USDA-ARS | U.S. Wheat and Barley Scab Initiative

# FY21 Performance Progress Report

**Due date:** July 26, 2022

## Cover Page

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|---|---|
| **Principle Investigator (PI):** | Pierce Paul |
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| **Phone:** | 330-263-3842 |
| **Fiscal Year:** | 2021 |
| **USDA-ARS Agreement ID:** | 59-0206-0-131 |
| **USDA-ARS Agreement Title:** | Fusarium Head Blight Risk Assessment, Management, and Education |
| **FY20 USDA-ARS Award Amount:** | $84,704 |
| **Recipient Organization:** | Ohio State University<br>Department of Plant Pathology<br>1680 Madison Ave.,<br>Wooster, OH 44691 |
| **DUNS Number:** | 07-165-0709 |
| **EIN:** | 31-6401599 |
| **Recipient Identifying Number or Account Number, if any:** | GRT00060644 |
| **Project/Grant Period:** | 5/13/21 - 5/12/23 |
| **Reporting Period End Date:** | 5/12/2022 |

## USWBSI Individual Project(s)

| USWBSI Research Category* | Project Title | ARS Award Amount |
|---|---|---|
| MGMT-IM | Efficacy of Miravis Ace in Combination with Resistance for FHB and DON Management | $72,738 |
| MGMT | Application of Model Ensembles and Machine Learning to the Prediction of Fusarium Head Blight | $11,966 |
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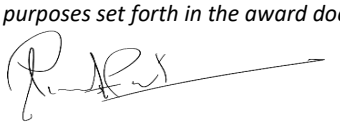
| | **FY21 Total ARS Award Amount** | $84,704 |

I am submitting this report as an: ☒ Annual Report ☐ Final Report

*I certify to the best of my knowledge and belief that this report is correct and complete for performance of activities for the purposes set forth in the award documents.*



07/26/2022

Principal Investigator Signature — Date Report Submitted

* BAR-CP – Barley Coordinated Project
DUR-CP – Durum Coordinated Project
EC-HQ – Executive Committee-Headquarters
FST-R – Food Safety & Toxicology (Research)
FST-S – Food Safety & Toxicology (Service)
GDER – Gene Discovery & Engineering Resistance
HWW-CP – Hard Winter Wheat Coordinated Project
MGMT – FHB Management
MGMT-IM – FHB Management – Integrated Management Coordinated Project
PBG – Pathogen Biology & Genetics
TSCI – Transformational Science
VDHR – Variety Development & Uniform Nurseries
NWW –Northern Soft Winter Wheat Region
SPR – Spring Wheat Region
SWW – Southern Soft Red Winter Wheat Region

**Project 1:** Efficacy of Miravis Ace in Combination with Resistance for FHB and DON Management

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1. **What are the major goals and objectives of the research project?**
   The overall goal of this project (as part of the FHB Integrated Management Coordinated Project [IM_CP]) is to develop best-management practices for FHB and mycotoxins in wheat that are robust to conditions experienced in production fields. The specific objectives are to:
   1) Evaluate the integrated effects of fungicide treatment and genetic resistance on FHB and DON, with emphasis on the new fungicide, Miravis Ace;
   2) Compare the efficacy of Miravis Ace when applied at early heading (Feekes 10.3) or at early anthesis (Feekes 10.5.1) to that of standard Feekes 10.5.1 applications of Prosaro and Caramba;
   3) Compare the efficacy of single and sequential applications of Miravis Ace, Prosaro, Caramba, and tebuconazole against FHB and DON;
   4) Determine the effects of rainfall timing, amount, and duration on the efficacy and residual life of Miravis Ace, Prosaro, and Caramba on wheat spikes;

2. **What was accomplished under these goals or objectives?** *(For each major goal/objective, address these three items below.)*

   a) **What were the major activities?**
   **Obj 1** (**Wheat IM Coordinated Project; IM_CP - Ohio):** An inoculated field experiment was conducted in Ohio during the 2020-2021 growing season follow the IM-CP standard protocol. Six fungicide treatments (1- nontreated, inoculated check; 2- Prosaro at Feekes 10.5.1; 3- Miravis Ace at Feekes 10.5.1; 4- Miravis Ace at Feekes 10.3; 5- Prosaro at Feekes 10.5.1, non-inoculated; and 6- Spharaex at Feekes 10.5.1) were applied to plots of cultivars with different levels of resistance to FHB.
   **Obj 2 and 3 (Wheat Uniform Fungicide Trial: UFT - Ohio):** Separate plots of a susceptible cultivar were subjected to eleven fungicide treatments: 1) an nontreated check; 2) Prosaro at Feekes 10.5.1; 3) Caramba at Feekes 10.5.1; 4) Miravis Ace at Feekes 10.3; 5) Miravis Ace at Feekes 10.5.1; 6) Miravis Ace at Feekes 10.5.1 followed by Prosaro at 4 days after early anthesis (DAA); 7) Miravis Ace at anthesis followed by Caramba at 4 DAA; and 8) Miravis Ace at anthesis followed by Folicur at 4 DAA; 9) Miravis Ace at 4 DAA; 10) Prosaro at 4 DAA; and 11) Spharaex at Feekes 10.5.1.
   **Obj 4 (Rainfastness):** Separate plots of a susceptible wheat cultivar were treated with Miravis Ace, Prosaro, or Caramba at Feekes 10.5.1 or left nontreated, after which separate groups of plots were subjected to simulated rainfall treatments of different durations (15, 30, 60, and 120 min), beginning at different times (0, 15, 30, and 60 min) after fungicide application.
   In all trials, Prosaro, Caramba, Miravis Ace, Spharaex, and Folicur were applied at 6.5, 13.5, 13.7, 7.3 and 4 fl. oz./A, respectively, along with a non-ionic surfactant (except for a few treatments in the rainfast experiment), plots were spray-inoculated with a spore suspension *Fusarium graminearum* at Feekes 10.5.1 (unless otherwise stated), and FHB index (IND), DON, FDK, foliar diseases severity, yield, and test weight data were collected and analyzed.

**b) What were the significant results?**

**Obj 1 (IM_CP - Ohio):** For all tested resistance classes, all fungicide treatments resulted in significantly lower mean IND and DON than the nontreated check, with treatments applied at Feekes 10.5.1 having lower mean responses, particularly for DON, than the Feekes 10.3 application of Miravis Ace. Management programs consisting of a fungicide application to an MR cultivar had the lowest overall mean levels of IND and DON than all other cultivar resistance by fungicide treatment combinations.

**Obj 2** and **3 (UFT - Ohio):** All fungicide-treated plots had significantly lower mean IND and DON than the nontreated check. For both responses, treatments consisting of sequential applications of Miravis Ace at anthesis followed by a DMI at 4-6 DAA resulted in significantly lower mean IND and DON than single-application treatments. Among single-application treatments, the Feekes 10.3 application of Miravis Ace had the highest mean level of DON.

**Obj 4 (Rainfastness):** When applied with a surfactant, all fungicide-treated plots had sufficiently lower mean IND and DON than the nontreated check, with Prosaro, Caramba and Miravis Ace having similar mean levels of IND and DON across rainfall treatments. However, mean FHB and DON levels were considerably higher when the fungicides were applied without the surfactant and plots were subjected to 120 min of simulated rainfall, beginning immediately after the treatments were applied.

**c) List key outcomes or other achievements.**

In Ohio, we successfully conducted experiments and generated data with a wide range of IND and DON levels, which allowed us to accomplish our objectives.

**Obj. 1** (**IM_CP - Ohio):** The integration of an early anthesis application of Miravis Ace, Prosaro, or Spharaex with moderate genetic resistance showed greater efficacy against IND and DON than fungicide application or genetic resistance alone.

**Obj 2** and **3 (UFT - Ohio):** When applied at early anthesis, Miravis Ace was just as effective or more effective then Prosaro and/or Caramba against IND. Spharaex also showed comparable efficacy to Prosaro and Caramba against IND and DON. However, the early heading application of Miravis Ace was less effective against DON than the early anthesis application of either Prosaro, Caramba, Miravis Ace or Spharaex. Two-treatment programs (Miravis Ace at early anthesis followed by a DMI 4-6 days later) were the most effective of all tested treatments against both IND and DON.

**Obj 4 (Rainfastness):** Prosaro, Caramba, and Miravis Ace were very rainfast once applied with the non-ionic surfactant Induce.

**3. What opportunities for training and professional development has the project provided?**

Two postdoctoral researchers and a graduate student contributed to the project, learning how to design field experiments and collect data to evaluate integrated management programs for FHB. They also learned and contributed to data analysis and the preparation of abstracts, posters, and talks for scientific meetings; graphs and tables for extension talks; and manuscripts for publication.

**4. How have the results been disseminated to communities of interest?**

Results were disseminated by way of posters, abstracts, and talks at scientific meetings, electronic newsletter articles, extension talks and field days, and peer-reviewed journal articles.

**Project 2:** Application of Model Ensembles and Machine Learning to the Prediction of Fusarium Head Blight

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1. **What are the major goals and objectives of the research project?**
   The overall goal of this project is to create better models for predicting Fusarium head blight (FHB). The objectives ware to:
   1) Enhance the FHB data matrix with observations collected in collaboration with the MGMT IM-CP during recent growing seasons (**Paul lab**);
   2) Improve predictive models for FHB through "ensemble modeling" approaches that combine estimates from multiple models resulting in a more robust estimate of disease risk (**DeWolf lab**);
   3) Further apply machine learning algorithms that better address non-linear relationships between weather and FHB risk (**DeWolf lab**); and
   4) Use the FHB observational matrix and the predictive models to develop a suite of case studies that will help stakeholders visualize and understand weather patterns that stimulate or suppress FHB epidemics (**DeWolf and Paul lab**).

2. **What was accomplished under these goals or objectives?** *(For each major goal/objective, address these three items below.)*

   a) **What were the major activities?**
   **Obj 1:** During the 2020-2021 growing season 33 integrated management trials were conducted as part of the MGMT_CP in 21 US wheat-growing states (AL, DE, IL, IN, KS, KY, LA, MD, MI, MO, MN, ND, NE, NY, OH, PA, SD, TN, VA, and WI). At least two commercial wheat cultivars, classified as susceptible, moderately susceptible or moderately resistant, were planted in each trial. FHB index, incidence and DON data were collected from nontreated, naturally infected, non-irrigated plots of each cultivar and edited for inclusion in the master data file for FHB risk model development and validation.
   **Obj 2:** Soft voting, weighted model averaging, and stacking ensemble modeling approaches were used to combine logistic regression models that are correlated in their predictions of FHB epidemics.
   **Obj 3:** Using our master dataset of 999 observations, Random Forest (RF) variable selection coupled with nested resampling were used to build FHB prediction models.
   **Obj 4** will be the focus of FY22 and beyond

   b) **What were the significant results?**
   **Obj 1:** A total of 58 new cases (unique combination of cultivar resistance class x trial) with a range of mean IND levels were collected across states and gain market classes, expanding the range of environmental conditions available in our dataset for model development.
   **Obj 2:** The stacking ensemble modeling approach outperformed the soft voting and weighted regression averaging approaches, resulting in an overall increase in prediction accuracy relative to the original logistic regression models.
   **Obj 3:** A total of 58 RF models were built, each with no more than 14 predictors.

**c) List key outcomes or other achievements.**

**Obj 1:** The MGMT_CP continues to be an excellent source of new observations from a range of environments for FHB model development.
**Obj 2:** Ensembling simple, correlated logistic regression models yielded promising results in terms of prediction accuracy, and as such, could potentially be used to develop more accurate FHB risk assessment models.
**Obj 3:** RF models had overall superior predictive performance than previously reported simple logistic regression models.

**3. What opportunities for training and professional development has the project provided?**
The postdocs and graduate student who contributed to the MGMT_CP learned certain basic aspects of data mining for predictive model development.

**4. How have the results been disseminated to communities of interest?**
A manuscript was published in *PLOS Computational Biology*, and another is being prepared for publication in Phytopathology.

# Publications, Conference Papers, and Presentations

Please include a listing of all your publications/presentations about your FHB work that were a result of funding from your FY21 grant award. Only citations for publications published (submitted or accepted) or presentations presented during the **award period** should be included.

**Did you publish/submit or present anything during this award period?**

☒ Yes, I've included the citation reference in listing(s) below.
☐ No, I have nothing to report.

## Journal publications as a result of FY21 grant award

*List peer-reviewed articles or papers appearing in scientific, technical, or professional journals. Include any peer-reviewed publication in the periodically published proceedings of a scientific society, a conference, or the like.*

Identify for each publication: Author(s); title; journal; volume: year; page numbers; status of publication (published [include DOI#]; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

**PEER-REVIEWED ARTICLES:**

1. Moraes, W. B., Madden, L. V., and Paul, P. A. 2021. Characterizing heterogeneity and determining sample sizes for accurately estimating wheat Fusarium head blight index in research plots. *Phytopathology* 112:315-334. https://apsjournals.apsnet.org/doi/10.1094/PHYTO-04-21-0157-R.
   Published
   Acknowledgement of federal support (yes)

2. Moraes, W. B., Madden, L. V., and Paul, P. A. 2022. Efficacy of Genetic Resistance and Fungicide Application against Fusarium Head Blight and Mycotoxins in Wheat under persistent Pre- and Post-anthesis Moisture. Plant Dis. https://apsjournals.apsnet.org/doi/10.1094/PDIS-02-22-0263-RE.
   Accepted April 2022 (first look)
   Acknowledgement of federal support (yes)

## Books or other non-periodical, one-time publications as a result of FY21 grant award

*Report any book, monograph, dissertation, abstract, or the like published as or in a separate publication, rather than a periodical or series. Include any significant publication in the proceedings of a one-time conference or in the report of a one-time study, commission, or the like.*

Identify for each one-time publication: Author(s); title; editor; title of collection, if applicable; bibliographic information; year; type of publication (book, thesis or dissertation, other); status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

**DISSERTATION:**

1. Moraes 2021. Sampling for Fusarium Head Blight (FHB) Index Estimation and Quantifying the Effects of Environmental Conditions on FHB Development, Mycotoxin Contamination of Grain, and their Management in Wheat. Doctoral Dissertation. Department of Plant Pathology, The Ohio State University, Columbus, OH.
   Published
   Acknowledgement of federal support (yes)

## Other publications, conference papers and presentations as a result of FY21 grant award

Identify any other publications, conference papers and/or presentations not reported above. Specify the status of the publication.

**ABSTRACTS**

1. Ng, S. J., Bucker Moraes, W., Madden, L. V., and Paul, P. A. 2021. Rainfastness of fungicides for Fusarium head blight and deoxynivalenol reduction in soft red winter wheat. *Phytopathology* 111:S2.58.
2. Bucker Moraes, W., Schwarz, P. B., Madden, L. V., and Paul, P. A. 2021. Effect of moisture on wheat grain contaminating with zearalenone, an estrogenic metabolite produced by the fungus *Fusarium graminearum*. *Phytopathology* 111:S2.70.

**PROCEEDINGS**

1. Bucker Moraes, W., Schwarz, P., B., Baik, B-K, Madden, L. V. and Paul, P. A. (2021). Effects of environmental conditions after Fusarium head blight visual symptom expression on deoxynivalenol-3-glucoside accumulation in wheat. *Proceedings of the 2021 National Fusarium Head Blight Forum*; Virtual. December 6-7, 2021. Retrieved from: https://scabusa.org/forum/2021/2021NFHBForumProceedings.pdf
2. Bucker Moraes, W., Schwarz, P., B., Baik, B-K, Madden, L. V. and Paul, P. A. (2021). Temperature, moisture, grain development, and harvesting strategy effects on zearalenone contamination of grain harvested from Fusarium head blight affected wheat spikes. *Proceedings of the 2021 National Fusarium Head Blight Forum*; Virtual. December 6-7, 2021. Retrieved from: https://scabusa.org/forum/2021/2021NFHBForumProceedings.pdf
3. Cinderella, J. A., Anderson, K., Bergstrom, G. C., Bockus, W. W., Bradley, C. A., Breunig, M., Byamukama, E., Chilvers, M. I., Cowger, C., Faske, T. R., Friskop, A. J., Kelly, J., Kleczewski, N. M., Mideros, S., Paul, P. A., Price, T., Rawat, N., Rupp, J., Shim, S., Stevens, J., Telenko, D., Koehler, A. M. (2021). Baseline Fungicide Sensitivity to Pydiflumetofen in Fusarium graminearum isolated from wheat across 16 states. *Proceedings of the 2021 National Fusarium Head Blight Forum*; Virtual. December 6-7, 2021. Retrieved from: https://scabusa.org/forum/2021/2021NFHBForumProceedings.pdf
4. Paul, P. A. (2021). Pre-flowering fungicide applications for Fusarium head blight management in wheat. *Proceedings of the 2021 National Fusarium Head Blight Forum*; Virtual. December 6-7, 2021. Retrieved from: https://scabusa.org/forum/2021/2021NFHBForumProceedings.pdf