Washington Grain Commission
Wheat and Barley Research Annual Progress Report

Project #: 5682

Progress Report Year: 1 of 3 (2016)

Title: Control of Rusts of Wheat and Barley

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Executive summary: During 2016, 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 and mechanisms of interactions between the pathogen and plants.

Impact: 1) Stripe rust was accurately forecasted in 2016. Rust updates and advises were provided on time to growers based on the forecasts using prediction models and field surveys, which effectively protected both winter wheat and spring wheat crops from potentially huge yield losses, which ensured bumper harvest under the extremely severe stripe rust epidemic. 2) We identified 5 races of barley stripe rust and 34 races of wheat stripe rust in the US, of which 4 and 25 were detected in Washington, respectively. Four of the races from Washington were new. The virulence information is used to guide breeding programs for using effective resistance genes in developing resistant varieties. 3) We used molecular markers developed in our lab to study the stripe rust pathogen and determined the population changes in the past and present. 4) We evaluated more than 35,000 wheat and 3,000 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 2016, we collaborated with breeders in releasing, pre-releasing, or registered 7 wheat and 1 barley 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 5 genes for stripe rust resistance in three wheat lines and identified molecular markers. We officially named one stripe rust resistance gene, and published 6 papers on molecular mapping of stripe rust resistance genes. 6) We developed 29 new wheat germplasm lines with single new genes or combinations of genes for resistance to stripe rust and registered them in the USDA National Small Grains Collection to make them available for breeding programs to use. 7) We provided seeds of our developed 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. 8) We tested 47 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. The data of the fungicides and varieties are used for guiding the integrated control of stripe rust. 8) We published 22 journal articles and 15 meeting abstracts in 2016.

Outputs and Outcomes:

Progress, Timelines, and Communication are presented in Outcome Reporting file (file name: Chen_WGC 2016 Annual Report Outcome Reporting.pdf)

Publications:

<u>*Scientific Journals*:</u>

Klarquist, E. F., **Chen, X. M.**, Carter, A. H. 2016. Novel QTL for stripe rust resistance on chromosomes 4A and 6B in soft white winter wheat cultivars. Agronomy 6:4.

Chen, J., Wheeler, J., O'Brien, K., Zhao, W., Klassen, N., Zhang, J., Bowman, B., Jackson, Ch., Marshall, J. M., and **Chen, X. M.** 2016. Release of 'UI Platinum' hard white spring wheat. Journal of Plant Registrations 10:36-40.

Xia, C. J., Wang, M. N., Wan, A. M., Jiwan, D. A., See, D. R., **Chen, X. M.** 2016. Association analysis of SP-SNPs and avirulence genes in *Puccinia striiformis* f. sp. *tritici*, the wheat stripe rust pathogen. American Journal of Plant Sciences 7:126-137.

Tian, Y., Zhan, G. M., **Chen, X. M.**, Tungruentragoon, A., Lu, X., Zhao, J., Huang, L. L., and Kang, Z. S. 2016. Virulence and SSR marker segregation in a *Puccinia striiformis* f. sp. *tritici* population produced by selfing a Chinese isolate on *Berberis shensiana*. Phytopathology 106:185-191.

Zhan, G. M., Wang, F. P., **Chen, X. M.**, Wan, C. P., Han, Q. M., Huang, L. L., and Kang, Z. S. 2016. Virulence and molecular diversity of the *Puccinia striiformis* f. sp. *tritici* population in Xinjiang in relation to other regions of western China. Plant Disease 100:99-107.

Wang, Z. Y., Zhao, J., **Chen, X. M.**, Peng, Y. L., Ji, J. J., Zhao, S. L., Lu, Y. J., Huang, L. L., and Kang, Z. S. 2016. Virulence variations of *Puccinia striiformis* f. sp. *tritici* isolates collected from *Berberis* spp. in China. Plant Disease 100:131-138.

Chen, X. M., Evans, C. K., and Liu, Y. M. 2016. Control of stripe rust of winter wheat with various foliar fungicides, 2015. Plant Disease Management Reports 10:CF:022.

Chen, X. M., Evans, C. K., and Liu, Y. M. 2016. Responses of winter wheat cultivars to fungicide application for control of stripe rust in 2015. Plant Disease Management Reports 10:C023.

Cheng, P., **Chen, X. M.**, and See, D. 2016. Grass hosts harbor more diverse isolates of *Puccinia striiformis* than cereal crops. Phytopathology 106:362-371.

Li, K., Hegarty, J., Zhang, C. Z., Wan, A. M., Wu, J. J., Gina L Brown-Guedira, G. L., **Chen, X. M.**, Fu, D. L., and Dubcovsky, J. 2016. Fine mapping of barley locus *Rps6* conferring resistance to wheat stripe rust. Theoretical and Applied Genetics 129:845–859.

Xia, C. J., Wan, A. M., Wang, M. N., Jiwan, D. A., See, D. R., and **Chen, X. M.** 2016. Secreted protein gene derived-single nucleotide polymorphisms (SP-SNPs) reveal population diversity and differentiation of *Puccinia striiformis* f. sp. *tritici* in the United States. Fungal Biology 120:729-744.

Wan, A. M., **Chen, X. M.**, and Yuen, J. 2016. Races of *Puccinia striiformis* f. sp. *tritici* in the United States in 2011 and 2012 and comparison with races in 2010. Plant Disease 100:966-975.

Berg, J. E., Lamb, P. F., Miller, J. H., Wichman, D. M., Kephart, K. D., Stougaard, R. N., Pradhan, G. P., Nash, D. L., Grey, W. E., Gettel, D., Jin, Y., Kolmer, J. A., **Chen, X. M.**, Bai, G., Murray, T. D., and Bruckner, P. L. 2016. Registration of 'Northern' wheat. Journal of Plant Registrations 10:135-138.

Liu, M. Y., Lei, L., Powers, C., Liu, Z., Campbell, K. G., **Chen, X. M.**, Bowden, R. L. Carver, B. F., and Yan, L. L. 2016. *TaXa21-A1* on chromosome 5AL is associated with resistance to multiple pests in wheat. Theoretical and Applied Genetics 129:345–355.

Bulli, P., Zhang, J. L., Chao, S. M., **Chen, X. M.**, and Pumphrey, M. 2016. Genetic architecture of resistance to stripe rust in a global winter wheat germplasm collection. G3: Genes, Genomes and Genetics 6:2237-2253.

Zhao, J., Wang, M. N., **Chen, X. M.**, and Kang, Z. S. 2016. Role of alternate hosts in epidemiology and pathogen variation of cereal rusts. Annual Review of Phytopathology 54:207-228

Xiang, C., Feng, J. Y., Wang, M. N., **Chen, X. M.**, See, D. R., Wan, A. M., and Wang, T. 2016. Molecular mapping of *Yr76* for resistance to stripe rust in winter club wheat cultivar Tyee. Phytopathology 106:1186-1193.

Klos, K. E., Gordon, T., Bregitzer, P., Hayes, P., **Chen, X. M.**, del Blanco, I. A., Fisk, S., and Bonman, J. M. 2016. Barley stripe rust resistance QTL: Development and validation of SNP markers for resistance to *Puccinia striiformis* f. sp. *hordei*. Phytopathology 106:1344-1351.

Wang, J. J., Tao, F., An, F., Zou, Y. P., Tian, W., **Chen, X. M.**, Xu, X. M., and Hu, X. P. 2016. Wheat transcription factor TaWRKY70 is positively involved in wheat high-temperature seedling-plant resistance to *Puccinia striiformis* f. sp. *tritici*. Molecular Plant Pathology 17 DOI: 10.1111/mpp.12425

Akin, B., **Chen, X. M.**, Morgunov, A., Zencirci, N., Wan, A. M. 2016. High-temperature adult-plant (HTAP) stripe rust (*Puccinia striiformis* f. sp. *tritici*) resistance in facultative winter wheat. Crop & Pasture Science 67:1064-1074.

Wan, A. M., Muleta, K. T., Zegeye, H., Hundie, B., Pumphrey, M. O., and **Chen, X. M.** 2016. Virulence characterization of wheat stripe rust fungus *Puccinia striiformis* f. sp. *tritici* in

Ethiopia and evaluation of Ethiopian wheat germplasm for resistance to races of the pathogen from Ethiopia and the United States. Plant Disease 101:73-80.

Wu, J. H., Wang, Q. L., **Chen, X. M.**, Wang, M. J., Mu, J. M., Lv, X. N., Huang, L. L., Han, D. J., and Kang, Z. S. 2016. Stripe rust resistance in wheat breeding lines developed for central Shaanxi, an overwintering region for *Puccinia striiformis* f. sp. *tritici* in China. Canadian Journal of Plant Pathology 38:317-324.

Popular Press Articles:

January 11, 2016. First Forecast of Stripe Rust for 2016 and 2015 Fungicide and Variety Yield Loss Tests. Xianming Chen, E-mail sent to growers and the cereal group.

January 17, 2016. Pacific Northwest stripe rust outlook 'moderate'. Matthew Weaver, *Capital Press*, http://www.capitalpress.com/Profit/20160117/pacific-northwest-stripe-rust-outlook-moderate

February, 2016. Initial forecast predicts little stripe rust. Xianming Chen. *Wheat Life*, February 2016, page 14.

February 10, 2016. Stripe rust forecast is good news for wheat growers by Tim Murray. *On Solid Ground*. CAHNRS, WSU. http://cahnrs.wsu.edu/blog/2016/02/stripe-rust-forecast-is-good-news-for-wheat-growers/?utm_campaign=auto-draft&utm_source=on-solid-ground-february-2016-2016-10&utm_medium=email&utm_content=link-19.

March 4, 2016. Stripe Rust Forecast and Update, March 4, 2016. Xianming Chen, E-mail sent to growers and cereal group.

March 31, 2016. Stripe Rust Update, March 31, 2016. Xianming Chen, E-mail sent to growers and cereal group.

April 13, 2016. Stripe Rust Update, April 13 2016. Xianming Chen, E-mail sent to growers and cereal group.

April 14, 2016. Expert predicts severe stripe rust across PNW. Matthew Weaver, *Capital Press*. http://www.capitalpress.com/Profit/20160414/expert-predicts-severe-stripe-rust-across-pnw

April 30, 2016. Experts anticipate stripe rust epidemic. Josh Babcock, *Daily News*, http://dnews.com/local/experts-anticipate-stripe-rust-epidemic/article_420a5da4-9c32-5072-9cdc-a9274e2bc8ff.html

May, 2016. Stripe rust developing early in warm, wet spring weather. Xianming Chen, *Wheat Life*, May, 2016, pages 12-14.

May 5, 2016. Stripe Rust Update, May 5, 2016. Xianming Chen, E-mail sent to growers and cereal group.

May 26, 2016. Stripe Rust Update, May 26, 2016. Xianming Chen, E-mail sent to growers and cereal group.

June 3, 2016, All systems are go for grain crops, Region appears to have mostly avoided threats of late frost, stripe rust epidemic. Kathy Hedberg, *The Lewiston Tribune*.

June 2016, Stripe rust found throughout Pacific Northwest wheat fields. Xianming Chen, *Wheat Life*, June 2016, pages 12-14.

June 17, 2016, Stripe rust Update, June 17, 2016. Xianming Chen, E-mail sent to growers and cereal groups.

July, 2016. Stripe rust developing on spring wheat, barley crops. Xianming Chen, *Wheat Life*, July, 2016, pages 14-16.

July 25, 2016. Stripe rust pressure ‘severe’ in Northwest wheat, expert says. Matthew Weaver. *Capital Press*.

September 29, 2016. Estimates of yield losses caused by stripe rust and increase by fungicide application on PNW wheat varieties. Xianming Chen, E-mail sent to growers and cereal group.

November 9, 2016. Widespread Stripe Rust Infection on Winter Wheat in Washington. Xianming Chen, E-mail sent to growers and cereal group.

All 2016 nursery data were sent to growers, cereal group, and/or collaborators.

Presentations and Reports:

Xianming Chen presented an invited talk “Wheat Stripe Rust Integrated Control Based on Forecasting, Monitoring, and Resistance” at American Phytopathological Society Rust Symposium, 8-9 March, 2016, Pensacola, Florida. (About 100 people)

Xianming Chen presented the following posters at American Phytopathological Society Rust Symposium, 8-9 March, 2016, Pensacola, Florida (About 100 people)

1) “Wheat stripe rust integrated control based on forecasting, monitoring, and resistance”
2) “Virulence changes of *Puccinia striiformis* f. sp. *tritici* in 1968-2015 in the US”

Xianming Chen and graduate students, visiting students, and postdoctoral associates presented the following talks or posters at the American Phytopathological Society Pacific Division Meetings at La Conner, WA, June 29-30, 2016 (About 200 people):

1) “Characterization of somatic recombinant isolates of *Puccinia striiformis*, the stripe rust pathogen”

2) “Molecular mapping of stripe rust resistance genes in spring wheat line W18”
3) “Variation of telial formation in the *Puccinia striiformis* f. sp. *tritici* population”
4) “Towards construction of genetic linkages for mapping virulence genes in *Puccinia striiformis* f. sp. *tritici*, the wheat stripe rust pathogen”
5) “Pyramiding stripe rust resistance genes on wheat chromosomes 2B, 4B, and 7B”
6) “Expression profiling of pathogenesis-related protein genes in wheat resistance to the stripe rust pathogen (*Puccinia striiformis* f. sp. *tritici*)”
7) “Virulence characterization of *Puccinia striiformis* f. sp. *tritici* in the US for the past 48 years using the *Yr* single-gene differentials”
8) “Developing a wheat germplasm with linked genes *Yr64* and *Yr65* for resistance to stripe rust”
9) “Development of *Puccinia striiformis* f. sp. *tritici* mutants for avirulence characterization”
10) “Seedling reactions of Mexican wheat varieties and advanced lines to four races of *Puccinia striiformis* f. sp. *tritici*, the stripe rust pathogen”.

Xianming Chen presented the following posters at the American Phytopathological Society Annual Meeting, July 31-August 3, 2016, Tampa, Florida (over 2000 people):

1) “Stripe rust epidemics of wheat and barley and races of *Puccinia striiformis* identified in the United States in 2015”
2) “Molecular mapping of effective stripe rust resistance genes in wheat germplasm PI 182126”

Xianming Chen presented an invited talk “Recent Progress of Stripe Rust Research in the United States”. November 24, 2016 Northwest A&F University, Yangling, China (about 200 people)

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

- 6/16/2016: Lind Field Day (about 100 people)
- 7/13/2016: Farmington Field Day (about 25 people)
- 7/14/2016: St John Field Day (about 25 people)
- 7/14/2016: Lamont Field Day (about 16 people)

WGC project number: 5682
WGC project title: Control of Rusts of Wheat and Barley
Project PI(s): Xianming Chen
Project initiation date: 7/1/2016
Project year: 1 of 3 (2016)

Objective	Deliverable	Progress	Timeline	Communication
1. Conduct disease forecast and field survey for guiding disease management	**1) Stripe rust predictions.** Accurate prediction before the rust season will allow growers to prepare for appropriate control measures including choosing resistant varieties to plant and possible fungicide application. **2) Field disease monitoring updates and recommendations.** Disease updates and recommendations will allow growers to implement appropriate control.	All planned studies for the project in 2016 have been completed on time. There is no any delay, failure, or problem in studies to this objectives. Forecasts of wheat stripe rust epidemic were made in January based on the November and December weather conditions and in March based on the the entire winter weather conditions using our prediction models. Further forecasts were made throughout the season based on rust survey data and past and forecasted weather conditions. These forecasts and rust updates were reported to wheat researchers and growers. Field surveys were conducted by our program and collaborators throughout the Pacific Northwest (PNW) and the country. Stripe rust started earlier than normal in eastern PNW but normal as always in western PNW. The early started stripe rust created high disease pressure and the stripe rust favorable weather conditions throughout the growth season made the disease an extremely severe epidemics. The timely applications of fungicides on susceptible and moderately susceptible wheat varieties prevented major yield loss and ensured bumper harvest. Barley stripe rust was relatively significant compared to the recent year, but still not severe enough to be a major concern. Leaf rust of wheat was normal in western but absent in eastern PNW; and leaf rust of barley was normal in western but absent in eastern PNW. Stem rust of wheat and barley was basically absent in the PNW in 2016.	All studies and services were completed on time.	The rust forecasts and survey data were communicated to growers and other researchers 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. Identify races and characterize populations of the wheat and barley stripe rust pathogens for providing useful pathogen information to breeding programs for developing resistant varieties and to growers for managing diseases.	**1) New races. 2) Distribution, frequency, and changes of all races. 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.	In 2006, we collected and received 444 stripe rust samples throughout the country and 39 of them from Washington. We have completed about 90% of the race ID work for the 2016 samples as scheduled by this time. So far we have detected 34 wheat stripe rust races and 5 barley stripe rust races, of which 25 and 4 were detected respectively in Washington. The distribution and frequency of each race and virulence factor in the US 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 used molecular markers developed in our lab to study the stripe rust pathogen and determined the population changes in the past and present, and use molecular markers to tag virulence genes in the pathogen. We completed molecular characterization of historical stripe rust populations from 1968 to 2009 and also for the collections in the recent years up to 2013.	The race identification work for the 2016 stripe rust samples will be completed by late February, 2017, as scheduled. The race ID work for 2017 samples will start in March. Molecular work of the 2014-2015 samples and DNA extraction of the 2016 samples will be completed by June, 2017.	The rust race data were communicated to growers and researchers through e-mails, website, project reports, meeting presentations and publications in scientific journals (for detailed information, see the lists in the main report file).

3. Screening wheat and barley germplasm for supporting breeding programs to develop rust resistant varieties	**1) Stripe rust reaction data of wheat and barley germplasm and breeding lines. 2) Reactions to other diseases when occur. 3) Resistant germplasm for use in breeding programs. 4) New varieties for growers to grow.** The stripe rust data will allow breeding programs to get rid of susceptible lines or select lines for further improvement, and more importantly for releasing new varieties for with stripe rust resistance combined with other desirable traits fro grower to grow.	In 2016, we evaluated more than 35,000 wheat and 3,000 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 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 2016, we collaborated with public breeding programs in releasing and registered 7 wheat varieties and 1 barley variety. Varieties developed by private breeding programs were also resulted from our germplasm screening program.	All germplasm tests were completed and the data were provided to collaborators on time. The 2016-17 winter wheat nurseries were planted in fields in September and October 2016. The 2017 spring crop nurseries will be planted in March-April, 2017. The greenhouse tests of the 2016 spring nurseries and the 2016-17 winter wheat nurseries have been conducting in the greenhouse during the winter, and will be completed by May, 2017	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.
4. Identify and map new stripe rust resistance genes and develop new germplasm for use in breeding programs to diversify resistance genes in new varieties	**1) New stripe rust resistant sources. 2) New resistance genes with their genetic information. 3) Molecular markers for resistance genes. 4) New germplasm with improved traits.** 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.	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 effective resistance. Through our intensive testing, varieties with durable resistance to stripe rust have been developed. In 2016, we completed studies for mapping five stripe rust resistance genes in three wheat crosses, and identified molecular markers for these genes. We officially named one stripe rust resistance gene. We also collaborate with other laboratories in mapping of numerous stripe rust resistance loci in various wheat germplasm collection through genome-wide association study approach, and published 6 papers on molecular mapping of stripe rust resistance genes. We developed 29 new wheat germplasm lines with single new genes or combinations of genes for resistance to stripe rust and registered them in the USDA National Small Grains Collection to make them available for breeding programs to use. In 2016, we phenotyped eight mapping populations for stripe rust responses and advanced progeny populations for 30 winter wheat crosses for mapping stripe rust resistance genes.	All experiments scheduled for 2016 were successfully completed. Mapping populations of winter wheat were planted in fields in October 2016 and those of spring wheat will be planted in April, 2017 for stripe rust phenotype data. Populations with adequate phenotype data are genotyped with molecular markers for mapping resistance genes. Progenies of new crosses will be advanced in fields in 2017.	New genes and molecular markers were published in scientific journals (see the publication and presentation lists in the report main file)

5. Improve the integrated control strategies by screening new chemicals and determining potential yield losses and fungicide responses of individual varieties	**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.** The information is used for developing more effective integrated control program based on individual varieties for growers to use to control stripe rust.	In 2016, we evaluated 23 fungicide treatments on winter wheat and 47 fungicide treatments on spring wheat for control of stripe rust in experimental fields near Pullman, WA. Treatments with two applications were more effective than only one application in reducing rust and increasing yield. For winter wheat, most treatments significantly increased gain yield compared with the non-treated check, and the significant increases ranged from 19 bushes (164%) to 91 bushes (797%). For spring wheat, most fungicide treatments significantly increased yield compared with the non-treated check. The significant increases of grain yield ranged from 8 bushes (65%) to 56 bushes (449%) depending upon fungicide treatments. In 2016, we tested 23 winter wheat and 15 spring wheat varieties commonly grown in the PNW, plus highly susceptible checks. For winter wheat, stripe rust caused 71% yield loss on the susceptible check and from 0 to 32% yield losses at an average of 8% on commercially grown varieties. Fungicide application increased yield by 0 to 47% at an average of 10% on commercially grown varieties. For spring wheat, stripe rust caused 54% yield loss on the susceptible check and from 0 to 43% yield losses at an average of 20% on commercial varieties. Fungicide application increased grain yields by 0 to 74% on commercial varieties at an average of 29%. These results will 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	For this objective, all tests scheduled for 2016 were successfully completed. For the 2016-17 growing season, the winter wheat plots of the fungicide and variety studies were planted in October, 2016 and the spring plots will be planted in April, 2017. The tests will be completed in August (for winter wheat) and September (for spring wheat), 2017	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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