Fusarium Head Blight Management Coordinated Project: Integrated Management Trials 2018-2021

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Introduction: Efforts to evaluate integrated management strategies for Fusarium head blight (FHB) and deoxynivalenol (DON) management in wheat and barley continued in 2018, 2019, 2020, and 2021. The focus of the integrated management coordinated project (IM_CP) over the four years 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 and 2021 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 four 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, 2020 and 2021. The standard protocol consisted of the application of fungicide treatments in Table 1 (sub-plot) 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]). 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. Separate linear mixed models (multi-location analysis) were fitted to arcsine square root-transformed IND and log-transformed DON data pooled across environments (trial x state x year combinations), with management combination (15 levels) as fixed effect and environment, block nested within environment, cultivar nested within block and environment as random effects. Contrasts were used to compare pairs of fungicide programs within each resistance class.

Table 1. The following core treatments were randomly assigned to experimental units. All fungicide treatment mixtures included a nonionic surfactant at a rate of 0.125% (vol/vol)

Treatment	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 and 2001, DAA = days after anthesis

Results and Discussion: Mean Fusarium head blight index (IND) data from 84 environments and deoxynivalenol (DON) grain contamination data from 70 environments are shown in Figures 1A and B, 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 84 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 for S (interquartile range [IQR] 3 to 17%) and MS (IQR 2 to 9%) cultivars than for MR (IQR 1 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 (13.3%), whereas the application of Miravis Ace at anthesis followed by tebuconazole at 4-6 DAA to MR (MR_IV) or MS cultivars (MS_IV) and anthesis-only application of Miravis Ace to moderately resistant cultivars (MR_II) resulted in the lowest means (1.8, 1.0, and 1.8%, respectively) (**Fig. 2A**). However, it should be noted that only 13 trials included MS_IV and the mean IND levels in these trials were low (0 to 9%). In comparison, 81 and 38 trials included MR_II and MR_IV, respectively. Mean IND levels ranged from 0 to 31% for MR_II and from 0 to 67% for MR_IV. 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, and pairwise differences between fungicide programs were statistically significant ($P < 0.05$), except for comparisons between MR_I and MR_III, MR_I and MR_IV, MR_II and MR_IV, MS_I and MS_III, MS_II and MS_IV, S_I and S_III, and S_II and S_IV (**Fig. 2A**).

Deoxynivalenol: Mean DON contamination of grain ranged from 0 to 70 ppm across the 70 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 (6 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 (treatment IV) had the lowest overall mean DON contamination (0.7 to 1.1 ppm) (**Fig. 1B** and **2B**). However, it should be noted that this treatment was only evaluated in 2020 and 2021, where a total of 38, 13, and 37 trials included 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; Miravis Ace at anthesis and Prosaro at anthesis had significantly lower mean log-transformed DON than the Feekes 10.3-5 application of Miravis Ace; and pairwise differences between fungicide programs were statistically significant, except for comparisons between I and II, I and IV, II and IV for the MR cultivar, between I and II, I and IV, II and IV, III and IV for the MS cultivar, and between I and II, I and IV, and II and IV for the S cultivar (**Fig. 2B**).

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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123, 59-0206-0-118; 59-0206-6-014, 59-0206-0-191; 59-0206-9-009, 59-0206-0-185; and 59-0206-8-187, 59-0206-0-131. This is a cooperative project with the U.S. Wheat & Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

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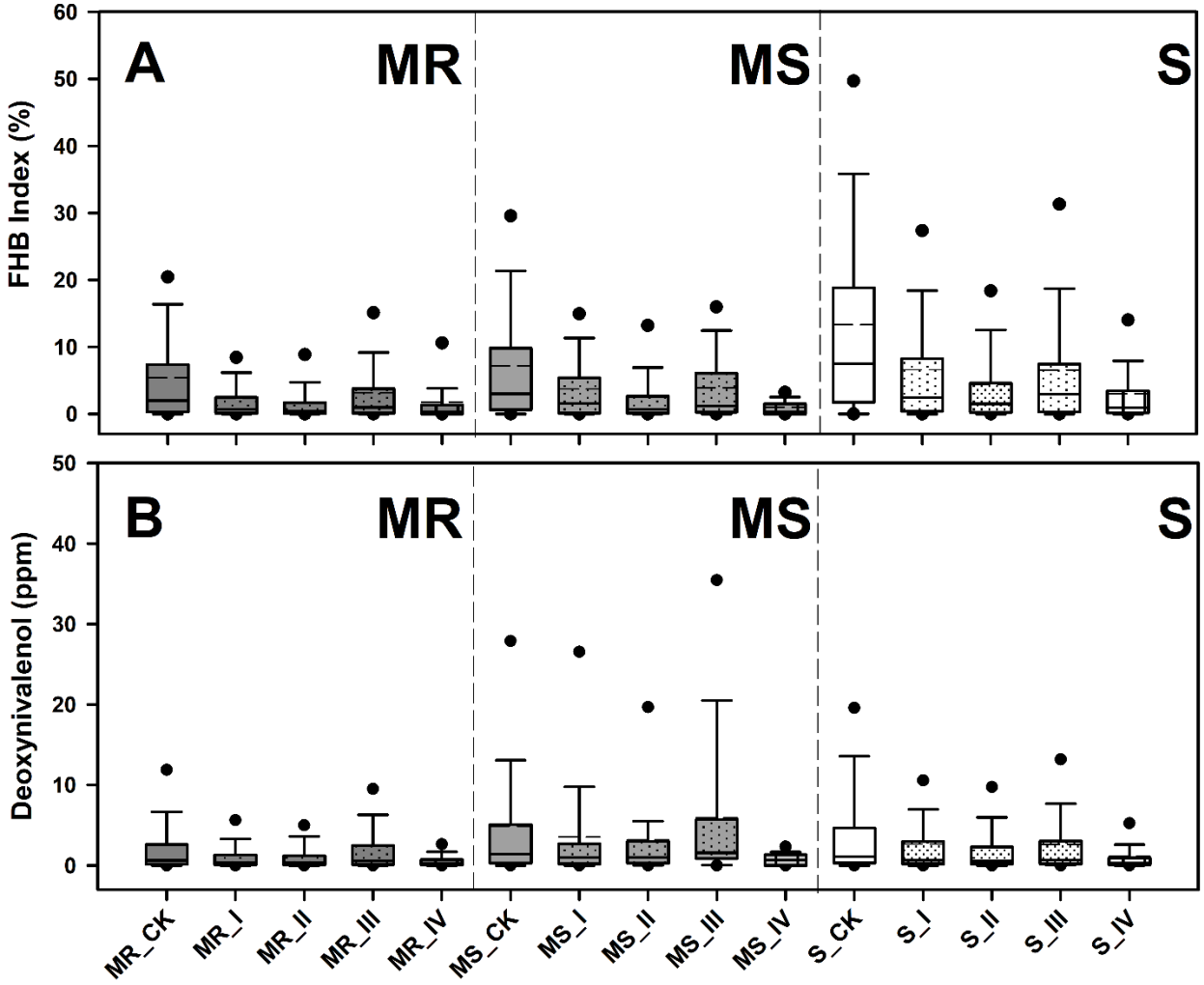

Fig. 1. Boxplots showing the distribution of **A**, mean Fusarium head blight index and **B**, deoxynivalenol grain contamination for different fungicide program x cultivar resistance management combinations. **S**, **MS**, and **MR** represent susceptible, moderately susceptible, and moderately resistant, 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 84 trials, whereas for DON, each bar in B represent the mean across 70 trials. However, it should be noted that treatment IV was only evaluated in 2020 and 2021, where 38, 13, and 37 trials included MR, MS, and S cultivars, respectively.

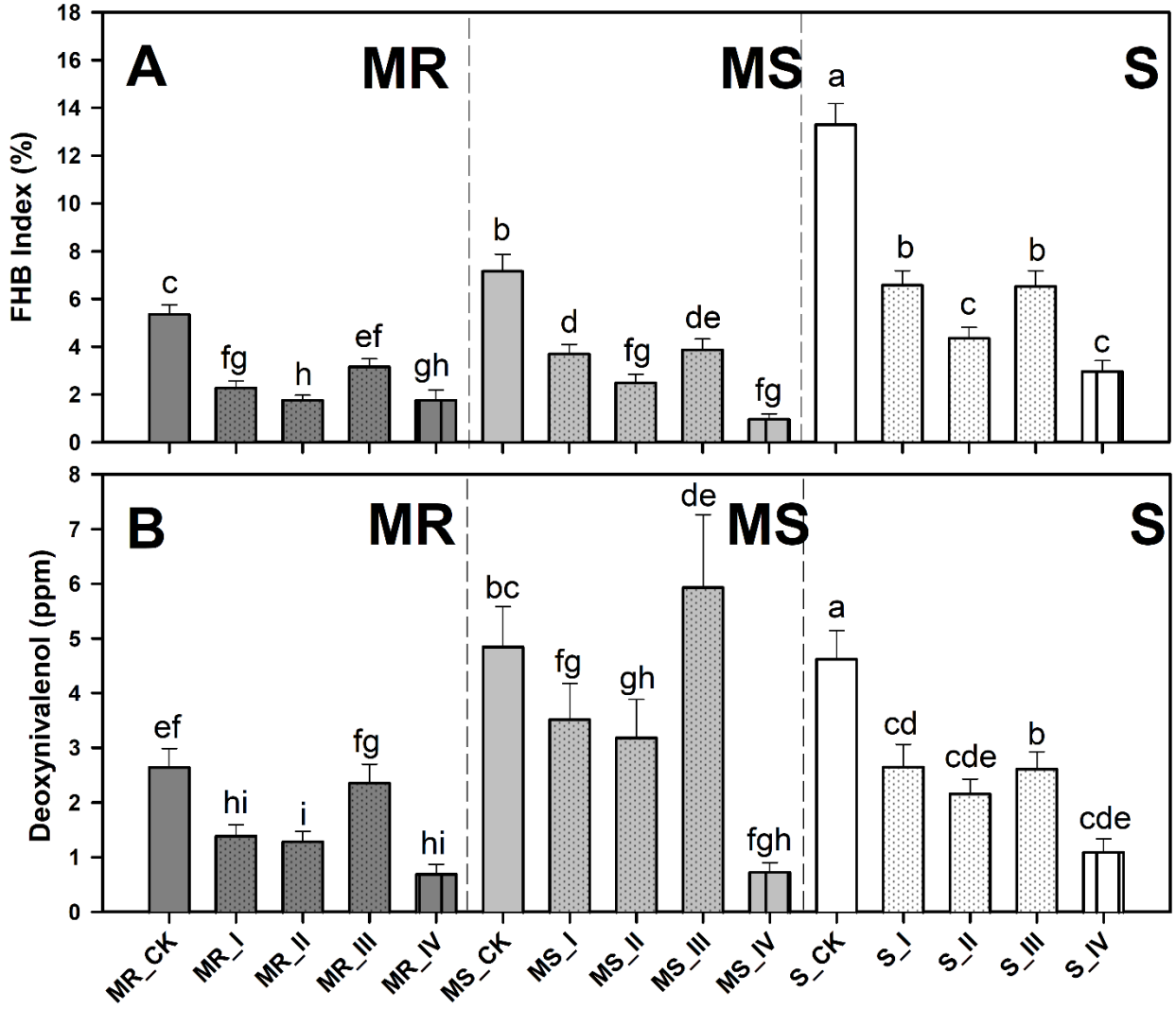

Fig. 2. Arithmetic mean **A**, Fusarium head blight index (IND) and **B**, deoxynivalenol (DON) grain contamination for different fungicide program x cultivar resistance management combinations. **S**, **MS**, and **MR** represent susceptible, moderately susceptible, and moderately resistant, respectively, 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 84 trials, whereas for DON, each bar in B represent the mean across 70 trials. Errors bars are standard errors of the mean. However, it should be noted that treatment IV was only evaluated in 2020 and 2021, where 38, 13, and 37 trials included MR, MS, and S cultivars, respectively. Models were fitted and means were compared on the arcsine square root-transformed scale for IND and log-transformed sale for DON, with management combinations as a fixed effect. Graphs are shown on the raw data scale for convenience.