USDA-ARS
U.S. Wheat and Barley Scab Initiative
FY19 Final Performance Report
Due date: July 24, 2020

Cover Page

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Fiscal Year:	2019
USDA-ARS Agreement ID:	59-0206-8-191
USDA-ARS Agreement Title:	Improving FHB Resistance in Barley and Wheat using Breeding and Genomics Methods
FY19 USDA-ARS Award Amount:	$ 182,865
Recipient Organization:	Virginia Polytechnic Institute and State University 1880 Pratt Drive, Suite 2006 Blacksburg, VA 24060
DUNS Number:	003137015
EIN:	54-6001805
Recipient Identifying Number or Account Number:	422671
Project/Grant Reporting Period:	6/17/19 - 6/16/20
Reporting Period End Date:	6/16/2020

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
BAR-CP	Variety Development, Selection and Mapping of Resistance to FHB and DON in Barley	$ 52,602
VDHR-SWW	Improving FHB Resistance in Winter Wheat via Traditional, GS, MAS and DH Methods	$ 120,000
VDHR-SWW	Developing Doubled Haploids to Expedite Variety Development in Soft Red Winter Wheat	$ 10,263
	FY19 Total ARS Award Amount	**$ 182,865**

Carl A. Griffey

Principal Investigator — 7/27/2020 Date

* MGMT – FHB Management
FST – Food Safety & Toxicology
GDER – Gene Discovery & Engineering Resistance
PBG – Pathogen Biology & Genetics
EC-HQ – Executive Committee-Headquarters
BAR-CP – Barley Coordinated Project
DUR-CP – Durum Coordinated Project
HWW-CP – Hard Winter Wheat Coordinated Project
VDHR – Variety Development & Uniform Nurseries – Sub categories are below:
SPR – Spring Wheat Region
NWW – Northern Soft Winter Wheat Region
SWW – Southern Soft Red Winter Wheat Region

Project 1: *Variety Development, Selection and Mapping of Resistance to FHB and DON in Barley*

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

The primary goal of the project is to evaluate and enhance FHB resistance in commercially viable winter barley cultivars by identifying, mapping, and incorporating unique and/or complementary FHB resistance QTL from different sources using MAS and conventional breeding methods.

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

a) What were the major activities?

The program continues to develop and advance populations and pure lines derived from crosses between superior winter barley cultivars and lines with FHB resistant cultivars from our program and spring barley lines from other programs. The program is conducting research to characterize and validate QTL and to identify diagnostic markers for FHB resistance in our barley cultivars Eve and Nomini. Current diagnostic markers for FHB resistance (ten SSR markers each for QTL on chromosomes 2H and 6H) from spring barley along with markers for other diseases (three SNP markers for leaf rust, three SNP markers for powdery mildew, eleven markers for net blotch, three SSR markers for spot blotch), yield (one SNP marker) and quality (one SNP marker) are being used to characterize parents and for MAS in the Virginia Tech barley program.

A recombinant inbred population and a doubled haploid population, both consisting of a commercially available winter feed and malt barley crossed to 'Nomini', a six-row winter feed barley, was evaluated in order to identify and characterize FHB resistance QTL in 'Nomini'. The first population consisted of 160 individuals derived from the cross 'Thoroughbred' (VA90-44-110 / 'Plaisant' (PI584894)) (Brooks et al., 2005) / 'Nomini' ('Boone' / 'Henry' // VA 77-12-41) (Starling et al., 1994). The second population consisted of 89 doubled haploid lines each derived from the cross 'Violetta' / 'Nomini'. Violetta was developed by Limagrain Cereals Seeds' partners. The common parent between both populations, 'Nomini', was derived from the cross 'Boone' / 'Henry' // VA 77-12-41. 'Nomini' is an early-maturing, medium tall, six-row winter feed barley with compact spikes. When surveying the barley breeding program at Virginia Tech for resistance to Fusarium head blight across Virginia locations from 2009-2011, 'Nomini' exhibited 11%, 13.8, 5.5%, and 11.5 ppm lower than average FHB incidence, index values, Fusarium-damaged kernels and deoxynivalenol concentration, respectively (Berger et al., 2014). Contrastingly in the same study, 'Thoroughbred' exhibited 10.3%, 5.3, 4.7%, and 3.4 ppm higher than average FHB incidence, index values, Fusarium-damaged kernels and deoxynivalenol concentration, respectively.

Breeding populations derived from crosses made with FHB resistance sources (Island, Gen129, AC Alberte, Atahulpa, Quest, MN Brite, FEG-4-98, and Fredrickson) are in advanced generations. This season (2019-20), we evaluated and selected pure lines from nearly 600 hulled and hulless FHB headrows at the Eastern Virginia AREC in Warsaw, VA. We also evaluated 104 FHB resistant lines in an observation yield trial, and 58 populations were evaluated for FHB resistance in our scab nursery and advanced in the program.

b) What were the significant results?

Linkage analysis identified a gene region on chromosome 6H associated with FHB resistance for lower FHB severity, FDK, and reduced DON accumulation in 'Eve' barley (Figure 1). Genes associated with heading date and plant height were also located in the same gene region as those for FHB resistance. Through further analysis, it was determined that the FHB resistance identified in Eve likely is similar to that previously reported on chromosome 6H.

Preliminary linkage analysis has identified several QTL regions in the Thoroughbred / Nomini RIL population along chromosome 2H (Table 1). Similarly, in the Violetta / Nomini DH population QTL regions were identified on chromosomes 2H and 7H (Table 2). However, significant correlations (Table 3.) differentiating row-types, plant height, and flowering dates with FHB traits were seen in this population across 2018 and 2019 in the Virginia FHB site, as previously reported by others. Continued evaluation of this population in FY20 in additional NC and KY sites may help validate QTLs identified in VA sites. Lines from both populations exhibiting FHB and DON values lower than the parents and checks across 2018-2019 and with adequate to superior agronomic traits were advanced into observation tests in 2020-2021.

c) List key outcomes or other achievements.

Pure lines derived from crosses between known FHB resistant spring barley lines and adapted winter barley lines are being developed and evaluated for FHB resistance and agronomic performance. Elite barley line, VA11B-141 LA, was released in 2019 and showed three-year average DON values that were 3 to 6 ppm lower than those of current cultivars Atlantic, Secretariat, and Thoroughbred. A two-row, elite, hulless line VA15H-73 exhibiting superior resistance to FHB and DON accumulation was also released in 2020. New SNP markers tightly linked to the FHB resistance QTL on 6H were identified and can be used to incorporate and pyramid FHB resistance genes into adapted cultivars via MAS breeding.

3. Was this research impacted by the COVID-19 pandemic (i.e. university shutdowns, reduced or lack of support personnel, etc.)? If yes, please explain how this research was impacted or is continuing to be impacted.

Research from this project was not directly affected by the COVID-19 pandemic. Issues related to weather and freeze affected the results from two of the three locations in which the mapping populations were grown in 2019, not due to the pandemic.

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

This project has provided training to employees at the Eastern VA AREC including current and new research specialists, undergraduate students as well as professional development by allowing a post-doc research associate to attend the annual USWBSI meeting and participate in poster presentation sessions.

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

Data on FHB index, FDK, ISK, and DON obtained from the Virginia's state wheat variety trial are reported at field days, online (https://pubs.ext.vt.edu/SPES/SPES-46/SPES-46.html) and in the extension bulletin VCE Publications / SPES / SPES-46 "Small Grains in 2018" to promote selection and production of FHB resistant cultivars. The results on FHB resistant QTL mapping were disseminated through USWBSI annual meetings.

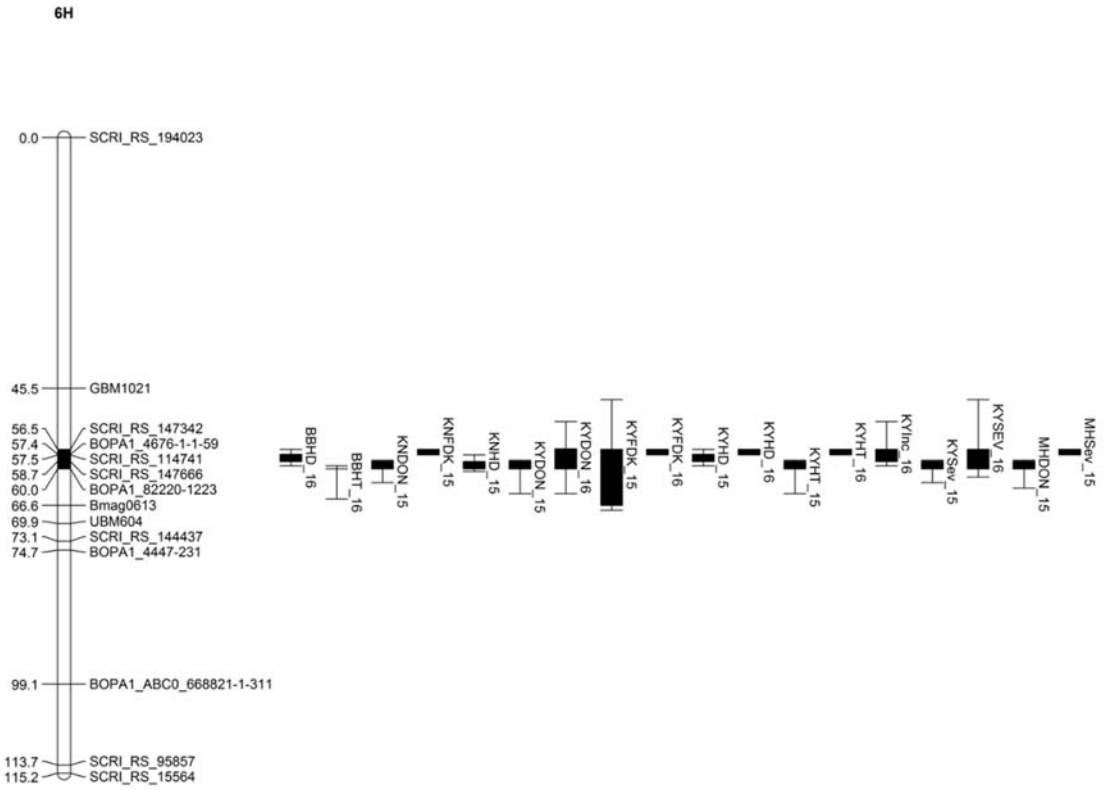

Figure 1. Chromosome map of 6H, derived from the moderately resistant parent Eve, identifying the gene region associated with FHB resistance.

Table 1. Resistance quantitative trait loci (QTL) on Chromosome 2H associated with Fusarium head blight (FHB) in the winter barley mapping population Thoroughbred/Nomini.

Trait	Chr	Position	Left Marker	Right Marker	LOD	PVE(%)	Add	LeftCI	RightCI	Positive Parent
LKY_INC_17	1	173.3	SCRI_RS_139220	JHI-Hv50k-2016-11229	3.1023	48.0295	-8.5962			Nomini
MHV_INC_19	2	16	JHI-Hv50k-2016-138564	JHI-Hv50k-2016-138894	3.7885	9.654	-5.4089			Nomini
MHV_SEV_17	2	130	BOPA2_12_30897	JHI-Hv50k-2016-107038	3.0892	8.6114	-1.721			Nomini
MHV_DON_18	2	132	JHI-Hv50k-2016-107038	JHI-Hv50k-2016-107022	5.6599	27.8819	-5.3463			Nomini
KNC_DON_18	2	148	SCRI_RS_220533	JHI-Hv50k-2016-103164	5.2841	14.66	-2.025	147.5	148.5	Nomini
MHV_DON_17	2	149	JHI-Hv50k-2016-102691	JHI-Hv50k-2016-102606	3.0892	7.7381	-0.3862			Nomini
MHV_FDK_18	2	180	JHI-Hv50k-2016-85641	JHI-Hv50k-2016-84124	3.3531	14.2469	-3.1514			Nomini
KNC_FDK_18	2	271	SCRI_RS_231057	JHI-Hv50k-2016-65609	7.9852	38.8315	-3.8857	270.5	272.5	Nomini
MHV_DON_18	5	133	JHI-Hv50k-2016-313298	JHI-Hv50k-2016-312680	4.6409	7.254	-2.7373			Nomini
MHV_HT_19	6	117	JHI-Hv50k-2016-384807	JHI-Hv50k-2016-384956	3.0208	7.4177	-0.6235			Nomini

Table 2. Resistance quantitative trait loci (QTL) on Chromosome 2H and Chromosome 7H associated with Fusarium head blight (FHB) in the winter barley mapping population Nomini/Violetta.

Trait	Chr.	Position	Left Marker	Right Marker	LOD	PVE(%)	Add	LeftCI	RightCI	Positive Parent
MHV_18_FD	2	92.4	SCRI_RS_165509	SCRI_RS_116694	7.2637	23.5632	1.2162	91.88	93.878	Violetta
MHV_19_FD	2	102.4	JHI-Hv50k-2016-106227	JHI-Hv50k-2016-105458	5.6601	23.8543	1.0707	101.9	102.88	Violetta
MHV_18_DON	2	102.4	JHI-Hv50k-2016-106227	JHI-Hv50k-2016-105458	9.8449	25.0875	8.3503	101.9	102.88	Violetta
MHV_18_SEV	2	108.4	JHI-Hv50k-2016-104475	JHI-Hv50k-2016-104031	3.3081	8.2829	-5.5689	107.9	108.88	Violetta
MHV_18_SEV	2	105.4	JHI-Hv50k-2016-104475	JHI-Hv50k-2016-104031	3.4553	11.7811	6.6424	104.9	105.88	Nomini
MHV_19_FDK	2	111.4	JHI-Hv50k-2016-104031	SCRI_RS_9469	3.8937	16.966	-2.6797	108.9	112.88	Nomini
MHV_18_SEV	4	133	JHI-Hv50k-2016-230903	BOPA2_12_10562	3.7452	9.1967	5.975	132.5	133.5	Nomini
MHV_19_HT	6	82	JHI-Hv50k-2016-409395	JHI-Hv50k-2016-409501	3.5667	23.0161	-1.6872	81.5	82.5	Nomini
MHV_18_DON	7	46	JHI-Hv50k-2016-460104	BOPA2_12_31305	3.3261	7.0147	-4.4969	45.5	46.5	Nomini
MHV_19_SEV	7	82	JHI-Hv50k-2016-473439	JHI-Hv50k-2016-473444	4.4169	18.5772	-3.6981	81.5	83.5	Violetta
MHV_18_FDK	7	95	SCRI_RS_198541	JHI-Hv50k-2016-482898	3.1681	14.3312	5.1092	93.5	96.5	Violetta
MHV_18_SEV	7	99	JHI-Hv50k-2016-485353	JHI-Hv50k-2016-487016	3.7706	8.9535	-5.8945	98.5	101.5	Violetta
MHV_18_DON	7	138	JHI-Hv50k-2016-492881	JHI-Hv50k-2016-498292	3.2632	15.5563	6.6171	134.5	140.5	Violetta

Table 3. Pearson correlations (below) for Nomini / Violetta doubled haploid winter barley population using averages for two years in a Virginia FHB nursery among nine traits based on least squares of each doubled haploid genotype and the corresponding heatmap.

	FD	HT	Row	INC	SEV	IND	FDK	ISK	DON
FD	1	-0.04	**-0.19**	**0.8**	**0.77**	**0.78**	**0.21**	**0.83**	**0.58**
HT		1	-0.1	-0.11	-0.14	-0.12	**-0.16**	-0.13	-0.1
Row			1	0.08	0.09	0.11	**0.15**	0.09	**-0.35**
INC				1	**0.8**	**0.82**	**0.21**	**0.94**	**0.44**
SEV					1	1	**0.32**	**0.95**	**0.36**
IND						1	**0.31**	**0.96**	**0.36**
FDK							1	**0.28**	**0.41**
ISK								1	**0.42**
DON									1

Bolded text means significant correlations

Project 2: *Improving FHB Resistance in Winter Wheat via Traditional, GS, MAS and DH Methods*

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

The ultimate goal of the proposed research is to incorporate unique FHB resistance QTL from complementary types and sources of resistance into commercially viable cultivars using Genomic prediction, Marker Assisted Selection (MAS) and Doubled Haploid (DH) technologies in conjunction with conventional breeding methods. The project addresses CP milestones 1 and 2 by selecting and crossing FHB resistant parents on the basis of agronomic performance, FHB resistance, and marker haplotypes of parents for known and validated QTL for traits of interest. The program is implementing marker assisted selection (MAS) to pyramid *Fhb1* and other QTL into our germplasm.

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

a) What were the major activities?

Breeding populations (296) were evaluated and selections made in an irrigated and grain spawn inoculated scab nursery at Mt. Holly, VA in 2019-20. Pure lines evaluated and selected in headrows at Warsaw, VA in 2019 will be tested in observation yield trials in 2020 and includes 25 FHB-MAS derived lines and 71 FHB-MAS-DH lines. Wheat lines (258 SRW, 193 HRW, and 70 Durum) in preliminary, advance, and state yield trials were evaluated for agronomic performance at two to seven locations and for FHB resistance in a scab nursery at Mt. Holly, VA. Elite lines in regional (50 entries in the Gulf Atlantic, 76 entries in Mason Dixon, and 45 entries in the Uniform Bread Wheat trials), and uniform scab nurseries (48 entries in southern, 50 entries in northern, and 37 entries in preliminary northern scab nurseries) were evaluated in yield test plots and in a scab nursery at Mt. Holly. Our program also evaluates lines in these uniform nurseries for seedling resistance to two races of leaf rust in greenhouse trials. Agronomic and disease data are provided to all cooperators and grain samples of entries in the three uniform scab nurseries are sent to the Soft Wheat Quality Lab for quality analyses each year. Lines included in these tests currently are being analyzed for DON content.

Molecular markers linked to 15 scab resistance genes located on wheat chromosomes 2D, 3B (*Fhb1*), and 5A of Ning 7840, 1B and 6A of Jamestown, 1A and 2A of Tribute, 3B and 4B of Ernie, 2B and 3B of Bess, 3B of Massey, and 1A, 4A, and 6A of Neuse are being used to screen parental lines of crosses and in marker-assisted selection to pyramid different FHB resistance genes. MAS enrichment was applied in 14 SRW-FHB populations in 2016 (Table 4) and 10 SRW-FHB populations in 2017 (Table 5). Doubled haploid lines developed by Heartland Plant Innovations (HPI) were created from MAS-enriched F_1 plants in 2018 (Table 6) and grown in headrows during the 2019-20 field season. During 2019-20, FHB breeding materials evaluated in scab nursery and/or field tests included: 296 populations, 3,000 headrows, and more than 800 pure lines.

b) What were the significant results?

Seven FHB resistant lines, having *Fhb1* in the pedigree, have been developed from our Marker-assisted breeding program with above average yield and improved scab resistance which performed well in the 2019 state wheat test. Lines 15VDH-FHB-MAS25-08, 15VDH-FHB-MAS38-01, 15VDH-FHB-MAS33-13, 15VDH-FHB-MAS34-18, and 15VDH-FHB-MAS33-30 were all in the top 10% of the same test ranked per ISK Index values (Range 4.5-12; average of 25). Line 15VDH-FHB-MAS25-08 has exhibited two-year average ISK Index levels significantly lower than average and has been included in regional testing in 2020. A summary of other scab resistant breeding stocks and lines developed and evaluated in our program from 2013 to 2020 is presented in Table 7.

c) List key outcomes or other achievements.

A large number of superior lines are being obtained from our FHB-MAS-DH project where the primary goal is to pyramid gene *Fhb1* with multiple other QTL for FHB resistance. More than 55% of the entries in our 2020 FHB Wheat Observation Test were developed using DH and/or MAS breeding techniques. Two SRW wheat lines VA09MAS1-12-5-1-1 ('Featherstone 125') and DH12SRW056-058 ('Liberty 5658') having moderate resistance to FHB along with an HRW wheat line VA14HRW-25 ('Hardy 2519') were released in 2019.

3. Was this research impacted by the COVID-19 pandemic (i.e. university shutdowns, reduced or lack of support personnel, etc.)? If yes, please explain how this research was impacted or is continuing to be impacted.

No, this research was not significantly affected by the COVID-19 pandemic.

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

This project has provided training to employees at the Eastern VA AREC as well as those working for the program on the Virginia Tech campus. These including current and new research specialists, undergraduate students (2 student interns working at EVAREC and 4 student interns on campus). Also, the project provided professional development by allowing a post-doc research associate to attend the annual USWBSI meeting and participate in poster presentation sessions.

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

Data on FHB index, FDK, ISK, and DON obtained from the Virginia's state wheat variety trial are reported online (https://pubs.ext.vt.edu/SPES/SPES-46/SPES-46.html) and in the

extension bulletin VCE Publications / SPES / SPES-46 “Small Grains in 2019” to promote selection and production of FHB resistant cultivars. Information on FHB resistance of cultivars and the FHB disease forecasting website are also shared with producers at annual field days. Data on seedling resistance to leaf rust, resistance to FHB and other prevalent diseases as well as agronomic traits (e.g. heading date, height, lodging tolerance, yield, and test weight) and quality (samples provided to Soft Wheat Quality Lab) are collected and provided to cooperators in the three uniform scab nurseries.

Table 4. Soft red winter wheat (SRW) scab top cross populations enriched via MAS in 2016 and evaluated in F_4 headrows in 2019-20 at Warsaw, VA.

Pop no.	Short Pedigree	Traits for MAS	F_5 Rows Tested in 2020
1	NC8248-14 /Jamestown// MDC07026-F2-19-13-1	**Fhb1, FHB1B-Jtw, FHB3B-Bess, FHB1A-Nse, FHB4A-Nse, FHB6A-Nse**, Sbm1, Lr37, Lr/Sr24	40
2	NC8248-14 /Featherstone73// MDC07026-F2-19-13-1	**Fhb1, FHB3B-Bess, FHB4A-Nse, FHB6A-Nse**, Sbm1, Lr37, Lr9, Lr/Sr24, Sr36	20
3	NC8248-14 /Hilliard// MDC07026-F2-19-13-1	**Fhb1, FHB1B-Jtw, FHB3B-Bess, FHB1A-Nse, FHB6A-Nse**, Sbm1, Lr37, Lr/Sr24, Sr36	16
4	NC8248-14 /Hilliard//L11541	**Fhb1, FHB1B-Jtw, FHB3B-Bess, FHB6A-Nse**, Sbm1, Lr37, Lr/Sr24, Sr36	8
5	NC8248-14 /GA03564-12E6// MDC07026-F2-19-13-1	**Fhb1, FHB1B-Jtw, FHB3B-Bess, FHB4A-Nse, FHB6A-Nse**, Sbm1, Lr37, Lr/Sr24, Sr36, 1A.1R	4
6	NC8248-14 /GA03564-12E6// L11541	**Fhb1, FHB1B-Jtw, FHB3B-Bess, FHB6A-Nse**, Sbm1, Lr37, Lr/Sr24, Sr36, 1A.1R	16
7	NC8248-14 /VA12W-54// L11541	**Fhb1,, FHB3B-Bess, FHB4A-Nse**, Sbm1, Lr37, Lr/Sr24, Sr36, Lr46, H13	8
8	NC8248-14 /Berkeley// MDC07026-F2-19-13-1	**Fhb1, FHB1B-Jtw, FHB4A-Nse, FHB6A-Nse**, Sbm1, Lr37, Lr/Sr24, Sr36, H13	16
9	NC8248-14 /Berkeley//L11541	**Fhb1, FHB1B-Jtw, FHB3B-Bess, FHB3B-Msy, FHB4A-Nse, FHB6A-Nse**, Sbm1, Lr37, Lr/Sr24, Sr36, Lr46, H13	12
10	NC8248-14 /L11541// VA11W-108PA	**Fhb1, FHB1B-Jtw, FHB3B-Bess, FHB4A-Nse, FHB6A-Nse**, Sbm1, Lr/Sr24, Sr36	12
11	NC8248-14 /L11541// TXGA06343-17-3-5-EL2	**Fhb1, FHB1B-Jtw, FHB3B-Bess, FHB6A-Nse**, Sbm1, Lr37, Lr/Sr24, Sr36	4
12	NC8248-14 /L11541//VA14FHB-28	**Fhb1, FHB3B-Bess, FHB4A-Nse, FHB6A-Nse**, Sbm1-het, Lr/Sr24, Sr36	4

Pop no.	Short Pedigree	Traits for MAS	F_5 Rows Tested in 2020
13	NC8248-14 /L11541// VA07MAS3-7304-3-2-4-3	**Fhb1, FHB1B-Jtw, FHB4A-Nse, FHB6A-Nse**, Sbm1-het, Lr37, Sr36	4
14	NC8248-14 /L11541// VA09MAS6-122-7-1	**FHB1B-Jtw, FHB3B-Bess, FHB4A-Nse, FHB6A-Nse**, Sbm1-het, Lr37, Lr/Sr24, Sr36	4

Table 5. Soft red winter wheat scab top cross populations enriched via MAS in 2017 and grown out in 2019 for evaluation in F_3 headrows in 2019-2020 in Warsaw, VA.

Pop No.	Cross Pedigree	Max# FHB QTLs	Marker Traits	No. F_3 Rows
1	VA12W-68/MDC07026-F2-19-13-1//Hilliard	2.1	**Fhb1-het, FHB1B_Jtw-het, FHB3B_Msy-het**, H13-het, Yr17/Lr37/Sr38-het, Sr24/Lr24, Sbm1	8
2	VA12W-68/MDC07026-F2-19-13-1//TXGA06343-17-3-5-EL2	2.2	**Fhb1-het, FHB3B_Msy-het,** H13-het, Yr17/Lr37/Sr38-het, Sr24/Lr24, Sbm1, Lr46	8
3	VA12W-68/TXGA06343-17-3-5-EL2// MDC07026-F2-19-13-1	2.1	**Fhb1-het,, FHB6A_-het, FHB3B_Msy-het,** , H13-het, Yr17/Lr37/Sr38-het, Sr24/Lr24, Sbm1, Lr46-het	8
4	TXGA06343-17-3-5-EL2/ MDC07026-F2-19-13-1// VA12W-68	2.1	**Fhb1-het, FHB6A-Nse-het, FHB3B_Msy-het,** , H13-het, Yr17/Lr37/Sr38, Sbm1	8
5	TXGA06343-17-3-5-EL2/ MDC07026-F2-19-13-1// VA11W-108PA	1.1	**Fhb1-het,, FHB1B_Jtw-het,** Yr17/Lr37/Sr38-het, Sbm1	16
6	TXGA06343-17-3-5-EL2/ Jamestown//15MW-133 (MDC07026-F2-19-13-3)	5.2	**Fhb1-het, FHB1A-Nse-het, FHB6A_Nse-het, FHB6A-Jte-het, FHB1AL-Trib-het**, Yr17/Lr37/Sr38-het, Sr24/Lr24, Sbm1	8
7	KY06C-1178-16-10-3/USG3895 //GAJT141-14E45	4.1	**Fhb1, FHB1B-Jtw-het, FHB6A_Nse**, H13-het, Yr17/Lr37/Sr38-het, Sbm1, 2 +12, vrn-A1-short-het	8
8	VA11W-108PA/VA07MAS3-7304-3-2-4-3/ L11541	3	**Fhb1-het, FHB1B-Jtw-het, FHB6A_Nse-het, FHB6A-Jte-het,**, H13-het, Yr17/Lr37/Sr38-het, Sr24/Lr24, Sbm1, 5+10-het, vrn-A1	8
9	USG3895/VA12W-72//15MW-33 (MDC07026-F2-19-13-3)	3.3	**Fhb1-het, FHB6A_Nse-het, FHB1AL-Trib-het,**, Yr17/Lr37/Sr38, Sr24/Lr24, Sbm1, 2+12	8
10	USG3895/MD272-8-4-14-6// VA11W-279	4.3	**Fhb1-het, FHB1A-Nse-het, FHB4a-Nse-het, FHB3B-Msy-het, FHB1AL-Trib-het,** Sbm1, H13-het, Yr17/Lr37/Sr38, Sr36/Pm6-het, Sbm1, 1RS:1BL-het, 2+12	16

Table 6. FHB doubled haploid (DH) lines developed from MAS enriched F_1 plants by Heartland Plant Innovation in spring of 2019 to be evaluated in 2019-2020 headrows.

Pop no.	Short Pedigree	DH Rows Tested in 2019
1	13VTK59-148/VA16W-105	316
2	NC14-23372/Hilliard	231
3	NC14-23372/13VTK429-3	260

Table 7. Scab resistant breeding stocks developed and evaluated by the Virginia Tech wheat breeding program from 2013 to 2020.

Breeding Nursery / Test	2013	2014	2015	2016	2017	2018	2019	2020
Populations	140	386	265	233	140	176	247	296
SRW, MAS, and DH Headrows	1300	2800	2160	8000	3400	4400	2700	2500
Preliminary yield test	40	10	15	7	20	20	28	16
Advance yield test	38	5	3	6	13	13	9	6
VA state yield test	2	5	7	5	12	18	21	11
Southern FHB uniform test	6	6	8	8	8	8	9	8
Northern FHB uniform test	4	4	5	4	5	5	5	5
Preliminary northern FHB test	6	6	5	5	5	5	5	6

Project 3: *Developing Doubled Haploids to Expedite Variety Development in Soft Red Winter Wheat*

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

One of the main objectives of the VDHR research area is to increase the efficiency of coordinated project breeding programs in developing and releasing FHB-resistant varieties. Doubled haploids (DH) shorten variety development time in fall-sown small grains by approximately three years.

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

a) What were the major activities?

Research is focused on shortening breeding cycles through the development of doubled haploid populations and enhancing FHB resistance via MAS breeding efforts in selection of parents, designing crosses, gene introgression and pyramiding, population enrichment, and selection of pure lines. Marker haplotypes of parents for validated FHB resistance QTL and other traits of importance such as dwarfing genes, disease and insect resistance, rye translocations, and quality are being assessed and utilized to enhance breeding efficiency. Molecular markers linked to 15 scab resistance genes located on wheat chromosomes 2D, 3B (*Fhb1*), and 5A of Ning 7840, 1B and 6A of Jamestown, 1A and 2A of Tribute, 3B and 4B of Ernie, 2B and 3B of Bess, 3B of Massey, and 1A, 4A, and 6A of Neuse are being used to screen parental lines of crosses and in marker-assisted selection to pyramid different FHB resistance genes. Marker assisted selection (MAS) was applied in 13 SRW-FHB top cross populations in 2016 and 2017 (See Tables 4 and 5 above). Individual top-cross F_1 plants having multiple FHB resistance QTL and other traits of interest were delivered to Heartland Plant Innovations in 2016 and 2017, and to NCSU in 2018 to develop DH lines for breeding programs in VA, AR, GA, LA, NC and KY. Other MAS plants were grown out in the greenhouse and are being advance in our breeding program using the Pedigree method. Lines selected from DH populations also have been shared with and evaluated in the aforementioned breeding programs.

b) What were the significant results?

The VT program has developed 10 or more top cross populations (~100 seed / cross) over the past three years, from which individual seedlings have been screened via MAS to identify genotypes having multiple genes/QTL for FHB resistance. This data and selected DH lines have been shared with southern breeders who cooperate in the DH project. During the past three years, breeders in AR, GA, LA, NC, and KY have selected plants from which DH lines were developed by Heartland or NCSU for their programs. In 2019-20, 807 DH lines (Table 3) developed via MAS through Heartland Plant Innovations (HPI) were evaluated in Warsaw, VA and superior lines will be advanced into observation tests in 2021.

c) List key outcomes or other achievements.

Concurrent deployment of MAS and DH breeding methods has greatly accelerated the rate at which superior wheat lines having multiple QTL for FHB resistance, including gene *Fhb1*, are being developed and tested in the southern region. The proportion of wheat lines having enhanced FHB resistance has increased significant as a result of this regional project.

3. Was this research impacted by the COVID-19 pandemic (i.e. university shutdowns, reduced or lack of support personnel, etc.)? If yes, please explain how this research was impacted or is continuing to be impacted.

No, this research was not significantly affected by the COVID-19 pandemic.

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

This project has greatly enhanced collaborative breeding efforts between breeding programs in the southern and Mid-Atlantic regions. It also has provided novel training to small grains employees located on campus and at the Eastern VA AREC including research associates, research specialists, graduate and undergraduate students.

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

Genotypic and phenotypic data, MAS selected top-cross progeny, and selected DH lines have been shared with southern breeders who cooperate in the DH project. Information and progress garnered from the project also has been showcased and shared with producers at field days and annual grower meetings.

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the FY19 award period (6/17/19 - 6/16/20). The term "support" below includes any level of benefit to the student, ranging from full stipend plus tuition to the situation where the student's stipend was paid from other funds, but who learned how to rate scab in a misted nursery paid for by the USWBSI, and anything in between.

1. **Did any graduate students in your research program supported by funding from your USWBSI grant earn their MS degree during the FY19 award period?**
   No.

   If yes, how many?

2. **Did any graduate students in your research program supported by funding from your USWBSI grant earn their Ph.D. degree during the FY19 award period?**
   No.

   If yes, how many?

3. **Have any post docs who worked for you during the FY19 award period and were supported by funding from your USWBSI grant taken faculty positions with universities?**
   No.

   If yes, how many?

4. **Have any post docs who worked for you during the FY19 award period and were supported by funding from your USWBSI grant gone on to take positions with private ag-related companies or federal agencies?**
   No.

   If yes, how many?

FY19 Final Performance Report
PI: Griffey, Carl
USDA-ARS Agreement #: 59-0206-8-191
Reporting Period: 6/17/19 - 6/16/20

Release of Germplasm/Cultivars

Instructions: In the table below, list all germplasm and/or cultivars released with full or partial support through the USWBSI during the FY19 award period. All columns must be completed for each listed germplasm/cultivar. Use the key below the table for Grain Class abbreviations.

NOTE: Leave blank if you have nothing to report or if your grant did NOT include any VDHR-related projects.

Name of Germplasm/Cultivar	**Grain Class**	**FHB Resistance** (S, MS, MR, R, where R represents your most resistant check)	**FHB Rating** (0-9)	**Year Released**
VA11B-141 LA (SB255)	Barley	MR	1.2	2019
DH12SRW056-058 (Liberty 5658)	SRW	MR	2.3	2019
VA14HRW-25 (Hardy 2519)	HRW	MR	2.7	2019
VA09MAS1-12-5-1-1 (Featherstone 125)	SRW	MR-MS	3.9	2019
13VTK429-3	SRW	MR	3.2	2020
VA15H-73 (2R)	Hulless	R	0.5	2020
VA16M-81 (Avalon)	Malt	MR	2.7	2020

Add rows if needed.

NOTE: List the associated release notice or publication under the appropriate sub-section in the 'Publications' section of the FPR.

Abbreviations for Grain Classes

Barley - BAR
Durum - DUR
Hard Red Winter - HRW
Hard White Winter - HWW
Hard Red Spring - HRS
Soft Red Winter - SRW
Soft White Winter - SWW

Publications, Conference Papers, and Presentations

Instructions: Refer to the FY19-FPR_Instructions for detailed more instructions for listing publications/presentations about your work that resulted from all of the projects included in the FY19 grant award. Only citations for publications published (submitted or accepted) or presentations presented during the **award period (6/17/19 - 6/16/20**) should be included. If you did not publish/submit or present anything, state 'Nothing to Report' directly above the Journal publications section.

NOTE: Directly below each citation, you **must** indicate the Status (i.e. published, submitted, etc.) and whether acknowledgement of Federal support was indicated in the publication/ presentation.

Journal publications.

Nothing to Report.

Books or other non-periodical, one-time publications.

Nothing to Report.

Other publications, conference papers and presentations.

Griffey, C., W. Brooks, M. Vaughn, J. Fitzgerald, and W. Thomason. 2019. "Challenges and Efforts to Maintain Winter Barley as a Viable Crop in the Eastern U.S." In: S. Canty, A. Hoffstetter, H. Campbell and R. Dill-Macky (Eds.), *Proceedings of the 2019 National Fusarium Head Blight Forum* (p. 94), Milwaukee, WI; December 8-10. University of Kentucky, Lexington, KY.
Status: Abstract Published and Presentation Given
Acknowledgement of Federal Support: Yes (Abstract and Presentation)

Fitzgerald, J., W. Brooks, N. Meier, D. Van Sanford, P. Murphy, N. McMaster and D. Schmale. 2019. "Evaluation of Winter Barley Cultivar Nomini for Quantitative Resistance to Fusarium Head Blight." In: S. Canty, A. Hoffstetter, H. Campbell and R. Dill-Macky (Eds.), *Proceedings of the 2019 National Fusarium Head Blight Forum* (p. 90), Milwaukee, WI; December 8-10. University of Kentucky, Lexington, KY.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: Yes (Abstract and Presentation)

Oakes, J., J. Fitzgerald, and C. Griffey. 2019. "Assessment of Fusarium Head Blight in Small Grains Using Aerial Methods." In: S. Canty, A. Hoffstetter, H. Campbell and R. Dill-Macky (Eds.), *Proceedings of the 2019 National Fusarium Head Blight Forum* (p. 19), Milwaukee, WI; December 8-10. University of Kentucky, Lexington, KY.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: No

Mehl, H., W. Thomason, C. Griffey, and J. Fitzgerald. 2019. "Fungicide Efficacy and Timing for Management of Fusarium Head Blight in Malting Barley in Virginia." In: S. Canty, A. Hoffstetter, H. Campbell and R. Dill-Macky (Eds.), *Proceedings of the 2019 National Fusarium Head Blight Forum* (p. 17), Milwaukee, WI; December 8-10. University of Kentucky, Lexington, KY.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: Yes (Abstract and Presentation)

Mndolwa, E., P. Bregitzer, C. Griffey, J. Fitzgerald, J. Marshall et al. 2019. "Evaluation of Aberdeen Barley (*Hordeum vulgare* L.) Germplasm for Fusarium Head Blight Resistance." In: S. Canty, A. Hoffstetter, H. Campbell and R. Dill-Macky (Eds.), *Proceedings of the 2019 National Fusarium Head Blight Forum* (p. 103), Milwaukee, WI; December 8-10. University of Kentucky, Lexington, KY.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: Yes (Abstract and Presentation)

Baldwin, T., P. Bregitzer, C. Griffey, J. Fitzgerald, et al. 2019. "Fusarium Head Blight Biomass Measurements in Barley from 2018 U.S. Nurseries." In: S. Canty, A. Hoffstetter, H. Campbell and R. Dill-Macky (Eds.), *Proceedings of the 2019 National Fusarium Head Blight Forum* (p. 85), Milwaukee, WI; December 8-10. University of Kentucky, Lexington, KY.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: Yes (Abstract and Presentation)

Winn, Z., R. Acharya, J. Lyerly, G., Brown-Guedira, C. Cowger, C. Griffey, J. Fitzgerald, and P. Murphy. 2019. Preliminary Mapping of Fusarium Head Blight Resistance in NC13-20076 Soft Red Winter Wheat." In: S. Canty, A. Hoffstetter, H. Campbell and R. Dill-Macky (Eds.), *Proceedings of the 2019 National Fusarium Head Blight Forum* (p. 125), Milwaukee, WI; December 8-10. University of Kentucky, Lexington, KY.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: Yes (Abstract and Presentation)