U.S. Wheat and Barley Scab Initiative

FY22 Research Category Program Descriptions and Research Priorities (PD-RP)

The U.S. Wheat & Barley Scab Initiative is guided by a Steering Committee that includes producers, farm organizations, food processors (i.e. millers, pasta manufacturers, maltsters and brewers), scientists (from Land Grant universities, USDA, and private companies), and consumer groups. Each year, the Steering Committee submits to the USDA-ARS a comprehensive and optimized research plan designed to achieve the Initiative´s goals. That plan is the USWBSI's recommendation for how the USDA-ARS can most effectively employ the funds appropriated by the U.S. Congress for collaborative scab research. The following are the program descriptions and FY22 research priorities for the USWBSI Research Categories.

Research Areas

FHB Management (MGMT)
Food Safety and Toxicology (FST)
Gene Discovery and Engineering Resistance (GDER)
Pathogen Biology and Genetics (PBG)
Variety Development and Host Resistance (VDHR) (includes the three Nursery Coordinated Projects)

Commodity-based Coordinated Projects

Barley Coordinated Project (BAR-CP)
Durum Coordinated Project (DUR-CP)
Hard Winter Wheat Coordinated Project (HWW-CP)

FHB Management (MGMT)

Program Description

The FHB Management (MGMT) research area supports research to develop effective and economical disease management practices that reduce FHB severity and mycotoxins in small grain crops to meet the immediate and long-term needs of the wheat and barley industries.

This research area involves:

- tillage practices, crop sequences, and other cultural practices targeting *Fusarium*-infested residues;
- fungicides and biocontrol agents with demonstrated field efficacy, and their application technologies;
- the refinement and deployment of disease prediction and forecasting models, and disease management decision tools; and
- studies of pathogen survival, inoculum production, dispersal, infection, colonization, mycotoxin production, fungicide sensitivity, and factors accounting for unacceptable levels of mycotoxins in symptomatic or asymptomatic grain.

NOTE: Priority will be given to multi-PI, collaborative, integrated pre-proposals that address the research priorities listed below. Project pre-proposals pertaining to integrated management (IM) studies will be developed as a multi-

PI, collaborative, integrated proposal. The Coordinator for the Integrated Management Coordinated Project (IM-CP) is listed in the FY22 RFP.

FY22 Research Priorities derived from the Action Plan Goals

1. Develop integrated management strategies for FHB and mycotoxins that are robust to conditions experienced in production fields of wheat and barley.
2. Develop and validate the next generation of management tools, forecasting models, and fungicide application technologies for FHB and mycotoxin control.
3. Enhance communication and end user education/outreach.
4. Investigate how genotypic and phenotypic diversity in populations of FHB-causing *Fusarium*, and *Fusarium* species complexes, influences the management of FHB. Priority aspects of pathogen diversity include fungicide sensitivity, mycotoxin profiles, and ability to cause severe disease on widely used sources of genetic resistance in wheat and barley. (Collaborative Goal with PBG)
5. Document how cropping system factors (climate, residue management, crop rotation) influence both the frequencies of *Fusarium* species causing FHB within an area and the risk of severe disease. (Collaborative Goal with PBG)

Food Safety and Toxicology (FST)

Program Description

The Food Safety and Toxicology (FST) research area supports research on food safety and food processing issues related to the presence of *Fusarium* spp. mycotoxins in wheat and barley grain. Practical outcomes of research in this area include: 1) analytical tools that can be used by small grain producers, elevators, millers, and processors, to rapidly and reliably identify mycotoxin-contaminated grain; 2) develop appropriate strategies to deal with contaminated grain; and 3) diagnostic data on *Fusarium* spp. mycotoxins required for development of FHB resistant/tolerant varieties of wheat and barley.

FY22 Research Priorities derived from Action Plan Goals

1. Provide analytical support for DON/trichothecene quantitation for the Initiative's stakeholders.
2. Support research on DON/trichothecene safety that is needed by producers, grain processors, researchers, risk assessors, and regulators.

Gene Discovery and Engineering Resistance (GDER)

Program Description

The Gene Discovery and Engineering Resistance (GDER) research area (RA) places its primary focus on understanding mechanisms of resistance to Fusarium head blight (FHB) and identification of wheat and barley gene variants that can be deployed to increase FHB resistance and/or reduce DON accumulation. The GDER RA also supports utilization of gene editing and transgenic strategies as methodologies to better understand resistance mechanisms with the goal to improve FHB resistance. However, GDER places priority on strategies that can be deployed without transgenesis; gene discovery and transformation of non-cereal systems will be supported only for the purpose of rapidly screening potential anti-*Fusarium* genes**.**

FY22 Research Priorities derived from Action Plan Goals

1. Identify native and induced wheat and barley gene variants that improve FHB resistance and/or reduce DON accumulation.
2. Develop assays that can be used to rapidly validate candidate wheat and barley genes for resistance or susceptibility to FHB and/or reduced DON accumulation.
3. Utilize new technologies to develop effective FHB resistance and/or reduced DON accumulation.

Pathogen Biology and Genetics (PBG)

Program Description
Research in this area includes studies that address mycotoxin biosynthesis *in vivo* or *in planta*, host/parasite interactions, and host resistance mechanisms that target the pathogen. Research in PBG should complement and be linked to whole plant research that will lead to disease control and/or toxin reduction strategies.

FY22 Research Priorities derived from Action Plan Goals
1. Identify important genes, proteins or small molecules produced during the plant-fungal interaction that may be used to develop FHB resistance or to reduce DON contamination in barley and wheat.
2. Develop new understanding about molecular regulators (transcriptome, proteome, metabolome, epigenetic factors) of fungal development (e.g., asexual and sexual development, growth and development, infection structures) during initial infection that may be utilized to boost FHB resistance. This would include mechanisms controlling fungal secretion (ER, Golgi, endosomes, exosomes), and regulators which may be targeted to prevent FHB disease and toxin contaminations in wheat and barley.
3. Develop an improved understanding of plant-pathogen interactions in relation to abiotic factors, and identify genes or genetic variants that contribute to pathogen adaptation to wheat and barley agroecosystems. Identify molecular mechanisms of fungal adaptation to abiotic and biotic factors influencing FHB and toxin production.
4. Develop novel RNAi based strategies targeting critical genes for fungal growth, pathogenesis, and/or mycotoxin biosynthesis to control FHB and mycotoxin contamination.
5. Identify epiphytic or endophytic microbes or microbial communities or viruses that may be useful for development of effective biological control practices for FHB.
6. Investigate how genotypic and phenotypic diversity in populations of FHB-causing *Fusarium*, including diversity of *Fusarium* species complexes, influences the management of FHB. Priority aspects of pathogen diversity include fungicide sensitivity, mycotoxin profiles, and ability to cause severe disease on widely used sources of genetic resistance in wheat and barley. (Collaborative Goal with MGMT)
7. Document how cropping system factors (climate, residue management, crop rotation) influence both the frequencies of *Fusarium* species causing FHB within an area and the risk of severe disease. (Collaborative Goal with MGMT)

Variety Development and Host Resistance (VDHR)

Program Description
The VDHR research area for spring wheat and soft winter wheat will be organized around participation in the Uniform Nurseries. States will be aligned as follows: Uniform Regional Scab Nursery for Spring Wheat Parents (SPR-CP) ID, MN, MT, ND, and SD; Uniform Northern Winter Wheat FHB Screening Nursery (NWWCP) - KY, IL, IN, MI, MO, NY, and OH; Uniform Southern Soft Red Winter Wheat FHB Screening Nursery (SWW-CP) - AR, GA, LA, MD, NC, SC, TX, and VA. VDHR research will be commodity-based in the case of barley, durum and hard winter wheat coordinated projects.

Each Uniform nursery will be coordinated by a regional committee. Nurseries will be conducted in collaboration with a pathologist wherever possible and a subset of promising entries may be grown at multiple locations in Integrated Management Trials. The nurseries will also be evaluated for milling and baking quality, and haplotyped at the USDA regional genotyping labs. The most promising lines may be entered in the nurseries for a second year of testing at the lines originator's request. Collaborators will submit candidate parents for crossing, and pre-breeding populations derived from these crosses/populations will be shared. Mapping of new resistance sources will be accomplished through joint phenotyping of populations. All collaborators will screen varieties and breeding lines entered into statewide performance trials for FHB resistance and provide this information to growers.

FY22 Research Priorities derived from Action Plan Goals

1. Increase and document the number of released varieties from public programs with improved FHB resistance, high grain yield and grain quality that are tested in statewide variety trials and available to farmers, to reduce DON in the US grain supply.
2. Increase efficiency of coordinated project breeding programs to develop and release FHB resistant varieties.
   - Enhance cooperation and coordination of research among programs. For example, phenotypic data should be uploaded to the T3 database, and early generation populations could be shared among programs. Sharing of DHs funded by the Initiative is another example of cooperation. A coordinated genomic selection program also has the potential to increase efficiency.
   - Develop more robust quantitative scoring techniques to reduce reliance on subjective visual scores and increase consistency across research programs.
3. Evaluate and implement modern breeding technologies to further enhance short term and long-term improvement of FHB resistance, and to efficiently introgress effective resistance genes into breeding germplasm.
   - Enhance selection efficiency through technologies such as genomic selection, marker-assisted selection, doubled haploid production and/or high throughput phenotyping.
   - The utilization of speed breeding techniques where feasible has the potential to increase efficiency.

Barley Coordinated Project (BAR-CP)

Project Description

Minimizing the impact of Fusarium head blight (FHB) on barley production in the U.S. requires a multi-dimensional coordinated research effort with focused outputs. The Barley Coordinated Project (CP) seeks to combine existing lines of productive research with new avenues of investigation to develop a set of tools and disease management strategies that will minimize disease risk and mycotoxin contamination to producers and end-users of barley. This toolbox will be developed in coordination with other research areas (see below) and will consist of: 1) varieties with enhanced levels of resistance to FHB, lower levels of mycotoxins, superior agronomic performance, and good end-use quality; 2) chemical and biological formulations, application procedures, and a disease forecasting model that maximize efficacy; 3) a set of best management practices that incorporate our current understanding of the tools available to combat this disease; and 4) New tools developed through emerging technology and understanding of the disease to reduce the impact of FHB on barley.

FY22 Research Priorities derived from Action Plan Goals

The Barley CP is organized around four of the Research Areas (RA) outlined in the USWBSI Action Plan. A set of 14 objectives are established within these four RAs that the CP will address either directly or indirectly via coordination with these other RAs.

1. Variety Development and Host Resistance (VDHR)
   - Objective 1. Increase and document the number of released barley varieties from public programs with improved FHB resistance, high grain yield and grain quality that are tested in statewide variety trials and available to farmers, to reduce DON in the US grain supply.
   - Objective 2. Increase efficiency of coordinated barley breeding programs to develop and release FHB resistant varieties. This includes added resources to T3 database and increased efficiency on scoring barley for resistance.
   - Objective 3. Evaluate and implement modern breeding technologies to further enhance short term and long-term improvement of FHB resistance in barley, and to efficiently introgress effective resistance genes into barley germplasm. This includes enhanced selection efficiency through technologies such as genomic selection, marker-assisted selection, doubled haploid production and/or high throughput phenotyping and utilization of speed breeding techniques.
2. Gene Discovery and Engineering Resistance (GDER)

- Objective 4. Identify native and induced barley gene variants that improve FHB resistance and/or reduce DON accumulation.
- Objective 5. Develop assays that can be used to rapidly validate candidate barley genes for resistance or susceptibility to FHB and/or reduced DON accumulation.
- Objective 6. Utilize new technologies to develop effective FHB resistance and/or reduced DON accumulation in barley.

3. Pathogen Biology and Genetics (PBG)
   - Objective 7. Identify important genes, proteins or small molecules produced during the barley-fungal interaction that may be used to develop FHB resistance or to reduce DON contamination in barley
   - Objective 8. Develop new understanding about molecular regulators (transcriptome, proteome, metabolome, epigenetic factors) of fungal development (e.g., asexual and sexual development, growth and development, infection structures) during initial infection that may be utilized to boost FHB resistance. This would include mechanisms controlling fungal secretion (ER, Golgi, endosomes, exosomes), and regulators which may be targeted to prevent FHB disease and toxin contaminations in barley.
   - Objective 9. Develop an improved understanding of plant-pathogen interactions in relation to abiotic factors, and identify genes or genetic variants that contribute to pathogen adaptation to barley agroecosystems.
   - Objective 10. Develop novel RNAi based strategies targeting critical genes for fungal growth, pathogenesis, and/or mycotoxin biosynthesis to control FHB and mycotoxin contamination in barley.
   - Objective 11. Identify epiphytic or endophytic microbes or microbial communities or viruses that may be useful for development of effective biological control practices for FHB in barley.
   - Objective 12. Investigate how genotypic and phenotypic diversity in populations of FHB-causing *Fusarium*, including diversity of *Fusarium* species complexes, influences the management of FHB. Priority aspects of pathogen diversity include fungicide sensitivity, mycotoxin profiles, and ability to cause severe disease on widely used sources of genetic resistance in barley.
4. FHB Management (MGMT)
   - Objective 13. Develop integrated management strategies for FHB and mycotoxins that are robust to conditions experienced in production fields of barley.
   - Objective 14. Develop and validate the next generation of management tools, forecasting models, and fungicide application technologies for FHB and mycotoxin control in barley.

Durum Coordinated Project (DUR-CP)

Project Description

The Durum Coordinated Project (DUR-CP) has been created under the direction of the USWBSI to accomplish the initiative action plans. The DUR-CP's main objective is to develop FHB resistant durum wheat germplasm (lines/cultivars) with low DON levels, good agronomic traits, and good quality traits that will serve the producers, the domestic pasta industry, and the international export market. Reducing the impact of FHB requires a multidisciplinary effort and therefore the CP includes plant breeders, pathologists, geneticists, agronomists and other researchers working in the area of disease management. The CP also includes stakeholders such as millers and pasta manufactures.

FY22 Research Priorities derived from Action Plan Goals for VDHR

1. Search for novel sources of resistance to FHB in durum and its relatives.
2. Identify, map, and validate FHB resistance QTL in the newly identified sources of resistance and develop user-friendly molecular markers to assist selection in durum breeding and germplasm development.
3. Incorporate FHB resistance QTL from diploid, tetraploid and hexaploid wheat accessions into adapted durum backgrounds and develop elite durum germplasm with the assistance of molecular markers in selection.
4. Develop durum varieties with enhanced level of FHB resistance and reduced DON accumulation.
5. Investigate genetic mechanism of suppressors and enhancers affecting FHB resistance expression in durum wheat.

6. Evaluate chemical management strategies that reduce FHB and/or DON in durum.
7. Develop and promote best integrated management strategies to reduce FHB and/or DON in durum wheat.

Hard Winter Wheat Coordinated Project (HWW-CP)

Project Description

The HWW-CP is an efficient coordinated project that will measure its success by reducing DON in the hard winter wheat grain supply to the food grade level acceptable in the European Union (EU). This level is currently lower than the US standard. Because half of our grain is exported and the majority of it shipped to the EU, the risk is that it can be sourced from high scab areas within the HWW region (e.g. the Eastern Great Plains). As the popularity of whole grain products increases, our goal is to ensure that the DON concentration in these products is also below established thresholds. Based upon the timelines expected for success in reducing DON, the HWW-CP includes the scientific activities of plant breeders, pathologists, geneticists and supporting research programs. We coordinate with disease management efforts because we realize that in addition to improved varieties, improved management will optimize project success (as measured by reducing DON) within expected timelines. HWW-CP germplasm and information are publicly available and made available to other participating researchers in other research areas of the USWBSI. The HWW-CP remains focused on reducing DON levels as quickly as possible and by using the most efficacious methods to do so (breeding and management). Membership in the HWW-CP includes all researchers currently funded within the CP, individuals designated as representatives from other research areas of the USWBSI, all interested FHB researchers who may or may not be funded by the USWBSI, stakeholders representing members from groups that fund our research (e.g. the KS, NE, SD, ND, TX, and MT Wheat Commissions), and members of groups that are key to our industry and who non-monetarily support HWW-CP research. These are "independent" stakeholders, such as major mills and bakeries, private wheat breeders, and chemical company representatives.

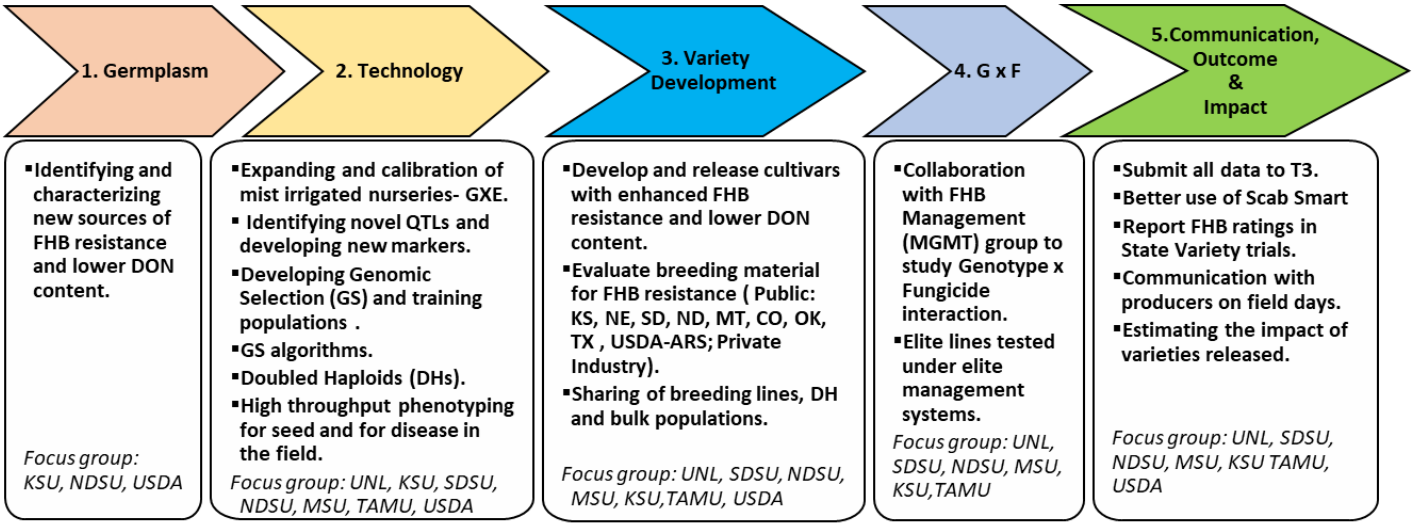

Fig. 1 Flowchart of HWW-CP activities

FY22 Research Priorities derived from Action Plan Goals

The HWW-CP is organized around two of the research areas – Variety Development and Host Resistance (VDHR) and FHB Management (MGMT) as outlined in the USWBSI Action Plan. Three major objectives and associated research activities have been established within this CP. In addition, the HWW-CP works closely with other USWBSI Research Areas (RAs) to support the stated goal of reducing DON levels specified by the EU. Specifically, the HWW-CP works most closely with the MGMT RA.

1. Increase and document the number of varieties with improved FHB resistance and high grain yield and grain quality that are tested in statewide variety trials and available to farmers, to reduce DON in the US grain supply.

- Increase efficiency of coordinated project breeding programs to develop and release FHB resistant varieties. Enhance cooperation and coordination of research among USWBSI supported programs. For example, phenotypic data should be uploaded to the T3 database, and early generation populations would be shared among programs.
- Characterize genotype x fungicide "specific" treatment responses for enhancing FHB resistance and the reduction of DON so information can be given to the MGMT group to help them optimize their program using advanced breeding lines and new varieties. Management practices need to use the most resistant varieties to develop the best systems with the lowest DON concentrations.
- Test and evaluate regional germplasm to include breeding lines from the public (including programs which are not part of the CP, but develop lines which may be grown within the scab prone regions of the CP) and private breeding programs as well as irrigated field nurseries representative of all FHB environments throughout the region.

2. Evaluate and implement new breeding technologies and germplasm to further enhance short-term and long-term improvement of FHB resistance and to efficiently introgress effective resistance genes into breeding germplasm.
   - Create new genetic resources and efficiently introgress resistance genes into breeding germplasm for long-term improvement in FHB resistance. Example: New sources of FHB resistance should be introgressed into winter backgrounds and rapidly tested in mist nurseries to quantify their level of resistance.
   - Enhance selection efficiency through technologies such as genomic selection, marker-assisted selection, doubled haploid production leading to pyramiding of major and minor genes for FHB resistance.
   - Develop high throughput phenotyping technologies to increase selection accuracy for FHB resistance in the field, greenhouse, and seed lab (Disease severity, incidence, *Fusarium* Damaged Kernels (FDK))
3. Enhance communication and coordination to increase the impact of our research beyond the region.
   - Enhance communication and end-user education/outreach relating to resistant varieties and effective management practices and have end-use stakeholder representatives on the HWW-CP.
   - Enhance cooperation with other RAs by having HWW-CP representatives on MGMT and GDER RAs.
   - *Associated coordination activities:*
   - Coordinate efforts among RA groups on FHB management in hybrid wheat and the CRISPR-CAS9 system for improved FHB resistance.