Washington Grain Commission
Wheat and Barley Research Annual Progress Report

Project #: 5665

Progress Report Year: 2 of 3 (2014)

Title: Control of Wheat and Barley Rusts

Cooperators: K. Campbell, A. Carter, S. Guy, S. Hulbert, K. Murphy, M. Pumphrey, & D. See

Executive summary: During the second year (2014) of the project, studies were conducted according to the objectives of the project proposal and all objectives specified for the second year were successfully completed. In addition to the major accomplishments and their impacts listed below, this project results in genetic resources and techniques for further studying the biology and genetics of the pathogens and mechanisms of interactions between the pathogen and plants.

Impact: 1) Stripe rust was accurately forecasted in 2014. Rust updates and advises were provided on time to growers based on the forecasts using prediction models and field surveys, which prevented unnecessary use of chemicals in the State of Washington. 2) We identified 29 races of wheat stripe rust and two races of barley stripe rust in the US, of which 26 and one were detected, respectively in Washington. The virulence information is used to guide breeding programs for using effective resistance genes in developing resistant varieties and selected predominant races with different virulence patterns are used in screening breeding lines for stripe rust resistance. 3) We used molecular markers developed in our lab to study the stripe rust pathogen and identified different genetic groups in different epidemiological regions. 4) We evaluated more than 30,000 wheat and 5,000 barley entries for resistance to stripe rust. From the tests, we identified new sources of resistance and resistant breeding lines for breeding programs to release new varieties for growers to grow. In 2014, we collaborated with breeders in releasing or pre-releasing eight wheat and one barley varieties; and registered seven wheat varieties. The germplasm evaluation data were also used to update the Seed Buyer's Guide for growers to choose resistant varieties to grow. 5) We completed studies for mapping six genes for stripe rust resistance in two wheat lines and identified molecular markers. We officially named and published five new genes for stripe rust resistance. 6) We provided seeds of our recently developed new wheat germplasm lines to several breeding programs in the US and other countries for developing stripe rust resistant varieties. Use of these lines by breeding programs will diversify resistance genes in commercial varieties. 7) We tested 30 fungicide treatments for control of stripe rust and provided the data to chemical companies for registering new fungicides. We tested potential yield loss due to stripe rust and increase from fungicide application for 23 winter wheat and 15 spring wheat varieties currently grown in the Pacific Northwest, especially in Washington. The data of the fungicides and varieties are used for guiding the integrated control of stripe rust. 8) We published 28 journal articles and 4 meeting abstracts in 2014.

Outputs and Outcomes:

Progress, Timelines, and Communication are given in Outcome Reporting file (file name:

WGC2014 Report XMChen Outcome reporting.pdf)

Publications:

Scientific Journals:

Graybosch, R. A., Baenziger, P. S., Santra, D., Regassa, T., Jin, Y., Kolmer, J., Wegulo, S., Bai, G. H., Amand, P. S., **Chen, X. M.**, Seabourn, B., Dowell, F., Bowden, R., and Marshall, D. M. 2014. Release of 'Mattern' waxy (amylose-free) winter wheat. Journal of Plant Registrations 8:43-48.

Zeng, Q. D., Han, D. J., Wang, Q. L., Yuan, F. P., Wu, J. H., Zhang, L., Wang, X. J., Huang, L. L., **Chen, X. M.**, Kang, Z. S. 2014. Stripe rust resistance and genes in Chinese wheat cultivars and breeding lines. Euphytica 196:271-284.

Case, A., Naruoka, Y., **Chen X. M.**, Garland-Campbell, K. A., Zemetra, R. S., Carter, A. H. 2014. Mapping stripe rust resistance genes in a Brundage x Coda winter wheat recombinant inbred line population. PLoS ONE 9(3): e91758.

Zhou, X. L., Wang, M. N., **Chen, X. M.**, Lu, Y., Kang, Z. S., and Jing, J. X. 2014. Identification of *Yr59* conferring high-temperature adult-plant resistance to stripe rust in wheat germplasm PI 178759. Theoretical and Applied Genetics 127:935-945.

Chen, X. M., Evans, K. C., and Liu, Y. M. 2014. Control of stripe rust of winter wheat with various foliar fungicides. Plant Disease Management Reports 8:CF023.

Chen, X. M., Evans, K. C., and Liu, Y. M. 2014. Control of stripe rust of spring wheat with various foliar fungicides. Plant Disease Management Reports 8:CF034.

Chen, X. M., Evans, K. C., and Liu, Y. M. 2014. Control of stripe rust on winter wheat cultivars with foliar fungicide in 2013. Plant Disease Management Reports 8:CF35.

Chen, X. M., Evans, K. C., and Liu, Y. M. 2014. Control of stripe rust on spring wheat cultivars with foliar fungicide in 2013. Plant Disease Management Reports 8:CF036.

Zeng, Q. D., Yuan, F. P., Xu, X., Shi, X., Nie, X. J., Zhuang, H., **Chen, X. M.**, Wang, Z. H., Wang, X. J., Huang, L. L., Han, D. J., Kang, Z. S. 2014. Construction and characterization of a bacterial artificial chromosome library for hexaploid wheat line 92R137. BioMed Research International. Volume 2014, Article ID 845806, 9 pages.

Chen, W. Q., Wellings, C., **Chen, X. M.**, Kang, Z. S., and Liu, T. G. 2014. Wheat stripe (yellow) rust caused by *Puccinia striiformis* f. sp. *tritici*. Molecular Plant Pathology 15:433-446.

Lu, Y., Wang, M. N., **Chen, X. M.**, See, D., Chao, S. M., and Jing, J. X. 2014. Mapping of *Yr62* and a small effect QTL for high-temperature adult-plant resistance to stripe rust in spring wheat PI 192252. Theoretical and Applied Genetics 127:1449-1459.

Sharma-Poudyal, D., **Chen, X. M.**, and Rupp, R. 2014. Potential oversummering and overwintering regions for the wheat stripe rust pathogen in the contiguous United States. International Journal of Biometeorology 58(5):987-997.

Basnet, B. R., Ibrahim, A. M. H., **Chen, X. M.**, Singh, R. P., Mason, E. R., Bowden, R. L., Liu, S. Y., Devkota, R. N., Subramanian, N. K., and Rudd, J. C. 2014. Molecular mapping of stripe rust resistance QTL in hard red winter wheat TAM 111 adapted in the US high plains. Crop Science 54:1361-1373.

Berg, J. E., Hofer, P., Davis, E. S., Stougaard, R. N., Kephart, K. D., Lamb, P. F., Wichman, D. M., Eckhoff, J. L., Miller, J. H., Nash, D. L., Grey, W. E., Jin, Y., **Chen, X. M.**, and Bruckner, P. L. 2014. Registration of 'SY Clearstone 2CL' wheat. Journal of Plant Registrations 8:162-164.

Haley, S. D., Johnson, J. J., Peairs, F. B., Stromberger, J. A., Hudson-Arns, E. E., Seifert, S. A., Valdez, V. A., Kottke, R. A., Rudolph, J. B., Bai, G. H., **Chen, X. M.**, Bowden, R. L., Jin, Y., Kolmer, J. A., Chen, M.-S., Seabourn, B. W., and Dowell, F. E. 2014. Registration of 'Antero' wheat. Journal of Plant Registrations 8:165-168.

Haley, S. D., Johnson, J. J., Peairs, F. B., Stromberger, J. A., Hudson, E. E., Seifert, S. A., Kottke, R. A., Valdez, V. A., Nachtman, J. J., Rudolph, J. B., Bai, G. H., **Chen, X. M.**, Bowden, R. L., Jin, Y., Kolmer, J. A., Chen, M-S., and Seabourn, B. W. 2014. Registration of 'Cowboy' wheat. Journal of Plant Registration 8:169-172.

Berg, J. E., Lamb, P. F., Miller, J. H., Wichman, D. M., Stougaard, R. N., Eckhoff, J. L., Kephart, K. D., Nash, D. L., Grey, W. E., Gettel, D., Larson, R., Jin, Y., Kolmer, J. A., **Chen, X. M.**, Bai, G., and Bruckner, P. L. 2014. Registration of 'Warhorse' wheat. Journal of Plant Registration 8:173-176.

Dugan, F. M., Cashman, M. J., Wang, M. N., **Chen, X. M.**, and Johnson, R. C. 2014. Differential resistance to stripe rust (*Puccinia striiformis*) in collections of basin wild rye (*Leymus cinereus*). Plant Health Progress doi:10.1094/PHP-RS-14-0002.

Chen, X. M. 2014. Integration of cultivar resistance and fungicide application for control of wheat stripe rust. Canadian Journal of Plant Pathology 36:311-326.

Sthapit, J., Newcomb, M., Bonman, J. M., **Chen, X. M.**, and See, D. 2014. Genetic diversity for stripe rust resistance in wheat landraces and identification of dual resistance to stem rust and stripe rust. Crop Science 54:2131-2139.

Carter, A. H., Jones, S. S., Cai, X., Lyon, S. R., Balow, K. A., Shelton, G. B., Higginbotham, R. W., **Chen, X. M.**, Engle, D. A., Baik, B., Guy, S. O., Murray, T. D., and Morris, C. F. 2014. Registration of 'Puma' soft white winter wheat. Journal of Plant Registrations 8:273-278.

Berg, J. E., Wichman, D. M., Kephart, K. D., Eckhoff, J. L., Stougaard, R. N., Lamb, P. F., Miller, J. H., Nash, D. L., Grey, W. E., Johnston, M., Gettel, D., Larson, R., Jin, Y., Kolmer, J. A., **Chen, X. M.**, Bai, G., and Bruckner, P. L. 2014. Registration of 'Colter' wheat. Journal of Plant Registrations 8:285-287.

Cheng, P., Xu, L. S., Wang, M. N., See, D. R., and **Chen, X. M.** 2014. Molecular mapping of genes *Yr64* and *Yr65* for stripe rust resistance in hexaploid derivatives of durum wheat accessions PI 331260 and PI 480016. Theoretical and Applied Genetics 127:2267-2277.

Millet, E., Manisterski, J., Ben-Yehuda, P., Distelfeld, A., Deek, J., Wan, A., **Chen, X. M.**, and Steffenson, B. J. 2014. Introgression of leaf rust and stripe rust resistance from Sharon goatgrass (*Aegilops sharonensis* Eig) into bread wheat (*Triticum aestivum* L.). Genome 57:309-316.

Wan, A. M., and **Chen, X. M.** 2014. Virulence characterization of *Puccinia striiformis* f. sp. *tritici* using a new set of *Yr* single-gene line differentials in the United States in 2010. Plant Disease 98:1534-1542.

Cheng, P., and **Chen, X. M.** 2014. Virulence and molecular analyses support asexual reproduction of *Puccinia striiformis* f. sp. *tritici* in the U.S. Pacific Northwest. Phytopathology 104:1208-1220.

Zhou, X. L., Han, D. J., **Chen, X. M.**, Gou, H. L., Guo, S. J., Rong, L., Wang, Q. L., Huang, L. L., and Kang, Z. S., 2014. Characterization and molecular mapping of stripe rust resistance gene *Yr61* in winter wheat cultivar Pindong 34. Theoretical and Applied Genetics 127:2349-2358.

Zhan, G. M., Tian, Y., Wang, F. P., **Chen, X. M.**, Jiao, M., Guo, J., Huang, L. L., and Kang, Z. S. 2014. First report of a novel fungal hyperparasite of *Puccinia striiformis* f. sp. *tritici*, the causative agent of wheat stripe rust. PLoS ONE 9(11):e111484.

Popular Press Articles:

January 3, 2014. First Forecast of Stripe Rust for 2014 Wheat Crop. Xianming Chen. E-mail sent to growers and cereal group.

March 13, 2014. Stripe rust forecast and update. Xianming Chen. E-mail sent to growers and cereal groups.

March 2014. Low level of stripe rust predicted for 2014 wheat crop. Xianming Chen. *Wheat Life* April Pages 8-10.

April 25, 2014. Stripe Rust Update, April 25, 2014. Xianming Chen. E-mail sent to growers and the cereal group.

April 29, 2014. OSU wheat variety lacks rust resistance gene. Matthew Weaver. Capital Press. http://www.capitalpress.com/Washington/20140429/osu-wheat-variety-lacks-rust-resistance-gene

May 23, 2014. Stripe Rust Update, May 23, 2014, Xianming Chen. E-mail sent to growers and the cereal group.

June, 2014. Control of Rusts of Wheat and Barley in 2013. Xianming Chen and associates, Pages 65-66 in: 2014 Dryland Field Day Abstracts, Highlights of Research Progress, Department of Crop and Soil Sciences Technical Report 14-1. Washington State University Extension,

June 13, 2014. Stripe Rust Update, June 13, 2014, Xianming Chen. E-mail sent to growers and the cereal group.

July 3, 2014. Stripe Rust Update July 3, 2014, Xianming Chen. E-mail sent to growers and the cereal group.

August 2014. "No rust, no fuss". Page 56 in *Wheat Life*, August/September, 2014.

November 16, 2014. Researchers isolate stripe rust resistance markers in barley by John O'Connell. Capital Press.

All 2014 nursery data were sent to growers, cereal group, and/or collaborators.

Presentations and Reports:

Xianming Chen, June 22, 2014, presented "Integrated management of stripe rust" at Northwest A&F University, Yangling, China (about 100 people)

Xianming Chen, June 28, 2014, presented "Understanding fungal pathogen biology using a genomics approach" at the 4th BIT International Congress of Microbiology, Dalian, China (about 50 people).

Xianming Chen, August 10-13, 2014, presented 3 posters titled "Stripe rust epidemics of wheat and barley and races of *Puccinia striiformis* identified in the United States in 2013", "Regional differences in genetic structure of *Puccinia striiformis* f. sp. *tritici*, the wheat stripe rust pathogen, in the U.S. revealed by SSR markers", and "Molecular mapping of *YrSP*, a wheat gene for resistance to stripe rust" (about 2,000 participants).

Xianming Chen, November 7-14, 2014, presented "Genetics of Plant Resistance – Theory and Practice; Past, Present, and Future Perspective", "Molecular Plant-pathogen Interactions", and

"Genetics of Plant Resistance – Stripe Rust as an Example", Northwest A&F University. Yangling, Shaanxi, China (about 60 people).

Xianming Chen participated or talked about rusts, research progress, and disease management in the following field days:

- 6/12/2014: Lind Field Day (about100 people)
- 7/16/2014: Farmington Field Day (about 30 people)
- 7/16/2014: St. John Field Day (about 15 people)
- 7/16/2014: Lamont Field Day (about 20 people)

WGC project number: 5665
WGC project title: Control of Wheat and Barley Rusts
Project PI(s): Xianming Chen
Project initiation date: 7/1/2013
Project year: 2 of 3 (2014)

Objective	Deliverable	Progress	Timeline	Communication
1. Predict and monitor rust epidemics and provide best available control recommendations on a yearly basis; further study the biology of the rust pathogens, identify races and determine population changes of the stripe rust pathogens of wheat and barley; and collaborate in race identification of the leaf rust and stem rust pathogens.	**1) Rust forecasts and updates.** Stripe rust was accurately forecasted in 2014. Rust updates and advises were provided on time to growers during the crop season based on the forecasts and field surveys, which prevented unneccessary use of fungicides. 2**) Stripe rust races.** We identified 29 races of wheat stripe rust and 2 races of barley stripe rust in the US, and 26 and 1 of them were detected respectively in Washington. The virulence information is used to guide breeding programs for using effective resistance genes in developing resistant varieties and selected predominant races with different virulence patterns are used in screening breeding lines for stripe rust resistance. 3**) Molecular markers for studying stripe rust populations.** We used molecular markers developed in our lab to study the stripe rust pathogen and identified different genetic groups in different epidemiological regions.	All planned studies for the project in 2014 have been completed on time. There is no any delay, failure, or problem in studies to this objectives. In 2014, stripe rust, leaf rust and stem rust of wheat and barley were monitored throughout the Pacific Northwest (PNW) through field surveys and disease nurseries. Prediction of wheat stripe rust epidemic was made using our forecasting models. Stripe rust forecast was reported to wheat researchers and growers as early as in early January and continued as the season was progressing. Stripe rust was low in eastern PNW but normal in western PNW. Leaf rust of wheat was normal in western but absent in eastern PNW; and leaf rust of barley was severe in western but absent in eastern PNW. Stem rust of wheat and barley was absent in the PNW. The forecasts and updates reduced unnecessary use of fungicide. A total of 327 stripe rust samples were obtained throughout the country in 2014 and 196 (60%) of them from Washington. We have completed about 95% of the race ID work for the 2014 samples as scheduled by this time. So far we have detected 29 wheat stripe rust races and 2 barley stripe rust races, of which 26 and 1 were detected respectively in Washington. The frequencies and distribution of the races were determined. We completed molecular characterization of stripe rust populations of 2010 and 2011 using 17 co-dominant simple sequence repaet markers and 97 single-nucleotide polymorphism markers and found the pathogen population in the PNW is more diverse that the eatsern US population and determined the differences of spore movement between epidemiological regions.	All studies and services were completed on time. The race identification work for the 2014 stripe rust samples will be completed by late February, 2014, as scheduled, and the race ID work for 2014 samples will start in February. Molecular characterization of the 2012-2013 samples and DNA extraction of the 2014 samples will be completed by June, 2015.	The rust forecasts, survey results, and race data were communicated to growers through e-mails, telephones, website, project reports, presentations at growers' meetings, field days, public magazines like Wheat Life, and publications in scientific journals (for detailed information, see the lists in the main report file).

2. Support breeding programs for developing rust resistant varieties; identify and develop new rust resistant germplasm; and map new resistance genes and develop molecular markers for stripe rust resistance genes.	**1) Stripe rust reaction data of various wheat and barley nurseries.** In 2014, we tested more than 30,000 wheat and 5,000 barley entries for resistance to stripe rust and other foliar diseases, and provided the data to breeding programs to eliminate susceptible lines and select rust resistant lines for developing new varieties. **2) New rust resistant sources.** Through the germplasm screening, we identified new resistant sources and characterized the types of resistance. **3) New wheat varieties.** Through the tests, we collaborated with breeders to release new varieties. In 2014, we collaborated with breeders in releasing or pre-releasing 8 wheat and 1 barley varieties; and registered 7 wheat varieties. The germplasm evaluation data were also used to update the Seed Buyer's Guide for growers to choose resistant varieties to grow. **4) Stripe rust resistance genes mapped and molecular markers developed.** In 2014, we completed studies for mapping 6 genes for stripe rust resistance in 2 wheat lines and identified molecular markers, and officially named five new genes for stripe rust resistance. **5) Supplied seeds of germplasm to breeding programs.** In 2014, we provided seeds of our newly developed wheat germplasm lines to several breeding programs for developing stripe rust resistant wheat varieties.	In 2014, we evaluated more than 30,000 wheat and 5,000 barley entries for resistance to stripe rust. The entries included germplasm, breeding lines, rust monitoring nurseries, and genetic populations from various breeding and extension programs. All nurseries were planted and evaluated at both Pullman under artificial inoculation and Mt. Vernon locations under natural stripe rust infection. Some of the nurseries were also tested in Walla Walla and Lind, WA . Because natural stripe rust was low in eastern WA, the artificial inoculation at the Pullman sites allowed us to have high quality data of germplasm screening nurseries. Germplasm and breeding lines in the variety trial and regional nurseries also were tested in the greenhouse with selected races of stripe rust for further characterization of resistance. Disease data of regional nurseries were provided to all breeding and extension programs, while data of individual breeders' nurseries were provided to the individual breeders. Through these tests, susceptible breeding lines can be eliminated, which should prevent risk of releasing susceptible cultivars and assisted breeding programs to release new cultivars of high yield and quality, good adaptation, and effective disease resistance. Through the germplasm screening, we have established a collection of wheat germplasm with stripe rust resistance, which are valuable sources of stripe rust resistance for further characterization of resistance, identified new effective resistance genes, and for development of wheat varieties with superior resistance. Through our intensive testing, varieties with durable resistance to stripe rust have been developed. In 2014, we collaborated with public breeding programs in releasing 8 wheat varieties and 1 barley variety; and registered 7 wheat varieties. Varieties developed by private breeding programs were also resulted from our germplasm screening program. In 2014, we completed studies for mapping stripe rust resistance genes in two wheat lines and developed mapping populations for identification of stripe rust resistance genes in Madsen and Eltan.	All germplasm tests were completed and the data were provided to collaborators on time. The 2014-15 winter wheat nurseries were planted in fields in September and October 2014. The 2015 spring crop nurseries will be planted in April, 2015. The greenhouse tests of the 2014 spring nurseries and the 2014-15 winter wheat nurseries have been conducting in the greenhouse during the winter, and will be completed by May, 2015	The data of variety trials and regional nurseries were sent to growers and collaborators through e-mails and websites. Summary information of varieties were sent to growers and collaborators through rust updates and recommendations through e-mails, website, Seed Buyer's Guide, variety release documents. Test data of individual breeding programs were sent to the individual breeders. New genes and molecular markers were published in scientific journals (see the publication and presentation lists in the report main file).

3. Determine effectiveness of fungicides for rust control and develop more effective strategies for integrated rust management.	**1) New fungicides and information on appropriate use of fungicides.** In 2014, we tested 30 fungicide treatments for control of stripe rust and provided the data to collaborators. Chemical companies will use the data for registeration of new fungicides. **2) Yield loss by stripe rust and yield increase by fungicide application of major grown varieties.** The potential yield loss due to stripe rust and increase from fungicide application for 23 winter wheat and 15 spring wheat varieties commonly grown in the PNW, plus susceptible checks, were studied in 2014. The data, together with such studies in the past, are used to guide stripe rust management on the individual variety basis. **3) Integrated control strategies.** From the fungicide and variety studies, together with race information, we developed an integrated control strategy consisting of primarily growing resistant varieties and secondarily using fungicides. As stripe rust was low in 2014, the overall resistance to stripe rust in the wheat varieties grown in Washington was adequate for protecting crops from stripe rust damage.	In 2014, we evaluated 30 fungicide treatments for control of stripe rust in experimental fields near Pullman, WA. Susceptible winter wheat varieties 'PS 279' and spring wheat 'Lemhi' were used in the studies. The tests were conducted as a randomized complete block design with four replications in each experiment. The experimental fields were inoculated with a spore mixture of two races predominant in the region in the previous year. Fungicides were applied at different rates and different stages of crop growth. Stripe rust severities were recorded five times in both winter wheat and spring wheat during the rust season. Grains were harvested and weighted for each plot. Rusts and yield data were analyzed to determine the efficacy for each fungicide treatment. For winter wheat, all fungicide treatments significantly reduced rust severity; all treatments but one significantly increased test weight; and all treatments but one significantly increased yield. For spring wheat, all treatments significantly reduced rust severity; but none of them significantly increased test weight. 23 treatments significant increased yield while the increases by the other 7 treatments were not statistically significant. In 2014, we tested 23 winter wheat and 15 spring wheat varieties commonly grown in the PNW, plus highly susceptible checks. The experiments were in a randomized complete split-blot design with four replications. For each blot, a half was sprayed with a fungicide to control stripe rust and the other half was not sprayed to allow stripe rust to develop. Stripe rust data were recorded three ot four times during the disease season. Grain yield and test weight were recorded at harvest. The data were used to determine stripe rust resistance level, yield loss caused by stripe rust, and yield increase by fungicide application for each variety. The results were used to estimate damage by stripe rust and also used to guide growers for selecting cultivars to grow and determine whether fungicide application is needed based on individual varieties. The results were sent to the cereal group including growers, organizations, industries, and scientists.	For this objective, all tests scheduled for 2014 were successfully completed. For the 2014-15 growing season, the winter wheat plots of the fungicide and variety studies were planted in October, 2014 and the spring plots will be planted in April, 2015. The tests will be completed in August (for winter wheat) and September (for spring wheat), 2015	The results were communicated to growers and collaborators through e-mails, presentations in growers meetings, field days, plot tours, project reports and reviews, and published in scientific journals (see the publication and presentation lists in the report main file).

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