and included incidence and severity estimates on 100 spikes per experimental unit. Incidence is defined as proportion of 100 rated spikes exhibiting disease symptoms. Severity is the mean severity per infected head. Disease index is the product of incidence and severity and is the overall 'amount' of disease in the field. Harvest data collected included plot yield, test weight, moisture content, assessment of *Fusarium*-damaged kernels (FDK's), and mycotoxin concentration in grain. A Burkard volumetric spore collector was placed for daily monitoring of airborne inoculum. Weather data was collected using a weather station established within the plot area, consisting of Campbell Scientific data logger and sensors. Parameters measured included temperatures and relative humidity in and above the crop canopy, wind, solar radiation, precipitation, soil temperature, soil wetness and leaf wetness estimations.

Each year, two planting dates (PD), 10-13 days apart, were utilized creating two identical studies upon which all measurements were collected. The planting dates were included to provide more opportunity for experiencing epidemic-like conditions, and were not intended to be included together in combined analysis. However as data is complete for both plantings each year, and interesting observations have been made regarding the comparison of planting dates within years, some combined analysis and comparative analysis will be discussed.

No additional inoculum in the form of spore suspension or colonized grain (for ascospore spawn) was added to the study areas. The study was dependant on inoculum formed locally (e.g.: beneath the crop canopy on plant residue), or externally (e.g.: on adjacent fields with corn or small grain residue). No environmental modification was implemented to alter the conditions for disease development.

RESULTS AND DISCUSSION

The years 2003, 2004 and 2005 were distinctly different in terms of statewide levels of FHB on spring wheat, and this difference is mirrored in the overall disease levels observed in this study. In general, 2004 had the highest levels of disease in spring wheat in the eastern and northeastern parts of SD, while 2003 was a more typical of non-epidemic years for the region, with only moderate levels of FHB in most of the state. In 2005, disease was extremely high in winter wheat throughout the state, but spring wheat crops generally had less FHB than in 2004. Therefore, within this study is represented three distinct categories: low disease (2003), moderate disease (2005), and high disease (2004). As mentioned, two planting dates (PD) were utilized, and in each year PD 2 exhibited higher disease and toxin levels than PD 1.

Establishment of local inoculum levels - The objective in placing three levels of maize residue was to establish three distinct levels of local ascospore inoculum within experimental plots. In general, head washing data from all plots over three years showed no differences among residue treatments except at distinct dates when peaks indicate a gradient of spike-borne inoculum highest for the 80% residue treatment plots, and lowest for the 0% residue plots. The data is not shown, but could indicate that when the environment is highly favorable for spore release or dispersal, local inoculum from high residue situations may play a significant role in the total inoculum load available for host infection on that date. The lack of distinct differences in spike-borne inoculum among residue treatments for most days may indicate that a high degree of interplot interference or a significant level of external inoculum was present at the study sites.

Effects of high and low residue levels on FHB - In general, residue treatments had no significant effects on visual disease estimates; however toxin concentrations were significantly affected (tables 1 and 2). Mean deoxynivalenol (DON) concentration for grain from all 0% residue plots (PD and varieties combined) was 2.9 ppm while the grain from the 80% treatment contained 3.9 ppm DON. For 'Norm' plots, which had significantly higher toxin levels in all cases than 'Alsen', DON levels were 4.9 ppm in the 0% plots and 5.8 ppm in the 80% residue plots (years and PD's combined). For 'Alsen', DON was at 1.0 ppm and 2.0 ppm for the 0% and 80% residue treatments, respectively.

The effect of the residue on DON levels was perhaps most apparent for PD 1, though disease levels were generally lower than for PD 2. In PD 1, 'Norm', DON was 52% higher in the high residue plots compared to the 0% plots, whereas for 'Alsen', the high residue treatment had 131% more DON than the 0% treatment. The large differences in DON accumulation among residue treatments may be a result of higher levels of local inoculum incident on spikes, allowing for greater surface colonization potential, and perhaps high levels of superficial infections. The fungal colonies may not significantly exacerbate disease symptoms, however fungal biomass may be higher when local inoculum is incident and viable on the spike surface or other niches that are not good infection sites. Future investigations will focus on the relationship of disease, DON accumulation and surface colonization/ inoculum load.

Effects on differentially susceptible varieties - As indicated above, there was no strong significant effects of residue treatments on visual disease estimates (incidence, severity, or index); however, there were significant differences in disease estimates among the two varieties. As expected, 'Norm' was higher than 'Alsen' in incidence, severity and disease index in all cases. There were no significant variety by residue interactions for disease estimates. Interaction between variety and year was observed for PD 2 and for the combined PD's, but not for PD 1. The interaction in all cases represented a larger response to high disease pressure in 'Norm' than in 'Alsen'. Figure 1 and 3 represent examples of this interaction. In figures 1-3, years are arranged on the x-axis in order of lowest to highest disease pressure. It is clear that 'Norm' had greater disease relative to 'Alsen' each year, but also that greater disease pressure had a stronger influence on 'Norm' than on 'Alsen' for PD 2 and for the combined data. For PD 1 (Fig. 2), the overall disease pressure was lower each year than for PD 2. The interaction was not detected for PD 1.

CONCLUSION

In each year of this study, there was no clear effect of residue treatment on disease estimates. The purpose of the residue was to establish distinct local inoculum levels, and observe the influence on disease. It is clear that even though it appears that there was an influence on local inoculum levels on certain days, it was not noted for most days. For those instances when inoculum levels peaked, and differences among residue treatments were apparent in spike-borne inoculum levels, the peaks may or may not have coincided with peak susceptibility of the host. The residue treatments did have an effect on toxin accumulation and this is likely due to increased fungal colonization that was not detectable visually, during disease rating. The disassociation between visual estimates of disease and DON contamination has been noted numerous times by other researchers (Paul, et al., 2005) and this set of experiments may show that, indeed, increased levels of inoculum may result in higher levels of toxin, though not necessarily in higher disease levels, for a given variety.

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Table 1. Mean DON Concentrations for 'Norm' grain

	Planting Date 1		Planting Date 2		PD1+2	
(ppm)	0%	80%	0%	80%	0%	80%
2003	0.80	0.40[1]	0.78	1.28	0.79	0.84
2004	4.43	7.93	17.18	18.23	10.81	13.08
2005	1.75	2.05	2.15	2.43	1.95	2.24
3 year avg	2.46	3.74	7.24	7.86	4.85	5.80

1. Limit of detection = 0.5 ppm, values below detection assigned value of 0.25 ppm. therefore some averages may result from a large number of such samples.

Table 2. Mean DON Concentrations for 'Alsen' grain

	Planting Date 1		Planting Date 2		PD1+2	
(ppm)	0%	80%	0%	80%	0%	80%
2003	0.25[1]	0.25[1]	0.25[1]	0.25[1]	0.25[1]	0.25[1]
2004	0.53	1.53	3.75	7.38	2.14	4.46
2005	0.25[1]	0.52	0.70	1.00	0.48	0.76
3 year avg	0.35	0.81	1.69	3.11	1.00	1.96

1. Limit of detection = 0.5 ppm, values below detection assigned value of 0.25 ppm. therefore some averages may result from a large number of such samples.

Fig. 1: Disease Index (Inc*Sev), PD1+2

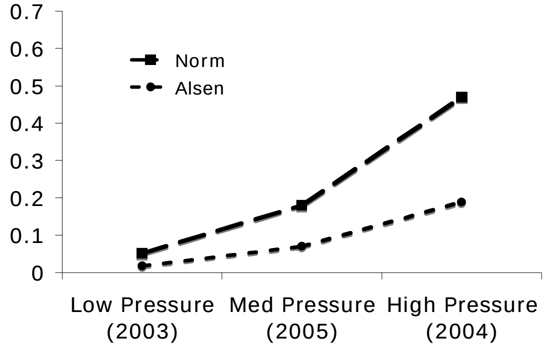


Fig. 2: Disease Index (Inc*Sev), PD 1 only.

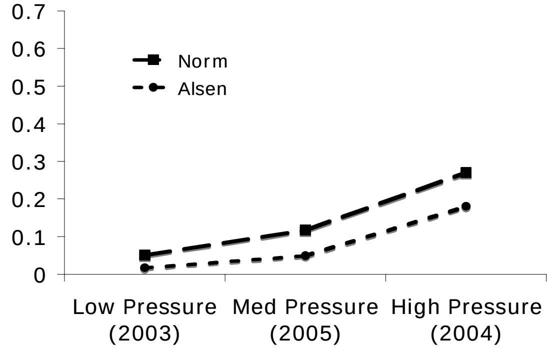
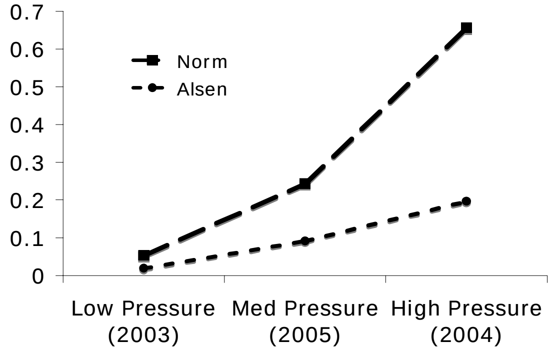


Fig. 3: Disease Index (Inc*Sev), PD 2 only.



RELATIONSHIP BETWEEN FHB INDEX AND DON: A QUANTITATIVE SYNTHESIS OF EIGHT YEARS OF RESEARCH

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ABSTRACT

The reemergence of Fusarium head blight (FHB) in the 1990s has forced researchers from multiple institutions, representing various states and wheat-growing regions, to collaborate in an effort to better understand this disease and to reduce its detrimental impact on the wheat and barley industries. Among the many collaborative research efforts currently in progress are Uniform Fungicide Trials designed to investigate fungicide effectiveness in managing FHB and deoxynivalenol (DON), and Uniform FHB Screening Nurseries for the development of resistant cultivars. In both types of investigation, trials have been conducted according to standard protocols over multiple years and locations. Collaborative research allows for the collection of a large amount of data from a range of environmental conditions and wheat cropping systems, enabling the evaluation of various responses (effects) under different disease pressures. The inherent variability among years and locations, however, has led to contrasting conclusions being drawn about several of the responses being investigated. Of notable mention are the relationship between FHB and DON and the percent control of FHB and DON achieved through Folicur application.

Meta-anslyses were conducted to evaluate the relationship between FHB and DON and the overall effectiveness of Folicur at reducing FHB and DON. Meta-analysis is the quantitative synthesis of the results from multiple individual studies. It is regarded as an objective approach for integrating and interpreting results and drawing conclusions from multiple studies, and allows the investigator to evaluate study-specific characteristics likely to influence relationships and treatment effects. In meta-analysis, some measure of magnitude of treatment effect or association between variables (called effect size) is gathered from the results of individual studies, converted to a common metric, and analyzed to determine the magnitude, significance, heterogeneity, and precision of the mean effect size across studies. For the purpose of evaluating the relationship between FHB and DON, correlation and regression coefficients (intercepts and slopes) were used as measures of the strength of the relationship between the two variables. Response ratio and percent control were used as measures of the effectiveness of Folicur against FHB and DON.

The results from eight years of fungicide trials and resistance screening nurseries were gathered for this analysis. The effects of wheat type, study type, study location, disease level, and DON level on the relationship between FHB and DON were determined, and the influence of wheat type on the effectiveness of Folicur was evaluated. There were significant positive relationships between DON and all commonly used measures of Fusarium head blight intensity. The overall mean correlation (r) between index (IND) and DON was 0.62. Approximately 70% of the 158 studies analyzed had r values greater than 0.50. Correlations were significantly affected by wheat type (spring versus winter wheat), study type (fungicide versus. genotype trials) and study location (U.S. spring- and winter-wheat-growing regions, and other wheat-growing regions). The strongest correlations were observed in studies with spring wheat cultivars, in fungicide trials, and in studies conducted in U.S. spring-wheat-growing regions. There were minor effects of magnitude of disease intensity (and, indirectly, environment) on the correlations. The overall mean regression slope and intercept for the relationship between IND and DON, 0.22 and 2.94, respectively, were significantly different from zero ($P < 0.001$). Thus,

for every unit increase in IND there was on average a 0.22 ppm increase in DON; furthermore, when there was no visual symptoms of Fusarium head blight (IND = 0), the overall mean DON level was 2.94 ppm.

In preliminary investigations, the overall percent control of FHB index (across 118 studies) resulting from the application of Folicur was approximately 41%; however, the overall percent control of DON (across 91 studies) was only 22%. Wheat type significantly affected the percent control of IND and DON. These analyses are still ongoing and will be repeated following the inclusion of data from 2005. Results to date confirm the high variability in disease control by Folicur and indicate that the fungicide is considerably more effective in reducing disease index than in reducing DON concentration.

COLONIZATION OF WHEAT CULTIVARS BY *FUSARIUM GRAMINEARUM* AT HARVEST AND IN OVERWINTERED RESIDUES

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OBJECTIVE

To establish the effect of the overwintering of residues and resistance in wheat to FHB on the colonization, survival and inoculum production of *Fusarium graminearum*.

ABSTRACT

Fifteen wheat cultivars were grown at two locations in Minnesota (Oklee and Humboldt) in 2004. The experimental design was a randomized complete block design with two replications. Immediately prior to harvest, 30 bundles (3-5 plants/bundle) were arbitrarily sampled from each plot. Thirty plants per plot were assayed to determine the incidence of colonization of nodes by Fusaria in mature plants to harvest. The remaining plants (25-35 per plot) from each plot were buried superficially (2-5 cm soil cover) at Umore Park,Rosemount, MN in October 2004. The buried plants were recovered in April 2005 and assayed to determine colonization of nodes by *F. graminearum* and other Fusaria in wheat residues left in the field over the winter. Isolations from nodes on *Fusarium*-selective Komada's medium indicated that there was a significant (P = 0.01) increase in the colonization of nodes by *F. graminearum* in the six months from harvest 2004 (5.8%) to spring 2005 (41.6%). Overwintered nodes of the wheat cultivars Norpro (53.6%), Mercury (50.1%), Parshall (48.4%), MN97803 (47.5%), Dapps (47.1%), Oxen (44.4%), Briggs (42.6%) and Reeder (41.1%) had higher levels of *F. graminearum* colonization than nodes of cultivars Oklee (39.3%), Granite (37.1%), Hanna (36.95%), Alsen (34.6%), Walworth (34.4%), Knudson (34%), and Verde (33%). The data suggests that *F. graminearum* continues colonizing wheat residues over the winter, and the rate of this colonization is cultivar dependent.

INTRODUCTION

Fusarium head blight (FHB), caused predominantly by *Fusarium graminearum*, is a devastating disease of wheat and barley. Understanding the factors affecting the epidemiology of FHB in the U.S. is a high priority for researchers. Among the factors influencing epidemics is the primary inoculum of *F. graminearum*. The impact of wheat cultivars with some resistance to FHB on the colonization of host residues and the subsequent production of inoculum is generally unknown. The main objectives of this study were 1) to examine the colonization by *F. graminearum* of nodes from wheat plants at harvest, 2) to compare colonization by *F. graminearum* at harvest with that of nodes of plants which overwintered in the field, and 3) to examine the effect of host resistance to FHB on the colonization of wheat residues.

MATERIALS AND METHODS

Fifteen wheat cultivars included in the 2004 Red River On-Farm Yield Trials were sampled at two trial locations in Minnesota (Oklee and Humboldt). Each cultivar was grown in 7.6 m x 2.0 m plots arranged in a randomized complete block design with two replications. Cultivars were subject to natural infection by Fusarium head blight fungi. Prior to harvest 30 bundles (3-5 plants/bundle) of mature plants were arbitrarily sampled from each plot. Thirty plants per plot were used to determine the incidence of Fusariua colonizing nodes prior to harvest. On October 20, 2005 the remaining plants (25-35) were placed in a furrow in a field (UMore Park, Rosemount, MN) and covered loosely with 2-5 cm of soil known to have 735-819 CFU/g of *F. graminearum* in the surface soil (0-2 cm deep). The buried plants were recovered the following spring (April 2005) and used to determine the incidence of Fusaria colonization of nodes following six months in the field.

To isolate Fusaria, the nodes were excised from plants collected at harvest and from residues recovered the following spring. The excised nodes were split in two and the node pieces surface sterilized with 70% ethanol for 30 s and 0.5% NaOCl for 60 s then rinsed three times in sterile distilled water. Surface sterilized nodes were then plated onto Komada's medium (selective for *Fusarium* spp.). Nodes plated onto Komada's medium were incubated at 20-24ºC under fluorescent lights (12:12, light:dark) for ca. 12 days. *Fusarium* isolates were identified to species according to Burgess et al. (1994). The incidence of colonization of nodes by *F. graminearum* was determined as the percentage of plated nodes from which *Fusarium* spp. were recovered.

Data obtained were analyzed using SAS PROC ANOVA.

RESULTS

Regardless of trial location and sampling date, *F. graminearum* was the pathogenic *Fusarium* species most frequently isolated at harvest and in the following spring (Fig. 1 and Fig. 2). Other pathogenic Fusaria were isolated at much lower frequencies (Fig. 1 and Fig. 2).

There was a significant increase of colonization by *F. graminearum* of nodes from harvest (October 2004) to the following spring (April 2005). At harvest, the overall incidence of *F. graminearum*-colonized nodes at Oklee and Humboldt was 5.4% and 2.2%, respectively, whereas, in the following spring, the incidences were 41.7% (Oklee) and 41.6% (Humboldt).

Not all the wheat cultivars were colonized at the same level (P = 0.03). The wheat cultivars Norpro (53.6%), Mercury (50.1%), Parshall (48.4%), MN97803 (47.5%), Dapps (47.1%), Oxen (44.4%), Briggs (42.6%) and Reeder (41.1%) had higher levels of *F. graminearum*-colonized nodes than Oklee (39.3%), Granite (37.1%), Hanna (36.95%), Alsen (34.6%), Walworth (34.4%), Knudson (34%), and Verde (33%) (Fig 3).

DISCUSSION

Previously, we have shown the increase of colonization of nodes by *F. graminearum* in overwintered standing wheat plants in comparison with the levels of colonization immediately prior to harvest (Salas and Dill-Macky, 2004). The data presented here supports this finding and indicates that the burial of residues may promote the colonization of residues by *F. graminearum* (harvest = 5.8% vs. spring = 41.6%) over the winter months. The high level of colonization of nodes presented in this study may have resulted from Fusarium spp. within the plant or from inoculum present in the soil and other residues in the proximity of the buried residues.

Our findings may help explain the high incidence of FHB frequently observed in wheat produced using conservation tillage systems (Dill-Macky and Jones, 2000). Residues which are partially buried residues during chisel plowing in the fall may be subject to further colonization by *F. graminearum* over the winter. If these residues are then brought to the surface through cultivation operations in the spring (including planting), perithecia and ascospores may develop providing inoculum to infect subsequent wheat crops. It is known that *F. graminearum* can colonize and survive as a saprophyte on buried crop residues (Sutton, 1982); perithecia can develop in Fusarium-infected kernels at the soil surface or buried at 5 or 10 cm (Inch and Gilbert, 2003); and resurfacing of previously buried residues can lead to the production of perithecia and ascospores (Pereyra et al., 2004).

It is interesting to note that the rate of colonization of residues of wheat cultivars was directly correlated to the differential colonization of the plants of those wheat cultivars by *F. graminearum* (Salas et al., 2004). Moderately FHB resistant cultivars such as Alsen, Hanna, or Verde had lower levels of colonization by *F. graminearum* than the susceptible or moderately susceptible cultivars Norpro, Mercury, Reeder, or Oxen. Thus this study supports the finding that cropping resistant cultivars may help lower the inoculum of Fusarium in subsequent growing seasons as reported in a previous study by Salas and Dill Macky (2005).

AKNOWLEDGEMENTS

We thank Amar M. Elakkad, Karen J. Wennberg, and Beheshteh Zargaran for technical assistance and Jochum J. Wiersma for providing us access to the wheat cultivars grown on the Red River Valley On-Farm Yield Trials.

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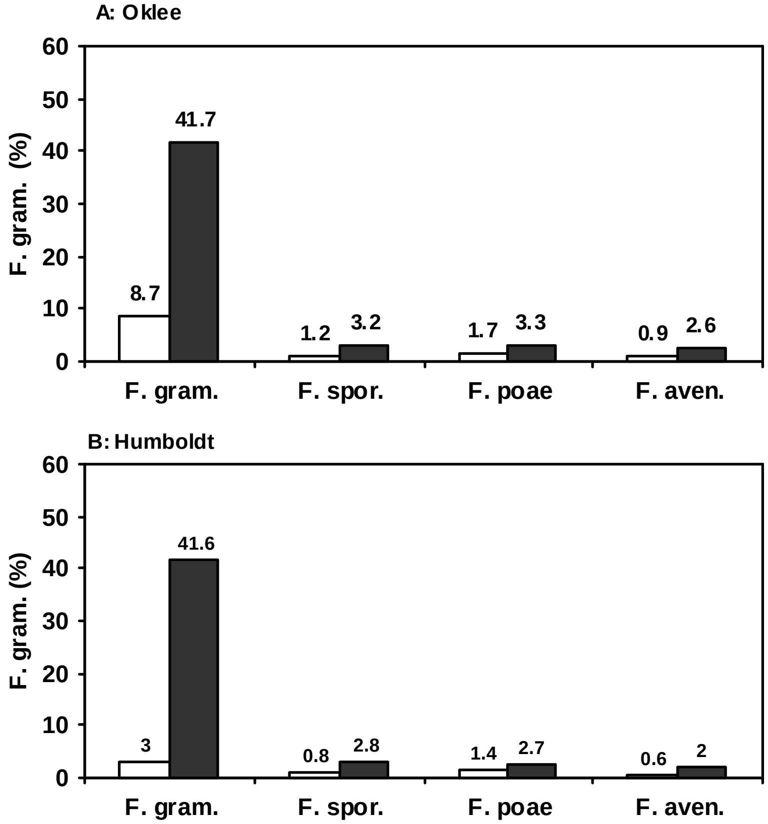

Fig. 1. Overall incidence of colonization of wheat nodes by pathogenic Fusaria (*F. graminearum, F. sporotrichioides, F poae,* and *F. avenaceum*) in plants collected prior to harvest (□) or overwintered buried residues (■) (nodes) at Oklee (A) and Humboldt (B), Minnesota.

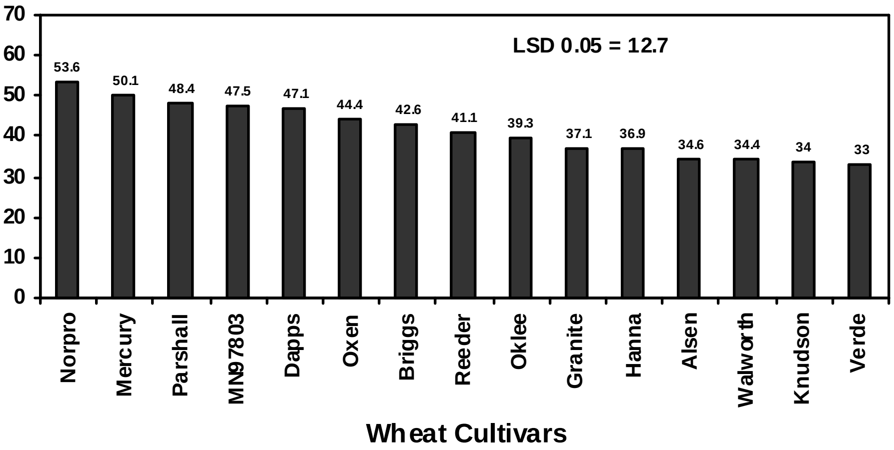

Fig. 2. Overall incidence of colonization of nodes from overwintered residues by *Gibberella zeae* (*F. graminearum*) in fifteen wheat cultivars in the 2004 Red River Valley On-Farm Yield Trials.

EFFECT OF RESIDUE MANAGEMENT AND HOST RESISTANCE ON THE EPIDEMIOLOGY OF FUSARIUM HEAD BLIGHT

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OBJECTIVE

To examine the effect of the post-planting burning of wheat residues and host resistance on the *F. graminearum* population in soil, airborne *F. graminearum* inoculum, and the subsequent colonization of a Fusarium head blight susceptible wheat crop by *F. graminearum*.

ABSTRACT

Fusarium head blight (FHB) caused by *Fusarium graminearum* limits wheat production in the U. S.. Despite the importance of the inoculum of *F. graminearum* in the epidemiology of FHB, little is known about factors affecting levels of inoculum. We examined the effect of burning residue(unburned control, light and severe burns) and resistance in wheat to FHB (FHB susceptible - Wheaton, Norm; FHB moderately susceptible - 2375, Ingot; FHB moderately resistant - BacUp, Alsen) in plots established at Rosemount, MN in May 2003. All plots were left in situ (unharvested) over the winter. In April 2004, plots were chisel plowed, planted to Wheaton, and burned as in 2003. *F. graminearum* was isolated from wheat residues and surface soil at planting, air within the canopy at anthesis and early dough, and from Wheaton plants at hard dough in 2004. The severe burn treatment significantly reduced; the survival of *F. graminearum* in straw, the populations of the pathogen in soil and in the air, and the colonization of Wheaton, in comparison with the lighter burn or control treatments. Plots previously planted to FHB susceptible wheat cultivars (Wheaton and Norm) had higher populations of *F. graminearum* in soil and air samples, and the subsequent crop of Wheaton was more heavily colonized than in plots of Wheaton following Ingot, BacUp, 2375 and Alsen. Our data confirms that grain producers would benefit from reducing wheat residues and by cropping FHB resistant cultivars.

INTRODUCTION

Fusarium head blight is a major disease of wheat in the U. S.. Although cereal residues are considered to be the major source of inoculum inciting FHB epidemics (Salas and Dill-Macky, 2004), little is known about the role of residues in determining inoculum levels. This study examined the impact of residue destruction and host resistance on; the *F. graminearum* population in soil, airborne inoculum, and the subsequent colonization of a FHB susceptible wheat crop.

MATERIALS AND METHODS

A field experiment with two factors, burn (control, light and severe burns conducted after planting) and FHB host resistance (FHB susceptible - Wheaton, Norm; FHB moderately susceptible - 2375, Ingot; FHB moderately resistant - BacUp, Alsen) was established at UMore Park in Rosemount MN in 2003 over residue of a 2002 Norm wheat crop. Cultivars (plots, 3.7 m x 7.6 m) were grown to maturity and left in situ over the winter (unharvested). In April 2004, plots were chisel plowed, planted to Wheaton and the residue burning treatments repeated so that each plot had the same burn treatment as in 2003.

From each plot in 2004, all wheat straw visible on the soil surface of a 0.5 m^2 quadrat, five surface soil samples (collected at points 1 m apart along a 5-m transect in each plot, 0-2 cm depth) and 30 Wheaton plants at hard dough growth stage were collected.

Nodes were excised from the residue of the wheat grown in 2003 and crowns, nodes and kernels from the 2004 Wheaton plants. The excised node and crown tissues and kernels were surface sterilized with 70% ethanol for 30 s and 0.5% NaOCl for 60 s then rinsed three times in sterile distilled water. Surface sterilized tissues were then plated onto Komada's medium (selective for *Fusarium* spp.). Soil samples were air dried for 4 days at 20-24ºC, sifted, and 6 mg of fine soil particles (<250 µ) from each plot was dispersed onto Komada's agar medium on each of five Petri plates. Airborne inoculum of *F. graminearum* within the canopy was trapped by exposing three Komada plates/plot at soil level between 9 AM and 10 AM for ten minutes.

All plates were incubated at 20-24ºC under cool white and UVA (1:1) fluorescent lights (12 hr photoperiod) for 14 days. Fusaria, including F. *graminearum*, were identified according to Burgess et al. (1994). The incidence of colonization of nodes by *F*. *graminearum* was determined as the percentage of plated nodes from which *Fusarium* spp. were recovered.

All data obtained was analyzed using SAS PROC ANOVA.

RESULTS

In comparison with the non-burned treatment, residue burning significantly reduced; the amount of straw at the soil surface, the survival rate of *F. graminearum* in nodes and the population of *F. graminearum* in soil (Table 1). Burning also reduced the airborne inoculum within the canopy at anthesis and early dough, and the subsequent colonization of the wheat crop (Table 1).

Populations of *F. graminearum* in soil after a crop of the FHB-susceptible cultivars (Norm and Wheaton) were higher than those following moderately susceptible or resistant cultivars (Fig. 1). Similarly, airborne inoculum was higher in plots previously planted to Norm and Wheaton (Fig. 2) and high levels of colonization by *F. graminearum* was seen in the Wheaton planted into these plots (Fig. 3).

While *F. graminearum* colonized nodes throughout the whole canopy, kernels were the most heavily colonized tissue examined (Fig.4).

DISCUSSION

Our data support the findings of others and indicate that wheat residues can harbor *F. graminearum*, provide a local source of inoculum (Pereyra et al., 2004) and need to be managed. Heavily colonized residues were demonstrated to increase inoculum levels in soil and air, thus providing greater inoculum for FHB epidemics.

Wheat cultivars were shown to be differentially colonized by *F. graminearum*, as in our previous studies (Salas and Dill-Macky, 2004). This differential colonization of cultivars affects the production of *F. graminearum* inoculum, thus cultivar selection could impact the risk of future FHB epidemics. Residues of FHB susceptible cultivars are likely to release more inoculum than FHB moderately resistant cultivars.

Cultural practices that eliminate wheat residues and/or the cropping of FHB resistant cultivars may help producers to reduce their risk of FHB.

ACKNOWLEDGEMENTS

We thank Amar M. Elakkad, Karen J. Wennberg, Beheshteh Zargaran, and Hilda Manzano for technical assistance.

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Table 1. Effect of residue destruction on; residue dry matter (number of nodes/m^2), survival of *F. graminearum* (FG) in nodes, the population of FG in soil at the time of planting, airbone inoculum of FG at anthesis and early dough, and colonization by FG of a subsequent wheat crop of the FHB-susceptible cultivar Wheaton.

Burning[1]	Nodes (no./m$^{2)}$	FG survival (%)	FG in soil (cfu/g)	Airborne FG (cfu/Petri plate)		Wheaton FG Colonization (%)
				Anthesis	Early Dough	
Control	62 a[2]	33.0 a	693 a	7.6 a	15.1 a	18.4 a
Light	46 b	13.1 b	598 b	6.6 a	12.2 b	17.7 a
Severe	36 c	9.0 b	522 b	4.8 b	9.8 c	11.3 b

[1] Control, non-burned residues; Light, one pass with an alfalfa burner (1.3 m/s); Severe, one pass with an alfalfa burner (0.5 m/s)

[2] Means followed by different letters within a column are significantly different at P=0.05 level.

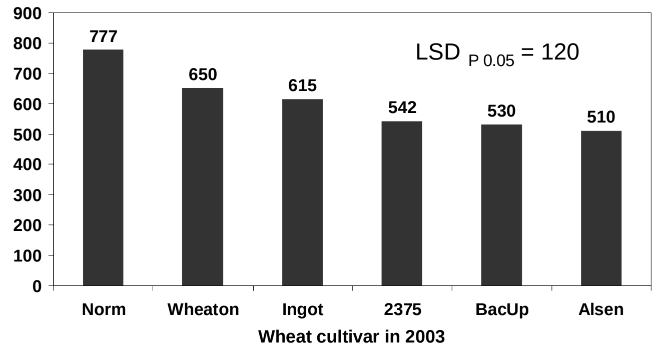

Fig. 1. Effect of the cultivar of 2003 wheat crop on populations of *F. graminearum* (FG) in soil in 2004.

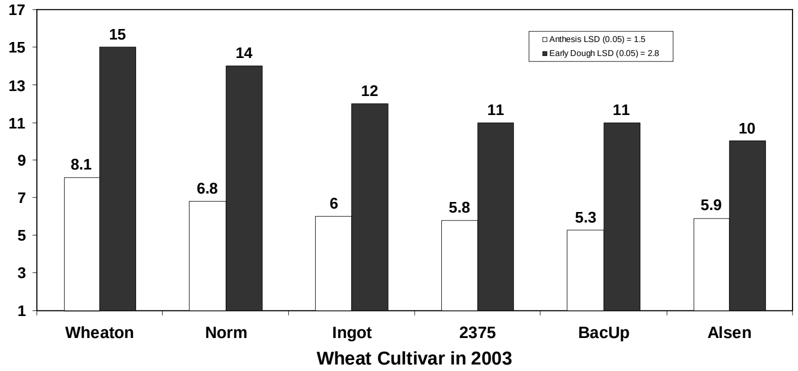

Fig. 2. Effect of the wheat cultivar in 2003 on airborne inoculum (cfu/Petri plate) of *F. graminearum* (FG) within the canopy of the 2004 wheat (cv. Wheaton) at anthesis and early dough growth stages.

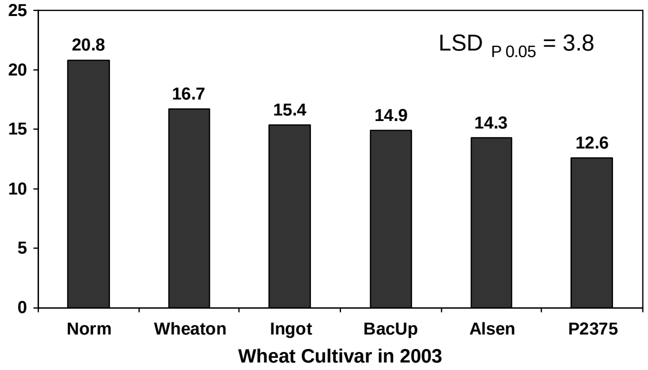

Fig. 3. Effect of wheat cultivar in 2003 on the colonization by *F. graminearum* (FG) of 2004 wheat (cv. Wheaton) at the hard dough growth stage.

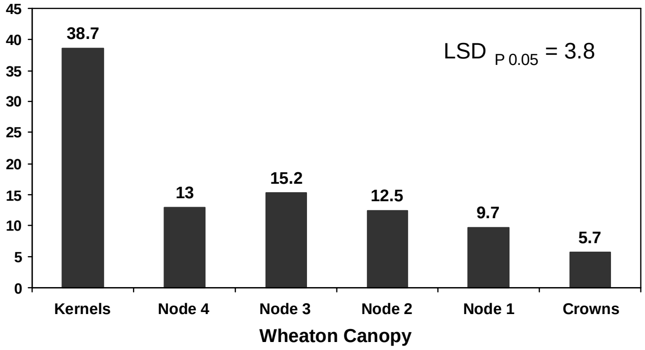

Fig. 4. Incidence of *F. graminearum* (FG) in kernels, node and crown tissues of Wheaton wheat (2004) at the hard dough growth stage.

VALIDATION OF THE DONCAST PREDICTION TOOL IN WHEAT ACROSS FRANCE AND URUGUAY

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ABSTRACT

Forecasting *Fusarium* toxins is useful as a tool to help prevent entry of toxins into the food chain. Wheat fields under an array of agronomic practices were sampled for deoxynivalenol (DON) content at harvest across Ontario from 1996 to 2004. A robust site-specific, DON forecast (DONcast) was developed and commercialized for wheat and has been used to make fungicide spray decisions in Ontario, Canada, for more than 5 years. This model is delivered online, and is sponsored by the crop protection industry and the Ontario Wheat Producers Marketing Board. (http://www.ownweb.ca/ lib/fusarium.cfm). There is growing interest amongst producers to use this tool pre-harvest to make marketing decisions and for grain handlers to use the tool for grain sourcing. For example, in the country of Uruguay in South America, DONcast is being used to alert growers, regulators, and grain handlers of pending problems with DON in locally grown wheat (http://www.inia.org.uy/online/site/157852I1.php). In France, a pilot study is underway to investigate the forecasting tool under European weather and cropping systems. From field data collected in France during 2004, 72% of samples were predicted correctly to contain either above or below 1.0 ppm DON, and 83% of samples were predicted correctly at a 2.0 ppm threshold. Most of the inaccurate predictions were false positives. Similarly, in Uruguay in 2004, 68.3 and 74.8% of samples were predicted correctly to be above or below a threshold of 1.0 and 2.0 ppm, respectively. It is well known that DON predictions are very sensitive to coincidental weather around heading, varietal susceptibility to *Fusarium* and DON accumulation, and to the management of previous crop residue. DONcast has successfully taken these factors into account, and we have demonstrated its robustness across varied environments.

GENETIC STRUCTURE OF ATMOSPHERIC POPULATIONS OF *GIBBERELLA ZEAE*

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ABSTRACT

Gibberella zeae, causal agent of Fusarium head blight (FHB) of wheat and barley and Gibberella ear rot (GER) of corn, may be transported over long- distances in the atmosphere. Epidemics of FHB and GER may be initiated by regional atmospheric sources of inoculum of *G. zeae*, but little is known about the origin of inoculum for these epidemics. We hypothesized that atmospheric populations of *G. zeae* are genetically diverse—potentially originating from multiple locations, and mixed over large geographic distances. We tested this hypothesis by examining the genetic structure of the New York atmospheric populations (NYAPs) of *G. zeae*, and comparing the structure of these NYAPs to populations of *G. zeae* collected from seven different states across the continental United States. Viable, airborne spores of *G. zeae* were collected in rotational (lacking any apparent within-field inoculum sources of *G. zeae*) wheat and corn fields in Aurora, NY in May through August over three years (2002-2004). In all, 780 isolates of *G. zeae* were used for the analysis; 257 isolates were used from four NYAPs, and 523 isolates were used from eight populations collected across the United States. We observed the presence or absence of alleles at 23 amplified fragment length polymorphism (AFLP) loci, based on three separate primer-pair combinations. Normalized genotypic diversity was high (ranging from 0.91 to 1.0) in NYAPs of *G. zeae*, and nearly all of the isolates in each of the populations represented unique AFLP haplotypes. Pairwise calculations of Nei's unbiased genetic identity were uniformly high (> 0.99) for all of the possible NYAP comparisons, and tests for differences among allele frequencies at each of the 23 loci demonstrated that the NYAPs differed at only a single locus. Although the NYAPs were genotypically diverse, they were genetically similar and potentially part of a large, interbreeding population of *G. zeae* in North America. Estimates of the fixation index (G_{ST}) and the effective migration rate (*Nm*) for the NYAPs indicated significant genetic exchange among populations. Low levels of linkage disequilibrium in the NYAPs suggested that sexual recombination in these populations may not be exclusive. When NYAPs were compared to populations of *G. zeae* collected across the United States, the observed genetic identities between the populations were relatively high (ranging from 0.92 to 0.99). However, there was a significant negative correlation ($R = -0.59$, $P < 0.001$) between genetic identity and geographic distance, suggesting that genetic isolation may occur on a continental scale. While the contribution of long-distance transport of *G. zeae* to regional epidemics of FHB and GER remains unclear, diverse atmospheric populations of *G. zeae* suggest that inoculum may originate from multiple locations over large geographic distances. The long- distance transport of *G. zeae* suggests that the management of inoculum sources on a local scale, unless performed over extensive production areas, will not be effective for the management of FHB and GER.

TEMPORAL SCALES OF GENETIC DIVERSITY WITHIN NEW YORK ATMOSPHERIC POPULATIONS OF *GIBBERELLA ZEAE*

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ABSTRACT

Ascospores of *Gibberella zeae* are transported through the atmosphere to wheat spikes and corn ears, where they cause Fusarium head blight (FHB) and Gibberella ear rot (GER), respectively, on susceptible cultivars. We hypothesized that atmospheric populations of *G. zeae* remain genetically diverse over time. We tested this hypothesis by examining various temporal scales of genetic diversity within New York atmospheric populations (NYAPs) of *G. zeae*. We analyzed data from 23 amplified fragment length polymorphism (AFLP) loci for 30 temporal sub-populations comprising a total of 218 isolates of *G. zeae*. Genetic identities were uniformly high (very close to 1) when comparing temporal sub-populations of *G. zeae* collected over consecutive calendar dates, during day and night sample periods, during two-hour sampling intervals throughout the night, and collected during consecutive day and night sample periods at two different field locations in a similar year. We did not observe a significant correlation between genetic identity and time for any of the temporal sub-population comparisons. Tests for differences in allele frequencies across all 23 AFLP loci demonstrated that temporal sub-populations of *G. zeae* collected over consecutive day and night sample periods at two different field locations in a similar year differed at only a single locus. Although field isolates of *G. zeae* are homothallic and may reproduce sexually without a partner, outcrossing under natural conditions may contribute to high levels of diversity in local atmospheric populations of the pathogen. The perpetuation of high levels of genotypic diversity within atmospheric populations of *G. zeae* may result from the continued mixing of atmospheric inoculum sources over time, potentially being transported and mixed over large geographic distances. Our findings suggest that spore sampling during any temporal period would provide an accurate measure of the diversity present in atmospheric populations of *G. zeae*.

ENVIRONMENTAL FACTORS INFLUENCING SCAB OF BARLEY IN THE NORTHERN GREAT PLAINS

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ABSTRACT

We are investigating the relationship between environmental factors, crop stage, and barley genotype with Fusarium head blight (FHB) and DON accumulation in the grain. This project is associated with the established spring and winter wheat FHB-modeling effort and aims to produce the information required to either validate one of the current wheat models for barley, or generate novel models.

Varieties of regionally adapted barley of both 2- and 6-row types were planted at 18 locations in Minnesota, North Dakota, and South Dakota. At least two varieties were common to each location. Plots were a minimum of 1.5m x 4.6m in size and replicated four times in an RCBD. Additional varieties were planted based upon availability and local producer preference. Crop stage was monitored regularly throughout the season and the date at which each plot was at Feekes 10.3 stage was noted. No additional inoculum was introduced into the plots. The incidence and severity of FHB was recorded on a minimum of 25 heads per plot at the soft-dough stage (approximately 21 days after 10.3). Environmental variables consisting of temperature, relative humidity, and precipitation were recorded with an on-site, or nearby, weather station.

When field severity (disease index) was averaged across all blocks and varieties, locations had varying levels of disease with values ranging from 0.20 to 27.68%. Locations in western Minnesota all had relatively low disease (< 3%), whereas those in the Dakotas had a much broader range (<1 to 25%). DON data is pending for many locations; however, the concentrations were relatively low (<2.7 ppm) for the ones currently available. Preliminary investigations into the relationship between disease and weather indicates that the relationship is similar to that described for wheat. Locations where plants were heading when temperature was between 20 and 30°C and mean relative humidity was high (> 70%) and/or frequent rainfall events had occurred resulted in correspondingly high disease severity. Sub-optimal combinations of temperature and RH/precipitation had correspondingly reduced final levels of disease. Winter-habit, feed barley was planted at collaborators' locations in Indiana, Pennsylvania, and Ohio and had trace levels of disease.

THE FUSARIUM HEAD BLIGHT EPIDEMICS OF THE WINTER AND SPRING WHEAT CROPS IN SOUTH DAKOTA FOR 2005

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ABSTRACT

South Dakota is a transition state for wheat production and resides at the Northern and Southern boundaries of the (hard, red) winter and spring wheat “belts”, respectively. In South Dakota, FHB has historically only been a concern for spring wheat producers. Winter wheat production was focused in regions with limited precipitation and the crop usually escapes infection because flowering occurs when temperatures are cooler than optimum for FHB. Winter wheat has recently been expanding into the eastern, and southeastern regions of the state. These regions receive regular precipitation, increasing the yield potential for wheat crops substantially. However, they are also the center of corn production and corn residue serves as an excellent source of *Fusarium graminearum* inoculum. The dominant winter wheat varieties grown in SD are also susceptible to scab. The planting of a susceptible winter wheat crop into a region with high precipitation and substantial inoculum potential greatly increased the probability of an epidemic. Rain events and optimal temperatures for infection during flowering of the wheat crop in southeastern SD resulted in a widespread, severe epidemic in 2005.

Spring and winter wheat fields were sampled throughout SD for FHB field severity approximately 3 weeks after flowering and used to generate yield loss estimates. Counties in regions with FHB epidemics were sampled more intensively and data were pooled by crop reporting districts for all instances. FHB field severity in SD ranged from trace to 7% and 60% for spring and winter wheat, respectively. The weighted impact of each district was calculated using the % acreage each represented in SD * average yield/a * the estimated % FHB. Mean estimated % FHB field severity in winter wheat was greatest in the east central (30%) and southeast (60%) districts, with the latter having the highest weighted impact. For spring wheat, the northeast and east-central districts both had 7% estimated FHB severity, with the former having the greatest weighted impact. Using the average price/bushel for 2004, monetary loss estimates were also generated. Losses in SD due directly to FHB infection (direct kernel blighting) were estimated to be $11.4 million and $24.7 million for the 2005 spring and winter wheat crops, respectively.

ACCUMULATION MANNER OF DEOXYNIVALENOL AND NIVALENOL IN WHEAT INFECTED WITH *FUSARIUM GRAMINEARUM* AT DIFFERENT DEVELOPMENTAL STAGES

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ABSTRACT

The manner in which the accumulation of deoxynivalenol (DON) and nivalenol (NIV) progresses in wheat grain infected with *Fusarium graminearum* and the influence of the infection timing on the toxins' contamination were investigated. Five wheat cultivars with different resistance levels were tested in a greenhouse environment, and one of the cultivars was also tested in a field. In both the experiments, the wheat cultivars were spray inoculated with a mixture of two isolates of different chemotypes of *F. graminearum* at three stages: at anthesis, 10 days after anthesis (DAA), and 20 DAA; these were sampled at 10 DAA, 20 DAA, and at maturity and were subsequently analyzed for their toxin content. The results indicated that high levels of DON and NIV can be produced after 20 DAA even by early infection. In addition, it was also indicated that infection at a late stage, at least as late as 20 DAA after which clear Fusarium head blight symptoms were not observed on the spikes, can cause grain contamination with these toxins. Thus, our results indicated the importance of the late stage in grain development in addition to the early stage in DON and NIV contamination, suggesting that the development of control strategies that cover the late stage as well as the early stage would be desirable to reduce the risk of toxin contamination in wheat.