Project FY22-IM-022: Fungicide Combinations and Genetic Resistance for FHB and DON Management

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1. What are the major goals and objectives of the research project?

In this funding cycle, the **goal** of this proposal is the continuance of integrated management (IM) and uniform fungicide (UFT) trials that would allow us to evaluate new combinations of AIs either as pre- or tank-mixtures or as sequentially applied treatments. For the wheat IM trial, we conducted inoculated experiments consisting of four cultivars with different levels of resistance to FHB subjected to at least five fungicide treatments, all applied at Feekes 10.5.1, plus two untreated checks. The **objectives and expected outcomes** of this FHB Management Coordinated Project (MGMT_CP) are to:

1) Evaluate the integrated effects of fungicide treatment and genetic resistance on FHB and DON in wheat and barley, with emphasis on new combination fungicides, Prosaro Pro and Sphaerex.
2) Compare the efficacy of Prosaro Pro and Sphaerex to that of Prosaro, Caramba, and Miravis Ace.
3) Generate data to further quantify the economic benefit of FHB and DON management programs.
4) Generate data to validate and advance the development of FHB risk prediction models.

Two new fungicides, Prosaro Pro, a mixture of two DMIs (prothioconazole and tebuconazole) and an SDHI (Fluopyram, Pyridinyl-ethyl-benzamide), and Sphaerex, a mixture of two DMIs (metconazole and prothioxonazole) are being promoted for the control of FHB and other diseases of small grain crops. Both Sphaerex and Prosaro Pro were recently registered for use in wheat. As is commonly the case, these new products will likely be marketed at higher prices than Prosaro (tebuconazole + prothioconazole) and Caramba (metconazole), the current industry standards for FHB management, and are being developed as replacements for the latter two fungicides. Therefore, the obvious questions being asked by stakeholders and researchers are whether the efficacy of these new fungicides against FHB and its associated mycotoxins, particularly DON, will be high enough to justify the added cost, and whether they are just as or more effective than current industry standards. **Approach:** Designated fields for FHB screening and fungicide trials will be planted with wheat and barley trials at the Aberdeen R&E Center in a randomized complete block design to address the goals of both IM and UFT experiments. Appropriate fungicide treatments will be applied after inoculation with macroconidia of fungal isolates. Plots will be rated, harvested and assessed for effectiveness of treatments. **Mutual Interest:** Stakeholders will benefit by having efficacy data of the standard available fungicides compared to new fungicides, combinations and timing of applications.

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

We evaluated the integrated effects of fungicide treatment and genetic resistance on FHB and DON in wheat and barley, with emphasis on new combination fungicides, Prosaro Pro and Sphaerex for the IM trials. For the UFT, 13 treatments, including the inoculated check, were evaluated for FHB development, yield, test weight, grain moisture, DON and FDK.

Integrated Management

What were the major activities?

Following standard protocol developed for the MGMT CP, we planted the wheat and barley trials and applied fungicides according to six different treatments to evaluate the efficacy of integrated effects of fungicide treatment and genetic resistance on FHB and DON in wheat and barley, with emphasis on new combination fungicides, Prosaro Pro and Sphaerex. Fungicides were applied in hard red and white spring wheat of various resistance classes (susceptible, moderately susceptible and moderately resistant). Fungicides were applied at early anthesis with one treatment having an additional application 4-6 days after the first. There were two checks, one untreated and not inoculated and the other untreated and inoculated. Rating of disease occurred 21-24 days after inoculation, plots were harvested at maturity, and FDK and DON was determined from harvested grain samples.

Table 1. The following fungicide treatments were randomly assigned to experimental units
Wheat:

Treatment[a]	Product	Rate	Timing
1	Untreated check	…	…
2	Untreated, non-inoculated	…	
3	Prosaro	6.5 fl oz/A	Feekes 10.5.1 (early anthesis)
4	Miravis Ace	13.7 fl oz/A	Feekes 10.5.1 (early anthesis)
5	Prosaro Pro	10.3 fl oz/A	Feekes 10.5.1 (early anthesis)
6	Sphaerex	7.3 fl oz/A	Feekes 10.5.1 (early anthesis)

[a]**All treatments will be applied with NIS @ 0.125 v/v**

What were the significant results?

There were significant differences between varieties for disease incidence, severity and Index (Table 2). UI Gold and IDO1904S were susceptible and had lower test weight and higher DON. Holmes performed similar to the resistant check, Rollag. All fungicide treatments significantly reduced FHB incidence, severity and Index (Table 3) compared to the two checks (untreated inoculated and untreated non-inoculated check) and when compared across varieties (Table 4). Test weight was improved with all fungicides except Sphaerex, and DON was reduced with all fungicide treatments. There were no significant effects on yield for fungicide application. There were significant variety by fungicide differences for DON (Table 4).

Table 2. Fungicide effects on disease, yield, test weight, FDK and DON results across four spring wheat varieties.

Variety	DISEASE						Yield	Test Wt	DON	
	Incidence	(%)	Severity	(%)	Index	(%)	(bu/A)	(lb/bu)	(ppm)	
A IDO1904S	52.0	a	32.0	a	18.9	a	98 a	58.4 ab	5.6	A
B Holmes	7.6	b	17.4	c	2.4	c	91 b	60.9 a	1.2	C
C UI Gold	42.8	a	27.4	b	12.7	b	98 a	55.3 b	4.1	B
D Rollag	16.0	b	14.2	c	2.2	c	72 c	61.0 a	0.4	C
P-value (Alpha = 0.05)	<0.001		<0.0001		<0.01		<0.0001	<0.05	<0.0001*	

Table 3. Variety effects on disease, yield, test weight, FDK and DON results across fungicide treatments.

Fungicide Treatment		DISEASE			Yield	Test Wt	DON
		Incidence (%)	Severity (%)	Index (%)	bu/A	(lb/bu)	(ppm)
1	Untreated check	42.9 a	24.1 a	10.4 a	83.1 a	56.5 cd	6.5 A
2	Untr, non-inoc	47.8 a	23.6 ab	12.8 a	87.2 a	55.6 d	5.5 A
3	Prosaro	26.7 b	18.1 bc	6.0 b	86.8 a	57.6 abc	1.5 B
4	Miravis Ace	21.5 b	13.8 c	3.9 b	80.4 a	59.0 abc	1.1 B
5	Prosaro Pro	18.9 b	18.4 abc	4.6 b	82.8 a	58.3 ab	1.3 B
6	Sphaerex	27.1 b	19.1 abc	6.6 b	83.9 a	56.9 bcd	1.1 B
P-value (Alpha = 0.05)		<.0001	0.0055	<.0001	0.608 ns	0.0002	<.0001

Table 4. Disease, yield, test weight, FDK and DON results for four spring wheat varieties with two untreated controls (one inoculated, one not inoculated) and four different fungicide treatments.

FACTOR			DISEASE			Yield	Test Wt	DON
Variety		Fungicide	Incidence (%)	Severity (%)	Index (%)	bu/A	(lb/bu)	(ppm)
IDO1904S	1	Untreated check	39.25 bcd	22.5 a-g	9.5 bcd	84.8 a-d	55.0 f-i	14.0 A
IDO1904S	2	Untreated, non-inoculated	57.25 ab	26.5 a-e	15.3 ba	74 d	52.5 i	11.2 B
IDO1904S	3	Prosaro	26 cde	18.8 d-h	5.3 d-g	92.8 abc	57.0 c-g	3.1 D
IDO1904S	4	Miravis Ace	20.25 de	16.0 e-i	4.0 d-g	74 d	58.5 a-e	1.7 E D
IDO1904S	5	Prosaro Pro	17.25 de	21.5 b-h	3.8 d-g	86.8 a-d	57.0 c-g	2.0 E D
IDO1904S	6	Sphaerex	39 cd	20.0 d-h	8.5 c-f	88.8 a-d	54.5 ghi	1.8 E D
Holmes	1	Untreated check	47.5 abc	30.3 a-d	9.0 b-e	83.3 a-d	58.0 b-f	3.0 D
Holmes	2	Untreated, non-inoculated	55.5 ab	24.3 a-f	13.3 bc	99.5 a	56.5 d-h	2.6 E D
Holmes	3	Prosaro	17.75 de	13.5 f-i	3.3 d-g	84.3 a-d	60.0 abc	0.4 E D
Holmes	4	Miravis Ace	13 e	7.5 i	1.3 g	79.8 bcd	61.0 a	0.5 E D
Holmes	5	Prosaro Pro	13.5 e	11.5 ghi	2.0 fg	87.3 a-d	59.5 a-d	0.5 E D
Holmes	6	Sphaerex	16.75 de	13.8 f-i	2.5 fge	76.8 cd	59.0 a-e	0.3 E D
UI Gold	1	Untreated check	65.75 a	32.3 ab	20.8 a	86 a-d	53.0 i	8.1 C
UI Gold	2	Untreated, non-inoculated	61.25 ab	33.8 a	20.8 a	80.3 bdc	53.5 ih	7.4 C
UI Gold	3	Prosaro	52.75 ab	28.3 a-d	14.0 bc	85.8 a-d	53.5 ih	2.4 E D
UI Gold	4	Miravis Ace	45.75 abc	20.8 c-h	9.5 bcd	81.3 bcd	56.0 e-h	2.1 E D
UI Gold	5	Prosaro Pro	39.5 bdc	33.8 a	12.8 bc	80 bcd	56.5 d-h	2.6 E D
UI Gold	6	Sphaerex	47.25 abc	32.0 abc	15.0 abc	82.3 a-d	54.0 ghi	1.9 E D
Rollag	1	Untreated check	19.25 de	11.3 hig	2.50 efg	78.3 bcd	60.0 abc	0.8 E D
Rollag	2	Untreated, non-inoculated	17.25 de	9.8 hi	1.75 fg	95 ab	60.0 abc	0.7 E D
Rollag	3	Prosaro	10.25 e	12.0 hig	1.50 g	84.3 a-d	60.0 abc	0.3 E
Rollag	4	Miravis Ace	7 e	11.0 hig	0.75 g	86.8 a-d	60.5 abc	0.2 E
Rollag	5	Prosaro Pro	5.25 e	7.0 i	0.00 g	77 cd	60.0 abc	0.2 E
Rollag	6	Sphaerex	5.25 e	10.8 hig	0.25 g	87.8 a-d	60.0 abc	0.2 E
P-value (Alpha = 0.05)			0.6227 ns	0.303 ns	0.5 ns	0.19 ns	0.422 ns	<.0001

Table 5. Correlations of disease and agronomic traits.

Pearson Correlation Coefficients, N = 96 Prob > |r| under H0: Rho=0						
	INC	**SEV**	**IND**	**YLD**	**TW**	**DON**
INC	1	0.51936 <.0001	0.94295 <.0001	-0.04119 0.6903	-0.77659 <.0001	0.53162 <.0001
SEV	0.51936 <.0001	1	0.64474 <.0001	0.00815 0.9372	-0.53121 <.0001	0.40213 <.0001
IND	0.94295 <.0001	0.64474 <.0001	1	-0.01967 0.8491	-0.81533 <.0001	0.56581 <.0001
YLD	-0.04119 0.6903	0.00815 0.9372	-0.01967 0.8491	1	0.08998 0.3833	-0.12008 0.2439
TW	-0.77659 <.0001	-0.53121 <.0001	-0.81533 <.0001	0.08998 0.3833	1	-0.64308 <.0001
DON	0.53162 <.0001	0.40213 <.0001	0.56581 <.0001	-0.12008 0.2439	-0.64308 <.0001	1

When results were split into variety and fungicide effects, there were no statistically significant differences between treatments except for DON. All fungicide treatments resulted in lower disease and DON compared to the two checks except Sphearex. DON content was lowest (0.84 ppm) on plots treated with Prosaro Pro applied on the moderately resistant variety Rollag. All untreated checks produced DON level higher than 1ppm on spring wheat (Tables 1 - 3).

None of the fungicides had significant effect on yield or FDK, but improved test weight compared to the untreated check for all treatments except Sphearex. Disease incidence and disease index was reduced for all fungicide treatments. DON averaged approximately 50% less for all treatments.

List key outcomes or other achievements.

New fungicides have been added to the list of effective fungicides to reduce the impact of FHB and accumulation of DON. Sphaerex was as effective as the other fungicides in reducing disease incidence, severity and index. The most effective control of FHB occurred with the combination of resistant varieties and application of fungicides applied at anthesis.

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

New staff have joined the Cereals breeding program and have been trained in assessment of FHB disease.

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

The results of all the trials are published in our Annual Small Grains Report, disseminated to collaborating breeders, presented at various grower seminar and field events, and reported annually at the Scab Forum and in the biennual Scabinar.

5. What do you plan to do during the next reporting period to accomplish the goals and objectives? There are no proposed changes in the 2025 experiments to continue the trials.

Uniform Fungicide Trials:

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

2. What were the major activities?

The UFT trial at the University of Idaho research farm in Aberdeen, Bingham County ID, used soft white spring wheat 'WB6211CLP' (highly FHB-susceptible) to evaluate fungicide efficacy against Fusarium Head Blight (FHB). In order to get the optimum disease development, experimental plots were set up in a randomized complete block design with four replications, planted on May 1, 2024, and irrigated as needed to replace evapotranspiration. An additional sprinkler system was installed across the experimental plot to create conducive environment for disease infection and development. Different fungicide combinations were used as treatments (See Table 1, Treatments). A *Fusarium graminearum* spore suspension (100,000 spores/ml) was used for inoculation on July 8, the same day as the anthesis fungicide treatments were carried out. The second fungicide application was applied 15 July for treatments 8 and 9. The FHB index was calculated as (incidence × severity) / 100. FHB ratings, including incidence and severity, were recorded 23 days after anthesis. There was no evidence of phytotoxicity after fungicide treatments. Plots were harvested on 6 Sept with a small plot combine. Yield and test weight was determined with the HarvestMaster system on the combine. Analysis used PROC GLIMMIX in SAS 9.4 with LSD ($\alpha = 0.05$) for mean comparisons.

Trt No	Treatment Name	Form Conc	Form Unit	Form Type	Rate	Rate Unit	Other Rate	Other Rate Unit	Appl Code	Appl Description	Amt Product to Measure
1	Untreated Check										
2	Prosaro			EC	475	ml/ha	6.5	fl oz/a	**C**	Anthesis	3.2 mL/mx
	Induce 90 SL	100	%	SL	0.125	% v/v			**C**	Anthesis	1.25 mL/mx
3	Miravis ERA			SC	745	ml/ha	10.2	fl oz/a	**C**	Anthesis	5.3 mL/mx
	NIS	100	%	SL	0.125	% v/v			**C**	Anthesis	1.25 mL/mx
4	Miravis Ace			SC	1000	ml/ha	13.7	fl oz/a	**C**	Anthesis	5.345 mL/mx
	NIS	100	%	SL	0.125	% v/v			**C**	Anthesis	1.25 mL/mx
5	Prosaro Pro			SC	752	ml/ha	10.3	fl oz/a	**C**	Anthesis	4 mL/mix
	NIS	100	%	SL	0.125	% v/v			**C**	Anthesis	1.25 mL/mx
6	Sphaerex			SC	533	ml/ha	7.3	fl oz/a	**C**	Anthesis	2.9 mL/mx
	NIS	100	%	SL	0.125	% v/v			**C**	Anthesis	1.25 mL/mx
7	Miravis Ace			SC	1000	ml/ha	13.7	fl oz/a	**C**	Anthesis	5.345 mL/mx
	NIS	100	%	SL	0.125	% v/v			**C**	Anthesis	1.25 mL/mx
	Prosaro Pro			SC	752	ml/ha	10.3	fl oz/a	**C**	Anthesis	4 mL/mx
	NIS	100	%	SL	0.125	% v/v			**C**	Anthesis	1.25 mL/mx
8	Miravis Ace			SC	1000	ml/ha	13.7	fl oz/a	**C**	Anthesis	5.345 mL/mx
	NIS	100	%	SL	0.125	% v/v			**C**	Anthesis	1.25 mL/mx

	Sphaerex			SC	533	ml/ha	7.3	fl oz/a	D	4-6 days after anthesis	2.9 mL/mx
	NIS	100	%	SL	0.125	% v/v			D	4-6 days after anthesis	1.25 mL/mx
9	Miravis Ace			SC	1000	ml/ha	13.7	fl oz/a	C	Anthesis	5.345 mL/mx
	NIS	100	%	SL	0.125	% v/v			C	Anthesis	1.25 mL/mx
	Tebuconazole			SC	290	ml/ha	4.0	fl oz/a	D	4-6 days after anthesis	1.561 mL/a
	NIS	100	%	SL	0.125	% v/v			D	4-6 days after anthesis	1.25 mL/mx
10	Prosaro Pro			SC	993	ml/ha	13.6	fl oz/a	C	Anthesis	5.3 mL/mx
	NIS	100	%	SL	0.125	% v/v			C	Anthesis	1.25 mL/mx
11	A23751 [C]				251	g A/ha	8.59	FL OZ/A	C	Anthesis	0.4 g or 1.1 mL/mx
	NIS				0.125	% V/V	0.125	% V/V	C	Anthesis	1.25 mL/mx
12	A23751 [C]				300	g A/ha	10.3	FL OZ/A	C	Anthesis	0.5 g or 1.3 mL/mx
	NIS				0.125	% V/V	0.125	% V/V	C	Anthesis	1.25 mL/mx
13	A23751 [C]				251	g A/ha	8.59	FL OZ/A	C	Anthesis	0.4 g or 1.1 mL/mx
	TEBUSTAR 3.6 EC				75	g A/ha	2.38	FL OZ/A	C	Anthesis	0.1 g or 0.3 mL/mx
	NIS				0.125	% V/V	0.125	% V/V	C	Anthesis	1.25 mL/mx

What were the significant results?

Untreated check plots achieved an FHB score of 47%. Fungicide treatments effectively decreased FHB incidence, severity, and index as compared to untreated inoculated plots, with significant reductions ($P<0.01$) observed across disease and yield metrics. The untreated check plot had a lower test weight (55 lbs/bu) and the lowest grain yield (77 bu/A). Several other treatments had yields that were statistically comparable, but Treatment 8, which included Miravis Ace and Sphaerex, produced the greatest yield at 100 bu/A. Mean FHB incidence, severity, and index ranged from 15 to 70%, 17 to 68%, and 3 to 47%, respectively, with untreated plots showing the highest values. Test weight ($P<0.0001$), yield ($P<0.01$), FHB incidence ($P<0.01$), FHB severity ($P<0.0001$), and DON ppm ($P<0.0001$) all had significant effects from fungicide application. All fungicide applications successfully decreased FHB infection and DON accumulation from the untreated inoculated control (Table).

trt no	Treatment	Incidence 21 DAA	Severity	Index	Yield (bu/A)	TW (Ib/bu)	Grnmstr (%)	DON (ppm)
1	Untreated Check (Inoculated)	70 a	68 a	47.3 a	77 d	55 f	11.0 a	11.6 a
2	Prosaro	21 cd	23 bc	5.0 bc	95 abc	58 cde	10.6 bcd	1.6 bcd
3	Miravis ERA	35 bcd	25 bc	9.1 bc	98 ab	59 bcd	10.5 cd	1.9 bcd
4	Miravis Ace	30 bcd	22 bc	6.6 bc	88 bc	59 abc	10.8 abc	1.6 bcd
5	Prosaro Pro	32 bcd	25 bc	10.3 bc	90 abc	58 e	10.8 ab	3.3 b
6	Sphaerex	34 bcd	24 bc	8.7 bc	86 dc	58 de	10.7 a-d	2.0 bcd
7	Miravis Ace + Prosaro Pro	15 d	17 c	2.6 c	97 abc	60 a	10.5 d	0.8 d
8	Miravis Ace + Sphaerex	30 bcd	20 bc	5.9 bc	100 a	59 ab	10.5 cd	1.0 d

9	Miravis Ace + Tebuconazole	29	bcd	23	bc	6.6	bc	95	abc	59	abc	10.6	bcd	1.1	cd
10	Prosaro Pro	40	bc	33	b	14.8	b	90	abc	58	cde	10.7	bcd	2.2	bcd
11	A23751(8.59 fl. oz./A) [C]	32	bcd	33	b	11.0	bc	94	abc	59	abc	10.6	bcd	1.5	bcd
12	A23751 (10.3 fl. oz./A) [C]	27	bcd	24	bc	6.5	bc	92	abc	58	cde	10.6	bcd	1.9	bcd
13	A23751 [C] + TEBUSTAR 3.6 EC	46	b	32	bc	14.1	bc	95	abc	58	cde	10.6	bcd	3.2	bc
	Mean	**34**		**28**		**11.4**		**92**		**58.4**		**11**		**2.6**	
	LSD P=.05	**6**		**4**		**3**		**3**		**0.2**		**0.1**		**1.0**	
	CV	**48.3**		**35.1**		**73.9**		**8.7**		**0.8**		**1.8**			
	Treatment Prob (F)	**<0.01**		**<0.0001**		**<0.0001**		**<0.01**		**<0.0001**		**0.123^{ns}**		**<0.0001**	

List key outcomes or other achievements.

Fungicide treatments improved yield and grain quality while effectively controlling FHB, thus supporting their role in FHB management strategies for (soft white) spring wheat.

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

New staff have joined the Cereals breeding program and have been trained in assessment of FHB disease.

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

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5. What do you plan to do during the next reporting period to accomplish the goals and objectives?

There are no proposed changes in the 2025 experiments to continue the trials.