

Washington Grain Commission
Wheat and Barley Research Annual Progress Report

Project #: 3144

Progress Report Year: 1 of 3 (2019)

Title: Improving Control of Rusts of Wheat and Barley

Cooperators: K. Garland Campbell, A. Carter, M. Pumphrey, & D. See

Executive summary: During 2019, studies were conducted according to the objectives of the project proposal, and all objectives specified for the first year have been 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, rust resistance, and mechanisms of interactions between the pathogens and plants.

Impact: 1) Stripe rust was accurately forecasted in 2019. Rust updates and advises were provided on time to growers based on the forecasts using prediction models and field surveys, which protected both winter wheat and spring wheat crops from stripe rust damage and reduced unnecessary use of fungicides. 2) We identified 25 (including 1 new) races of the wheat stripe rust pathogen and 8 (including 1 new) races of the barley stripe rust pathogen in the US, of which 23 and 7 were detected in Washington, respectively. The virulence information is used to guide breeding programs for using effective resistance genes in developing resistant varieties. 3) We identified stripe rust mutants with relatively low sensitivity to DMI fungicides using molecular markers of the chemical-targeting gene and determined the frequencies of the mutants in the pathogen population. The results support fungicides containing two or more chemicals with different modes of action or rotation of chemicals. 4) We identified candidate virulence genes by whole-genome sequencing a mutant population of the stripe rust pathogen. The candidate virulence genes will be used to develop virulence-specific markers for monitoring virulence changes in the pathogen population. 5) We evaluated more than 35,000 wheat, barley, and triticale 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 2019, we collaborated with breeders in releasing, pre-releasing, or registered 15 wheat and 2 barley varieties. The germplasm evaluation data were also used to update the Seed Buyer's Guide for growers to choose resistant varieties to grow. 6) We mapped 6 genes for all-stage and high-temperature adult-plant resistance to stripe rust in wheat landrace PI 181410. We completed two genome-wide association studies and mapped more than 30 genes for stripe rust resistance in each panel of 616 spring wheat and 857 winter wheat varieties and breeding lines in the US. These genes and their markers will be useful in breeding stripe rust resistant wheat varieties. 7) We tested 33 fungicide treatments for control of stripe rust on winter and spring wheat and provided the data to chemical companies for registering new fungicides. 8) We tested 24 winter wheat and 24 spring wheat varieties for yield loss caused by stripe rust and yield increase by fungicide application. The data of the fungicides and varieties are used for guiding the integrated control of stripe rust. 9) In 2019, we published 26 journal articles and 5 meeting abstracts.

Outputs and Outcomes:

WGC project number: 3144				
WGC project title: Improving Control of Rusts of Wheat and Barley				
Project PI(s): Xianming Chen				
Project initiation date: 7/1/2019				
Project year: 1 of 3 (2019)				
Objective	Deliverable	Progress	Timeline	Communication
1. Improve the understanding of rust disease epidemiology and the pathogen populations.	1) New races. 2) Information on distribution, frequency, and changes of all races, and possible fungicide tolerant strains. 3) New tools such as molecular markers and population structures. The information will be used by breeding programs to choose effective resistance genes for developing new varieties with adequate and durable resistance. We will use the information to select a set of races for screening wheat and barley germplasm and breeding lines. The information is also used for disease management based on races in different regions.	All planned studies for the project in 2019 have been completed on time. There is no any delay, failure, or problem in studies to this objective. The race identification for the 2018 collection was completed and summarized. The data and summary were sent to growers, collaborators and related scientists in May, 2019. In the 2019 crop season, we collected and received 336 stripe rust samples throughout the country and 65% of the samples were from Washington. We have completed about 95% of the race ID work for the 2019 samples as scheduled by this time. So far we have detected 25 wheat stripe rust races (including 1 new races) and 8 barley stripe rust races (including 1 new races), of which 23 wheat and 7 barley stripe rust races have been detected in Washington. The distribution and frequency of each race and virulence factor in WA and the whole country have been determined. Predominant races have been identified. The race and 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. We have used molecular markers developed in our lab to study the stripe rust pathogen and determined the population changes in the past and present. We sequenced more isolates of the stripe rust pathogen and developed more markers to study rust pathogen populations and identify candidate virulence genes. We have used a molecular marker developed from the DMI fungicide target gene to test the historical and recent stripe rust collections in the US and detected isolates with homozygous and heterozygous mutant isolates in the stripe rust populations. The fungicide target gene mutants exist in the State of Washington, although in low frequencies. Through whole-genome sequencing, we completed a molecular study and determined the effects of mutation on genome structure and on changing avirulence to virulence and identified effector genes associated to avirulence/virulence phenotypes.	The race identification work for the 2018 stripe rust samples was completed. The race ID work for 2019 samples was done about 95% of the entire work. Molecular work for both the population genetic study and the fungicide tolerance mutant study have been completed. DNA extraction of the 2018 samples have been completed and of the 2019 samples are underway.	The rust race data were communicated to growers and researchers through e-mails, websites, project reports, meeting presentations and publications in scientific journals (for detailed information, see the lists in the main report file).

<p>2. Improve rust resistance in wheat and barley varieties.</p>	<p>1) Stripe rust reaction data of wheat and barley germplasm and breeding lines. 2) Reactions to other diseases when occur. 3) New resistance genes with their genetic information and molecular markers. 4) New germplasm with improved traits. 5) New varieties for production. The genetic resources and techniques will be used by breeding programs for developing varieties with diverse genes for stripe rust resistance, which will make the stripe rust control more effective, efficient, and sustainable.</p>	<p>In 2019, we evaluated more than 35,000 wheat, barley and triticale 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 and Mt. Vernon locations under natural stripe rust infection. Some of the nurseries were also tested in Walla Walla and Lind, WA. 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. In 2019, we collaborated with public breeding programs in releasing and registered 15 wheat varieties and 2 barley varieties. Varieties developed by private breeding programs were also resulted from our germplasm screening program. Through our 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 effective resistance. Through our intensive testing, varieties with durable resistance to stripe rust have been developed. In 2019, we completed the study and mapped six genes for all-stage and high-temperature adult-plant resistance to stripe rust in wheat landrace PI 181410. We completed a whole-genome associate studies (GWAS) and mapped 37 loci on 15 chromosomes in a panel of 616 US spring wheat cultivars and breeding lines and identified 34 loci also on 15 chromosomes together with 15 previously reported genes identified with specific markers in a panel of 857 US winter wheat cultivars and breeding lines. We determined the frequencies and distributions of stripe rust resistance genes used in various regions in the US with the PNW had the highest number of genes. We selected new wheat germplasm lines with single new genes or combinations of genes for resistance to stripe rust to make them available for breeding programs and directly provided seeds to some US breeding programs. In 2019, we phenotyped 40 mapping populations for stripe rust responses to map stripe rust resistance genes, completed the bulk segregation tests of the resistance and susceptible bulks of the populations with molecular markers and identified 233 potentially different loci for stripe rust resistance in the 40 populations.</p>	<p>All 2019 germplasm tests were completed and the data were provided to collaborators on time. The 2019-20 winter wheat nurseries were planted in fields in September and October 2019. The 2019 spring crop nurseries will be planted in March-April, 2019. The greenhouse tests of the 2019 spring nurseries and the 2019-20 winter wheat nurseries have been conducting in the greenhouse during the winter, and will be completed by May, 2019. All experiments of the molecular mapping studies scheduled for 2019 were completed. Mapping populations of winter wheat were planted in fields in October 2019 and those of spring wheat will be planted in April, 2020 for stripe rust phenotype data. Populations with adequate phenotype data are genotyped with molecular markers for mapping resistance genes.</p>	<p>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, websites, 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 reported in scientific meetings and published in scientific journals (see the publication and presentation lists in the report main file).</p>
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<p>3. Improve the integrated management of rust diseases.</p>	<p>1) Data of fungicide efficacy, dosage, and timing of application for control stripe rust. 2) Potential new fungicides. 3) Stripe rust yield loss and fungicide increase data for major commercial varieties. 4) Stripe rust forecasts and updates. 5) Guidance for rust management. The information is used for developing more effective integrated control program based on individual varieties. Disease updates and recommendations will allow growers to implement appropriate control.</p>	<p>In 2019, we evaluated 31 fungicide treatments on winter wheat and 33 fungicide treatments on spring wheat, plus a non-treated check, for control of stripe rust in experimental fields near Pullman, WA. On winter wheat study, 28 treatments significantly reduced rust severity and increased grain yield; 23 treatments had higher test weight than the non-treated check, including all treatments with applications at Feekes 10; and 15 treatments produced yield higher than the non-treated check. All treatments of either only a Feekes 10 application or both Feekes 6 and Feekes 10 applications had significantly higher yield compared with the non-treated check. The significant yield responses ranged from 9.3 bu/A (11.1%) to 48.5 bu/A (57.9%). On spring wheat, all 33 fungicide treatments significantly reduced stripe rust severity; 18 treatments had significantly greater test weight than the non-treated check; and 32 treatments had significantly higher yield than the non-treated check. The significant yield responses ranged from 9.4 bu/A (20.7%) to 34.3 bu/A (75.4%). In 2019, we tested 23 winter wheat and 23 spring wheat varieties commonly grown in the PNW, plus highly susceptible checks. For winter wheat, stripe rust caused 35.8% yield loss on the susceptible check and from 0 to 18.6% (average of 5.5%) on commercially grown varieties. Fungicide application increased yield by 0 to 22.9% (average of 6.2%) on commercially grown varieties. For spring wheat, stripe rust caused 32.7% yield loss on the susceptible check and from 0 to 12.7% (average 2.3%) yield losses on commercial varieties. Fungicide application increased grain yields by 0 to 13.8% (average 2.5%) on commercial varieties. These results can be used by chemical companies to register new fungicides and used by growers for selecting resistant varieties to grow and use suitable fungicide application for control stripe rust on varieties without an adequate level of resistance. Forecasts of wheat stripe rust epidemic were made in January 2019 based on the November and December weather conditions and in March 2019 based on the entire winter weather conditions using our prediction models. Further forecasts were made throughout the crop season based on rust survey data and past and forecasted weather conditions. These forecasts and rust updates were reported to wheat growers and researchers. Field surveys were conducted by our program and collaborators throughout the PNW and other regions throughout the country. In the central and eastern PNW, the time of first observations of stripe rust were slightly later than normal and stripe rust pressure was generally low in commercial fields with necessary fungicide application only in few in fields in central Washington. In our experimental fields near Pullman artificially inoculated, stripe rust developed to adequate levels for reliable germplasm screening. Barley stripe rust was low. Leaf rust of wheat was low in western and absent in eastern PNW; leaf rust of barley in the western PNW was less than the previous years, and absent in the eastern PNW. Stem rust appeared as hotspots in some experimental fields around Pullman in 2019. In November 2019, significant stripe rust was observed in several early-planted winter wheat fields in Lincoln and Douglas counties.</p>	<p>For this objective, all tests scheduled for 2019 were successfully completed. For the 2019-20 growing season, the winter wheat plots of the fungicide and variety yield loss studies were planted in October 2019, and the spring plots will be planted in April, 2019. The tests will be completed in August (for winter wheat) and September (for spring wheat), 2020.</p>	<p>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).</p>
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Publications:

Scientific Journals:

Qie, Y. M., Liu, Y., Wang, M. N., Li, X., See, D. R., An, D. G., and **Chen, X. M.** 2019. Development, validation, and re-selection of wheat lines with pyramided genes *Yr64* and *Yr15* linked on the short arm of chromosome 1B for resistance to stripe rust. *Plant Disease* 103(1):51-58.

Yang, Y., Basnet, B. R., Ibrahim, A. M. H., Rudd, J. C., **Chen, X. M.**, Bowden, R. L., Xue, Q. W., Wang, S. C., Johnson, C., Metz, R., Mason, R. E., Hays, D. B., and Liu, S. Y. 2019. Developing KASP markers on a major stripe rust resistance QTL in TAM 111 using 90K array and genotyping-by-sequencing SNPs. *Crop Science* 59(1):165-175.

Li, Y. X., Wang, M. N., See, D. R., and **Chen, X. M.** 2019. Ethyl-methanesulfonate mutagenesis generated diverse isolates of *Puccinia striiformis* f. sp. *tritici*. *World Journal of Microbiology and Biotechnology* 35:28.

Chen, X. M., Sprott, J., Evans, C. K., and Liu, Y. M. 2019. Evaluation of foliar fungicides for control of stripe rust on winter wheat in 2018. *Plant Disease Management Reports* 13:CF068.

Chen, X. M., Sprott, J., Evans, C. K., and Liu, Y. M. 2019. Evaluation of foliar fungicides for control of stripe rust on spring wheat in 2018. *Plant Disease Management Reports* 13:CF067.

Chen, X. M., Sprott, J., Evans, C. K., and Liu, Y. M. 2019. Evaluation of Pacific Northwest winter wheat cultivars to fungicide application for control of stripe rust in 2018. *Plant Disease Management Reports* 13:CF066.

Chen, X. M., Sprott, J., Evans, C. K., and Liu, Y. M. 2019. Evaluation of Pacific Northwest spring wheat cultivars to fungicide application for control of stripe rust in 2018. *Plant Disease Management Reports* 13:CF065.

Zeng, Q. D., Wu, J. H., Liu, S. J., **Chen, X. M.**, Yuan, F. P., Su, P. P., Wang, Q. L., Huang, S., Mu, J. M., Han, D. J., and Kang Z. S. 2019. Genome-wide mapping for stripe rust resistance loci in common wheat cultivar Qinnong 142. *Plant Disease* 103(3):439-447.

Kiszonas, A. M., Higginbotham, R. W., **Chen, X. M.**, Garland-Campbell, K., Bosque-Peres, N.A., Pumphrey, M., Rouse, M., Hole, D., Wen, N., Craig, M. F., and Sykes, S. 2018. Effect of introgression of puroindoline genes into durum wheat on agronomic traits. *Agronomy Journal* 111(3):1254-1265.

Liu, L., Yuan, C. Y., Wang, M. N., See, D. R., Zemetra, R. S., and **Chen, X. M.** 2019. QTL analysis of durable stripe rust resistance in the North American winter wheat cultivar Skiles. *Theoretical and Applied Genetics* 132(6):1677-1691.

- Wan, A. M., Wang, M. N., and **Chen, X. M.** 2019. Variation in telial formation of *Puccinia striiformis* in the United States. *American Journal of Plant Science* 10(5):826-849.
- Hernandez, J., Steffenson, B. J., Filichkin, T., Fisk, S. P., Helgerson, L., Meints, B., Vining, K. J., Marshall, D., del Blanco, A., **Chen, X. M.**, and Hayes, P. M. 2019. Introgression of *rpg4/Rpg5* into barley germplasm provides insights into the genetics of resistance to *Puccinia graminis* f. sp. *tritici* race TTKSK and resources for developing resistant cultivars. *Phytopathology* 109(6):1018-1028.
- Liu, L., Wang, M. N., Feng, J. Y., See, D. R., and **Chen X. M.** 2019. Whole-genome mapping of stripe rust resistance quantitative trait loci and race-specificity related to resistance reduction in winter wheat cultivar Eltan. *Phytopathology* 109(7):1226-1235.
- Cheng, Y. K., Li, J., Yao, F. J., Long, L., Wang, Y. Q., Wu, Y., Li, J., Ye, X. L., Wang, J. R., Jiang, Q. T., Kang, H. Y., Li, W., Qi, P. F., Liu, Y. X., Deng, M., Ma, J., Jiang, Y. F., **Chen, X. M.**, Zheng, Y. L., Wei, Y. M., and Chen, G. Y. 2019. Dissection of loci conferring resistance to stripe rust at the adult-plant stage of Chinese wheat landraces in the middle and lower reaches of the Yangtze River via genome-wide association study. *Plant Science* 287(2019):110204.
- Radhakrishnan, G. V., Cook, N., Bueno-Sancho, V., Lewis, C. M., Persoons, A., Mitiku, A. G., Heaton, M., Davey, P., Abeyo, B., Alemayehu, Y., Badebo, A., Barnett, M., Bryant, R., Chatelain, J., **Chen, X. M.**, Dong, S. M., Henriksson, T., Holdgate, S., Justesen, A. F., Kalous, J., Kang, Z. S., Laczny, S., Legoff, J. -P., Lesch, D., Richards, T., Randhawa, H. S., Thach, T., Wang, M. N., Hovmøller, M. S., Hodson, D. P., and Saunders, D. G. O. 2019. Mobile and real-time plant disease (MARPLE) diagnostics for strain-level identification of complex fungal pathogens. *BMC Biology* 17:65.
- Kang, Z. H., Li, X., Wan, A. M., Wang, M. N., and **Chen, X. M.** 2019. Differential sensitivity among *Puccinia striiformis* f. sp. *tritici* isolates to propiconazole and pyraclostrobin fungicides. *Canadian Journal of Plant Pathology* 41(3):415-434.
- Ye, X. L., Li, J., Cheng, L. K., Yao, F. J., Long, L., Wang, Y. Q., Wu, Y., Li, J., Wang, J. R., Jiang, Q. T., Kang, H. Y., Li, W., Qi, P. F., Lan, X. J., Ma, J., Wei, Y. M., **Chen, X. M.**, Liu, C. J., Zheng, Y. L., and Chen, G. Y. 2019. Genome-wide association study reveals new loci for yield-related traits in Sichuan wheat germplasm under stripe rust stress. *BMC Genomics* 20:640.
- Li, Y. X., Xia, C. J., Wang, M. N., Yin, C. T., and **Chen, X. M.** 2019. Genome sequence resource of a *Puccinia striiformis* isolate infecting wheatgrass. *Phytopathology* 109(9):1509-1512.
- Kosman, E., **Chen, X. M.**, Dreiseitl, A., McCallum, B., Lebeda, A., Ben-Yehuda, P., Gulyaeva, E., and Manisterski, J. 2019. Functional variation of plant-pathogen interactions: new concept and methods for virulence data analyses. *Phytopathology* 109(8):1324-1330.
- Zhang, C. Z., Huang, L., Zhang, H. F., Hao, Q. Q., Lyu, B., Wang, M. N., Epstein, L., Liu, M., Kou, C. L., Qi, J., Chen, F. J., Li, M. K., Gao, G., Ni, F., Zhang, L. Q., Hao, M., Wang, J. R.,

Chen, X. M., Luo, M.-C., Zheng, Y. L., Wu, J. J., Liu, D. C., and Fu, D. L. 2019. An ancestral NB-LRR with duplicated 3'UTRs confers stripe rust resistance in wheat and barley. *Nature Communication* 10(9):4023(1-12).

Tian, Y., Meng, Y., Zhao, X. C., **Chen, X. M.**, Ma, H. B., Xu, S. D., Huang, L. L., Kang, Z. S., and Zhan, G. M. 2019. Trade-off between triadimefon sensitivity and pathogenicity in a selfed sexual population of *Puccinia striiformis* f. sp. *tritici*. *Frontiers in Microbiology* 10:2729.

Berg, J. E., Eberly, J. O., Lamb, P. F., Miller, J. H., Chen, C., Kephart, K. D., Pradhan, G. P., Stougaard, R. N., Nash, D. L., Holen, D. L., Cook, J. P., Gale, S., Jin, Y., Kolmer, J. A., **Chen, X. M.**, Bai, G., and Bruckner, P. L. 2019. Registration of 'FourOsix' hard red winter wheat. *Journal of Plant Registrations* 13(3):383-386.

Wang, J. H., Wang, J. J., Shang H. S., **Chen, X. M.**, Xu, X. M., and Hu, X. P. 2019. TaXa21, a LRR-rich receptor like kinase associated with TaWRKY76 and TaWRKY62, plays positive roles in wheat high-temperature seedling plant resistance to *Puccinia striiformis* f. sp. *tritici*. *Molecular Plant-Microbe Interactions* 32(11):1526-1535.

Liu, W. Z., Kolmer, J., Rynearson, S., **Chen, X. M.**, Gao, L., Anderson, J., Turner, M., and Pumphrey, M. 2019. Identifying loci conferring resistance to leaf and stripe rusts in a spring wheat population (*Triticum aestivum* L.) via genome-wide association mapping. *Phytopathology* 109(11):1932-1940.

Bruckner, P. L., Berg, J. E., Lamb, P. F., Carr, P., Wichman, D. M., Miller, J. H., Meccage, E., Miller, Z., Chen, C., Kephart, K. D., Eberly, J. O., Pradhan, G. P., Nash, D. L., Holen, D. L., Cook, J. P., Gale, S., Jin, Y., and **Chen, X. M.** 2019. Registration of 'Ray' hard red winter forage wheat. *Journal of Plant Registrations* 13(3):392-395.

Zhang, H. T., Nyamesorto, B., Giroux, M. J., Jin, Y., **Chen, X. M.**, and Huang, L. 2019. Registration of MNR434 and MNR527 wheat germplasm with new resistance to rusts. *Journal of Plant Registrations* 13(3):461-464.

Popular Press Articles:

January 8, 2019. First Stripe Rust Forecast and 2018 Fungicide and Variety Yield Loss Tests. E-mail sent to cereal group. <http://smallgrains.wsu.edu/2019-first-stripe-rust-forecast-and-2018-fungicide-and-variety-yield-loss-tests/>

March 22, 2019. Stripe Rust Forecast and Update, March 22, 2019, E-mail sent to cereal group. <http://smallgrains.wsu.edu/stripe-rust-forecast-and-update-march-22-2019/>

April, 2019. The rise and fall of stripe rust epidemics. Integrated management is key to savings. *Wheat Life*, April, 2019.

April 18, 2019. Stripe rust update April 18, 2019, E-mail sent to cereal group.
<http://smallgrains.wsu.edu/stripe-rust-update-april-18-2019/>

May 2, 2019. Stripe rust update May 2 2019, E-mail sent to cereal group.
<https://striperust.wsu.edu/2019/05/06/stripe-rust-update-may-2-2019/>

May 9, 2019. Stripe Rust Update May 9, 2019, E-mail sent to cereal group.
<https://striperust.wsu.edu/2019/05/10/stripe-rust-update-may-9-2019/>

May 29, 2019. Stripe Rust Update May 29, 2019, E-mail sent to cereal group.
<https://striperust.wsu.edu/2019/06/03/stripe-rust-update-may-29-2019/>

June 14, 2019. Stripe Rust Update June 14, 2019, E-mail sent to cereal group.
<https://striperust.wsu.edu/2019/06/17/stripe-rust-update-june-14-2019/>

July 12, 2019. Rust Update July 12, 2019. E-mail sent to cereal group.
<https://striperust.wsu.edu/2019/07/15/stripe-rust-update-july-12-2019/>

November 20, 2019. Stripe Rust Observed in Wheat Fields in Lincoln and Douglas Counties, Washington E-mail sent to cereal group. <https://striperust.wsu.edu/2019/11/27/stripe-rust-update-november-20-2019/>

Presentations and Reports:

In 2019, Xianming Chen presented invited talks at the following national and international meetings:

“Stripe rust update and North American race characterization”, NCERA 184 Annual Meeting, Pensacola Beach, Monday, March 4, 2019 (about 30 people)

“Whole-genome Sequencing of a Sexual Population of the Wheat Stripe Rust Pathogen Identified Candidates for Avirulence Genes”. Rust Workshop at 30th Fungal Genetics Conference, Pacific Grove, California, March 12, 2019 (about 40 people)

“Stripe rust virulence in the United States in 2018”. North American Cereal Workshop, Morden, Manitoba, March 26, 2019 (about 40 people)

“Whole-genome Sequencing of a Sexual Population of the Wheat Stripe Rust Pathogen Identified Candidates for Avirulence Genes”. North American Cereal Workshop, Morden, Manitoba, March 27, 2019 (about 40 people)

“Wheat Germplasm Exploration, Characterization, Development, and Utilization for Achieving Sustainable Control of Stripe Rust”, Triticeae Research Institute, Sichuan Agricultural University, Chengdu, Sichuan, China, May 18, 2019 (about 100 people)

“Wheat Germplasm Exploration, Characterization, Development, and Utilization for Achieving Sustainable Control of Stripe Rust”, College of Plant Protection, Northwest A&F University, Yangling, Shaanxi, China, May 22, 2019 (about 100 people)

“Discovery, development, and deployment of plant resistance for green protection of crops”, 2019 Yangling International Agri-Science Forum, October 23, 2019, Yangling, Shaanxi, China (about 300 people)

In 2019, Xianming Chen, students, and/or associates presented posters or oral presentations at the following national and international meetings:

Posters and student’s oral presentation

Poster entitled “Whole-genome Sequencing of a Sexual Population of the Wheat Stripe Rust Pathogen Identified Candidates for Avirulence Genes” at the 30th Fungal Genetic Conference, Pacific Grove, California, March 12-17, 2019 (about 500 people)

Poster entitled “Whole-genome mapping of QTL conferring all-stage and high-temperature adult-plant resistance to stripe rust in spring wheat landrace PI 181410” At the 1st International Wheat Congress, July 22 - 26, 2019, Saskatoon, SK, Canada (about 900 people).

Poster entitled “Stripe rust epidemics of wheat and barley and races of *Puccinia striiformis* identified in the United States in 2018” at the American Phytopathological Society 2019 Annual Meeting (Plant Health), Cleveland, Ohio, USA, August 3-7, 2019 (about 1,500 people)

Student oral presentation entitled “Whole-genome sequencing of a *Puccinia striiformis* f. sp. *tritici* mutant population identifies avirulence gene candidates” at the American Phytopathological Society 2019 Annual Meeting (Plant Health), Cleveland, Ohio, USA, August 3-7, 2019 (about 100 people)

Reports:

Report of race summaries of the 2018 stripe rust collection in the US. May 2019, <https://striperust.wsu.edu/races/data/>

Stripe data of various wheat and barley germplasm nurseries tested in 2019, <https://striperust.wsu.edu/nursery-data/2019-nursery-data/>

Chen, X. M., Evans, K. C., Wang, M. N., Sprott, J., Liu, L., Liu, Y. M., Liu, Y., Xia, C. J., and Li, Y. X. 2019. Cereal rust management and research in 2018. Pages 36-37 in: 2019 Dryland Field Day Abstracts, Highlights of Research Progress, University of Idaho, Oregon State University, and Washington State University.