Project FY22-BA-003: Determining FHB Susceptibility in Barley Cultivars in the Western US

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

The major goal of the project is to determine the level of resistance and susceptibility in currently produced and recently released varieties and advanced breeding lines of barley. FHB damage in spring grain continues to increase in southern and eastern Idaho. In 2015, fields of barley showed signs of disease, and many spring wheat fields tested at >5 ppm DON, even after appropriate treatments with fungicides. Large production areas north of Idaho Falls resulted in rejection of barley for malting due to high levels of DON. In 2018, 40,000 bu of barley was rejected from one producer alone near Rupert, Idaho. The level of FHB affected grain in the region continues to increase with temperatures. The majority of the barley varieties that are available to growers in the area are susceptible to FHB and growers need information to improve management. Breeders need information on advanced lines and breeding material to release selections with reduced vulnerability to FHB damage and DON accumulation. Management practices need to be tested under the unique conditions in the irrigated production regions of the Intermountain West to develop appropriate management practices to reduce FHB and DON.

> Project goals and objecv es: Our specific objecv es for this proposal were to: 1) determine the degree of suscepbi lity that exists in currently grown variee s and advanced lines to local *Fusarium graminearum* isolates; and 2) provide DON data to local breeders and growers to increase the ability to select the best varie0es for breeding and produc0on.

In adding to the body of knowledge associated with determining the genetics of resistance, we also initiated a barley association mapping study as part of a Master of Science research project. A four-location GWAS panel was planted in cooperation with Dr. Belayneh Yimer at the USDA-ARS in Aberdeen, ID. The locations included Fargo, ND (with Dr. Thomas Baldwin), Sidney, MT (with Dr. Frankie Crutcher), Kimberly, ID and Aberdeen, ID.

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

What were the major activities? Screening varieties from the Extension Variety Trials and a GWAS study of >300 barley cultivars at four locations.

An assessment of released barley cultivars and advanced lines from entries in the University of Idaho Extension Variety trials was conducted in on-station FHB nurseries at the Aberdeen Research and Extension Center. A second location at the USDA-ARS research facility at Kimberly, Idaho was added to increase the number of environments and to include an environment more conducive to infection (Kimberly, ID). Winter barley from the UI Extension Variety Trials and the NABSEN entries were planted as well at Kimberly. Resistant and susceptible checks for the spring barley nursery were: Chevron was included as the six-row resistant check; PI383933 and Stander as susceptible checks. ICB111809 was the two-rowed susceptible check, and Clho4196 was the 2-row resistant check. Experimental units consisted of two row plots with two replications using a randomized complete block design. Plots were 5-foot rows planted with a Hege 1000 headrow planter. Separate irrigation systems were designed and installed to provide an environment conducive for FHB infection while simultaneously meeting the irrigation needs of the crop.

Autoclaved corn was inoculated with *F. graminearum* and allowed to grow for three weeks before drying. Corn spawn was spread in the field approximately three weeks prior to anthesis or head emergence of the earliest lines at 60 grams per plot. Barley plots were inoculated with a spore suspension of macroconidia of *F. graminearum* at head emergence. Barley symptom development of FHB has been more difficult to induce and disease development was greater after inoculation with both corn spawn and a spore suspension of 100,000 conidia per L. Plots were inoculated twice (100,000 conidia per L) with conidial suspension starting at head emergence (Feekes GS 10.1, June 9) using a CO_2 backpack sprayer with three 8003 VS nozzles at a ground speed of 1 sec/ft at 40 psi. A second inoculation of each barley plot occurred one week after the first. An irrigation system with sprinkler nozzles every 20 feet was used both for irrigation and increasing humidity in the plant canopy. After inoculation, plots were irrigated every other day for two hours. A supplementary misting system with nozzles every 10 feet was also used for the barley screening nursery. The misters ran every 3 minutes every 2 hours between 9PM to 3AM and 9AM to 11AM.

The barley association mapping study evaluated 300 USDA-ARS Pacific Northwest adapted spring barley breeding lines for FHB reaction. Trials were planted at mist-irrigated nurseries in Aberdeen and Kimberly, in Fargo, ND and hill plots in Sidney, MT. We used local isolates of *F. graminearum* on infested corn spawn and macro-conidial suspension spray for artificial inoculation. Corn spawn was applied at rate of 30g/m^2 at tillering (2-3 weeks before heading). Macroconidial suspension was applied using a CO2 backpack sprayer, 8003 VS nozzle tips, calibrated to 40 psi, at a rate of 1 sec/ft near 50% heading and again 5-7 days later. At Sidney and Fargo locations, we relied on natural infection and a conducive climate for disease development. The experimental design was a randomized complete block with 2 replications per cultivar per location. Known resistant and susceptible lines were used as controls. Disease incidence and severity was assessed three weeks after macroconidial inoculation by in-field visual rating. DON accumulation was be measured at the UMN DON Testing Lab in collaboration with Dr. Yanhong Dong. A genome-wide association study was executed to identify QTL associated with low disease incidence, severity, and DON.

What were the significant results?

Low disease formed in the spring nurseries in 2023 compared to previous years. DON levels were obtained with the collaboration of Dr. Yanhong Dong, University of Minnesota. Disease development in 2023 as determined by the FHB Index in winter barley varieties ranged from “Resistant” of 0.1 (2WI14-7577) to Susceptible at 10.5 (Sunstar Pride). DON levels in harvested grain varied from a low of 0.2 ppm to 1.2 ppm. (In the 2022 experiments, Kimberly winter barley DON levels varied from 1.1 ppm to 27.4 ppm.)

FHB Index in spring barley in Kimberly ranged from “resistant” to susceptible. Released varieties were identified with high FHB Indices and DON levels (Diamondback feed barley and malt barleys LCS Diablo and LCS Genie). In 2022, the spring barley DON levels varied from 1.6 ppm to 100.4 ppm.

Table 1. Feed and food barley summary sorted by FHB Index – Kimberly. Chevron was included as the six-row resistant check; PI383933 was the six-row susceptible checks. ICB111809 was the two-row susceptible check, and Clho4196 was the 2-row resistant check.

Var#	Var	Class	Severity	INC %	INDEX		Yield (bu/A)		DON(ppm)	
20	clho4196 (2-R resist)	check	4 c	10g	0.4	c	6.8	j-r	.	
18	Chevron (6-R resist)	Malt	4 c	10g	0.4	c	4.9	rqp	.	
13	Altorado	Feed	4 c	10g	0.4	c	13.7	a-d	0.2	i
43	MerlinMax3.3	Feed	4 c	10g	0.4	c	3.7	r	1.1	a-d
50	PlanetMax3.16	Feed	4 c	10g	0.4	c	6.5	m-r	0.8	a-i
26	Golf	check	4 c	15fg	0.6	c	10.2	b-m	0.4	d-i
3	16ARS295-1	Feed	4 c	15fg	0.6	c	6.8	j-m	0.7	b-i
25	Goldenhart	Feed	4 c	15fg	0.6	c	8.0	i-q	0.2	i
34	LaureateMax3.8	Feed	4 c	15fg	0.6	c	6.4	n-r	0.6	b-i
42	MerlinMax3.19	Feed	4 c	15fg	0.6	c	8.6	g-p	1.2	ab
54	Transit (hulless)	Feed	4 c	15fg	0.6	c	8.8	f-p	0.3	hi
28	HO517-126	Feed	5 c	15fg	0.8	c	11.5	b-i	0.3	e-i
31	Idagold II	Feed	5 c	15fg	0.8	c	8.5	g-p	0.6	b-i
49	PlanetMax3.13	Feed	6 c	15fg	0.8	c	8.6	g-p	0.4	c-i
1	10ARS191-3	Feed	4 c	25d-g	1.0	c	14.3	ab	0.4	d-i
17	Champion	Feed	4 c	25d-g	1.0	c	10.1	c-m	0.3	ghi
41	MerlinMax3.18	Feed	7 c	15fg	1.0	c	5.3	orqp	0.8	a-i
44	MerlinMax3.6	Feed	5 c	20efg	1.0	c	6.4	m-r	1.5	a
47	Oreana	Feed	4 c	25d-g	1.0	c	7.6	i-q	0.2	i
51	PlanetMax3.3	Feed	4.65 c	25d-g	1.2	c	6.7	k-r	1.0	a-e
52	PlanetMax3.6	Feed	4 c	30c-f	1.2	c	8.0	g-p	1.0	a-e
40	MerlinMax3.11	Feed	5.5 c	25d-g	1.6	c	4.2	rq	1.0	a-g
19	Claymore	Feed	7.6 c	25d-g	1.8	c	13.8	abc	0.3	hi
33	Kardia	Feed	6.1 c	35cde	2.2	c	10.2	b-m	0.5	b-i
32	Julie (hulless)	Feed	6 c	40bcd	2.4	c	7.9	i-q	0.2	i
27	HO516-429	Feed	8.8 c	35cde	3.2	c	15.7	a	0.3	f-i
29	Carleton	Feed	14 c	30c-f	5.2	c	9.7	d-m	0.3	hi
48	PI383933 (6-R susc)	check	27.75 b	55b	15.4	b	5.2	rqp	0.9	a-h
22	Diamondback (SB6)	Feed	54.0 a	80a	40.8	a	9.4	e-m	.	
	P=0.05		<0.0001	<0.0001	<0.0001		<0.0001		0.051	

Table 2. Malt barley summary sorted by FHB Index – Kimberly. Chevron was included as the six-row resistant check; PI383933 was susceptible checks. ICB111809 was the two-row susceptible check, and Clho4196 was the 2-row resistant check.

Var#	Var	Class	Severity	INC %	INDEX		Yield (bu/A)		DON(ppm)	
20	clho4196 (2R resis)	check	4 c	10g	0.4	c	6.8	j-r	.	
8	AAC Prairie	Malt	4 c	10g	0.4	c	10.9	b-j	0.4	b-i
18	Chevron (6-R resis)	Malt	4 c	10g	0.4	c	4.9	rqp	.	
26	Golf	check	4 c	15fg	0.6	c	10.2	b-m	0.4	d-i
6	2IM17-2221	Malt	4 c	15fg	0.6	c	13.4	a-e	0.2	i
16	CDC Copeland	Malt	4 c	15fg	0.6	c	14.1	abc	0.2	i
5	17ARS072-5	Malt	5 c	15fg	0.8	c	10.8	b-j	0.3	f-i
24	GemCraft	Malt	5 c	15fg	0.8	c	10.3	b-r	0.3	e-i
2	16ARS067-13	Malt	4.6 c	20efg	1.0	c	11.6	b-i	0.5	b-i
11	ABI Voyager	Malt	6 c	15fg	1.0	c	10.6	b-k	0.5	b-i
39	Merit 57	Malt	4.6 c	20efg	1.0	c	10.5	b-n	0.2	i
7	2IM18-4142	Malt	4.6 c	25d-g	1.2	c	10.5	b-m	0.4	d-i
12	AC Metcalfe	Malt	7 c	15fg	1.2	c	11.6	a-h	.	
14	BC Leandra	Malt	6 c	20efg	1.2	c	9.6	d-m	0.4	d-i
21	Conrad	Malt	4.6 c	25d-g	1.2	c	10.8	b-k	0.5	b-i
38	LGBU16-1320A/LG8016-1320A	Malt	5 c	25d-g	1.2	c	11.6	a-h	0.9	a-i
4	17ARS069-1	Malt	5.3 c	25d-g	1.4	c	11.7	a-i	0.4	b-i
15	BC Lexy	Malt	4 c	35cde	1.4	c	13.8	abc	0.6	b-i
45	Moravian 179	Malt	5.3 c	25d-g	1.4	c	9.4	g-m	0.5	b-i
53	S14230-41513	Malt	4.65 c	30c-f	1.4	c	11.3	b-i	0.6	b-i
37	LCS Odyssey	Malt	6 c	30c-f	1.8	c	9.6	g-m	0.7	b-i
9	ABI Eagle	Malt	5.6c	35cde	2.0	c	12.7	a-f	0.5	b-i
23	Esma	Malt	6.3 c	35cde	2.2	c	12.4	a-g	1.0	a-f
46	Moravian 69	Malt	4.9 c	45bc	2.2	c	8.1	h-p	0.8	a-i
10	ABI Raptor	Malt	8.6 c	30c-f	2.6	c	11.8	a-h	0.6	b-i
36	LCS Genie	Malt	7 c	40bcd	2.8	c	7.6	i-r	0.6	b-i
35	LCS Diablo	Malt	7.6 c	45bc	3.6	c	13.9	abc	1.1	abc
30	ICB111809 (2-R sus)	Malt	9.6 c	40bcd	4.0	c	8.9	g-p	.	
48	PI383933	check	27.75 b	55b	15.4	b	5.2	rqp	0.9	a-h
	P=0.05		<0.0001	<0.0001	<0.0001		<0.0001		0.051	

Spring barley nurseries in Aberdeen were not planted correctly, so we had to rely on the Kimberly nursery for both spring and winter barley results.

The NABSEN winter barley results were reported to Dr. Erick Stockinger, coordinator. The results for the EVT winter barley trials are reported in Table 3.

Table 3. Winter barley summary sorted by FHB Index – Kimberly. Endeavor was included as the two-row resistant check; Wintmalt was the 2-row susceptible check.

Var#	Variety	Severity		INC %		INDEX		Yield (bu/A)		DON (ppm)	
9	13ARS537-19	4.5	h	17.5	jk	0.8	j	33.7	gfdec	2.4	onkmlqp
31	Endeavor (resistant)	5.5	h	22.5	h-k	1.2	ij	46.1	ba	2.55	onkmlqp
28	DH170472	4.4	h	30.0	f-k	1.3	ij	27.0	mglfkpjeioqhn	1.65	onqp
2	11ARS652-7	6.0	gh	30.0	g-k	1.7	ij	39.6	bac	3.9	onkmlijqp
27	DH162310	4.8	h	37.5	d-k	1.8	ij	15.8	xcwbpvautszroqy	6.75	gkflijeh
61	Thunder	5.5	h	40.0	d-k	2.3	ij	32.9	gfdech	2.9	onkmlqp
57	Scoular Barley	5.4	h	45.0	c-k	2.4	ij	23.7	mglfkpjtsiroqhn	3.8	onkmlijqp
19	Avalon	5.5	h	42.5	c-k	2.7	ij	28.1	mglfkdjeichn	4.65	onkmlijqhp
22	Charles	6.1	gh	47.5	b-k	2.9	ihj	27.1	mglfkpjeiohn	4.05	onkmlijqp
21	BC Fay	6.3	gh	50.0	b-k	3.2	ihj	27.3	mglfkdjeiohn	3.5	onkmlqp
37	LCS Calypso	5.3	h	65.0	a-h	3.4	ihj	25.1	mglfkpjesiroqhn	3.6	onkmlqp
25	DH141917	6.4	gh	62.5	a-i	4.5	ihj	31.4	gfdjeich	6.6	gkmflijeh
4	12ARS777-1 (hulless)	7.9	gh	60.0	a-j	4.7	ihj	21.1	mxlwkpvjutsiroqn	2.55	onkmlqp
5	12ARS777-2 (hulless)	7.3	gh	67.5	a-g	5.0	ihj	22.9	mglfkpvjutsiroqhn	2.81	onkmlqp
38	Lightning	7.4	gh	70.0	a-f	5.3	ihj	26.8	mglfkpjeiroqhn	7.1	gkfijeh
3	12ARS578-3	9.4	fgh	62.5	a-i	5.9	ihj	27.4	mglfkdjeiohn	2.25	onkmlqp
36	KWS Donau	8.5	gh	72.5	a-f	6.1	ihj	33.9	fdec	6.7	gkflijeh
74	WintMalt (Susc)	8.2	gh	77.5	a-e	6.4	ihj	48.7	a	2.35	onkmlqp
20	BC Clementine	9.7	fgh	65.0	a-h	6.5	ihj	39.6	bac	5.85	ognkmflijeh
62	Upspring	12.5	fgh	70.0	a-f	9.0	ihj	30.3	gfkdjeich	2.75	onkmlqp
32	Flavia	11.9	fgh	85.0	abc	10.1	ihj	31.8	gfdjeich	12.05	dc
26	DH150683	18.6	fgh	70.0	a-f	16.2	ihj	29.6	glfkdjeich	4.8	ognkmlijqhp
39	Marouetta	20.8	fgh	100.0	a	20.8	igfhj	17.4	mxwbpvautszroqyn	3.55	onkmlqp
35	Hirondella	54.8	d	90.0	ab	47.6	ecd	28.3	mglfkdjeich	9.55	gdfce
30	Eight-Twelve	58.3	dc	97.5	a	57.0	bcd	28.4	mglfkdjeich	9.45	gdfceh
59	Sunstar Pride	58.1	cd	100.0	a	58.1	bcd	38.9	bdac	13.9	bc
64	UTWB10406-9	76.4	abc	100.0	a	76.4	ba	32.5	gfdeich	6.45	gnkmflijeh
63	UTWB10201	79.5	ab	97.5	a	77.3	ba	26.9	mglfkpjeioqhn	17.9	ba
65	UTWB11135-1	94.8	a	100.0	a	94.8	a	29.5	glfkdjeich	21.15	a
	P=0.05	< 0.0001		< 0.0001		< 0.0001		< 0.0001		< 0.0001	

The association mapping study revealed important insights into the genetic architecture underlying FHB tolerance, deoxynivalenol (DON) accumulation, and related agronomic traits in Idaho-adapted germplasm. Numerous models and significance thresholds were used to provide a comprehensive investigation of the marker-trait associations. We identified a total of 97 markers associated with FHB index and 43 markers associated with DON accumulation, with notable concentrations on chromosome 2H and 7H, respectively. Additionally, many marker-trait associations were identified for plant height and heading date. Linkage-disequilibrium (LD) decay analysis was used to determine the presence of confounding QTL associated with multiple traits. Marker-trait associations thought to be independent of plant height and heading date were cross referenced with the results of previous studies.

Two highly significant markers were identified for FHB resistance, JHI-Hv50k-2016-106330 and JHI-Hv50k-2016-458804. The marker JHI-Hv50k-2016-106330 located on chromosome 2H was found to be highly significant for FHB index in the Sidney dataset, and significant at a lower threshold in the Kimberly dataset. It was the only significant marker identified in two environments. However, the marker was found to be in LD with a marker significant for heading date. JHI-Hv50k-2016-458804 was found to be highly significant for DON accumulation by multiple models but was found to be in LD with markers for plant height and heading date. These findings suggest potential pleiotropic effects or confounding quantitative trait loci (QTL). Future trials should investigate the highly significant markers further to determine if they are consistently associated with agronomic traits across multiple years and environments. The multi-trait associations illustrate the complex genetic interactions underlying FHB resistance in barley. Our results emphasize the importance of plant height and heading date as key determinants influencing FHB reaction and DON accumulation in barley.

List key outcomes or other achievements.

The results of the previous FHB experiments and this study was/will be presented numerous times at the local, national and international level. Consultants and breeding companies in the area have used this data to improve variety recommendations, and growers now regularly spray to reduce FHB and DON in susceptible and moderately susceptible spring barley cultivars when planted after corn. Growers are now aware of the varieties that are less likely to get FHB and suffer high DON, and to spray those varieties they know are vulnerable, especially when following corn in their crop rotations.

Several cultivars were identified in the GWAS panel as potential sources of resistance to Fusarium head blight (FHB). These include GemCraft, CDC Meredith, CDC Mindon, CDC Copeland, Conlon, Julie, Kardia, Newdale, Thunder, and Transit. It's possible that additional sources of resistance exist within the USDA-ARS breeding program and amongst the genetic resources available at the National Small Grains Collection, either yet to be characterized for FHB reaction or awaiting publication of data.

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

We have trained two graduate students on these projects (one PhD candidate and one MS candidate) as well as provided additional training for a post-doc and a support scientist who have or will present the results at the USWBSI Forum. The Master's student, Clayton Balfe, successfully defended his thesis in April of 2024 and has taken an industry position.

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

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

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

The barley entries for the GWAS experiment will be increased in 2024 to repeat the study a second year for publication. The trial locations will be reduced from four to two, to repeat the trial at the most effective locations (Aberdeen and Kimberly) for identifying QTL for resistance to FHB. The resulting publication will be developed in the fall of 2025.

The screening of released barley cultivars and those entered into the Extension Variety Trials from international sources will continue. Advanced lines from regional barley breeders also will continue to be solicited for inclusion in the screening trials.