

**MARYLAND GRAIN PRODUCERS UTILIZATION BOARD
PROGRESS REPORT 2016**

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Variety Development and Accelerated Breeding for Scab Resistance in SRW Wheat

The specific objectives of this project are to: 1) advance wheat populations derived from the previous Maryland Breeding Program, select and evaluate pure lines, and identify cultivars for joint or exclusive release; 2) incorporate and combine scab resistance genes from newly improved scab resistant germplasm and/or scab-tolerant native wheat lines to develop and release commercially viable cultivars; and 3) accelerate release of scab resistant cultivars and/or germplasm using doubled haploid and molecular marker assisted breeding technologies.

Experiment 1: Selection, evaluation and release of SRW wheat cultivars derived from Maryland breeding populations. In 2014, we planted 243 wheat populations (F₂-F₈ generation) from the Maryland Breeding Program. These populations were grown in standard size yield plots at Warsaw, VA and evaluated for critical agronomic traits. Sixty four populations were selected and advanced in 2015 and were evaluated in 225 ft² plots at Blacksburg and Warsaw, VA. Heads selected from 54 of the initial advance generation populations were grown and evaluated in 2,700 headrows at Warsaw, VA in 2015; from which 44 pure lines were selected and were evaluated in observation yield tests at two Virginia test sites in 2016. Six lines selected from the 2016 observation test will be evaluated in our replicated preliminary yield test at three Virginia sites in 2017. In 2016, we evaluated 3,286 headrows derived from 15 MD wheat populations, and 27 lines were selected for evaluation in the 2017 Virginia wheat observation test. Two F₅ and four F₄ populations were advanced and evaluated in 2016, and heads were selected from one of these populations and will be evaluated in headrows in 2017. Desirable headrows derived from these populations will be harvested and the resulting pure lines will subsequently be evaluated in observation yield tests at Blacksburg and Warsaw, VA.

Experiment 2: Phenotypic evaluation of scab resistance and yield performance-Advanced Line Testing. In the 2016 crop year, we evaluated 367 elite lines for agronomic performance in the Virginia State Test (Table 1), SRW Wheat Advance Test and Preliminary Test (Table 2), and Scab Observation Nursery at two to seven locations. These wheat lines also were evaluated for scab resistance in a replicated field trial in our inoculated and mist-irrigated scab nursery at Blacksburg, VA. An additional 263 wheat lines, including entries in the Southern, Northern and Preliminary Northern Uniform Scab Nurseries, and entries in two Regional Yield Nurseries (Gulf Atlantic and Mason Dixon) were evaluated for scab resistance in the Blacksburg scab nursery. More than 8,000 wheat headrows derived from scab breeding populations or as doubled haploid lines were planted at Warsaw and evaluated in 2016 for agronomic traits and disease resistance to identify superior scab resistant pure lines. Approximately 3,300 wheat FHB headrows derived from scab breeding populations (1,400 rows), MAS enriched populations (750 rows) or as doubled haploid lines (1,160 rows) were selected and will be evaluated in observation yield tests in 2017.

Advancement of Breeding Populations. During fall 2015, 176 SRW wheat scab breeding populations were planted at Mt. Holly, VA and were evaluated in 225 ft² blocks. Selection in F₂, F₃ and F₄ populations included mass-bulk selection of spikes from plants possessing desirable traits as well as scab resistance. Individual heads were harvested from selected F₄ and later generation populations. These head selections were threshed and planted fall 2016 in headrow tests and new pure lines will be selected on the basis of agronomic traits and resistance to other prevalent diseases at Warsaw, VA in 2017. Selected pure lines will be evaluated for scab resistance in replicated disease assessment tests at Mt. Holly, VA the following year. More than 300 single and 240 three-way crosses including scab resistant parents were made during spring 2016, and will be evaluated in F₁ progeny rows at Warsaw in 2017. Selected crosses will be advanced as breeding populations and evaluated in 225 ft² blocks in the irrigated scab nursery at Mt. Holly, VA during 2018.

Experiment 3: Mapping, marker-assisted evaluation and selection of scab resistance in SRW wheat.

Molecular DNA markers linked to scab resistance genes/QTL (quantitative trait loci) located on wheat chromosomes 3BS (*Fhb1*), 2DL and 5AS of Ning 7840 (Sumai 3 derivative), those on 3BL and 5A of Ernie and Massey, the QTL on 1B of Jamestown, and QTL on 1A, 2A, and 3B of Tribute were used in characterization and selection of scab resistance in parental lines used in crosses and for marker assisted selection (MAS). During summer 2014, seed (87 – 135 seed per cross) of the 13 top crosses listed in the Table 3 below were sent to the Eastern Regional Genotyping Lab in Raleigh, NC. Haplotypes of individual plants for gene *Fhb1* and scab resistance QTL on chromosomes 2DL, 3BSc, and 5AS were determined, and 41 plants having *Fhb1* combined with 2 or 3 of the other FHB resistance QTL were sent to Heartland Plant Innovations in December 2015 to develop 15-20 DH lines from each of the 41 selected plants. Seed of the requested 685 DH lines was delivered in late November and the lines were planted in Plains, GA. During fall 2016, 318 of these DH lines were planted in observation yield plots at Warsaw, VA and 475 other DH lines were planted in headrows. These DH lines will be evaluated at Warsaw in 2017. Among the remaining plants, 549 having the major scab resistance gene *Fhb1* and/or other combinations of multiple resistance genes (Table 4) were grown out in a greenhouse at Virginia Tech and seed of these lines were planted in headrows at Warsaw, VA in fall 2015. These MAS F₂ lines were evaluated in the field during spring 2016, and 760 head selections from desirable lines were threshed and planted in headrows in fall 2016 for advancement using the pedigree breeding method.

Thirty-four FHB-MAS selected plants derived from 6 SRW wheat top-crosses developed in spring 2016 (Table 5) were sent to Heartland Plant Innovations for development of 539 DH lines. The remaining 618 FHB-MAS selected plants are currently being grown in a greenhouse at Virginia Tech. Seed from these plants will be planted in headrows during fall 2017 and advanced as described above using the pedigree method. As noted in Table 5, these FHB-MAS selected plants potentially carry up to seven different genes or QTL for resistance to FHB, thus facilitating the development of superior lines having multiple FHB resistance genes.

Characterization of genes/QTL governing scab resistance in the adapted and elite SRW wheat cultivars Jamestown and Tribute and identification of diagnostic DNA markers for known and novel QTL in these sources will be completed and final results published in 2017. Genes on chromosome 1B conferring scab resistance in Jamestown have been confirmed in three separate populations. FHB resistance in Tribute is associated with genes on chromosomes 1A, 2A, and 3B. Thus, it appears that Jamestown and Tribute differ for genes conferring resistance to scab. Results from these studies will facilitate further progress in breeding and development of cultivars having higher levels of scab resistance. Diagnostic DNA markers (SSR and SNP) associated with novel QTLs can be used in breeding programs to enrich and enhance scab resistance via marker assisted breeding and accelerated via development of doubled haploid lines.

Table 1. Performance of top yielding lines in the 2015-16 VT State Wheat Test

Line	Yield	Test	Date	Mature	Plant	Powdery	Leaf	Stripe	FHB	Hessian
	% of	Weight	Headed	Height	Lodging	Mildew	Rust	Rust	Index	Fly
	Mean	(Lb/bu)	(Julian)	(In)	(0-9)	(0-9)	(0-9)	(0-9)	(0-100)	Res.
	(5)	(5)	(2)	(2)	(3)	(4)	(4)	(3)	(1)	
Hilliard	119 +	58.0 +	117	31 +	1	1 -	2 -	0 -	17	BC
VA11W-108PA	118 +	57.7 +	117	30	1	1 -	1 -	0 -	17	BC
MAS 61	117 +	56.5	119 +	29	2 +	3 +	1 -	1	10 -	BCO
Pioneer Brand 26R59	114 +	56.7	119 +	26 -	1	1 -	4 +	0 -	24	O
VA11W-106	113 +	57.5 +	120 +	29	1	2	1 -	0 -	21	
MAS 67	113 +	55.4 -	118	28	1	3 +	3	1	9 -	BCOL
VA12FHB-8	112 +	55.9	116 -	29	2	1 -	1 -	4 +	23	BC
VA09MAS6-122-7-1	112 +	58.5 +	117 -	25 -	1 -	1 -	1 -	0 -	22	
VA12W-72	112 +	58.0 +	114 -	28 -	1	1 -	2 -	0 -	14	BCOL
VA12W-31	111 +	56.8	120 +	29	2	1 -	1 -	3 +	21	
L11541	110 +	58.4 +	120 +	29	2	1 -	0 -	2	11	---
SS EXP 8550	110 +	55.7	121 +	32 +	1	1 -	2 -	0 -	12	BCOL
VA12W-68	109 +	57.8 +	115 -	28	1	1 -	2 -	0 -	22	BCOL
MAS 35	109 +	56.0	120 +	30	1	3 +	2 -	3 +	10 -	
VA12W-248	109 +	57.4 +	116 -	32 +	2	2	1 -	6 +	23	
VA11W-279	108 +	58.5 +	113 -	27 -	2	0 -	0 -	1 -	23	BCOL
MAS 6	107 +	54.5 -	119 +	28 -	1	2	3	1	16	BCOL
MAS 7	107 +	55.7	121 +	30	2	2	5 +	1 -	11	
VA08MAS1-188-6-4-1	107 +	57.3 +	117	28	1	0 -	1 -	1	20	C
VA12W-101	107 +	55.9	120 +	26 -	2	1 -	1 -	0 -	14	B
SY 547	107 +	56.7	118	31 +	2	1 -	2 -	3 +	11	
USG 3197	106 +	54.3 -	119 +	31	1	2	2	2	5 -	BCO
Pioneer Brand 26R10	100	55.5 -	120 +	29	1 -	3	6 +	0 -	21	BCOL
Jamestown	84 -	59.0 +	110 -	26 -	2	2	2	1 -	15	BC
Mean (N=133)	100	56.4	118	29	1	2	3	2	21	
LSD (0.05)		0.7	1	1	1	1	1	1	10	
C.V.		1.8	1	4	44	36	31	57	24	

A plus or minus sign indicates a performance significantly above or below the test average.

The 0-9 ratings indicate a genotype's response to disease or lodging where 0 = highly resistant and 9 = highly susceptible.

The number in parentheses below column headings indicates the number of locations on which data are based.

Seedlings were tested for resistance to biotypes B, C, O, and L of Hessian Fly.

Table 2. Performance of top yielding lines in the 2016 VT Preliminary Wheat Test

Line	Yield Rank	Yield % of mean	Yield Bu/A N=3		Test Weight Lb/Bu	Head Date Julian		Height Inch		Lodge (0-9)	Powdery Mildew (0-9)	Leaf Rust (0-9)	Stripe Rust (0-9)	FHB Index 0-100				
Locations	All	All	All		All	BgW		BgW		BgW	All	All	All	BSN				
DH12SRW056-058	1	125	74	++	58.6	+	115	-	30	+	0.3	2.0	1.9	0.9	-	11		
VA09MAS1-12-5-1-3	2	121	71	++	59.1	+	121	+	31	+	0.7	0.8	1.4	1.3		24		
VA09MAS6-122-7-1-1	3	120	71	++	58.0	+	117		26	-	0.2	0.9	0.6	-	0.4	-	15	
DH11SRW069-70	4	120	70	++	54.6	-	122	+	30	+	0.3	1.1	1.4	0.6	-	23		
DH11SRW065-26	6	119	70	++	56.8		116		28		0.2	1.8	1.0	-	0.5	-	19	
DH12SRW057-006	7	118	69	++	60.2	+	120	+	28		0.2	0.3	-	1.6	0.4	-	27	
VA09MAS1-12-5-1-1	8	118	69	++	59.9	+	119	+	31	+	0.7	2.6	+	1.0	-	0.6	-	21
VA09MAS6-122-7-1-4	9	117	69	+	58.2	+	116		26	-	0.5	1.0	0.8	-	0.6	-	10	-
DH11SRW061-16	10	116	68	+	58.8	+	114	-	28		0.7	0.6	-	1.1	-	0.6	-	17
VA09MAS2-131-6-2-4	12	114	67	+	56.2		116		27	-	0.3	0.9	0.8	-	1.5		17	
HILLIARD	14	113	67	+	57.3		118		31	+	0.5	0.6	-	1.1	-	0.6	-	21
SHIRLEY	39	107	63		53.8	-	121	+	29		0.3	0.1	-	0.8	-	5.4	+	25
PIONEER 26R10	88	96	56		54.5	-	121	+	30	+	0.3	1.5	5.6	+	0.6	-	18	
PIONEER 25R32	110	88	52	-	53.4	-	122	+	31	+	0.8	1.4	5.0	+	0.6	-	11	-
PIONEER 26R46	121	77	45	-	56.8		115		29	+	0.7	0.9	3.1	+	2.6		54	+
MEAN (N=126)			59		57.0		117		28		0.5	1.5	2.0	1.9		23.4		
LSD			5.2		0.9		1.4		1.1		0.7	0.9	0.9	1.0		12.8		

Table 3. Top crosses characterized for 4 FHB-QTL and selected plants sent to Heartland Plant Innovations for DH line development in 2015 and evaluated in 2016

MD08-26-H2-7-12-9 / USG 3555 // VA12W-150 MD08-26-H2-7-12-9 / Jamestown // Featherstone 73 MD08-26-H2-7-12-9 / Jamestown // VA12W-54 MD08-26-H2-7-12-9 / 12V51 // VA11W-95 MD08-26-H2-7-12-9 / 12V51 // VA12W-150 MD08-26-H2-7-12-9 / Featherstone73 // Hilliard MD08-26-H2-7-12-9 / Featherstone73 // VA12W-54 MD08-26-H2-7-12-9 / Featherstone73 // VA12W-150 MD08-26-H2-7-12-9 / VA11W-278 // Hilliard MD08-26-H2-7-12-9 / VA11W-278 // VA12W-150 MDC07027-12-24 / Hilliard // Featherstone 73 MDC07027-12-24 / Hilliard // SS8412 MDC07027-12-24 / Hilliard // VA11W-278
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Table 4. Plants Selected from 13 Wheat Top Crosses with Multiple Scab Resistance Genes to Develop Doubled Haploid (DH) Lines or to Advance as F₂ MAS Headrows		
No. MAS Plants	Potential Scab QTL Combinations†	2015-16 Test
9	<i>Fhb1</i> + FHB-QTL on: 1B, 2DL, 3BL, 5AS	145 DH Headrows
7	<i>Fhb1</i> + FHB-QTL on: 2DL, 3BL, 5AS	120 DH Headrows
3	<i>Fhb1</i> + FHB-QTL on: 1B, 2DL, 5AS	60 DH Headrows
4	<i>Fhb1</i> + FHB-QTL on: 2DL, 3BL	60 DH Headrows
11	<i>Fhb1</i> + FHB-QTL on: 2DL, 5AS	195 DH Headrows
7	<i>Fhb1</i> + FHB-QTL on: 3BL, 5AS	105 DH Headrows
1	<i>Fhb1</i> + FHB-QTL on: 2DL, 3BL, 5AS	F₂ MAS Headrows
13	<i>Fhb1</i> + FHB-QTL on: 2DL, 3BL	F₂ MAS Headrows
63	<i>Fhb1</i> + FHB-QTL on: 2DL, 5AS	F₂ MAS Headrows
15	<i>Fhb1</i> + FHB-QTL on: 3BL, 5AS	F₂ MAS Headrows
19	FHB-QTL on: 2DL, 3BL, 5AS	F₂ MAS Headrows
80	<i>Fhb1</i> + FHB-QTL on 2DL	F₂ MAS Headrows
19	<i>Fhb1</i> + FHB-QTL on 3BL	F₂ MAS Headrows
107	<i>Fhb1</i> + FHB-QTL on 5AS	F₂ MAS Headrows
11	FHB-QTL on: 2DL, 3BL	F₂ MAS Headrows
90	FHB-QTL on: 2DL, 5AS	F₂ MAS Headrows
14	FHB-QTL on: 3BL, 5AS	F₂ MAS Headrows
117	<i>Fhb1</i>	F₂ MAS Headrows

†A majority of the F₂ MAS lines also have Jamestown's FHB-QTL on chromosome 1B

Table 5. Plants Selected for FHB Resistance via Marker Assisted Selection sent for Development of Doubled Haploid Lines

Cross: Pedigree	No. FHB QTL	Marker Traits: Bes=Bess, Jtw=Jamestown, Msy=Massey, Nse=Neuse	No DH Lines
NC8248-14 / Hilliard // MDC07026-F2-19-13-1	6	Fhb1, FHB1B_Jtw, FHB3B_Bes, FHB1A_Nse, FHB4A_Nse, FHB6A_Nse, Sbm1, Lr37, Lr/Sr24, Sr36	105
NC8248-14 / VA12W-72 // MDC07026-F2-19-13-1	5	Fhb1, FHB1B_Jtw, FHB3B_Bes, FHB4A_Nse, FHB6A_Nse, Sbm1, Lr37, Lr/Sr24, Sr36, Lr46, H13	104
NC8248-14 / MDC07026-F2-19-13-4 // VA11W-108PA	4	Fhb1, FHB1B_Jtw, FHB3B_Bes, FHB6A_Nse, Sbm1, Lr37, Lr/Sr24, Sr36	40
NC8248-14 / MDC07026-F2-19-13-4 // VA11W-108PA	5	Fhb1, FHB1B_Jtw, FHB3B_Bes, FHB4A_Nse, FHB6A_Nse, Sbm1, Lr37, Lr/Sr24, Sr36	40
NC8248-14 / MDC07026-F2-19-13-4 // VA11W-279	7	Fhb1, FHB1B_Jtw, FHB3B_Bes, FHB3B_Msy, FHB1A_Nse, FHB4A_Nse, FHB6A_Nse, Sbm1, Lr37, Lr/Sr24, Sr36, H13	40
NC8248-14 / MDC07026-F2-19-13-4 // VA11W-279	7	Fhb1, FHB1B_Jtw, FHB3B_Bes, FHB3B_Msy, FHB1A_Nse, FHB4A_Nse, FHB6A_Nse, Sbm1, Lr37, Sr36, H13	50
NC8248-14 / MDC07026-F2-19-13-4 // VA12W-72	6	Fhb1, FHB1B_Jtw, FHB3B_Bes, FHB3B_Msy, FHB4A_Nse, FHB6A_Nse, Sbm1, Lr37, Lr/Sr24, Sr36, Lr46, H13	40
NC8248-14 / MDC07026-F2-19-13-4 // VA12W-72	6	Fhb1, FHB1B_Jtw, FHB3B_Bes, FHB3B_Msy, FHB4A_Nse, FHB6A_Nse, Sbm1, Lr37, Sr36, Lr46, H13	20
NC8248-14 / MDC07026-F2-19-13-4 // VA12W-72	6	Fhb1, FHB1B_Jtw, FHB3B_Bes, FHB3B_Msy, FHB4A_Nse, FHB6A_Nse, Sbm1, Lr37, Lr46, H13	20
NC8248-14 / MDC07026-F2-19-13-4 // VAO9MAS6-122-7-1	5	Fhb1, FHB1B_Jtw, FHB3B_Bes, FHB4A_Nse, FHB6A_Nse, Sbm1_het, Lr37, Lr/Sr24, Sr36	40
NC8248-14 / MDC07026-F2-19-13-4 // VAO9MAS6-122-7-1	5	Fhb1, FHB1B_Jtw, FHB3B_Bes, FHB4A_Nse, FHB6A_Nse, Sbm1_het, Lr37, Sr36	40
Total No. DH Lines:			539