USDA-ARS/
U.S. Wheat and Barley Scab Initiative
FY17 Final Performance Report
Due date: July 31, 2018

Cover Page

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Fiscal Year:	2017
USDA-ARS Agreement ID:	N/A
USDA-ARS Agreement Title:	Introgression of Scab Resistance from Emmer and Timopheev Wheat into Durum Wheat.
FY17 USDA-ARS Award Amount:	$ 128,500

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
DUR-CP	Development and Characterization of Elite Durum Wheat Lines with Scab Resistance.	$ 63,500
DUR-CP	Evaluation of Einkorn and Emmer Wheat Germplasm for Resistance to Fusarium Head Blight.	$ 30,000
VDHR-SPR	Evaluation and Characterization of Scab Resistance in New Synthetic Wheat Germplasm.	$ 35,000
	FY17 Total ARS Award Amount	**$ 128,500**

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Principal Investigator 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: *Development and Characterization of Elite Durum Wheat Lines with Scab Resistance.*

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

The major goal of this project is to develop high breeding value durum lines with a high level of FHB resistance that can be directly utilized in the U.S. durum breeding programs. The specific objectives of this project are: 1) to determine the FHB resistance QTLs in the resistant durum lines, 2) to rapidly incorporate these elite durum lines into ND durum breeding program for developing new durum germplasm and cultivars with combination of low cadmium, high yield, and excellent quality with FHB resistance, and 3) to develop PCR-based STARP (semi-thermal asymmetric reverse PCR) markers for three major FHB resistance QTLs introduced to durum wheat from bread wheat.

2. What was accomplished under these goals? *Address items 1-4) below for each goal or objective.*

Objective 1: Determine the FHB resistance QTLs in the resistant durum lines

1) Major activities
   - A panel of 288 tetraploid wheat genotypes consisting of 271 newly-developed durum lines, their parents, and checks (9 ND durum cultivars, 4 *T. dicoccum* accessions, and 4 *T. carthlicum* accessions) was previously genotyped using the Illumina wheat 90K-SNP arrays were evaluated for FHB resistance in six environments (year-location) in FHB field nurseries (Fargo and Prosper, ND) and greenhouse from 2015 to 2017.
   - The panel of 288 tetraploid wheat genotypes described above were genotyped using three STARP markers developed in Objective 3 (below) for the three major FHB resistance QTLs (*Fhb1* from Sumai and *Qfhb.rwg-5A.1* and *Qfhb.rwg-5A.2* from PI 277012) introduced to durum wheat from bread wheat.

2) Specific objectives
   - Identify the FHB-resistant QTL introduced to adapted durum germplasm from hexaploid bread wheat and other tetraploid wheat species or subspecies.

3) Significant results
   - Among 271 new durum lines, 25, 43, and 53 have marker alleles for *Fhb1* from Sumai 3 and 5AS and 5AL QTL from PI 277012, with 4 carrying all three marker resistance alleles and 23 carrying two QTL (14 with 5AS and 5AL, 6 with *Fhb1* and 5AS, and 3 with *Fhb1* and 5AL QTL), respectively.
   - Six durum lines have resistance alleles for 5AS QTL derived from *T. dicoccum* PI 272527, *T. carthlicum* PI 352281, and *T. carthlicum* PI 283888, and 18 lines have marker alleles for 5AL QTL derived from *T. dicoccum* PI 272527.

4) Key outcomes or other achievements
   - The presence of *Fhb1* from Sumai 3 and two 5A QTL from PI 277012 were detected in the new durum wheat germplasm with improved FHB resistance.

- The FHB resistance QTL were detected in the new durum germplasm with improved FHB resistance derived from related tetraploid species *T. dicoccum* and *T. carthlicum*.

Objective 2: Incorporate elite durum lines into ND durum breeding program.

1) Major activities
   - Among the durum lines with FHB resistance derived from cultivated emmer and hexaploid wheat, 10 lines were evaluated in a preliminary trial in two locations (Prosper and Langdon, ND) in the summer of 2017.
   - Three durum lines carrying *Fhb1* with a high level of FHB resistance, low DON, and good agronomic traits were previously crossed with five new ND durum breeding lines carrying *Cdu1* for low cadmium accumulation. Approximately 7,600 F_2 plants were genotyped with the STARP markers for *Fhb1* and *Cdu1* and approximately 400 F_2 plants homozygous for *Fhb1* and *Cdu1* have been selected in the past two years.
   - Among the F_2 plants that are homozygous for *Fhb1* and *Cdu1*, 123 were first selected and their F_3 families were initially evaluated in the FHB field nursery (Fargo, ND) and greenhouse in summer 2017 and 14 elite durum lines with FHB resistance were selected and advanced to F_6 generation. The 14 elite durum lines, along with their parents and checks, are being evaluated in the FHB field nurseries in two locations (Fargo and Prosper, ND) in summer 2018.
   - The 14 durum lines were increased and are being grown in a preliminary trial to evaluate agronomic performance, yield, and quality in two locations (Prosper and Langdon, ND) in summer 2018. They are also independently being evaluated for resistance to FHB and other major wheat diseases (e.g. leaf rust, tan spot, etc.), agronomic performance, yield, and quality in the FHB nurseries and a yield trial by the NDSU durum breeding program in summer 2018. The durum lines (F_4- F_5) derived from the remaining 328 F2 plants that were homozygous for *Fhb1* and *Cdu1* are being evaluated in the field FHB nurseries in two locations (Fargo and Prosper, ND) in summer 2018.

2) Specific objectives
   - Incorporate elite durum lines into ND durum breeding program to develop new durum germplasm and cultivars that combine low cadmium, high yield, and excellent quality with FHB resistance.

3) Significant results
   - Four of the durum lines developed from the crosses involved in bread wheat lines PI 277012 and/or Sumai 3 were confirmed to have a high level of FHB resistance, low DON, and good agronomic traits.
   - About 400 F_2 plants that are homozygous for *Fhb1* and *Cdu1* have been selected and derived lines have been advanced to F_4- F_6 generation.
   - Fourteen elite durum lines in F_6 generation with FHB resistance were increased for various trials including breeding trials in the NDSU durum breeding program.

4) Key outcomes or other achievements
   - The elite durum germplasm developed in this project provide a good promise to have the first FHB-resistant durum cultivar developed in the U.S. in the near future. They are now being extensively tested and used in the NDSU durum breeding program

Objective 3: Develop PCR-based STARP (semi-thermal asymmetric reverse PCR) markers for three major FHB resistance QTLs introduced to durum wheat from bread wheat.

1) Major activities
   - Hexaploid wheat PI 277012 were previously identified to carry two QTLs (*Qfhb.rwg-5A.1* and *Qfhb.rwg-5A.2*) on chromosome arms 5AS and 5AL conferred a high level of FHB resistance based on a SSR-based linkage map constructed using Grandin × PI 277012 derived doubled haploid (DH) population. The DH population was further analyzed using iSelect 9K SNP array. A total of 2,855 SNPs were added to the existent SSR-based genetic maps, with 53 and 32 SNPs being located in the 5AS and 5AL QTL regions, respectively.
   - Two and seven STARP markers were developed for the 5AS QTL (designated as *Rwgsnp28* and *Rwgsnp29*) and 5AL QTL (*Rwgsnp30*, *Rwgsnp31*, *Rwgsnp32*, *Rwgsnp33*, *Rwgsnp34*, *Rwgsnp35*, and *Rwgsnp36*), respectively based on sequencing analysis of the two alleles between PI 277012 and Grandin. The nine STARP markers were mapped into SSR and SNP integrated linkage map.
   - Six STARP markers, temporarily designated as FHB1-2, FHB1-5, FHB1-11, FHB1-13, FHB1-14, and FHB1-16 were developed for *Fhb1* by comparing Chinese Spring genome sequences with the Sumai3-derived BAC sequence around the *Fhb1* locus.

2) Specific objectives
   - Develop PCR-based STARP markers for three major FHB resistance QTLs introduced to durum wheat from bread wheat.

3) Significant results
   - A total of 13 PCR-based STARP markers were developed for the three major FHB resistance QTLs (*Fhb1* and two 5A QTL) introduced to durum from bread wheat.

4) Key outcomes or other achievements
   - The new STARP markers enabled high throughput marker-assisted selection of the three major FHB resistance QTLs in durum and wheat breeding for FHB resistance. They have been extensively used in NDSU durum breeding program and have been provided to the two USDA-ARS genotyping labs in Manhattan, KS and Raleigh, NC.

3. What opportunities for training and professional development has the project provided? Nothing to Report.

4. How have the results been disseminated to communities of interest? Nothing to Report.

Project 2: *Evaluation of Einkorn and Emmer Wheat Germplasm for Resistance to Fusarium Head Blight.*

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

The major goal of this project is to identify new sources of FHB resistance that can be used for improving durum wheat from diploid einkorn and tetraploid emmer wheat collections. The specific objective is to identify the einkorn and cultivated emmer accessions and lines carrying FHB resistance by screening the adapted einkorn and cultivated emmer lines as alternative cereals and the einkorn wheat collection at USDA-ARS National Small Grain Collection (NSGC) for reactions to FHB.

2. What was accomplished under these goals? *Address items 1-4) below for each goal or objective.*

1) Major activities
- Evaluated 16 adapted einkorn (*T. monococcum*) and 58 cultivated emmer wheat (*T. dicoccum*) lines in the FHB field nursery (Fargo, ND) in summer 2017. These lines were originally selected or developed as alternative cereal crops by the USDA-ARS North Central Soil Conservation Research Lab (Morris, MN).
- Evaluated approximately 1,276 einkorn wheat accessions (857 *T. monococcum* subsp. *aegilopoides*, 203 *T. monococcum* subsp. *monococcum*, and 216 *T. urartu* accessions) from USDA-ARS National Small Grain Collection (NSGC), Aberdeen, ID in a non-replicated experiment in greenhouse. Several *T. monococcum* and *T. urartu* accessions showed moderate levels of FHB resistance.

2) Specific objectives
- Identify the einkorn and cultivated emmer accessions and lines carrying FHB resistance by screening the adapted einkorn and cultivated emmer lines as alternative cereals and the einkorn wheat collection at USDA-ARS NSGC for reactions to FHB.

3) Significant results
- Eight emmer lines as alternative cereal crops showed low disease severities (20.6% - 36.3% averaged from three replications) in a preliminary evaluation in the FHB field nursery (Fargo, ND)
- Approximately 40 *T. monococcum* and *T. urartu* accessions from USDA-ARS NSGC showed moderate levels of FHB resistance in a non-replicated experiment in greenhouse.

4) Key outcomes or other achievements
- *T. monococcum* and *T. urartu* accessions with putative FHB resistance have been identified and they can be useful for improvement of durum wheat for FHB resistance.

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

Nothing to Report.

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

Nothing to Report.

Project 3: *Evaluation and Characterization of Scab Resistance in New Synthetic Wheat Germplasm.*

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

The major goals and objectives of the project are to: 1) Identify new synthetic hexaploid wheat (SHW) lines and wheat-alien species amphiploids carrying FHB resistance and 2) identify putative novel FHB-resistant QTLs in the FHB-resistant SHW lines.

2. What was accomplished under these goals? *Address items 1-4) below for each goal or objective.*

Objective 1: Identify the new SHW lines and wheat-alien species amphiploids carrying FHB resistance.

1) Major activities
   - All the SHW and amphiploid lines and their wheat parents were divided into two different groups in order to appropriately manage the experiments for efficient use of greenhouse and field spaces in the FHB disease evaluation. The first group of 150 SHW lines and their 73 tetraploid wheat parents were successfully evaluated for resistance to FHB in greenhouse for two seasons and field nurseries at two locations (Fargo and Prosper, ND) in 2015 and 2016.
   - In the second group, approximately 230 genotypes, including 49 tetraploid wheat genotypes (10 durum lines and cultivars, 14 *T. dicoccum* accessions, 18 *T. carthlicum* accessions, 4 *T. polonicum* accessions, 1 *T. turanicum* accession, and 2 *T. turgidum* accessions), 97 SHW lines, 81 wheat-alien species amphiploids and their wheat parents, were evaluated for FHB resistance in the greenhouse in the summer of 2017. A total of 190 genotypes with adequate seed stocks in the second group were also evaluated in the field nurseries in two locations (Fargo and Prosper, ND) in the summer of 2017.
   - Based on the data from the 2nd group evaluated in 2017, approximately 100 genotypes with low disease severities, including 34 tetraploid wheat genotypes (3 durum lines and cultivars, 13 *T. dicoccum* accessions, 14 *T. carthlicum* accessions, 3 *T. polonicum* accessions, and 1 *T. turgidum* accession), 44 SHW lines, 3 triticale lines, 17 wheat-alien species amphiploids and their wheat parents, were evaluated for FHB resistance in the greenhouse in the spring and summer of 2018. A set of 91 genotypes with adequate seed stocks were also evaluated in the field nurseries in two locations (Fargo and Prosper, ND) in the summer of 2018.
   - To determine if *Ae. tauschii* accessions contribute to the FHB resistance in the SHW lines, a set of 16 *Ae. tauschii* accessions have been tested for resistance to FHB in greenhouse.

2) Specific objectives
   - Identify the SHW lines and the wheat-alien species amphiploids carrying FHB resistance by evaluating 255 SHW lines, 81 amphiploids, and their tetraploid and hexaploid wheat parents for reactions to FHB.

3) Significant results
   - Seventeen SHW lines and five wheat-*Th. ponticum* amphiploid lines with a high level of FHB resistance have been identified.
   - The evaluation data showed that two *Ae. tauschii* accessions had a moderate level of FHB resistance while most *Ae. tauschii* accessions tested were highly susceptible.

4) Key outcomes or other achievements
   - The SHW and amphiploid lines with a high level of FHB resistance identified in this project are useful germplasm for developing adapted bread wheat germplasm.

Objective 2: Identify putative novel FHB-resistant QTLs in the FHB-resistant SHW lines.

Major activities of this objective, including genotyping 150 SHW lines and their 73 tetraploid parents in the first group using Illumina's iSelect wheat 9K array and conducting association mapping analysis, were completed in FY16 and reported in FY16 Final Performance Reports.

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

Nothing to Report.

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

Nothing to Report.

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the FY17 award period. 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 FY17 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 FY17 award period?** Yes

   If yes, how many? one

3. **Have any post docs who worked for you during the FY17 award period and were supported by funding from your USWBSI grant taken faculty positions with** No **universities?**

   If yes, how many?

4. **Have any post docs who worked for you during the FY17 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?

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 FY17 award period. All columns must be completed for each listed germplasm/cultivar. Use the key below the table for Grain Class abbreviations. *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**

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 FY17-FPR_Instructions for detailed instructions for listing publications/presentations about your work that resulted from all of the projects included in the FY17 grant. Only include citations for publications submitted or presentations given during your award period. If you did not have any publications or presentations, state 'Nothing to Report' directly above the Journal publications section.

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

Journal publications.

Zhao, M., Y. Leng, S. Chao, S.S. Xu, S. Zhong. 2018. Molecular mapping of QTL for Fuarium head blight resistance introgressed into durum wheat. Theoretical and Applied Genetics. Online First Issue https://doi.org/10.1007/s00122-018-3124-4.
Status: Published
Acknowledgement of Federal Support: YES

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

Nothing to Report.

Other publications, conference papers and presentations.

Zhang, Q., J.D. Faris, S. Chao, T.L. Friesen, S. Zhong, X. Cai, E.M. Elias, S.S. Xu. 2017. Identification and molecular mapping of quantitative trait loci for resistance to Fusarium head blight in cultivated emmer PI 272527. In: S. Canty, B. Wiermer, and D. Van Sanford (Eds.), Proceedings of the 2017 National Fusarium Head Blight Forum. East Lansing, MI/Lexington, KY: U.S. Wheat & Barley Scab Initiative. p. 97.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: YES

Zhao, M., Y. Leng, Y. Liu, P. Xi, J. Li, R. Wang, Y. Long, S. Chao, S.S. Xu, S. Zhong. 2017. Fine mapping of a novel major QTL for Fusarium head blight resistance in the wheat line PI 277012. In: S. Canty, B. Wiermer, and D. Van Sanford (Eds.), Proceedings of the 2017 National Fusarium Head Blight Forum. East Lansing, MI/Lexington, KY: U.S. Wheat & Barley Scab Initiative. p. 98.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: YES

Kumar, A., S. Xu, E.M. Elias, R. Dill-Macky, and S. Kianian. 2017. FHB resistance in durum wheat by means of epigenetic modification. In: S. Canty, B. Wiermer, and D. Van Sanford (Eds.), Proceedings of the 2017 National Fusarium Head Blight Forum. East Lansing, MI/Lexington, KY: U.S. Wheat & Barley Scab Initiative. p. 47.

Status: Abstract Published and Poster Presented

Acknowledgement of Federal Support: YES