National Workshop on New Virulences in Wheat and Barley Stem Rust

March 5-6, 2008, Baltimore Maryland

Workshop Summary

In 1999, high severities of stem rust caused by *Puccinia graminis* f. sp. *tritici*, were observed on previously stem rust resistant wheat lines in Uganda. This new race, labeled "Pgt-Ug99", was subsequently shown to attack the stem rust resistance genes Sr31 and Sr38, which were previously effective resistance genes. Since then, similar virulences have been confirmed in Kenya, Ethiopia, Yemen, and Iran, indicating that this new race, or its derivatives, has spread within North Africa and into the Middle East.

In response to the recent movement of Ug99 into the Middle East and the threat of eventual introduction into North America, three USDA agencies organized a National Workshop on New Virulences in Wheat and Barley Stem Rust, facilitated by the American Phytopathological Society (APS) in March 2008 at Baltimore Maryland. The cooperating USDA agencies include the Cooperative State Research, Education and Extension Service (CSREES), the Animal and Plant Health Inspection Service (APHIS), and the Agricultural Research Service (ARS). The purpose and goals of the workshop are to obtain input from organizations concerned with preparations for the possible introduction of new races of wheat stem rust into North America. Over 45 scientists and stakeholders with knowledge in critical fields of wheat germplasm resources, wheat genetics, wheat and pathogen genomics, fungal pathogen biology, disease management, and predictive modeling participated in the workshop, reviewed the current status of protective measures for stem rust in the United States, and reached agreement to develop a strategic action plan for stem rust research and response.

In addition to experts from the three USDA agencies, participants of the workshop included representatives from land grant universities, the National Wheat Improvement Committee, U.S. Wheat Associates, the North American Grain Export Association, the American Malting Barley Association, the National Plant Board, Borlaug Global Rust Initiative, and the North American Plant Protection Organization. The anticipated outcome of the workshop is a National Action Plan for the Coordination and Integration of Wheat Stem Rust Response, which outlines research goals and objectives, outreach and communication, guidance for safe movement of germplasm, surveillance/monitoring and detection, forecasting and disease management, and genetic resources protection strategies. The Action Plan will describe roles and responsibilities of Federal, state, university, and industry cooperators from a national and international perspective and will outline significant milestones to measure progress toward mitigation of this potentially devastating disease.

Participants of the workshop discussed actionable measures in six strategic areas: 1) a national communication network for stem rust surveillance and monitoring; 2) an effective diagnostic system to implement control measures in a timely manner; 3) the genetic basis for pathogen virulence and host resistance to stem rust; 4) development of high yielding germplasm with field resistance to stem rust; 5) an improved understanding of pathogen biology and epidemiology, and 6) a multi-tactical and economical stem rust management system. This Action Plan will further define actions that will be taken to solve the problem, assigns accountability for the work to be accomplished, and will provide a mechanism for peer review and assessment of progress to achieving the stated goals.

Workshop participants provided a summary of the current status of stem rust research and new initiatives. USDA-ARS has evaluated U.S. wheat and barley germplasm in Kenya and have confirmed that most U.S. wheat varieties are susceptible to Ug99. The ARS Cereal Disease Laboratory conducts annual surveys of stem rust through the major wheat growing areas of the United States to monitor endemic rust development and to collect samples to identify potential new races. CSREES supports an aerobiological modeling project which could be employed to assess potential pathways and timing of entry and a work group to define appropriate monitoring practices, both through the Critical Issues and Emerging Needs competitive grants program. ARS scientists have developed a set of SSR markers which indicate that the Ug99 race cluster is distinct from all known North American races. The USDA Office of Pest Management Policy and the Environment Protection Agency provided a list of registered and recommended fungicides for rust control and strategies for assessing chemical control needs. APHIS has engaged the regulatory agencies of Canada and Mexico, particularly to enhance preparedness for North America.

Summary of Workshop Sessions

Current Status of Stem Rust Relevant to N. America

Current Status:

Few U.S. wheat and barley varieties have resistance to the new virulent African stem rust race Ug99. As summarized in the FY09 Research Priorities of the National Wheat and Barley Improvement Committees, National Association of Wheat Growers, and American Malting Barley Association.

USDA-ARS led evaluation of U.S. wheat and barley germplasm in Kenya have confirmed that nearly all varieties in the U.S. spring wheat region (MN, SD, ND,

and MT) are susceptible, placing 16 million acres and 500 million bushes of production at critical risk. Varieties grown on up to half of the 30 million acres that comprise the U.S. hard winter wheat region (TX, OK, CO, KS, NE, and SD) are highly susceptible. In 2006 and 2007, two variants of Ug99 were identified in Kenya, which are virulent on the resistance genes Sr24 and Sr36. As a result, over 75% of U.S. winter wheat acreage is now considered vulnerable. All commercial barley varieties grown in the U.S. are highly susceptible to Ug99. This race threatens 4.2 million acres of barley planted throughout the Great Plains.

Recommended Action: An aggressive, coordinated research effort is needed to reduce critical vulnerability of U.S. cereal production to stem rust and other rust diseases.

Urgent Need and Expected Outcome: Identify and introduce new germplasm, genes and varieties with improved and sustainable rust resistance.

Critical Research Needs:

- Rust pathology and assessment
- Germplasm enhancement, gene discovery, development of molecular markers
- Regional variety development, evaluation, and implementation
- International exchange, coordination, evaluation, and pathogen monitoring

Surveillance and Monitoring Networks

Current Status:

Surveillance: The USDA-ARS Cereal Disease Laboratory, St. Paul, conducts annual surveys of wheat, oat, barley, and rye stem rust. Scientists make survey trips through representative areas of the Great Plains, the Midwestern states and southeastern states to monitor rust development in the small grain crops and to collect rust samples. Additional samples are submitted by university scientists from producer fields and other sites in their respective states. In March 2008, USDA partnered with university and industry disease experts to organize differential trap plots for wheat stem rust in the U.S. for the upcoming growing season. Differential plots were planted along known wheat rust pathways throughout the U.S. from Texas to Minnesota. These plots will be monitored by Cereal Disease Laboratory scientists through their annual rust survey trips along with observation from regional plant breeders and other disease experts. U.S. wheat and barley breeders are also carefully monitoring their nursery plots for wheat stem rust. The Cereal Disease Laboratory will issue Cereal Rust Reports every two weeks throughout the wheat and barley growing season as well as

send reports by email and mail to cooperators. Cereal rust alerts and bulletins are posted at: http://www.ars.usda.gov/Main/docs.htm?docid=9757

Wheat stem rust can be readily detected by visible sporulating lesions on the stems, leaves and awns of infected wheat plants that are easily recognizable by trained cereal breeders or pathologists. Ug99 can be detected by planting "trap" plots with known wheat differential varieties. Observation of a specific combination of infection responses on differential wheat varieties will indicate Ug99 infection. Putative stem rust samples can be sent to the Cereal Disease Laboratory for race verification.

A workshop is planned to develop a national protocol for enhanced surveillance and to deploy a pilot program to evaluate the surveillance protocols using leaf rust and stripe rust as model systems. This workshop will be hosted by the Cereal Disease Laboratory and is being coordinated by Dr Erick DeWolf of Kansas State University. The workshop will be held on July 30 and 31.

Expected workshop outcomes:

- Identify and survey epidemiologically important regions
- Developing protocols for surveillance of research plots and commercial fields
  - Establish priorities for sampling
  - Balance detection with capacity for ID
- Enhanced communication among cooperators
  - Establish new channels were needed
  - Develop recommendations for consistent reporting and synthesis of observations
- Develop strategies for documenting impacts of surveillance on disease management

Predictive Modeling: In FY08, USDA-CSREES Critical Issues Program is funding a project for aerobiological modeling of Ug99 for assessing potential pathways of introduction and timing of incursion, and to support rust surveillance.

Objectives:

- To construct risk analyses of aerial pathways and timing of TTKS urediniospore incursions from potential off-shore Western Hemisphere source regions into North American wheat production areas.
- To support the expanding efforts of Extension pathologists to survey for rusts in U.S. wheat production regions.

Molecular Diagnostics/DNA Detection:

Current status:

Sequencing of wheat stem rust pathogen: The draft assembly and annotation of *Puccinia graminis* f.sp. *tritici* genome has been completed. The project was led by Les Szabo, ARS, St. Paul with the Broad Institute. Ug99 (Kenya 2004 isolate, TTKSK has been sequenced and is currently being assembled. Sequencing of additional isolates is being planned.

Development of DNA detection markers: A set of SSR markers has been developed. Results using markers reveal that the Ug99 race cluster is distinct from all North American isolates tested (54) as well as limited worldwide collection (36).

Priorities and challenges:

- Diagnostic target is at the level or race genetic lineage rather than at the species level.
- Current collection of isolates from North Africa and surrounding regions is limited.
- What level of detection is sufficient?
- How can field screening provide for the most rapid response?
- Who will do the testing and what technologies will be used?

Management Decision Criteria

Fungicide Use and Efficiency

Current status: Development of resistant cultivars is the most effective means of control. Fungicides are the second line of defense, because of added expense and possible negative effects. NASS statistics (2006) indicate that 3% of U.S. wheat and barley acreage is treated with fungicides. The treatment percentage for South Dakota acreage is 23% and Michigan is 30%. But most of this use, both nationally and locally, is for fungal diseases other than rust, such as scab (*Fusarium* spp.).

Recommended fungicides for rust control for wheat (* IPM Center Crop Profiles):

- Propiconazole – IL, KS, KY, MN,ND, OK, OR, SD, TN, UT
- Mancozeb – KS, KY, MN, ND, OK, SC
- Azoxystrobin – IL, KY, OK, SD
- Pyraclostrobin – OK, UT
- Azoxystrobin + Propiconazole – OK, UT
- Propiconazole + Trifloxystrobin – KS, OK

Recommended fungicides for rust control for barley (*IPM Center Crop Profiles):

- Propiconazole – CA, CO, ID, KS, ND, WA
- Mancozeb – CO, ND
- Azoxystrobin – CO, KS
- Pyraclostrobin – CO
- Propiconazole + Trifloxystrobin – KS

Chemical Registrations/Availability

Environmental Protection Agency (EPA) registration of chemicals for wheat and barley:

- New active ingredients and new uses are reviewed on a set schedule by EPA
- New ingredients given 24 months review time
- New uses (of an "old" pesticide) given 15 months
- Work plan posted @ (http://www.epa.gov/opprd001/workplan/index.htm

Emergency exemptions

- Critical and urgent pest management problems can be addressed via section 18 exemption process
- Public agencies – state and federal partners can seek emergency exemptions
- Permits time-limited use of pesticide (1-year under specific exemptions and 3-years under quarantine exemptions), if EPA agrees there is emergency situation and risk assessments support use

Planning for possible emergency

- Regional and national approaches gain efficiencies for EPA
- Multi-state emergency exemption programs possible
- For soybean rust - MN and SD experts consolidated pest management requirements for benefit of everyone

Key next steps and suggestions

- Keep lines of communication with EPA open
- Look for opportunities for "Fast and Easy" short term approaches
- Consider obtaining "Blanket" Fixes" for key crops by working toward crop group tolerances ("Group 15: Cereal Grains Group")
- Approach pre-harvest interval via plant growth stage versus a set number of days

Cereal Rust Recovery Plan:

Current Status: The USDA Office of Pest Management Policy working in support of the National Plant Disease Recovery System (NPDRS) has developed a Recovery Plan for Wheat Rusts including Ug99. The plan is posted at: http://www.ars.usda.gov/research/docs.htm?docid=14271
The American Phytopathological Society (APS) helped direct and review the Recovery Plan, which was written by university and USDA scientists (Aug. 2006) with rust expertise.

Priorities and Needs Identified in Cereal Rust Recovery Plan:

- Focused national efforts on management of rust diseases
- Research on new stem rust races in Africa
- Search for new durable resistance genes
- Determine genetic basis of existing resistance in U.S. cultivars
- Locate molecular markers for resistance genes

Genetic Resources for Protection Strategies

Current status of resistance genes in U.S. wheat germplasm:

USDA-ARS-led evaluation and screening for Ug99 resistance places priority on evaluating breeding lines and cultivars. Results have identified these Ug99 resistance genes in currently grown varieties and breeding germplasm:

Genes	Type of wheat
Sr25	hard winter
SrTmp	hard, soft winter, spring
1A.1R	hard, soft winter
Thatcher	spring
Sr2	all classes
Sr24	all classes
Sr36	soft winter

Research Priorities for resistance breeding:

- Introduction of resistant germplasm including:
  international SR nurseries—CIMMYT
- Introgression of effective genes including:
  Sr22, (Sr26), Sr32, Sr35, S39, Sr40

Identifying new sources of genetic resistance

Potential sources of resistance have been identified or are being evaluated in the wild and weedy relatives of wheat and barley including:

- *T. monococcum* - Einkorn
- *T. turgidum* ssp. *dicoccoides* – Emmer
- *T. timopheevii* - Sanduri wheat
- *Ae. speltoides* - Spelt
- *Ae. sharonensis* - Sharon goatgrass
- *Ae. tauschii* – Tausch's goatgrass
- *Secale cerealis* - Rye
- *H. spontaneum* – Wild barley

Scientists at the U.S. National Small Grains Repository, Aberdeen, Idaho, and the Cereal Disease Laboratory are identifying new sources of resistance in the land races of wheat and barley. The land races are of interest because they may have novel genes, not widely deployed in modern cultivars. Pre-screening methods are being developed to evaluate the land races in greenhouse tests using "mimic" races of the African stem rusts. Accessions for evaluation in East Africa are screening first for resistance to U.S. stem rust races and then selected for geographic origin and reported rust resistance.

Research Needs and Priorities:

- Identify and introgress resistance form wild and related species into cereal germplasm
- Identify and utilize molecular markers to facilitate transfer of major, minor, adult plant, and novel genes for rust resistance

Defining a Strategic Plan for North America

Needs of federal agencies in addressing Ug99:

Representatives of federal agencies were asked to identify their priority needs. Responses were:

APHIS: Needs for good communication and coordination. The lesson leaned from the soybean rust effort is that it is important to share information and make sure that everyone has the same message. The NAPPO panel wants a coordinated North American approach.

APHIS recognizes research needs and priorities, and wants to facilitate safe entry of germplasm. APHIS, CEPHAS will conduct risk assessment and work with the APHIS PPQ responsible for import permits. APHIS is trying to be science-based. No one wants to be responsible for importing new pest.

ARS: Need to identify research priorities and develop coordinated action plan. USDA and university scientists need to determine genetic strategies and breeding plans that will expedite development of durable rust resistance in wheat and barley.

CSREES: Need to make sure everyone is working collaboratively. It is important to identify gaps that can be identified for funding opportunities.

Industry and other participants: Need a coordinated plan or white paper showing roles and responsibilities of federal agencies, land grant universities, and other groups. Need to make sure all bases are covered – no gaps in research or surveillance. Glaring omissions and other groups to be engaged need to be identified. Need partners from Canada and Mexico.

Questions were asked about the time line for accomplishing planning activities. Participants noted that the Recovery Plan developed for cereal rust is a useful starting point, but needs to be updated. Other participants noted the planning already done by the National Wheat and Barley Improvement Committees. Participants noted the need to develop a single document that all can support is needed. Possible development of three or four separate rust initiatives would not be helpful.

Possible models for the strategic or action plan were suggested. Strategic plan with too much specific detail will not get agreement from other North American countries. Specific details are country components. There are a couple of models: one is the research plan for Pierces Disease, which outlines broad categories: includes goals, approach, accomplishments and expected benefits. Another model is the one for soybean rust. Plan should go from macro to specific details (at the detail point need to cut out from other governments). Some activities such as diagnostics operations should be the same such as sampling protocols. If the methods are not identical, then they should be similar enough to compare across borders.

Not just research needs to be considered. Funding is another important issue as is communication and partnership with wheat and barley growers.

Questions were asked about possible planning for when and if Ug99 is detected in N. America. Communication plans and responses are needed. A short summary of the meeting should be written for *Phytopathology News.*

Short-term, urgent priorities (1-3 years):

- Adult screening (reliable) for both wheat and barley
    - Immediately look at plus or minus. What is the screening procedure?
    - APR resistance
    - Limiting factor – only have enough space and facilities to screen fixed lines but not segregated ones
- Facilitating flow of germplasm in and out of Africa with CIMMYT and other organizations
    - Short list of differentials is needed. If something strange shows up will need to delimit with a planned response.
    - Detection events will be enhanced by monitoring sites planted with clearly identifiable and interpretable vulnerabilities.
- Monitoring US wheat crop – that is the big target. It is important to monitor effectively and make sure that geographic regions of importance are covered. Clearly need monitoring sites where we expect first incursions come – need along the *Puccinia* pathway. First indicator is anything out of the ordinary. No need to put sentinel plots in Pacific Northwest. Need to insure that we have a system to monitor for occurrence of stem rust? If there is a stem rust epidemic in a field, it will be important to determine if it is due to a new race. Some planning can be deferred to the surveillance workshop. Natural introduction may be a long way off, but weather events

are not predictable. There could possibly be an introduction by some other means.

- International communication is crucial. We must assure that our neighbors are ready to communicate if they detect a new virulence or an unexpected reaction. Communication with our South American neighbors will be very important. CIMMYT partnerships could help with this information sharing, though that is not an official international channel.
- Fungicides
    - What are growers going to ask
        - Fungicide efficacy information will be critical.
        - While biological activity of fungicides is important, application of up-to-date spray technology may also be useful.
        - Cooperative information and communication in each region vulnerable to stem rust is needed.
    - Supply of fungicide is subject to the marketplace. Having some interaction with the fungicide industry is critical. We may already be able to get some information on efficacy of fungicides but need more information on timing of treatment, effective residual period. and application technology.
- Specific molecular diagnostics and training of diagnosticians.
    - Can already visually identify stem rust, so it is not necessary to send a sample to a lab for race typing unless there is another reason to do so. Only way to be tipped off about a special virulence is with a surveillance plot. Standard Operating Protocols (SOPs) for surge capacity must be defined. The National Plant Diagnostic Network (NPDN) is there for this purpose.

Other comments and observations:

- Continue germplasm screening.
- Need a mechanism for distribution of information sharing.
- How do you create an internal and external method of communication and a Listserv? What external information do you want to give?
- Need to identify vulnerable varieties. All germplasm screening information should be posted.
- Training opportunities can assure extension pathologists and their field staff to be able to recognize the pathogen.
- Detection may impact the market and should not be revealed until confirmed according to protocol (SOP – see above) and state response plans.
- Biotechnology solutions should be considered as it is a powerful technology. Need to engage the biotech providers.
- Need a pest information platform for the seed industry and that is being developed, the Industry PIPE (iPIPE). More industry data is needed. Asymmetric threat analysis based on a better database will enable establishment of baselines to assess anomalies in the normal pattern of disease outbreaks.

- Speakers were asked for permission to post their Power Point presentations and all agreed.

Workshop Planning and Coordination

The Workshop was planned and coordinated by the American Phytopathological. Society. Participants represented U.S., Canadian, and Mexican federal agencies concerned about Ug99, along with representatives from National Plant Board, National Wheat and Barley Improvement Committees, National Associations of Wheat and Barley Growers, North American Millers Association, American Malting Barley Association, Borlaug Global Rust Initiative, and leading disease and crop breeding experts from land-grant universities,

Program Planning Committee included: Rick Bennett and Kay Simmons, USDA, ARS; Matt Royer, USDA, APHIS; Marty Draper, USDA, CSREES, and Al Jennings, USDA, OPMP

Workshop Participants
ATTENDEES:

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