USDA-ARS/
U.S. Wheat and Barley Scab Initiative
FY14 Final Performance Report
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Cover Page

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Fiscal Year:	FY14
USDA-ARS Agreement ID:	59-0206-4-018
USDA-ARS Agreement Title:	Modeling The Effects of Weather on FHB And DON and Developing Robust Strategies to Minimize Losses.
FY14 USDA-ARS Award Amount:	$ 70,414

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
MGMT	Robust Integrated Management Guidelines to Minimize Losses due to FHB in Ohio.	$ 29,104
MGMT	Influence of Variable Pre-anthesis Rainfall Patterns on FHB and DON in Wheat.	$ 6,575
MGMT	Fate of Deoxynivalenol in Wheat after Visual Symptom Development.	$ 24,422
MGMT	Development of Prediction Models for Fusarium Head Blight and Deoxynivalenol.	$ 10,313
	FY14 Total ARS Award Amount	**$ 70,414**

Principal Investigator Date

* MGMT – FHB Management
FSTU – Food Safety, Toxicology, & Utilization of Mycotoxin-contaminated Grain
GDER – Gene Discovery & Engineering Resistance
PBG – Pathogen Biology & Genetics
EC-HQ – Executive Committee-Headquarters
BAR-CP – Barley Coordinated Project
DUR-CP – Durum Coordinated Project
HWW-CP – Hard Winter Wheat Coordinated Project
WES-CP – Western Coordinated Project
VDHR – Variety Development & Uniform Nurseries – Sub categories are below:
SPR – Spring Wheat Region
NWW – Northern Soft Winter Wheat Region
SWW – Southern Soft Red Winter Wheat Region

Project 1: *Robust Integrated Management Guidelines to Minimize Losses due to FHB in Ohio.*

1. **What major problem or issue is being resolved relevant to Fusarium head blight (scab) and how are you resolving it?**

Inclement weather often prevents fungicides from being applied at the recommended anthesis growth stage for FHB and DON management, therefore research is needed to evaluate and develop more robust guidelines for fungicide us in integrated FHB and DON management programs. In addition, new soft red winter wheat cultivars with different levels of resistance FHB are being released to replace old cultivar; these need to be evaluated in combination with fungicide in integrated management programs for efficacy against FHB and DON.

Two field experiments were conducted in 2014 to evaluate the integrated effects of Prosaro® and Caramb®a application timing, rate of active ingredient, and cultivar resistance on FHB and DON. In the first experiment, Prosaro (6.5 fl. oz./A) was applied to four cultivars with different levels of resistance to FHB (Hopewell, susceptible; Bromfield, moderately susceptible; and Truman and Malabar, both moderately resistant), and in the second, Prosaro and Caramba were applied to Hopewell at low and high rates (6.5 and 8.2 fl. oz./A for Prosaro and 13.5 and 17 fl. oz./A, for Caramba). In both experiments, treatments were either applied at 50% anthesis or between 2 and 7 days after anthesis. All plots were inoculated at anthesis, and FHB intensity and Fusarium damaged kernel (FDK) were rated, grain yield estimated, and grain samples tested for DON.

2. **List the most important accomplishments and their impact (i.e. how are they being used) to minimize the threat of Fusarium Head Blight or to reduce mycotoxins. Complete both sections; repeat sections for each major accomplishment:**

Accomplishment: The effects of cultivar and fungicide x rate combination on FHB index, FDK, and DON did not depend on application time. Averaged across application time, Truman and Malabar had significantly lower mean index, FDK, and DON than Hopewell and Bromfield, and Prosaro at the high rate had significantly lower mean index, and numerically, but not always statistically, lower mean FDK and DON than the other tested fungicide x rate combinations. Treatments applied between two and five days post-anthesis had significantly lower mean index and DON than those applied at anthesis, and comparable or significantly lower mean FDK. For all application times, treated plots had significantly higher mean yield than the untreated check. The use of a moderately resistant cultivar reduced mean index by 59 to 76% and DON by 72 to 74% when compared to the untreated-susceptible check, and fungicide alone reduced index by 3 to 84% and DON by 41 to 68%, relative to the check. However, combinations of moderate resistance and fungicide, particularly treatments made between at 2 and 4 days after anthesis, were the most efficacious, with mean percent control relative to the susceptible-untreated ranging from 68 to 96% for index and 81 to 88% for DON, and percent yield increase ranging from 8 to 12%.

Impact: Our results showed that both Caramba and Prosaro provided effective FHB, FDK, and DON control when applied at label-recommended rates up to 6 days after anthesis. In fact, in some cases, applications made between 2 and 5 days after 50% anthesis were more effective than applications made at anthesis. The highest levels of FHB/DON control and yield increase occurred when an application of Caramba or Prosaro was combined with moderate resistance. Producers now have additional research-based information that will allow for more flexibility when applying fungicides for FHB management. Results were made available to stakeholders during the 2014 and 2015 through extension presentations and newsletters.

Project 2: *Influence of Variable Pre-anthesis Rainfall Patterns on FHB and DON in Wheat.*

1. What major problem or issue is being resolved relevant to Fusarium head blight (scab) and how are you resolving it?

It is well known that FHB development and DON accumulation are strongly influenced by environmental conditions before and during anthesis and early grain-fill. However, the effect of variable moisture or rainfall patterns on FHB and DON still continues to be a major knowledge gap in our understanding of the epidemiology of FHB. Further research is needed to determine and characterize factors affecting toxin accumulation in wheat grain and the association between disproportionately high levels of DON and relatively low levels of FHB.

Field experiments were conducted in 2014 to investigate the effects of variable simulated rainfall patterns on FHB and DON. Beginning 8 days prior to anthesis and ending at 50% anthesis, the rainfall patterns (treatments) were: 1) rainfall every day; 2) rainfall on the first and last two days, separated by a four-day period without rainfall; 3) no rainfall on the first and last two days, separated by four days with rainfall; 4) rainfall every other day, and 5) check (no supplemental rainfall/irrigation; ambient rainfall). Plots subjected to the different rainfall treatments had three different sources of inoculum - corn spawn (*F. graminearium*-colonized corn kernels) or naturally-infected corn residue spread between the rows at jointing (Feekes GS 6), or without in-field inoculum (check). Twenty spikes were harvested daily from each plot and assayed for spores of *F. graminearum*. FHB index was evaluated at soft dough and a sample of grain from each plot was used to estimate Fusarium damaged kernels (FDK) and DON.

2. List the most important accomplishments and their impact (i.e. how are they being used) to minimize the threat of Fusarium Head Blight or to reduce mycotoxins. Complete both sections; repeat sections for each major accomplishment:

Accomplishment: Mean FHB index, FDK, and DON were numerically higher in plots that received simulated rain compared to the check, and for plots that received rain, the means were higher for those with corn spawn than those with naturally-infected corn residue or without in-field inoculum. Pre-anthesis rainfall patterns tended to influence FHB development and DON contamination in plots with corn spawn, but had little discernable effect on disease and toxin in plots with corn residue or without inoculum. In plots with corn spawn, more spores reached the infection court than in plots with residue or without in-field inoculum, and the every-day rainfall treatment (Rain_1) resulted in numerically higher mean FHB index than treatments with intermittent rainfall (Rain_2, Rain_3 and Rain_4). Interestingly, however, although mean FHB index was highest for Rain_1, plots that received rainfall on the first and last two days (Rain_2) or every other day (Rain_4) during the 8-day pre-anthesis window had higher or comparable mean FDK and DON. Rain_1 and Rain_2 also resulted in more spores reaching the spikes during the week before anthesis than Rain_3 and Rain_4.

Impact: In general, results from the 2014 experiment were comparable to those observed in previous field and growth chamber experiments, showing that disproportionality between FHB and DON may be associated with discontinuous rainfall/moisture patterns. These findings further contributed to our understanding of the effects of rainfall patterns on DON contamination of wheat grain, and will be useful for developing and refining DON prediction models. These models are useful tools to help guide fungicide application and grain marketing decisions.

Project 3: *Fate of Deoxynivalenol in Wheat after Visual Symptom Development.*

1. **What major problem or issue is being resolved relevant to Fusarium head blight (scab) and how are you resolving it?**

Major FHB epidemics and correspondingly high levels of DON accumulation are associated with warm temperatures, high relative humidity, and rainfall before, during, and even after anthesis. However, the specific effects of temperature and moisture on "*high DON with low/no visual symptoms*" (as stated in the USWBSI MGNT Action Plan) are still poorly understood. Furthermore, the effects of inoculum density and post-anthesis infection on this phenomenon warrant further investigation.

A series of controlled-environment studies were conducted to investigate the effects of cool-wet, cool-dry, warm-wet, warm-dry, hot-wet and hot-dry post-anthesis environmental conditions on DON accumulation in spikes with known levels of FHB or inoculated at different post-anthesis growth stages with different spore concentrations. Treatments consisted of groups of spikes with index levels ranging from 5 to 30% in experiment 1 and spore concentrations ranging from 10 to 50 x 10^3 spore per ml applied at anthesis or 7, 14, and 21 days after anthesis in experiment 2. In both cases, plants were placed in growth chambers set at 20, 25 or 30^{o}C, at higher (100%) or low (80%) RH. In a third experiment, groups of detached spikes with index levels ranging from 5 to 50% were placed in transparent boxes with saturated salt solution or water (to generate RH ranging from 70 to 100%) in growth chambers set at 20, 25 or 30^{o}C.

2. List the most important accomplishments and their impact (i.e. how are they being used) to minimize the threat of Fusarium Head Blight or to reduce mycotoxins. Complete both sections; repeat sections for each major accomplishment:

Accomplishment: One replicate of experiments 1 and 2 and two replicates of experiment 3 were completed, and spike and grain samples were collected and processed for DON analysis. DON results were not yet available at the time of this progress report.

Impact: We anticipate that our results will provide invaluable insights as to the effects of post-anthesis environmental conditions, inoculum density, and infection on DON accumulation, as well as the effects of post-symptom-development environmental conditions on DON accumulation in grain from spikes with known levels of visual symptoms. Our results will likely contribute to the generation of data useful for continued development of DON prediction models for wheat (a research need as stated in the USWBSI MGNT Action Plan).

Project 4: *Development of Prediction Models for Fusarium Head Blight and Deoxynivalenol.*

1. What major problem or issue is being resolved relevant to Fusarium head blight (scab) and how are you resolving it?

Fungicide applications for FHB management have to be made approximately three weeks before symptoms are seen, and since FHB does not develop every year, these applications are not always warranted. Consequently, produces always run the risk of making unnecessary application and incurring unnecessary expenses, or conversely, failing to apply a fungicide and suffering substantial grain yield and quality losses. Thus, the current FHB risk assessment system was developed to help guide fungicide application. Although the prediction accuracy of this system is approximately 80%, there is still room for improvement. Efforts to improve the system would benefit from the acquisition of data representing different patterns of associations between FHB and weather/host variables, as well as the exploration of novel data-mining and modeling approaches.

From 2010 to 2014, additional data were gathered from field experiments conducted in 16 US wheat-growing states as part of the USWBSI FHB coordinated integrated management projects. Plots were established following host or non-host crops of *F. graminearum*, and at least three commercial wheat cultivars, classified as susceptible (S), moderately susceptible (MS), or moderately resistant (MR), were planted in most trials. Each unique combination of location (latitude and longitude), previous-crop, cultivar resistance class, and flowering data was considered as a separate observation for the purpose of risk model development and validation.

2. List the most important accomplishments and their impact (i.e. how are they being used) to minimize the threat of Fusarium Head Blight or to reduce mycotoxins. Complete both sections; repeat sections for each major accomplishment:

Accomplishment: During the 2014 award period, data collected between 2010 and 2013 were organized, cleaned and added to the overall data matrix for model development and refinement, while data collected in 2014 were held back for subsequent use in model testing. With the aid of google map and addresses, latitude and longitude coordinates were added to the data matrix for each location-year to identify the closest reporting weather station with air temperature, dew point and pressure data. A total of 338 new observations were added to the data matrix, expanding the data set to 865 observations. Sixteen states are represented, with 74% of the observations coming from winter wheat and the remaining 26% from spring wheat. FHB epidemics, defined as FHB index ≥ 10% (based on the most susceptible cultivars), had occurred in 236 of the observations, and no FHB (i.e. FHB index = 0) was recorded in 184 of the remaining 629 observations. Working closely with Dr. DeWolf and his team at Kansas State, weather data from September 01 of the year preceding anthesis to 30 days post-anthesis were summarized and mean curves were plotted for epidemics and non-epidemics. For relative humidity, there was a clear and consistent separation between curves for epidemic and non-epidemic, beginning approximately 35 days pre-anthesis and continuing into the post-anthesis period, with the epidemic relative humidity curve being above the non-epidemic curve.

Impact: In collaboration with Dr. DeWolf and his team at Kansas State, the new data were used along with actual observations made by several PIs in locations with FHB epidemics to validate new prediction models and compare them to current models. These new models, which appeared to be more accurate than existing models based on ground-truth data, were successfully deployed in 2015 and used to help guide fungicide application in 30 US States. A recent survey showed that the estimated average annual monetary value of the FHB risk tool is $17,000 per user, giving an estimated minimum annual benefit for the country of over $170 million.

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the FY14 award period. The term "support" below includes any level of benefit to the student, ranging from full stipend plus tuition to the situation where the student's stipend was paid from other funds, but who learned how to rate scab in a misted nursery paid for by the USWBSI, and anything in between.

1. **Did any graduate students in your research program supported by funding from your USWBSI grant earn their MS degree during the FY14 award period?**
   No
   If yes, how many?

2. **Did any graduate students in your research program supported by funding from your USWBSI grant earn their Ph.D. degree during the FY14 award period?**
   Yes
   If yes, how many? one.

3. **Have any post docs who worked for you during the FY14 award period and were supported by funding from your USWBSI grant taken faculty positions with universities?**
   None
   If yes, how many?

4. **Have any post docs who worked for you during the FY14 award period and were supported by funding from your USWBSI grant gone on to take positions with private ag-related companies or federal agencies?**
   None
   If yes, how many?

Include below a list of all germplasm or cultivars released with full or partial support of the USWBSI during the FY14 award period. List the release notice or publication. Briefly describe the level of FHB resistance. *If not applicable because your grant did NOT include any VDHR-related projects, enter N/A below.*

N/A

Include below a list of the publications, presentations, peer-reviewed articles, and non-peer reviewed articles written about your work that resulted from all of the projects included in the FY14 grant. Please reference each item using an accepted journal format. If you need more space, continue the list on the next page.

Peer-reviewed publications:

1. Schisler, D. A., Boehm, M. J., **Paul, P. A.**, Rooney, A. P., and Dunlap, C.A. 2015. Reduction of Fusarium head blight using prothioconazole and prothioconazole-tolerant variants of the Fusarium head blight antagonist *Cryptococcus flavescens* OH 182.9. **Biological Control** 86:36-45.
2. Salgado, J. D., Madden, L. V., and **Paul, P. A.** 2015. Quantifying the effects of Fusarium head blight on grain yield and test weight in soft red winter wheat. **Phytopathology** 105:295-306.
3. Andersen, K. F., Madden, L. V., and **Paul, P. A.** 2015. Fusarium head blight development and deoxynivalenol accumulation in wheat as influenced by post-anthesis moisture patterns. **Phytopathology** 105:210-219.
4. Salgado, J. D., Madden, L. V., and **Paul, P. A.** 2014. Efficacy and economics of integrating in-field and harvesting strategies to manage Fusarium head blight of wheat. **Plant Dis.** 98:1407-1421.
5. Andersen, K. F., Morris, L., Derksen, R.C., Madden, L.V., and **Paul, P. A.** 2014. Rainfastness of prothioconazole+tebuconazole for Fusarium head blight and deoxynivalenol management in soft red winter wheat. **Plant Dis.** 98:1396-1406.
6. D'Angelo, D. L., Bradley, C. A., Ames, K. A., Willyerd, K. T., Madden, L. V., and **Paul, P. A.** 2014. Efficacy of fungicide applications during and after anthesis against Fusarium head blight and deoxynivalenol in soft red winter wheat. **Plant Dis.** 98:1387-1397.
7. Shah, D. A., De Wolf, E. D., **Paul, P. A.**, and Madden, L. V. 2014. Predicting Fusarium head blight epidemics with boosted regression trees. **Phytopathology** 104:702-714.

Presentations:

1. **Pierce A. Paul**. ***"Complex associations among Moisture, Fusarium Head Blight, and Deoxynivalenol in Wheat"***. North Central Division Meeting of the American Phytopathological Society. East Lansing, MI. June, 2015.
2. **Pierce A. Paul**. "***Efficacy, Stability, and Economics of Fusarium Head Blight Management: Lessons Learned After 12 Years of Multistate Research***". Department of Horticulture and Crop Science Seminar Series, The Ohio State University, Ohio Agricultural Research and Development Center, Wooster, OH. October, 2014.