Executive summary: In 2022, studies were conducted according to the objectives of the project proposal, and all objectives specified for the first year of this funding cycle were completed on time. 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, resistance, and mechanisms of interactions between the rust pathogens and plants.

Impact: 1) Stripe rust was forecasted and monitored throughout the 2022 crop season, and rust updates and advises were provided on time to growers. In January and March 2022, stripe rust was forecast at a moderate level and the disease was significant at the relatively late growth season. The recommendations made based on the forecasts and rust survey for rust management helped save growers multimillion dollars. 2) We identified 22 races of the wheat stripe rust pathogen and 12 races of the barley stripe rust pathogen from 330 samples throughout the U.S., of which 20 (91%) races of the wheat stripe rust pathogen and 12 (100%) races of the barley stripe rust pathogen were identified from 206 (62%) samples collected in Washington. The race information is useful in screening breeding lines and germplasm for developing stripe rust resistant varieties. 3) We completed and published the studies of molecular characterization of the U.S. stripe rust collections up to 2017 using simple sequence repeat (SSR) markers for determining genetic diversity, differentiation, and dynamics of the pathogen. The results have improved the understanding of stripe rust epidemiology and management. We completed SSR genotyping of the 2018 to 2021 stripe rust collections. We developed more than 200 secreted protein (SP) gene-based single nucleotide polymorphism (SNP) markers and used them to identify SP-SNP markers associated to virulence. 4) We evaluated more than 20,000 wheat and 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. 5) in 2022, we collaborated with public breeders in releasing, pre-releasing, or registered 13 wheat varieties. The germplasm evaluation data were also used to update the Seed-Buying Guide for growers to choose resistant varieties to grow. 6) We completed a study of identifying a new gene for stripe rust resistance in club wheat ‘Tres’, mapped the gene on the short arm of chromosome 1B, determined its difference from other stripe rust resistance genes, and officially named the gene as Yr85. The results make the gene important in differentiating wheat stripe rust races and monitoring pathogenic variation in the pathogen populations. 7) We tested 19 fungicide treatments for control of stripe rust on winter and spring wheats and provided the data to chemical companies for registering new fungicides and tested 23 winter wheat and 23 spring wheat varieties for yield loss caused by stripe rust and yield increase by fungicide application. The data of the fungicide and variety tests are used for guiding the integrated control of stripe rust. 8) In 2022, we published 22 journal articles and 5 meeting abstracts.
## Outputs and Outcomes:

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<th>Objective</th>
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<td>Improve the understanding of rust disease epidemiology and the pathogen populations.</td>
<td>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.</td>
<td>All planned studies for the project in 2022 have been completed on time. There is not any delay, failure, or problem in studies to this objective. The race identification for the 2021 collection was completed and summarized. The data and summary were sent to growers, collaborators and related scientists in February 2022. In the 2022 crop season, we collected and received 330 stripe rust samples throughout the country, of which 206 samples (62%) were collected by ourselves from Washington (WA). We have completed the race ID work for the 2022 samples and detected 22 races of the wheat stripe rust pathogen and 12 races of the barley stripe rust pathogen, of which all 20 (91%) wheat and 12 (100%) barley stripe rust races were detected in WA. The frequency and distribution of each race and virulence factors in WA and the whole country have been determined. Predominant races have been identified. The information on races and virulence factors 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 for breeding lines of wheat and barley with stripe rust resistance. We completed and published the studies of molecular characterization of the U.S. stripe rust collections up to 2017 using SSR markers for determining genetic diversity, differentiation, and dynamics of the pathogen. The results have improved the understanding of stripe rust epidemiology and spore movement among different regions in the U.S. We completed experiments the stripe rust collections from 2018 to 2021 using the set of SSR markers and have been analyzing the data for new genotypes. We developed more than 200 secreted protein (SP) gene-based single nucleotide polymorphism (SNP) markers and used them to characterize the wheat stripe rust collections and identified SP-SNP markers associated to virulence. The virulence and molecular studies have improved the understanding the epidemiology, biology and genetics of the pathogen, and provided information and resources for more efficiently monitoring and managing stripe rusts on wheat and barley.</td>
<td>The race identification work for the 2021 stripe rust samples was completed, summarized, and distributed. The race identification work for the 2022 samples has been completed; the data are being analyzed and summarized; and the data and summary will be distributed soon. Molecular work for the population genetic studies has been completed and published up to the 2017 collection, completed for the 2018-2021 collections, and is being conducted for the 2022 collection. Preliminary results have been obtained for the development of Kompetitive (KASP) markers for monitoring virulence genes in the rust populations.</td>
<td>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).</td>
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<td>2. Improve rust resistance in wheat and barley varieties.</td>
<td>In 2022, we evaluated more than 20,000 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 at both Pullman and Mt. Vernon locations, and some of the nurseries were also tested in Walla Walla, Central Ferry, 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. Excellent stripe rust data were obtained from all locations. The disease data of regional nurseries were provided to all breeding and extension programs, while the data of individual programs’ 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 2022, we collaborated with public breeding programs in releasing and registered 13 wheat varieties. Varieties developed by private breeding programs also were resulted from our germplasm screening program. Through our evaluation, 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 2022, we completed a study of identifying a new gene for race-specific resistance in club wheat 'Tres', mapped the gene on the short arm of chromosome 1B, and officially named the gene as Yr85. The results make the gene important in differentiating wheat stripe rust races and in monitoring pathogenic variation in stripe rust pathogen populations. In 2022, we obtained excellent stripe rust phenotypic data of 3 bi-parental mapping populations at both Pullman and Mount Vernon locations to validate resistance loci previously identified through the bulked analysis of 40 crosses. 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.</td>
<td>All 2022 germplasm tests were completed, and the data were provided to collaborators on time. The 2023 winter wheat nurseries were planted in fields in September and October, 2022. The 2023 spring wheat and barley nurseries will be planted in March-April, 2023. The greenhouse tests of the 2022 winter nurseries were completed and sent to collaborators. The greenhouse tests of 2022 spring nurseries and 2023 winter nurseries have been conducted during this winter, and will be completed by May 2023. All experiments of the molecular mapping studies scheduled for 2021 have been completed. Mapping populations of winter wheat were planted in fields in October, 2022 and those of spring wheat will be planted in April, 2023 for stripe rust phenotype data. 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-Buying Guide, and 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).</td>
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3. Improve the integrated management of rust diseases.

1) Data of fungicide efficacy, dosage, and timing of application for control of 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. 6) *Wheat Life* articles. The information is used for developing more effective integrated control programs based on individual varieties. Disease updates and recommendations will allow growers to implement appropriate control.

In 2022, stripe rust was accurately forecasted and monitored throughout the 2022 crop season, and rust updates and advises were provided on time to growers. Moderate stripe rust was forecasted in January and March and occurred in the late growth season. The recommendations prevented major yield loss and reduced unnecessary use of fungicides, saving growers multimillion dollars. In 2022, we planted field nurseries at Pullman, WA for evaluating 19 fungicide treatments on winter wheat and spring wheat, and 23 winter and 23 spring wheat varieties, plus a non-treated check in each nursery. In the fungicide test on winter wheat, all 19 fungicide treatments significantly reduced stripe rust severity and increased grain yield compared to the non-treated check, with 2 treatments provided the best control of stripe rust. Three treatments had higher grain test weight than the non-treated check. The significant yield responses ranged from 10.0 bu/A (85.7%) to 55.1 bu/A (469.6%). In the fungicide test on spring wheat, all 19 fungicide treatments significantly reduced stripe rust severity and increased grain yield compared to the non-treated check. Three treatments had higher yield than the check. The significant yield responses ranged from 21.5 bu/A (51.9%) to 46.7 bu/A (115.5%). In the test of 23 winter wheat varieties plus a susceptible check, the two applications of fungicide significantly reduced stripe rust of 12 commercial varieties; protected grain test weight of the check by 3.1 lb/bu and 4 commercial cultivars by 1.5 to 14.3 lb/bu; made significant yield differences for the susceptible check (53.4 bu/A more in the sprayed plots) and 17 commercial varieties with 9.7 to 68.3 bu/A more grain in the sprayed plots. Six commercial varieties showed no significant yield differences between the no-spray and spray treatments. These data indicated that stripe rust caused yield loss of 53.4 bu/A (87.6%) on the susceptible check and 16.8 bu/A (14.4%) yield loss on average across the commercially grown varieties under the extremely severe disease pressure from early inoculation of the pathogen in the experimental field. Similarly, in the test of 23 spring wheat varieties plus a susceptible check, the two applications of fungicide significantly reduced stripe rust severity on the susceptible check and 8 commercial varieties; protected grain test weight of the check by 6.7 lb/bu and 2 commercial varieties by 3.1 to 5.3 lb/bu; made significant yield differences for the susceptible check (39.4 bu/A more in the sprayed plots) and 3 commercial varieties with 31.1 to 31.8 bu/A more grain in the sprayed plots, indicating that stripe rust caused yield loss of 51.9% on the check and 6.3% on average across the commercially varieties.

For this objective, all tests scheduled for 2022 were completed. For the 2022-23 growing season, the winter wheat plots of the fungicide and variety yield loss studies were planted in October, 2022, and the spring plots will be planted in April, 2023. The tests will be completed in August (for winter wheat) and September (for spring wheat), 2023.

The results were communicated to growers and collaborators through e-mails, project reports and reviews, and published in scientific journals.
Publications:

*Scientific Journals:*


**Popular Press Articles:**


April 17, 2022. Stripe Rust Update, April 17, 2022. Xianming Chen, E-mail sent to cereal group. [https://striperust.wsu.edu/2022/04/19/stripe-rust-update-april-17-2022/](https://striperust.wsu.edu/2022/04/19/stripe-rust-update-april-17-2022/)

May 12, 2022. Stripe Rust Update, May 12, 2022. Xianming Chen, E-mail sent to cereal group. [https://striperust.wsu.edu/2022/05/12/stripe-rust-update-may-12-2022/](https://striperust.wsu.edu/2022/05/12/stripe-rust-update-may-12-2022/)


**Presentations and Reports:**

In 2022, Xianming Chen and associates presented invited talks at the following regional, national, and international meetings:

- May 19, 2022. Xianming Chen presented field experiments and research progress to faculty and students of the Ecological Agriculture Program, Evergreen College at Mount Vernon, WA.

- June 13, 2022. Xianming Chen presented stripe rust management at Hermiston Irrigated Cereal Field Day.

- June 30, 2022. Xianming Chen presented field experiments and progress of stripe rust research at Spillman Farm Field Day.


Xianming Chen attended the APS Plant Health 2022 annual meeting and presented “Characterization of Puccinia striiformis races causing barley and wheat stripe rusts in the United States in 2021 (Authors: Meinan Wang and Xianming Chen), August 7-10, 2022, Pittsburg, Pennsylvania.

Reports:

