FHB MANAGEMENT (MGMT)

Goal #1: Develop integrated management strategies for FHB and mycotoxins that are robust to conditions experienced in production fields of wheat and barley.

Milestones/Performance Expectations:
- Conduct experiments that evaluate the flexibility of the integrated management strategies in a wide range of production conditions and environments.
  - These experiments should: 1) consider the best available varieties with a range of FHB resistance for all wheat market classes and malting barley, 2) be conducted in multiple states and production regions, and 3) use the best available fungicides and application technology.
  - Specific areas of emphasis will include but are not limited to 1) developing fungicide recommendations that are more robust to conditions experienced in commercial production, and 2) evaluating the efficacy and economics of these strategies using multi-year, multi-location data.

Performance Measures: Summaries of results that will facilitate further evaluation and refinement of management strategies for FHB and mycotoxin in production fields.

Research Needs: Identify the best management methods for FHB/DON or Good Farming Practices (GFP) for FHB/DON management - through integrated management studies. Studies to measure integrated effects should include but are not limited to:
- Validating the integrated management strategies with next generation of wheat and barley varieties in multiple production environments.
- Developing economic analyses of effective integrated management strategies used alone and in combination (i.e. fungicide, biological control, cultivar, residue management).
- Evaluating flexibility of fungicide application timing within the context of the integrated management strategies. This may include but is not limited to evaluating the effectiveness of fungicides applied at heading or after anthesis to address whether slightly earlier or later, on-label applications are still profitable (e.g., when weather delays application)
- Deploying current FHB forecasting models: maintaining or improving weather observations used to make disease predictions; develop or refine methods for delivering timely management information to mobile devices and/or computers.

Outputs:
- Improved forecasting systems that help producers and their advisors evaluate the risk of disease based on environment, cultivar resistance and cropping system.
- FHB/DON management recommendations that are more flexible and robust to conditions experienced in production fields of wheat and barley.
- Document adoption of integrated management for FHB/DON on regional and national basis.

Resources: Multiple collaborative locations distributed across grain classes. A team approach will be used to reflect overlap across traditional research areas and regional/national scope. Teams will be composed of breeders, pathologists, agronomists, economists and other scientists from other disciplines as needed.

Anticipated Impact: Producers will make decisions based on regionally validated science-based information.
Goal #2: Help develop and validate the next generation of management and mitigation tools for FHB and mycotoxin control.

Milestones/Performance Expectations:
- Improved forecasting models of FHB epidemics and DON contamination.
- Test new fungicides and biological controls that have potential application as part of integrated management programs for FHB/DON.
- Investigate new ways to use current technologies that may improve flexibility of integrated management strategies or address specific knowledge gaps for these technologies.
- Acquire new data on harvest and post-harvest grain handling

Performance Measures: Evaluate the potential of new technologies for the management of FHB/DON.

Research Needs:
- Enhance forecasting capabilities for FHB and continued development of DON models for wheat and barley.
- Improve performance of biological control agents for potential use in production fields. Multi-environment testing of new compounds (fungicide or biocontrol) for which preliminary data indicate high levels of effectiveness; confirm FHB/DON control levels at recommended label rates for new fungicides.
- Evaluate application timing of new fungicides or biological control agents that may increase flexibility of integrated management.
- Investigate factors that may compromise the efficacy of fungicide products including quantifying properties such as spray application technologies, rain-fastness and systemic movement within plants.
- Determine if fungicides and biocontrol agents can be used to suppress the DON contamination of wheat and barley straw.
- Harvest and post-harvest grain handling: conduct experiments to identify practices that minimize DON and yield/test weight losses

Outputs:
- Increased accuracy of FHB and DON forecasts
- Improved understanding of factors influencing the efficacy of fungicide and biocontrol agents. New guidelines for post-harvest grain handling are made available

Resources: Multiple collaborative locations distributed across grain classes. A team approach will be used to reflect overlap across traditional research areas and regional/national scope. Teams will be composed of breeders, pathologists, agronomists, and other scientists from other disciplines as needed.

Anticipated Impact: These projects provide the next generation of strategies that will be tested through larger multi-state projects on integrated management. These projects address specific knowledge gaps identified through interaction with wheat and barley producers.
FHB MANAGEMENT (MGMT) (cont.)

Goal #3: Develop a full understanding of the factors influencing infection and toxin accumulation that can be used to develop the next generation of FHB and DON risk assessment measures.

Milestones/Performance Expectations:

- Improved understanding of the: 1) conditions leading to high DON with low/no visual symptoms; 2) relative contributions of in-field vs. external inoculum sources; 3) sensitivity to fungicides in natural populations of the pathogen in different cereal production regions and implications for efficacy of fungicidal control.
- Refined management recommendations based on new information gained through these applied research projects.
- Research results incorporated into the FHB and DON risk forecasting models.

Performance Measures: Information is acquired regarding factors essential for the next generation of FHB and DON risk assessment models, including: the role of post-flowering weather and late/secondary infections, the conditions leading to high DON with low/no visual symptoms, and relative contributions of in-field vs. external inoculum sources.

Research Needs:

- Evaluate the role of post-flowering weather on DON accumulation.
- Determine the potential contribution of late/secondary infections on DON accumulation including the importance of post-flowering inoculum density and the associations among inoculum density, weather, FHB, and DON accumulation.
- Further define the influence of weather and variety on infection efficiency between heading and grain maturity and how the timing of infection influences symptom development and DON accumulation.
- Evaluate the relative contributions of inoculum from in-field debris vs. airborne spores from nearby and distant sources; determine regional variability of the findings; and investigate ways to bring this information into disease forecasting models.
- Assess the sensitivity of *F. graminearum* population to fungicides within different cereal production regions in the U.S. where there has been intensive use of these fungicides. These projects will likely involve laboratory assays for evaluating sensitivity within naturally occurring populations of the fungus.
- Documentation of *F. graminearum* populations that are resistant to fungicides, and investigate the influence of fungicide resistance on product efficacy.

Outputs:

- Models describing associations among inoculum density/dose, inoculation timing, weather and variety on infection, fungal biomass and DON accumulation.
- Improved accuracy of FHB risk assessment models and development DON risk models.
- Regionally appropriate, specific recommendations for corn and small-grain debris management based on full understanding of relative contributions of inoculum from in-field debris vs. nearby and distant sources.
- Established "base line" for sensitivity within the U.S. population of *F. graminearum*.

Resources: A multi-state collaborative effort involving researchers from all major U.S. wheat and barley-growing regions.
Anticipated Impact: Risk forecasting and management recommendations available to growers are more useful because they reflect enhanced understanding of conditions throughout wheat development that affect FHB and DON levels.

Goal #4: Enhance communication and end-user education/outreach for an audience including, but not limited to, producers, agricultural advisors, research community, and grain processors.

Milestones/Performance Expectations:
- Resources and recommendations related to the integrated management of FHB/DON on the USWBSI and ScabSmart web sites.
- Information on FHB resistance of all contemporary varieties readily available to growers in an accurate, user-friendly manner.
- Improved dissemination of FHB information and management techniques through an interdisciplinary approach.

Performance Measures: Best FHB/DON management methods, validated by science-based research, are thoroughly publicized to producers, their advisors, and grain processors.

Research Needs:
- Continue to update and enhance the content of the ScabSmart web site.
- Make commentaries from the FHB forecasting site available USWBSI blog website and sent to users via mobile devices.
- Conduct surveys of growers to assess how they acquire information about the adoption of FHB management techniques, and potential barriers to adoption.
- Develop tools that will help growers assess and understand the value of adopting scab management practices.
- On-farm demonstrations of best available management options for FHB and DON.

Outputs:
- Timely information about scab risk is reaching growers via FHB alerts received by mobile devices.
- Information on FHB management available via national websites and customized for distribution through extension programs in states with a history of severe FHB.
- Results from on farm demonstrations of technologies developed by USWBSI.

Resources: Multiple collaborative locations distributed across grain classes. A team approach will be used to reach across traditional research areas and regional/national scope. Teams will be composed of pathologists, crop consultants, agronomists, breeders, economists and scientists from other disciplines as needed.

Anticipated Impact: Increased adoption of practices by producers and decision makers will result in FHB/DON reduction and lead to substantially reduced frequency of unacceptable DON levels in grain.
FOOD SAFETY AND TOXICOLOGY (FST)

Goal #1: Provide analytical support for DON/trichothecene quantitation for Initiative’s stakeholders.

Milestones/Performance Expectations:
- Maintain awareness of standardized sampling protocols adopted for regional (commercial field) and research testing for DON.
- Maximize coordination and efficiencies amongst labs with an effort towards matching lab utilization to potential impact to provide DON data in a timely manner.
- Provide accurate information and occurrence data regarding DON, ADONs and DON glucoside in a form accessible to the FHB research community

Performance Measure 1.1: Ensure awareness about optimal sampling, grinding and test protocols for mycotoxin analysis.

Research Needs: There is an ongoing need to increase and maintain awareness about optimal sampling and grinding protocols for the grain industry and initiative researchers. This will minimize incorrect data and enhance the effort to reduce DON.

Outputs:
- Session/meeting devoted to sampling /analytical methods will be provided as needed.
- Protocols will be included in USWBI web page
  - Links to protocols will be provided to initiative users.
  - Recommended methods will be updated/modified taking into account FGIS- and EU-recommended protocols.

Resources: Diagnostic lab directors

Anticipated Impact: Clarify stakeholder concerns over test accuracy and repeatability of data. Implementation of standardized sampling and grinding protocols can improve comparability/quality of data.

Performance Measure 1.2: Maximize capacity for the analysis of DON and other trichothecenes.

Research Needs: Initiative members need to maintain test capacity and turnaround time to make progress since the future focus will continue to be less DON.

Outputs:
- Diagnostic labs
  - Survey of initiative users for anticipated needs, and continued evaluation of new technology
  - Workshop(s)/continuing education devoted to sampling /analytical methods at initiative meeting(s) in order to optimize use of lab resources.
  - Coordinate use of labs to maximize USWBSI impact -
    - Solicit bulk discounts for initiative users.
    - Continued evaluation of new technologies.
• Facilitate on-site rapid testing  
  o Suggested rapid assay protocols (e.g. FGIS) will be included in USWBI web page.  
    Links to protocols will be provided to initiative users.

**Resources:** Diagnostic lab directors.

**Anticipated Impact:** Increased testing will enable breeders to achieve goals of DON reduction sooner.

**Performance Measure 1.3:** Diagnostic labs will include measurement of ADONs, other trichothecenes and DON conjugates and matrix-associated toxins in selected surveillance samples.

**Research Needs:** There is concern about change in *Fusarium* genotypes and masked (conjugated) trichothecene forms but there are limited data on occurrence of individual toxins other than DON. FDA survey data is very limited.

**Outputs:** An archive of data on occurrence of different trichothecenes and their relative ratios of these analytes.

**Resources:** Diagnostic lab directors.

**Anticipated Impact:** This data will assist discussion of “shifts” in observed mycotoxin profiles.

**Goal #2:** Provide requisite information on DON/trichothecene safety issues to producers, millers, researchers, risk assessors and regulators.

**Milestones/Performance Expectations:**
- Validate current FDA standard of DON ppm in flour and grain.
- Scientific studies of DON and related trichothecenes that enable extrapolation from animals to humans.
- Presentation of scientific study data at meetings and in high impact journals.
- Utilization of information to produce accessible outreach materials for the public.

**Performance Measure 2.1:** Conduct research on adverse effects of consuming DON and related trichothecenes that allow extrapolation from animals to humans and inform regulators thus enabling science-based risk assessment. Key considerations are groups at high risk and biomarkers of exposure/toxicity.

**Research Needs:** EU has established DON regulatory standards that are much lower than U.S. and there is pressure on CODEX to follow suit. There is continued concern about change in *Fusarium* genotypes and mycotoxin profiles as well as the occurrence of masked forms of DON.
FOOD SAFETY AND TOXICOLOGY (FST) (cont.)

Outputs:
- Publication of research/reviews in high impact journals that inform international risk assessors and regulators.
- Participation in national/international research meetings/forums/committees that inform risk assessors.
- Monitor new Food Safety and Modernization Act (FSMA) requirements and serve as conduit of this information to stakeholders.
- Develop preliminary data for getting grant funding from government or foundational sources.

Resources: Food safety researchers

Anticipated impact: Risk assessors and regulators will use data to make sound scientifically valid decisions that ensure public health but minimize economic effects to wheat and barley industries.

Performance Measure 2.2: Summarize known toxicology information on DON/other trichothecenes, their risks and rationale for regulations.

Research Needs: There is lack of easily comprehensible information on DON and its risks. This creates confusion among producers, millers and Initiative scientists.

Outputs:
- Web pages with questions and answers about DON safety.
- Initiative-originated reviews/position paper(s).

Resources: Scab Web support facility, food safety researchers.

Anticipated Impact: Improved understanding/communication of the importance of the problem among the producers, millers, researchers and government.
GENE DISCOVERY AND ENGINEERING RESISTANCE (GDER)

Goal #1: Gene Discovery and identifying mechanisms of resistance and susceptibility: Increased efficiency of identifying mechanisms of resistance and susceptibility, and detection and validation of host genes for resistance and susceptibility to FHB or DON accumulation.

Milestones/Performance Expectations:

- Utilize high-throughput genomics (e.g., next generation sequencing, metabolomics, functional genomics in model systems, etc.) and molecular plant pathology approaches to identify mechanisms and genes that confer resistance or susceptibility to FHB and DON accumulation.

Performance Measures: Identify mechanisms and genes that exhibit resistance or susceptibility to FHB and DON accumulation.

Research Needs:

- Rapid identification of mechanisms and genes conferring resistance or susceptibility to FHB and DON accumulation.
- Rapid high capacity assays for functional validation of genes for resistance or susceptibility to FHB and DON accumulation.
- Robust centralized wheat and barley transformation systems.
- Develop transformation of elite wheat and barley genotypes.
- Robust centralized transgenic field trials.

Outputs: An understanding of the mechanisms of resistance or susceptibility will be used to isolate and validate specific genes. Validated gene sequences will be used as targets for gene editing, and mining wheat and barley germplasm collections and mutant populations for alleles that confer resistance to FHB and DON accumulation.

Resources:

- USWBSI funding.

Anticipated Impact:

- Increased understanding of mechanisms of resistance and susceptibility, providing novel targets for gene discovery.
- Validated genes conferring resistance or susceptibility to FHB and DON.
- Proof of gene efficacy will provide options for incorporating novel alleles conferring resistance into commercial wheat and barley.

Goal #2: Identify and validate natural variants and mutations for incorporation into breeding programs.

Milestones/Performance Expectations:

- Mine germplasm and mutant collections and identify alleles that increase FHB and DON resistance.
- Edit target genes and promoters to identify alleles that increase FHB and DON resistance.
- Provide germplasm to breeders for incorporating novel resistance into wheat and barley breeding programs.
GENE DISCOVERY AND ENGINEERING RESISTANCE (cont.)

Performance Measure:
- Demonstrate that novel variants increase resistance.
- Introgress novel variants into adapted wheat and barley genotypes for breeders.

Research Needs:
- Robust technology for gene and promoter editing of elite wheat and barley genotypes.
- Sequenced wheat and barley collections for rapid identification of useful variants and mutants.
- More collaboration with breeders to incorporate validated FHB and DON resistance genes into VDHR programs.

Outputs: Germplasm provided to breeders that confer resistance to FHB and/or reduced levels of DON accumulation in wheat and/or barley.

Resources:
- USWBSI funding for research identifying and developing effective solutions for FHB resistance and reduced DON accumulation.
- USWBSI funded centralized transformation facility that can perform gene editing for initiative researchers.

Anticipated Impact:
- Development of novel wheat and barley germplasm with FHB resistance and DON reduction that can be used to complement the breeding effort or as a standalone solution.
PATHOGEN BIOLOGY AND GENETICS (PBG)

Goal #1: Characterize plant-fungal interactions to identify important genes, proteins or small molecules that may be used to develop FHB resistance or reduce DON contamination in barley and wheat.

Milestones/Performance Expectations:
- Characterization of cultivar/strain interactions with respect to colonization, disease spread, and mycotoxin production.
- Determine where and when DON is produced in different cultivars.
- Examine abiotic factors that impact pathogen biology, infection, and mycotoxin accumulation.

Performance Measure: New information will be gained regarding how plant infection occurs and DON accumulates in plants over time and how these processes vary between resistant and susceptible varieties, with consideration of the problem of high-DON, asymptomatic grain.

Research Needs:
- Elucidate the infection process, including late infections, the influence of environment on infection, and the role of trichothecenes in initial infection.
- Understand the interaction between FHB resistance and resistance to DON accumulation
- Identify fungal effectors and plant targets for use in developing FHB resistant cultivars.
- Discover genes for improved resistance, trichothecene reduction, and the production of novel antifungal compounds.
- Develop novel approaches to modulate pathogen genes for disease control and mycotoxin reduction (e.g. blocking DON biosynthesis) and collaborate with GDER for evaluation.
- Elucidate the dynamics of trichothecene production during infection of floral tissue and grain development in both wheat and barley.
- Identify genes under selection in the pathogen that are necessary for survival/fitness/aggressiveness under field conditions.
- Characterize the mechanism of fungal resistance to DON accumulation.
- Characterize functionally significant variation in the pathogen in relation to agronomic practices and environmental conditions.

Outputs:

Short-Term:
- Identify fungal effectors and potential plant targets
- Detailed histology of infection and accumulation of DON over time in different cultivars.
- Standardized techniques for screening, sampling and testing varieties developed based on knowledge of pathogen biology.
- Identification of infection patterns and accumulation of DON.

Long-Term:
- Understanding of the biology of DON accumulation of asymptomatic wheat and the role of DON as a pathogenicity factor in barley.
- Collaboration with VDHR, GDER and MGMT to implement discoveries into control programs.
- Use knowledge of plant resistance to improve disease control.
- Use knowledge of pathogen adaptation to inform agronomic control practices and disease forecasting.
PATHOGEN BIOLOGY AND GENETICS (cont.)

Resources: USWBSI funding for understanding the infection process and mycotoxin accumulation over time.

Anticipated Impact:
- Progress in breeding for resistance is accelerated, as a result of improved understanding of infection processes and the spatial and temporal dynamics of DON production.
- Identify how asymptomatic grain with high DON develops. Collaboration with other RACS to implement control measures based on these findings.
- Understanding of how infection and grain colonization occurs. Both of these will have impacts on breeding for resistance and will also impact development of more effective fungicide applications.
- Novel genetic traits are used in the development of resistant, transgenic plants.
- Fungicide efficacy is enhanced as management is increasingly informed by biological insights into pathogen behavior in planta.
- Novel molecular targets or biochemical strategies are made available for controlling the FHB pathogen.

Goal #2: Discover epiphytic and endophytic microbes and microbial communities useful for development of control for FHB.

Milestones/ Performance Expectations:
- Discovery of microbes or microbial consortia useful for FHB control.
- Identify microbial metabolites or enzymes from microbial communities useful for control of FHB or DON.
- Characterize interactions among microbes useful for control.

Performance Measure: Strategies for disease and mycotoxin management using microbes, microbial communities or microbial products.

Research Needs:
- Characterize the microbiome of wheat and barley; identify how plant-associated microbiomes change with management practices, host genotypes, pathogen genotypes, over time and in response to abiotic factors.
- Discover metabolites useful for reduction of FHB and for improved grain quality.
- Identify microbes or microbial consortia to lower DON and improve grain quality.
- Develop new strategies to reduce sporulation on potential inoculum sources of the pathogen.

Outputs
- Short-Term:
  - Identify microbial community features related to low DON or reduced FHB, or limited inoculum production.
  - Enabled sharing of microbiome data under different conditions and locations available on the web.
PATHOGEN BIOLOGY AND GENETICS (cont.)

Long-Term:
- Identify enzymes or other processes that detoxify DON
- Development of novel strategies for FHB control based on microbiome management.

Resources:
- Funding from USWBSI and competitive funding for wheat and barley phytobiome research.

Anticipated Impact:
- New technologies, based on biologicals, are available for FHB and DON control.
- Microbiome management is used to reduce inoculum production, infection rates, and pathogen secondary spread.
- Detoxifying enzymes or processes are available for use in plant protection and in preserving value of agricultural products.
- Improved grain quality and reduced DON
- Reduced initial infection, increased type I resistance.
VARIETY DEVELOPMENT AND HOST RESISTANCE (VDHR)

Goal #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.

Milestones/Performance Expectations

- Record the number of varieties released annually with improved FHB resistance to monitor the year-to-year change in commercially available, FHB resistant varieties. Where possible, determine the percentage of acreage planted to varieties with improved FHB resistance. This information will be collected annually and used to document the change of commercial availability of wheat and barley varieties with improved FHB resistance to document progress on reducing this disease.
- Document trends in DON level in newly released cultivars relative to susceptible checks using ScabSmart state webpages and variety trial publications and websites.
- Utilize ScabSmart to maintain data and information on FHB reaction (DON, index, severity etc.) and agronomic performance of available wheat varieties and breeding lines that are likely to be released.
- Increase seed in preparation for commercial release of at least three new breeding lines with scab resistance each year in each class of wheat/barley and each region.

Performance Measures:

- Attempt to document a positive trend in acreage planted to cultivars with enhanced FHB resistance and reduced DON levels in delivered grain.
- Continued improvement of the FHB resistance of breeding lines being increased for commercial release and/or varieties released and targeted for FHB prone regions by USWBSI breeders.
- Incorporation of FHB data from state performance trials into ScabSmart.

Research needs:

- ScabSmart results from comprehensive evaluation of breeding lines being increased for release and current commercial cultivars for FHB reaction (DON, index, severity, etc.) and other important traits under appropriate management practices.
- Evaluation of cultivars with improved FHB resistance in best-management practices for control of DON in conjunction with MGMT.
- Incorporation of DON and FDK data into all regional nursery and statewide variety trial datasets for streamlined data dissemination.

Outputs:

- Grower access to comprehensive information on FHB resistance of adapted cultivars for so they can fully incorporate FHB resistance in their variety selection.
- Information on best management practices involving varieties with enhanced FHB resistance
- Documentation of impact of VDHR and associated USWBSI programs on DON in grain channels.
VARIETY DEVELOPMENT AND HOST RESISTANCE (cont.)

Resources:
- Multi-location regional nurseries and existing trials of commercial cultivars.
- Database and website management.
- Mechanism for funding large regional projects for multiple years with MGMT and other programs.

Anticipated Impacts:
- With access to an improved variety selection tool, growers will select varieties with improved FHB resistance and therefore acreage of such varieties will increase.
- A package of Best Management Practices involving new varieties with FHB resistance can be promoted and adapted by usage.
- A more stable supply of high quality wheat and barley with reduced DON for end-users.

Goal #2: Increase efficiency of the CPs’ funded projects to develop and release FHB resistant varieties and germplasm.

Milestones/Performance Expectations
- Continue to improve the FHB resistance of entries submitted to the USWBSI sponsored FHB nurseries, in other regional performance nurseries, and among breeding lines that are in preparation for release.
- Continue the collaboration among USWBSI sponsored projects.
- Facilitate sharing of information and genetic resources among breeding programs; will include information from USWBSI breeders on shared databases:
  1) Crosses made to improve FHB resistance.
  2) DHs made to speed up release of FHB resistant varieties.
  3) Speed breeding applications and other efficiency-related usage on FHB-related breeding populations.
  4) Performance data from non-USWBSI funded trials (yield, quality, resistance to other diseases etc.) on lines with improved FHB resistance.
  5) Populations and plans for MAS.
  6) Sources of FHB resistance.
  7) QTL for FHB resistance present in advanced lines, and release status of lines with improved FHB resistance.
  8) Increased FHB resistance haplotyping of newly discovered FHB QTL by Genotyping Labs.
  9) More rapid release of improved cultivars with FHB resistance so growers have better choices.

Performance Measures:
- FHB related data is shared among all USWBSI sponsored breeders.
- Improved FHB resistance (DON, index, severity, etc.) of entries submitted to the USWBSI sponsored FHB nurseries and other regional nurseries.
- Number of breeding lines from USWBSI sponsored breeding programs with enhanced FHB resistance that are being increased for commercial release and/or have been released.
VARiETY DEVELOPMENT AND HOST RESISTANCE (cont.)

Research Needs:
- Increased capacity for field testing in mist-irrigated inoculated nurseries.
- Increased capacity for DON testing labs.
- Increased capacity for MAS including backcrossing and haplotyping as appropriate.
- Sharing of information and breeding populations developed with UWBSI support that are relevant to FHB improvement to enhance individual programs and germplasm exchange.
- Increased resources for genomic selection, including development of an inexpensive, rapid, and flexible genotyping platform.
- Increased resources for high throughput phenotyping.
- Marker data uploaded to T3 by genotyping labs.

Outputs: More frequent release of FHB resistant varieties with high yield and other desirable attributes that insure widespread adoption by producers and end-users.

Resources:
- Genotyping labs
- Mist-irrigated inoculated nurseries
- DON testing labs
- Infrastructure of university sponsored breeding programs.
- Mechanism for funding large regional projects for multiple years.
- Needed resource – Shared/Collaborative Doubled Haploid facilities.

Anticipated Impacts: Every grower in an FHB affected region will have an expanded and enhanced array of commercially competitive varieties with adequate FHB tolerance to select for growing on their farm. New varieties with improved FHB resistance will be released and available more frequently than they are now.

Goal #3: Evaluate and implement new breeding technologies and develop germplasm to further enhance short term and long term improvement of FHB resistance, and to efficiently introgress effective resistance genes into breeding germplasm.

Milestones/Performance Expectations:
- Identification of basic research needs of the breeding programs in each region and class of wheat and barley. Coordinate activities to address agreed upon priorities.
- Documenting the progress of the mapping and introgression of resistance from all sources. Annually, breeders/geneticists in each market class contribute data on the progress of the introgression.
- Identification and incorporation of different types of FHB resistance into germplasm lines and varieties.
- Development and implementation of improved breeding and selection methods for all FHB resistance sources and describing any associated markers.
- Implementation of genomic selection in breeding programs as appropriate to increase efficiency of selection and increase rate of genetic gain.
VARIETY DEVELOPMENT AND HOST RESISTANCE (cont.)

- Development of advanced phenotyping approaches to enable breeders to evaluate FHB resistance more accurately and/or in higher-throughput.
- Implementation of speed breeding technologies.

**Performance Measures:**
- Establishment of priorities for basic research.
- Establish cooperative teams of researchers to undertake the strategic testing of putative sources of resistance, all proposed mapping, and subsequent introgression.
- Establishment of research teams and initiation and completion of research.
- Identification of novel QTL and markers systems for the QTL.
- Validation of discovered genes.
- introgression of discovered genes and QTL through phenotypic and MAS.
- Performance of breeding lines with new sources of resistance in their pedigree.
- Validation of genomic selection prediction models on new breeding lines.
- Use of genomic predictions to select parents that produce superior crosses.
- Updated breeding methods based on current technology including double haploids and genomic selection.
- Identification of new, high-throughput phenotyping approaches that reduce the time required to accurately evaluate *Fusarium*-damaged kernels and other FHB-related traits.

**Research Needs:**
- Improved technology to establish novelty of sources of FHB resistance and inventory the frequency of resistance alleles in current breeding programs.
- Coordination to develop teams to conduct basic research and initiate introgressions.
- Investigate and elucidate the genetic basis of different types of FHB resistance gene expression.
- Identify novel mechanisms of FHB resistance and ways to screen for them.
- Sharing of pre-breeding populations, germplasm and information for MAS.
- Enhanced cooperative phenotyping of mapping populations (more environments in fewer years).
- Use of molecular markers to pyramid resistance genes in suitable germplasm.
- Investigation of integrated methods to improve FHB resistance to commercially needed levels.
- Enhanced technology for accurate testing of DON content.
- Uses of new genomic technologies to efficiently map resistance QTL and for use in development of adapted germplasm and cultivars.
- Development of breeder friendly tools for use of genome-wide markers in FHB resistance breeding.

**Outputs:** Identification of novel genes for FHB resistance, development of improved germplasm with diverse resistance, and development of improved methods for improving FHB resistance.

**Resources:**
- The capacity for assessing potential sources of FHB/DON resistance.
- Shared information on resistance sources, breeding population development, marker haplotypes, and mapping and introgression efforts.
- Regional or multi-regional coordination meetings / regional grants to facilitate establishment of priorities and collaboration.
- Mechanism for funding large regional projects for multiple years.
- High-throughput genotyping labs.
- Labs for DON analysis.
- Misted nurseries for FHB assessments.
- Doubled haploid production and coordinated distribution.
- T3 database of data management.

**Anticipated Impacts:**
- Development of improved germplasm and breeding methodology (MAS, genomic and other selection schemes) that will enhance the efficiency of breeding for FHB resistance.
- Improved understanding of the genetic basis of the mechanisms of FHB resistance.
- More collaborative, rapid, and efficient execution of basic research and incorporation of the results into variety development programs.