Wheat Disease: Integrated Management, Diagnostics and Germplasm Evaluation

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Principal Investigators:

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This proposal represents work of the wheat pathology group at SDSU and includes both collaborative and individual projects. It includes research & outreach (extension) objectives to address diseases that impact wheat yields, production and the sustainability of South Dakota wheat producers. It allows the scientists to focus their expertise on individual problems in their major areas of emphasis, and also to pool their expertise for collaboration on certain wheat disease and management issues.

Research in this proposal includes:

- Characterization of germplasm in the SDSU Wheat Breeding Programs in terms of resistance/susceptibility to multiple important diseases including viruses, rusts, and fungal blights;
- Development and evaluation of disease management products and systems against major diseases in the state; Investigation of the bacterial leaf diseases that have emerged as important pathogens; and
- Development and evaluation of multiple diagnostic tools to allow growers to identify problems earlier and more accurately.

Outreach components include:

- Delivery of high-quality disease management guidelines and variety information to producers and agronomists;
- Publication of "best management practices" including cropping system approaches to plant disease management; and
- Making available critical diagnostic services through the SDSU Plant Diagnostic Clinic.

Key Deliverables for South Dakota Wheat Growers

- HRSW, HWW germplasm characterized for multiple disease resistances
- Evaluation of wheat lines with WSMV
- Defined High Plains virus (HPV), Triticum mosaic virus (TriMV), and Brome mosaic virus (BMV) diagnostics
- Wheat Streak Mosaic Virus, Barley Yellow Dwarf Virus, and HPV disease profiles
- Better understanding of Bacterial leaf streak including genetic resistance
- Fungicide use and product guidelines
- Introduction of new lines/cultivars with improved disease resistance
- Best Management Practices for wheat health
- Seed treatment use/guidelines
- Statewide diagnostic services for wheat diseases
- Improved understanding of "plant health" and fungicides in the wheat system.

Objectives:
The following objectives encompass research, outreach, and service activities of several wheat disease related programs in the SDSU Plant Science Department. They are organized by Joint Objectives, Extension Plant Pathology (Osborne), Virology (Langham), and Small Grains Pathology (Stein).

1. *Development of high quality disease diagnostic tools for wheat* (collaboration w/ SDSU Plant Diagnostic Clinic, C. Tande).
   - **Justification/Rationale:** The first, most critical step in plant disease management is diagnosis or identification of disease threats to production. Disease problems in South Dakota arise from many different pathogen groups including fungi, viruses, bacteria, nematodes, and even from abiotic stresses such as drought and cold. Each of these distinct causal agents or stresses has differing management approaches that can be effective in their control or mitigation but when applied incorrectly or against different stressors, may be ineffective or damaging. Disease diagnostics serves two primary roles for growers in South Dakota: 1) identification of in-season issues and problems at-hand, to allow for management, and 2) post-mortem diagnoses to identify potential limitations that were experienced prior to sampling, thus allowing growers and managers to learn from past experiences and alter management for future activities.
   - **Approach:** New techniques are emerging that can be tested against South Dakota wheat situations to determine their suitability for use in the diagnostic clinic, on-farm, and in the hands of agricultural professionals statewide. Tools including Polymerase Chain Reaction (PCR), Real-time PCR, Enzyme-Linked ImmunoSorbent Assay (ELISA), and other new technologies will be investigated on customer-submitted samples through the SDSU Plant Diagnostic Clinic. Additional specific approaches are outlined in the Virology section below.

2. *Development and publication of a wheat disease/pest identification and management guide to include "best management practices."*
   - **Justification/Rationale:** Growers and wheat industry members have demanded a high-quality guide to aid in describing, identifying, and providing guidelines for management of major wheat diseases and pests. Similar guides currently exist for other regions of the country or for other unrelated crops; however, the northern hard wheat region is unique in its pathogen profiles and stressors that affect the crop each and every year.
   - **Approach:** The wheat pathology group, along with collaborators in entomology and weed science, seeks to assemble high-quality images and information into a concise print, on-line, and electronic "app" publication. Individual diseases, disorders, and pests will be profiled along with their key "best management" guidelines.

Extension Plant Pathology Objectives:

1. *Development and evaluation of integrated and chemical disease management strategies.*
   - **Justification/Rationale:** Fungicide management remains the primary response to epidemics (outbreaks) of fungal diseases such as scab, cereal rusts, and leaf diseases when varietal resistance or other cultural methods do not provide satisfactory control. For some diseases such as scab, genetic resistance is generally considered inadequate in

adapted varieties to manage epidemic levels. Other diseases such as stem rust, particularly the highly virulent "Ug99" race, may affect some or all of the adapted varieties in South Dakota due to low frequency of host resistance leaving producers and crop managers to rely on timely application of efficacious fungicides. Furthermore, endemic (routinely encountered) pathogens such as *Fusarium* spp. and *Bipolaris* spp., present in many of our SD soils, threaten to infect the wheat crop before it even emerges. Protectant seed treatments are often relied on to provide protection to seed and seedlings when they are most vulnerable to attack by such opportunistic pathogens.

In addition to the above-mentioned use of fungicides, producers are facing increased pressure from retail and marketing sources to increase fungicide usage in SD wheat crops. In recent years, fungicide usage in SD has skyrocketed. Acreage treated with fungicides increased from just over 40,000 acres to around 800,000 acres from 2002 to 2007, and perhaps double that figure by 2010 (NASS 2007). The number of farms using fungicides experienced a similar increase during this same period; from 176 to over 1600 (NASS 2007). This means that more farmers have adopted the technology and are using it on more acres than ever before. These figures likely under-estimate the impact from 2008, when a major spike in commodity prices spearheaded increased levels of inputs in much of the state

- **Approach:** The latest or even experimental products and formulations will be tested in integrated management regimens for efficacy in controlling or reducing many soilborne and foliar wheat diseases. Seed treatment products and foliar-applied fungicides will be evaluated at several locations across the state in replicated plots. Disease severity, yield, grain quality, and mycotoxin contamination will be evaluated along with an assessment of economic costs and benefits.

2. *Characterization of bacterial leaf diseases that have re-emerged in South Dakota*
   Justification/Approach combined with #3 below.

3. *Investigation and mapping of genetic resistance to bacterial leaf streak/black chaff*
   (collaboration with Dr. K. Glover, Dr. W. Berzonsky, and Dr. J. Gonzales)
   - **Justification/Rationale:** Bacterial diseases have become serious production concerns in South Dakota over the past three to four years due in large part to the variable and often unfavorable weather conditions. Bacterial leaf streak caused by *Xanthomonas translucens*, and bacterial leaf blight caused by *Pseudomonas syringae*, were thought to be the primary problems. In 2008, 2009 and 2010, we believe significant production losses were incurred as a result of these diseases either because of reduction in grain fill period due to damaged flag leaves, or direct yield losses because of reduced health and vigor throughout the season. Advanced germplasm lines have been discarded near the point of variety release primarily due to impact by these diseases in the latest stages of evaluation. In order to quantify losses, however, some background work on these diseases must be completed. Furthermore, breeders and the wheat seed industry are asking for information on disease reaction from commonly grown varieties, as well as, disease resistance information as these problems are difficult to manage using chemical or other applied techniques.
   - **Approach:** We wish to develop an efficient and reliable field screen for wheat bacterial diseases, especially bacterial leaf streak. This entails several steps including:

- Developing a characterized pathogen library for use in screening germplasm.
- Developing reliable and efficient inoculation techniques
- Testing and validating field screening techniques for spring and winter wheats
- Testing field data against greenhouse or lab methods.

The purpose in developing this field screening method is to properly evaluate and characterize the disease reaction in wheat varieties and elite germplasm to common troublesome bacterial pathogens. We are currently undertaking a family-based mapping program for a set of spring wheat lines currently in development. We believe that we can identify QTL's associated with the resistance to bacterial leaf streak as well as bacterial blight using this approach.

Virology Objectives

1. *Evaluating winter wheat lines in the AYP-CPT nurseries for their performance when infected with wheat streak mosaic virus (WSMV*) (Collaborator: Dr. W. Berzonsky, Winter Wheat Breeder).
   - **Justification/Rationale:** *Wheat streak mosaic virus* (WSMV) (Family: *Potyviridae*; Genus: *Tritimovirus*) causes the most economically important viral disease affecting winter wheat in South Dakota. Studies have shown that winter wheat losses due to WSMV range from 2.5-5 million bushels annually with greater losses than this occurring in epidemic years. Control of viral diseases depends on the development of preventative disease management strategies. The most effective and economical of these strategies is the development and deployment of host plant resistance or tolerance. Efforts to develop winter wheat cultivars with higher levels of disease resistance and tolerance require the evaluation of plant materials to determine their susceptibility or resistance. Collaborative efforts of the plant virology and winter wheat breeding projects have resulted in recently released varieties and breeding lines with improved tolerance. However, the development of wheat cultivars requires annual evaluation. Without this process, susceptible materials will not be eliminated from the breeding program, and previous advances in resistance and tolerance will be lost.
   - **Approach:** There are two basic portions of this objective:
     - Completing data collection and evaluation for 2010-2011 WSMV Winter Wheat Nursery—Inoculated in Fall 2010, this nursery will need to be evaluated for disease severity, stunting, maturity delays, yield losses, and losses in test weight during Spring and Summer 2011.
     - Initiating and inoculating the 2011-2012 WSMV Winter Wheat Nursery—During Summer 2011, WSMV infected plants will be grown and frozen for making inoculum. The nursery will be planted (Winter Wheat Breeding) and inoculated (Virology) during Fall 2011.
   - **Methods:** Winter wheat lines will be planted in four row plots in three replications, and half the plot will be inoculated using a high-pressure (80 psi) air compressor. Plants will be inoculated with sap extract [1:10 infected plant tissue and potassium phosphate buffer (KPB), pH 7.0] and 1 percent of silicon carbide powder (600 mesh) added. Plants will be rated through the spring for symptom development and severity. Data will be collected on the agronomic characters of each plot half to determine the effects of WSMV. All loss figures are calculated using the difference between the control and inoculated halves of the split plot in order to reduce the variability as much as possible.

2. *Define diagnostic standard to assist in clarifying the diagnosis of High Plains virus (HPV), Triticum mosaic virus (TriMV), and Brome mosaic virus (BMV) in wheat.*
    - **Justification/Rationale:** HPV, TriMV, and BMV are three unrelated viruses that infect wheat in the Great Plains. However, serological protocols utilized for the identification of these three viruses in wheat have come into question due to reports of cross reactions, overlapping responses, and poor reactions to antisera. This problem is occurring on a regional level, but here, in South Dakota, it has led to confusion in diagnostics and in defining which viruses are active in the state. An additional problem in South Dakota is that the high levels of WSMV infection limit the ability to detect these other viruses. Thus, development of protocols for improved detection of these viruses (HPV, TriMV, and BMV) is needed for diagnostics and for monitoring of these viruses in South Dakota.
    - **Approach:** This project is a two-year study. During year-one, samples of these viruses will be analyzed through differing ELISA and Western blot protocols and compared to determine the actual detection failure rate of the assays. Year-two will focus on improving the protocols of assays with the lowest failure rates or developing new assays based on these.
    - **Methods:** Samples from known and suspected sources of these viruses will be obtained. These will be analyzed in duplicated paired comparisons of assays currently in use. ELISA and Western blot will both be compared as they are the most commonly utilized detection systems. Rates of detection, cross reaction, and failure to detect will be compared. Antisera and kits from different sources will also be compared. Methods for the second year will be determined by year one results.

3. *Advising wheat virus testing and serving as expert consultant for Plant Diagnostic Clinic.*
    - **Justification/Rationale:** The Plant Disease Clinic receives wheat samples for viral testing that require viral expertise to diagnosis, select the required assays, or more extensive and time-consuming procedures than can be done in a diagnostic clinic.
    - **Approach:** This interaction allows the development of better diagnostics and allows addressing of newly developing problems. It also enables cooperative development of viral educational materials.
    - **Methods:** Methods will vary with the disease situation

Small Grains Pathology Objectives

1. *Screen wheat cultivars, germplasm, and other sources for resistance/susceptibility to multiple fungal diseases.*
    - **Justification/Rationale**: To best manage plant diseases, it is first necessary to understand the level of susceptibility in the available germplasm. This is important for both applied crop management and the development of new varieties. The South Dakota wheat crop is particularly unique in this manner because of the occurrence of both spring and winter wheat, often under no-till, which results in green-bridge and other scenarios that complicate disease management. For example, a single wheat field in the state might be infected with leaf rust, stripe rust, tan spot, Septoria leaf blight, common root rot, and Fusarium head blight. By understanding how germplasm will react to these diseases, growers and breeders can make informed management and advancement decisions.
    - **Approach:** Spring and winter wheat nurseries consisting of varieties and breeding materials will be evaluated for multiple diseases during the growing season. These may

include nurseries in other states (e.g. Castroville, TX, rust nursery), and will typically be performed in collaboration with the breeding projects. Disease severity for the pathogen(s) present on select lines will be noted and isolates collected for testing and further use. Rust samples will be sent to the USDA-ARS Cereal Disease Laboratory (St. Paul, MN) for race typing. Greenhouse studies examining specific diseases will also be conducted during the fall and winter, with an emphasis on the rusts and tan spot.

2. *Participate in the generation of adapted germplasm with novel sources of resistance that can be used by the SDSU wheat breeders in their varietal improvement efforts.*
   - **Justification/Rationale**: Breeding for resistance or tolerance to plant pathogens is one of the most effective ways to reduce crop losses due to disease. Unfortunately plant pathogens can move to a new region and/or adapt to the resistance traits deployed in modern wheat varieties. This results in the (re-)emergence of pathogens, which can result in significant losses from growers. For example, wheat leaf rust is constantly changing and adapting to the Lr genes present in the commonly grown varieties that were once resistant. Other pathogens are never fully controlled by genetic resistance and therefore a need exists to combine multiple sources of resistance into one variety. For example, the 'Sumai3' FHB resistance traits have had a very positive impact in the region's spring wheat crop, however losses can still occur under intensive epidemic pressures and varieties with even higher levels of resistance are required.
   - **Approach:** This project is essentially a pre-breeding effort where wheat lines with novel and under-utilized sources of genetic resistance for different diseases will be crossed with regionally adapted germplasm. This material will then be assessed for disease resistance in the greenhouse and/or field, and may be back-crossed or top-crossed further with adapted lines. Following selection, lines will eventually feed into the spring and winter wheat breeding programs. Target traits will include: resistance to Ug99 stem rust, wheat leaf rust, FHB, common root rot, and sawfly (solid-stem trait).

Deliverables

Joint Objectives Deliverables

- Wheat disease "best management practices (BMP)" will be developed and published for delivery to growers and crop managers, with subsequent incorporation into a wheat BMP guide produced by SD Cooperative Extension.
- Diagnostic services and improved diagnostic tools for growers statewide.
- Provide disease susceptibility information to Crop Performance Testing project for future varietal recommendation publications.

Extension Plant Pathology Deliverables

- Information on investigation of "plant health" and fungicides relative to wheat in SD.
- Improved understanding of bacterial diseases on wheat in South Dakota.
- Disease management efficacy results will be published in print and online each year at: http://www.sdstate.edu/ps/extension/plant-path/.
- SDSU CES Publications FS917 ("Managing Crop Diseases with Fungicides"), FS949 ("Managing crop disease with seed treatments"), FS952 (South Dakota Wheat Fungicide Recommendations), and FS965 ("Wheat Seed Treatments for South Dakota") will be updated as appropriate using the information generated.

- Information will be presented at >20 field days, crop clinics, and grower meetings across the state.

Virology Deliverables

- Rating and harvest of the 2011 WSMV Winter Wheat Nursery including yield losses, test weight losses, stunting and delay in maturity.
- Planting and inoculation of the 2012 WSMV Winter Wheat Nursery.
- Current information on the performance of wheat lines when inoculated with WSMV.
- WSMV, BYDV, and HPV disease profiles for upcoming publication.
- Improved diagnostics for HPV, TriMV, and BMV.
- Poster exhibitions at regional or national plant pathology meetings.
- Publication in appropriate scientific outlets.
- Fact sheets and other producer targeted information sources on wheat viruses as appropriate.

Small Grains Pathology Deliverables

- Improved understanding of fungal disease resistance/susceptibility in SD spring and winter wheat germplasm. This will include both cultivated varieties and germplasm.
- Development of wheat lines and breeding populations with multiple (stacked) and/or novel genetic sources of resistance. These will be fed into the breeding programs and/or used for mapping efforts (future collaborative work).