Fusarium Head Blight Management Coordinated Project: Integrated Management Trials 2018-2020

Jane Marian Luis[1], Sin Joe Ng[1], Gary Bergstrom[2], Kaitlyn Bissonnette[22], Kira Bowen[5], Carl Bradley[4], Emmanuel Byamukama[6], Martin Chilvers[11], Alyssa Collins[23], Christina Cowger[8], Heather Darby[13], Erick DeWolf[21], Ruth Dill Macky[12], Paul Esker[7], Andrew Friskop[9], Nathan Kleczewski[3], Alyssa Koehler[14], David Langston Jr.[16], Laurence Madden[1], Juliet Marshall[15], Hillary Mehl[16], Wanderson Moraes[1], Martin NegelKirk[11], Nidhi Rawat[10], Damon Smith[18], Darcy Telenko[19], Stephen Wegulo[24], Heather Young-Kelly[20] and Pierce A Paul[1*]

[1]The Ohio State University/OARDC, Wooster 44691; [2]Cornell University, Ithaca, NY 14853; [3]University of Illinois, Urbana, IL 61801; [4]University of Kentucky, Princeton, KY 42445; [5]Auburn University , Auburn, AL 36849; [6]South Dakota State University, Brookings, SD 57007; [7]The Pennsylvania State University, University Park, PA 16802; [8]North Carolina State University/USDA-ARS, Raleigh, NC 27695; [9]North Dakota State University, Fargo, ND 58102; [10]University of Maryland, College Park, MD 20742; [11]Michigan State University, East Lansing, MI 48824;[12]University of Minnesota, St. Paul, MN 55108; [13]University of Vermont and State Agricultural College, St. Albans, VT 05478; [14]The University of Delaware, Georgetown, DE 19947; [15]University of Idaho, Aberdeen, ID 83210; [16]Virginia Tech, Suffolk, VA 23437; [17]University of Nebraska-Lincoln, Lincoln, NE 68588; [18]University of Wisconsin-Madison, Madison, WI 53706; [19]Purdue University, West Lafayette, IN 47907; [20]The University of Tennessee at Knoxville, Jackson, TN 38301; [21]Kansas State University, Manhattan, KS 66506; [22]University of Missouri, Columbia, MO 65211; [23]The Pennsylvania State University, Manheim, PA 17545; and [24] University of Nebraska, Lincoln, NE 68583-0722
[*]Corresponding Author: PH: 330.263.3842; Email: paul.661@osu.edu

Introduction: Efforts to evaluate integrated management strategies for Fusarium head blight (FHB) and deoxynivalenol (DON) management in wheat and barley continued in 2018, 2019, and 2020. The focus over these three years of the integrated management coordinated project (IM_CP) was Miravis Ace, a new Succinate Dehydrogenase Inhibitor (SDHI; Adepidyn - Pydiflumetofen) + Demethylation Inhibitor (DMI; Propiconazole) premix fungicide that was recently labeled for managing diseases of wheat, barley, and other small grain crops. Preliminary results from a limited number of trials showed that when applied at early anthesis (Feekes 10.5.1) or within the first 6 days after early anthesis, Miravis Ace was just as effective as Prosaro and Caramba (3,4,5). This suggested that like the latter two fungicides, this new fungicide alone will not be sufficient to manage FHB and DON under highly favorable conditions. Based on results from the 2018 and 2019 IM_CP, Miravis Ace was most effective against FHB and DON when combined with genetic resistance, but the magnitude of the effect varied among trials, particularly when Miravis Ace was applied at early heading. The IM_CP experiment was repeated in 2020 following protocols similar to those used in 2018 and 2019, with the primary modification being the inclusion of a treatment consisting of the application of Miravis Ace at early anthesis followed by tebuconazole 4-6 days later. Again, the overall objective was to **evaluate the integrated effects of fungicide programs and genetic resistance on FHB and DON, with emphasis on the new fungicide, Miravis Ace**. Results from the last three years are summarized herein.

Materials and Methods: To accomplish the aforementioned objective, field experiments were conducted in 18 US wheat-growing states in 2018, 2019 and 2020. The standard protocol consisted of the application of fungicide treatment programs (sub-plot; **Table 1**) to plots of FHB-susceptible (S), -moderately susceptible (MS), and -moderately resistant (MR) cultivars (whole-plot). Hereafter, the combinations of fungicide programs by cultivar resistance classes will be referred to as: MR_CK (MR untreated), MR_I (MR treated with Prosaro at early anthesis [Feekes 10.5.1]), MR_II (MR treated with Miravis Ace at early anthesis), MR_III (MR treated with Miravis Ace at early heading [Feekes 10.3-5]), and MR_IV (MR treated with Miravis Ace at early anthesis followed by tebuconazole 4-6 days after anthesis [DAA]) for the MR cultivar. When referring to the same fungicide programs applied to the MS and S cultivars, the combinations were labelled MS_CK, MS_I, MS_II, MS_III, MS_IV, S_CK, S_I, S_II, S_III and S_IV. The experimental design was a randomized complete block, with at least 4 replicate blocks. In most experiments, plots were spray inoculated with a spore suspension of the fungus *Fusarium graminearum* approximately 24-36 hours after the anthesis treatments were applied, with or without mist-irrigation. Trials were naturally infected at some locations. FHB index (IND) was rated or calculated as previously described (2,6) on 60-100 spikes per plot at approximately Feekes 11.2. Plots were harvested and a sample of grain from each experimental unit was sent to a USWBSI-supported laboratory for mycotoxin analysis. Linear mixed models (multi-location) were fitted to the pooled arcsine square root-transformed IND and log-transformed DON data to evaluate the main and interaction effects of fungicide treatment and genetic resistance on IND and DON.

Table 1. The following core treatments were randomly assigned to experimental units. All fungicide treatments were applied along with a nonionic surfactant.

Treatment[a]	Product	Rate	Timing
1 (CK)	Untreated check	…	…
2 (I)	Prosaro	6.5 fl oz/A	Anthesis
3 (II)	Miravis Ace	13.7 fl oz/A	Anthesis
4 (III)	Miravis Ace	13.7 fl oz/A	Feekes 10.3
5 (IV)*	Miravis Ace fb Tebuconazole	13.7 and 4 fl oz/A	Anthesis/4-6 DAA

*Only tested in 2020, DAA = days after anthesis

Results and Discussion: Mean Fusarium head blight index (IND) and deoxynivalenol (DON) grain contamination data from 57 and 37 environments (trial x state x year combinations) are shown in Figures 1 and 2, respectively. The environments represent spring and winter wheats from five market classes (durum, hard red spring, hard red winter, soft red winter, and soft white winter).

FHB index: Means varied across the 57 environments and among management combinations within environments as shown by the spread of the data points around the median in **Fig 1A**. Means ranged from 0 to 80% across management combinations and were more variable across environments on S (interquartile range [IQR] 4 to 19%) and MS (IQR 2 to 9%) cultivars than on MR (IQR 2 to 7%) cultivars. This in part reflects the fact that there were fewer environments with S and MS cultivars than with MR cultivars (**Fig. 1A**). The susceptible, nontreated check (S_CK) had the highest mean IND (16.5%), whereas the application of Miravis Ace at anthesis followed by tebuconazole at 4-6 DAA to MS cultivars (MS_IV) and anthesis only application of Miravis Ace to moderately resistant cultivars (MR_II) resulted in the lowest means (1.7 and 2.1%, respectively) (**Fig. 2A**). However, it should be noted that only five trials included treatment MS_IV and the mean IND levels in these trials were low (0 to 9%). In comparison, there were 56 trials that included treatment MR_II and the mean IND levels ranged from 0 to 31%. For all tested resistance classes, all fungicide programs resulted in significantly lower mean IND (on the arcsine square root-transformed scale) than the nontreated check. Pairwise differences between fungicide programs were statistically significant ($P < 0.05$). The only exceptions were for comparisons between MR_I and MR_IV, MR_III and MR_IV, MS_I and MS_III, MS_I and MS_IV, MS_II and MS_IV, MS_III and MS_IV, S_I and S_III, and S_II and S_IV.

Deoxynivalenol: Mean DON ranged from 0 to 58 ppm across the 37 environments and among management combinations **(Fig. 1B**). Contrary to what was observed for IND, MS_III (application of Miravis Ace to MS cultivars at Feekes 10.3-5) had the highest mean level of DON contamination on the raw data scale (7 ppm). However, on the log-transformed scale, S_CK had the highest mean. Sequential application of Miravis Ace at anthesis followed by tebuconazole at 4-6 DAA had the lowest overall mean DON contamination (0.6 to 0.8 ppm) (**Fig. 1B** and **2B**). However, it should be noted that treatment IV was evaluated only in 2020, whereby 19, 5, and 19 trials were planted with MR, MS, and S cultivars, respectively. Within each resistance class, all treatments resulted in significantly lower mean DON (on the log-transformed scale) than the nontreated check, and Miravis Ace at anthesis and Prosaro at anthesis had significantly lower log-transformed DON and the Feekes 10.3-5 application of Miravis Ace. Pairwise differences between fungicide programs were statistically significant, except for comparisons between MR_I and MR_IV, MR_II and MR_IV, MS_I and MS_II, MS_I and MS_IV, MS_II and MS_IV, MS_III and MS_IV, S_I and S_III, and S_II and S_IV.

As additional data become available, a more complete set of analyses will be performed. However, the results summarized herein suggest that while a Feekes 10.3-5 application of Miravis Ace may suppress FHB IND to levels comparable to those achieved with an anthesis application of Miravis Ace or Prosaro, such an early application is considerably less effective than the anthesis applications in terms of DON suppression.

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References:

1. Dill-Macky, R., and Jones, R. K. 2000. The effect of previous crop residues and tillage on Fusarium head blight of wheat. Plant Dis. 84:71-76.
2. Paul, P. A., El-Allaf, S. M., Lipps, P. E., and Madden, L. V. 2005. Relationships between incidence and severity of Fusarium head blight on winter wheat in Ohio. Phytopathology 95:1049-1060.
3. Paul, P. A., Lipps, P. E., Hershman, D. E., McMullen, M. P., Draper, M. A., and Madden, L. V. 2008. Efficacy of triazole-based fungicides for Fusarium head blight and deoxynivalenol control in wheat: A multivariate meta-analysis. Phytopathology 98:999-1011.
4. Paul, P. A., Salgado, J. D., Bergstrom, G. C., Bradley, C., Byamukama, E., Byrne, A. M., Chapara, V., Cummings, J. A., Chilvers, M. I., Dill-Macky, R., Friskop, A. J., Kleczewski, N. M., Madden, L. V., Nagelkirk, M., Stevens, J., Smith, M., Wegulo, S. N., Wise, K. A., and Yabwalo, D. 2019. Integrated effects of genetic resistance and prothioconazole tebuconazole application timing on Fusarium head blight in wheat. Plant Dis. 103:223-237.
5. Salgado et al. 2018. Efficacy of Miravis Ace for FHB and DON management across environments and grain market classes: A progress report. In: Canty, S., A. Hoffstetter, B. Wiermer and R. Dill-Macky (Eds.), Proceedings of the 2018 National Fusarium Head Blight Forum (p. 40-44). East Lansing, MI/Lexington, KY: U.S. Wheat & Barley Scab Initiative.
6. Stack, R. W., and McMullen, M. P. 1998. A visual Scale to estimate severity of Fusarium head blight in wheat. NDSU Extension Service: Small Grains Publications. Online Publication/PP-1095.
7. Willyerd, K. T., Li, C., Madden, L. V., Bradley, C. A., Bergstrom, G. C., Sweets, L. E., McMullen, M., Ransom, J. K., Grybauskas, A., Osborne, L., Wegulo, S. N., Hershman, D. E., Wise, K., Bockus, W. W., Groth, D., Dill-Macky, R., Milus, E., Esker, P. D., Waxman, K. D., Adee, E. A., Ebelhar, S. E., Young, B. G., and Paul, P. A. 2012. Efficacy and stability of integrating fungicide and cultivar resistance to manage Fusarium head blight and deoxynivalenol in wheat. Plant Dis. 96:957-967.

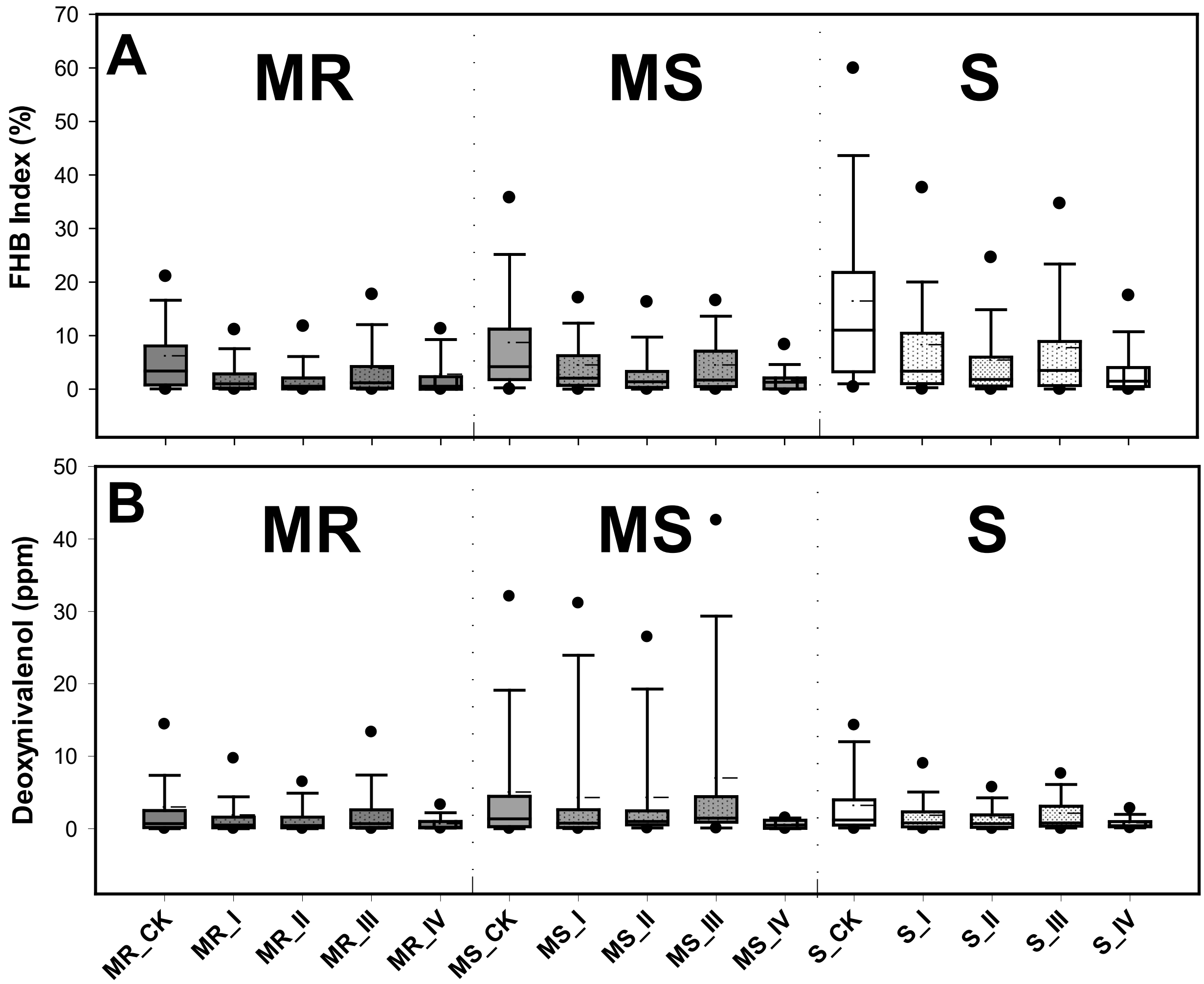

Fig. 1. Boxplots showing the distribution of **A**, mean Fusarium head blight index and **B**, deoxynivalenol grain contamination for different fungicide program x cultivar resistance management combinations. **S**, **MS**, and **MR** represent susceptible, moderately susceptible, and moderately resistant, respectively, whereas **CK** = nontreated, **I** = treated with Prosaro (6.5 fl. oz.) at anthesis, **II** = treated with Miravis Ace (13.7 fl. oz.) at anthesis and **III** = treated with Miravis Ace (13.7 fl. oz.) between Feekes 10.3 (early head emergence) and 10.5 (complete head emergence), and **IV** = treated with Miravis Ace (13.7 fl. oz.) at anthesis followed by tebuconazole (4 fl. oz.) at 4-5 days after anthesis. For FHB index, each bar in A represent the mean across 57 trials, whereas for DON, each bar in B represent the mean across 37 trials. However, it should be noted that treatment IV was evaluated only in 2020, whereby 19, 5, and 19 trials were planted with MR, MS, and S cultivars, respectively.

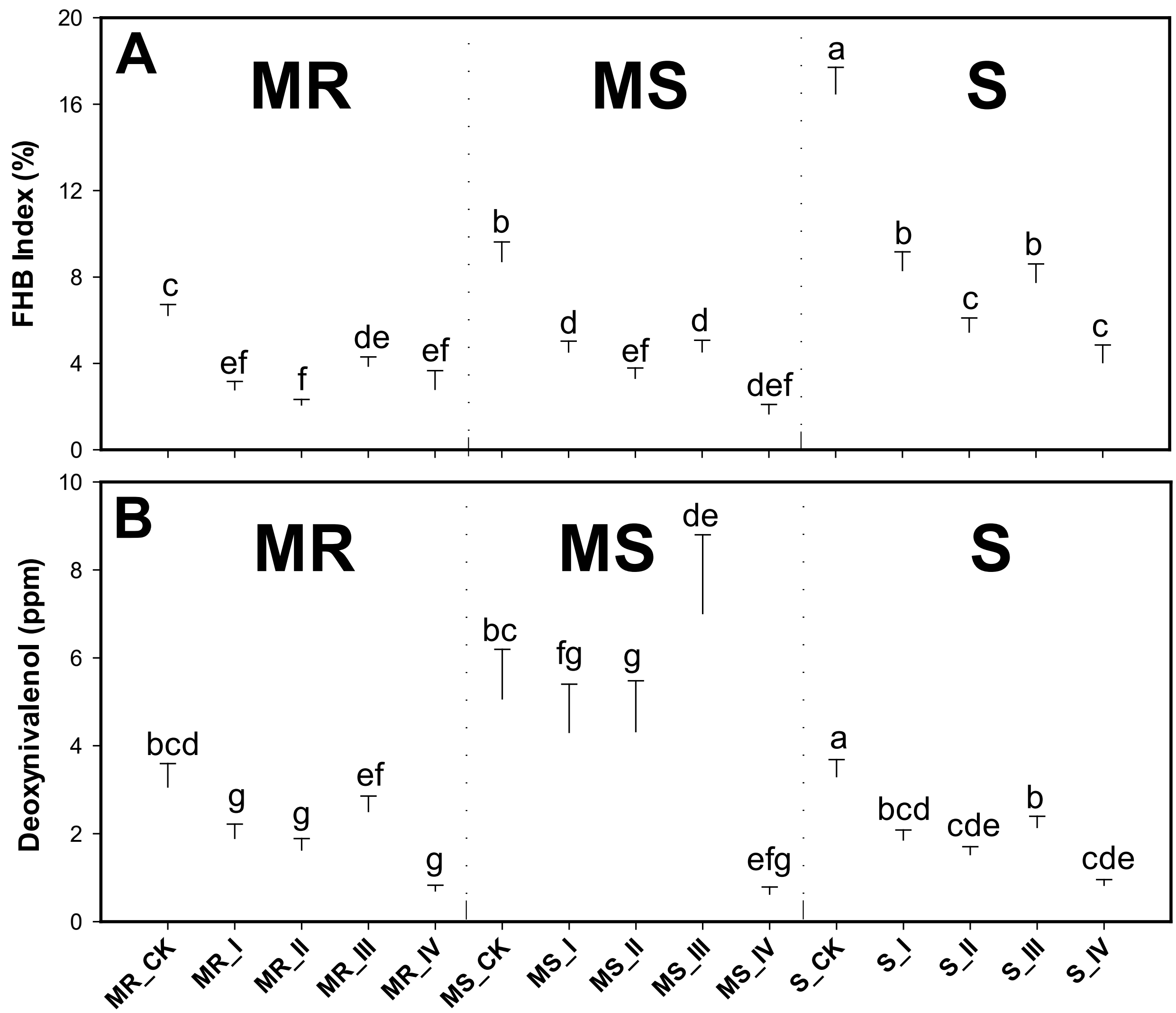

Fig. 2. Arithmetic mean **A**, Fusarium head blight index and **B**, deoxynivalenol grain contamination for different fungicide program x cultivar resistance management combinations. **S**, **MS**, and **MR** represent susceptible, moderately susceptible, and moderately resistant, respectively, whereas **CK** = nontreated, **I** = treated with Prosaro (6.5 fl. oz.) at Anthesis, **II** = treated with Miravis Ace (13.7 fl. oz.) at anthesis, **III** = treated with Miravis Ace (13.7 fl. oz.) between Feekes 10.3 (early head emergence) and 10.5 (complete head emergence), and **IV** = treated with Miravis Ace (13.7 fl. oz.) at anthesis followed by tebuconazole (4 fl. oz.) at 4-5 days after anthesis. For FHB index, each bar in A represent the mean across 57 trials, whereas for DON, each bar in B represent the mean across 37 trials. Errors bars are standard errors of the mean. However, it should be noted that treatment IV was evaluated only in 2020, whereby 19, 5, and 19 trials were planted with MR, MS, and S cultivars, respectively.