

Final Report

Project #: 3682
Progress Report Year: 2 of 2
Title: Control of Eyespot and Cephalosporium Stripe in Winter Wheat
Cooperators: **T. D. Murray, Plant Pathologist**
A. Carter, Crop & Soil Sciences, WSU
K. Garland-Campbell, USDA-ARS

Executive summary: Variety trials for eyespot and Cephalosporium stripe were conducted in 2018-19 and 2019-20. A total of 102 two new varieties and advanced lines were evaluated for resistance to eyespot and tolerance to Cephalosporium stripe in inoculated field trials. Data from these plots is used to update disease ratings in the Washington State Crop Improvement Association Seed Buyers Guide and the WSU Extension Small Grains variety selection tool.

Five growth chamber experiments were conducted to map eyespot disease resistance genes in Madsen and Cappelle-Desprez populations to determine whether the same genes control resistance to both species of the eyespot pathogen. Phenotyping and genotyping were completed, data analysis is nearly done, and a manuscript is in progress. In collaboration with colleagues in China, resistance to both species of cereal cyst nematode (CCN) was mapped in the same Madsen population and demonstrated that it carries two different genes, one each to *H. avenae* and *H. filipjevi*, both derived from VPM-1, the source of eyespot resistance. That work was published and available to breeders.

Two field experiments were conducted to determine the effect of new seed treatment fungicides and the effect of foliar fungicides on eyespot. Seed treatment fungicides did not reduce disease or improve yield over the untreated control; however, one of the foliar fungicide treatments resulted in significantly less disease and increased yield compared to the untreated control. If registered, it would be a new active ingredient for use in eyespot control.

Impact: Cephalosporium stripe and eyespot continue to be significant yield-limiting diseases for winter wheat production. Nearly all public and private breeding programs in the PNW are addressing these diseases because resistant/tolerant varieties are the most effective way to limit their impact. This project is the only place where all new varieties and advanced breeding lines are evaluated side-by-side for their reaction to eyespot and Cephalosporium stripe. The data we generate are shared with wheat breeders to support variety release and growers at variety testing field tours, online at the WSU Extension Small Grains website, and is used to provide ratings in the WSCIA seed buyer's guide and the WSU Small Grains Variety Selection tool for use by growers in making variety selection decisions.

The gene present in Madsen is the primary source of resistance in all PNW eyespot-resistant varieties and understanding its genetic control will insure it remains effective. We suspect differences in effectiveness among resistant varieties may be the result of minor genes that have not been identified and/or differences in resistance to the two eyespot fungi. Identifying minor genes affecting eyespot resistance and molecular markers for them will allow breeders to develop new varieties with more effective eyespot resistance. Screening wild relatives of wheat for new sources of eyespot resistance is an important long-term goal.

Results:

**2019-20 Eyespot Variety Trial
Plant Pathology Farm, Pullman, WA
Dr. Tim Murray**

Name	Disease		Name	Disease	
	Index	Rating		Index	Rating
LCS Blackjack	12.6	1.4	Appleby CL+	56.0	6.1
Rosalyn	14.9	1.6	WA 8305 CL+	56.4	6.2
LWW16-71088	16.7	1.8	IDO1906 HWW	56.7	6.2
OR2x2 CL+	23.8	2.6	UIL 17-6268 CL+	57.0	6.2
WA 8293	26.1	2.9	WA 8316	57.6	6.3
Resilience CL+	26.2	2.9	IDO1808 SWW	60.2	6.6
Madsen (resistant check)	26.8	2.9	UIL 17-6451 CL+	60.9	6.7
Nixon	30.4	3.3	Farnum	61.1	6.7
VI Bulldog	31.7	3.5	IDO1810 SWW	64.3	7.0
Puma	32.1	3.5	UIL 17-6834 CL+	64.7	7.1
ARS09X492-6CBW	32.4	3.5	Sequoia	65.1	7.1
Pritchett	33.8	3.7	UI Bronze Jade	65.7	7.2
08PN030-3	34.4	3.8	Scorpio	66.0	7.2
VI Frost	34.6	3.8	SY Dayton	66.9	7.3
WA 8271 (Devote)	37.0	4.1	aMaze	68.0	7.4
WA 8307	39.8	4.4	LCS Rocket	69.4	7.6
UI Sparrow	40.2	4.4	Eltan (susceptible check)	70.7	7.7
WA 8289	42.2	4.6	WB4311	70.9	7.8
IDO1608 HRW	43.8	4.8	WB1529	71.7	7.8
Stingray CL+	44.0	4.8	WA 8310	72.0	7.9
YS-201	44.0	4.8	Keldin	73.8	8.1
WA 8309	44.8	4.9	AP Redeye	73.9	8.1
WA 8287	45.2	5.0	IDO1806 HWW	76.8	8.4
ARS-Castella	47.2	5.2	LCS Ghost	77.2	8.5
WA 8306 CL+	49.0	5.4	IDO1607 HRW	77.6	8.5
WA 8308	50.5	5.5	IDO1506 HWW	79.5	8.7
WA 8290	51.1	5.6	WB4394	80.6	8.8
WA 8317	54.3	5.9	WA 8318 CL+	81.6	8.9
Purl	54.6	6.0	LCS Zoom	83.0	9.1
11PN044#84	54.6	6.0	LSD 5%	14.3	

Values represent the mean of three replicates. Plants were removed and evaluated for disease incidence and severity on 6/23/20 to 6/29/20. Eyespot severity was determined by evaluating stem bases, 1 to 2 internodes above the crown, for symptom severity using a 0 to 4 scale where 0 = no visual symptoms, 1, 2 and 3 = up to 25, 50 and 75% of the stem circumference colonized by a lesion(s), respectively, and a 4 = a stem with a lesion girdling the base. Disease severity is the weighted mean of all evaluated stems and incidence is the percentage of stems with symptoms. Disease index was calculated by multiplying disease incidence by disease severity and dividing by four and ranges from 0 to 100. The disease Index was significantly different among varieties (Pr > F = 0.0001).

Rating reflects the degree of resistance and ranges from 1 to 9, where 1 = highly resistant and 9 = highly susceptible.

2019-2020 Eyespot Foliar Fungicide Trial
Plant Pathology Farm, Pullman, WA
Dr. Tim Murray

Treatment	Rate, fl. oz/ac	Mean				
		DI%	DS	Index	Yield bu/ac	Bushel wt lbs/bu
Control		93.7	3.2	75.1	92.1	58.5
Miravis Ace	13.7	57.5	2.5	35.8	104.2	59.0
Miravis Ace	7.0	73.3	2.7	49.0	111.9	59.6
Tilt + Telaris	4 + 10	92.8	3.1	73.0	92.0	58.3
Aprovia Ace	7.0	93.3	3.2	75.4	90.3	58.3
Trivapro	9.4	96.1	3.3	78.1	91.1	58.0
Trivapro	13.7	96.4	3.3	79.9	92.2	57.8
Aprovia Ace	13.7	96.2	3.4	81.9	91.2	58.3
LSD 5%		10.5	0.2	9.7	12.2	1.0

The plot was planted 19 September 2019 with a 1:1 mixture of ‘Eltan’ and ‘Hill 81’ winter wheat cultivars. Inoculation with a suspension of conidia of both eyespot pathogens was made 6 November 2019. Plots were sampled during the first two weeks of June by digging plants from three locations in each plot and combining them. Tops were removed and outer leaf sheaths removed. Visual ratings of lesion severity were made using a 0 to 4 scale where: 0 = no visual symptoms, 1, 2 and 3 = up to 25, 50 and 75% of the stem circumference colonized by a lesion(s), respectively, and a 4 = a stem with a lesion girdling the base. Disease severity is the weighted mean of all evaluated stems and incidence is the percentage of stems with symptoms. Disease index is calculated by multiplying disease incidence by disease severity and dividing by four and ranges from 0 to 100. Plots were harvested on 8 August 2020 with a Wintersteiger NurseryMaster plot combine.

Publications:

- Murray, T.D. and H. Sheng. 2020. Reaction of winter wheat cultivars and breeding lines to eyespot in Washington, 2020. *Plant Disease Management Reports* [SUBMITTED 7 December 2020].
- Murray, T.D. and H. Sheng. 2020. Evaluation of fungicides to control eyespot in winter wheat, 2020. *Plant Disease Management Reports* [SUBMITTED 7 December 2020].
- Sheng, H., K. Esvelt Klos, and T.D. Murray. 2020. High-throughput single-seed PCR detection and real-time quantification of *Cephalosporium gramineum* in winter wheat seed. *Plant Disease* [SUBMITTED 15 OCTOBER 2020].
- Campbell, K.G., R.E. Allan, A.H. Carter, P. DeMacon, E. Klarquist, N. Wen, X. Chen, C.M. Steber, C. Morris, D. See, A. Esser, D. Engle, R. Higginbotham, C. Mundt, and T.D. Murray. 2020. Registration of 'Castella' Soft White Winter Club Wheat. *J. Plant Registrations* [SUBMITTED 1 October 2020].
- Campbell, K.G., R. Allan, A. Burke, X. Chen, P. DeMacon, R. Higginbotham, D. Engle, S. Johnson, E. Klarquist, C. Mundt, T. Murray, C. Morris, D. See, and N. Wen. 2020. Registration of "ARS Crescent" Soft White Winter Club Wheat. *J. Plant Registrations* [SUBMITTED 2 August 2020].
- Carter, A.H., K.A. Balow, G.B. Shelton, A.B. Burke, K.E. Hagemeyer, A. Stowe, J. Worapong, R.W. Higginbotham, X.M. Chen, D.A. Engle, T.D. Murray, and C.F. Morris. 2020. Registration of 'Stingray CL+' Soft White Winter Wheat. *J. Plant Registrations* [SUBMITTED 15 July 2020].
- Gill, K.S., N. Kumar, H.S. Randhawa, K. Murphy, A.H. Carter, C.F. Morris, R.W. Higginbotham, D.A. Engle, S.O. Guy, D. Lyon, T.D. Murray, X.M. Chen, and W.F. Schillinger. 2020. Registration of 'Resilience CL+' Soft White Winter Wheat. *J. Plant Registrations* [IN PRESS 3 November 2020].
- Murray, T.D. 2020. The war on wheat diseases. *Wheat Life* 63(1):42-45.
- Murray, T.D. and H. Sheng. 2020. Reaction of winter wheat cultivars and breeding lines to eyespot in Washington, 2019. *Plant Disease Management Reports* 14:CF177.
- Murray, T.D. and H. Sheng. 2020. Reaction of winter wheat cultivars and breeding lines to *Cephalosporium* stripe in Washington, 2019. *Plant Disease Management Reports* 14:CF178.
- Bomberger, R. and T. Murray. 2020. Wheat Streak Mosaic Virus in Eastern Washington. *Timely Topics*, June 22, 2020. <http://smallgrains.wsu.edu>.
- Murray, T. 2020. Stripe Rust Update. *Timely Topics*, May 6, 2020. <http://smallgrains.wsu.edu>.
- Murray, T. 2020. Stripe Rust Predicted to be Severe. *Timely Topics*, March 10, 2020. <http://smallgrains.wsu.edu>.
- Kruse, E.B., S. Revolinski, J. Aplin, D.Z. Skinner, T.D. Murray, C. Edwards, and A.H. Carter. 2020. Gene expression and carbohydrate accumulation in winter wheat lines with different levels of snow mold and freezing cold tolerance. *Plants* 9(11):1416.
- Carter, A.H., K.A. Balow, G.B. Shelton, A.B. Burke, K.E. Hagemeyer, A. Stowe, J. Worapong, R.W. Higginbotham, X.M. Chen, D.A. Engle, T.D. Murray, and C.F. Morris. 2020. Registration of 'Devote' Soft White Winter Wheat. *J. Plant Registrations* [IN PRESS 15 July 2020].
- Carter, A.H., K.A. Balow, G.B. Shelton, A.B. Burke, K.E. Hagemeyer, A. Stowe, J. Worapong, R.W. Higginbotham, X.M. Chen, D.A. Engle, T.D. Murray, and C.F. Morris. 2020. Registration of 'Scorpio' Hard Red Winter Wheat. *J. Plant Registrations* 2020:1-8.

- Carter, A. H., K. A. Balow, G. B. Shelton, A. B. Burke, K. Hagemeyer, T. Worapong, R. W. Higginbotham, X. M. Chen, D. A. Engle, T. D. Murray, and C. F. Morris. 2020. Registration of 'Purl' Soft White Winter Wheat. *J. Plant Registrations* 14:398-405.
- Gill, K.S., N. Kumar, A.H. Carter, H.S. Randhawa, C.F. Morris, B. Baik, R.W. Higginbotham, D.A. Engle, S.O. Guy, I.C. Burke, D. Lyon, T.D. Murray, and X.M. Chen. 2020. Registration of 'Curiosity CL+' Soft White Winter Wheat. *J. Plant Registrations* 14:377-387.
- Carter, A.H., R.E. Allan, K. Balow, A. Burke, X.M. Chen, D. Engle, K.A. Garland-Campbell, K. Hagemeyer, C. Morris, T. Murray, T. Paulitz, and G. Shelton. 2020. How 'Madsen' has shaped Pacific Northwest wheat and beyond. *J. Plant Registrations* 14:223-233.
- Gargouri, S., E. Khemir, A. Souissi, T.D. Murray, M. Fakhfakh, I. Achour, S. Chekali, M. Mlike, and T.C. Paulitz. 2020. Survey of take-all (*Gaeumannomyces graminis* var. *tritici*) on cereals in Tunisia and impact of crop sequences. *Crop Protection* 135:105.189.
- Nishio, Z., N. Iriki, M. Ito, T. Tabiki, and T. Murray. 2020. Mapping QTL conferring speckled snow mold resistance in winter wheat (*Triticum aestivum* L.). *Breeding Science* 70:246-252.
- Gill, K.S., N. Kumar, H.S. Randhawa, A.H. Carter, J. Yenish, C.F. Morris, B. Baik, R.W. Higginbotham, S.O. Guy, D.A. Engle, X.M. Chen, T.D. Murray, and D. Lyon. 2020. Registration of 'Mela CL+' Soft White Winter Wheat. *J. Plant Registrations* 14:144-152.
- Murray, T.D. and H. Sheng. 2019. Reaction of winter wheat cultivars and breeding lines to eyespot in Washington, 2018. *Plant Disease Management Reports* 13:CF038.
- Murray, T.D. and H. Sheng. 2019. Reaction of winter wheat cultivars and breeding lines to *Cephalosporium* stripe in Washington, 2018. *Plant Disease Management Reports* 13:CF039.
- Murray, T. 2019. Stripe Rust Remains at Very Low Levels. April 22, 2019. *Timely Topics*, <http://smallgrains.wsu.edu>.
- Murray, T. 2019. No Shortcuts on Green Bridge Management for Soilborne Diseases. *Timely Topics*, March 27, 2019. <http://smallgrains.wsu.edu>.
- Li, H., T.D. Murray, R.A. McIntosh, and Y. Zhou. 2019. Breeding for new cultivars warrants sustainable production of wheat. *The Crop Journal* 7:715-717.
- Kruse, E.B., K.L.E. Klos, J. Marshall, T.D. Murray, B.P. Ward, and A.H. Carter. 2019. Evaluating Selection of a Quantitative Trait: Snow Mold Tolerance in Winter Wheat. *Agrosystems, Geosciences & Environment* 2:190059.
- Lozada, D.N., J.G. Godoy, T.D. Murray, Ward, B.P., and A.H. Carter. 2019. Genetic dissection of snow mold tolerance in US Pacific Northwest winter wheat through genome-wide association study and genomic selection. *Frontiers in Plant Science*.
- Cui, L., D. Qiu, L. Sun, Y. Sun, Y. Ren, H. Zhang, J. Li, J. Zou, P. Wu, H. Liu, L. Yang, Y. Zhou, Y. Wang, Y. Lv, Z. Liu, T.D. Murray, and H. Li. 2019. Resistance to *Heterodera filipjevi* and *H. avenae* in winter wheat is conferred by different QTL. *Phytopathology* 110:472-482.

Presentations:

- Identification and Management of Winter Wheat Diseases. 2020 Last Chance Pesticide Seminar, Asotin, WA, December 8, 2020.
- Identification and Management of Winter Wheat Diseases. Spokane Ag Show, Spokane, WA, February 6, 2020.

Identification and Management of Winter Wheat Diseases. 2020 Nutrien Grower Meeting, Spokane, WA, January 31, 2020.

Effect of Soil Acidity on Wheat Diseases. Soil Acidity Workshop, WSU Farmers Network, Pullman, WA, January 16, 2020.

Identification and Management of Winter Wheat Diseases. Walla Walla Cereal Seminar, Walla Walla, WA, January 14, 2020.

Diagnosing and Managing Diseases of Wheat. WSU Wheat Academy, Pullman, WA, December 10, 2019.

Identification and Management of Winter Wheat Diseases. Far West Agricultural Association Annual Meeting, Pasco, WA, December 9, 2019.

Biology and Management of Winter Wheat Diseases. Washington State Crop Improvement Association Annual Meeting, Spokane, WA, November 18, 2019.

Wheat Production and Disease Constraints in Washington. 111 Summer Workshop, Jilin Agricultural University, Jilin, China, August 23, 2019.

Climate Change and its Impact on Winter Wheat Diseases in the Northwestern U.S.A., 111 Summer Workshop, Jilin Agricultural University, Jilin, China, August 25, 2019.

Climate Change and its Impact on Wheat Diseases, 2nd International Conference on Northeast Asia Biodiversity, Baishan, China, August 27, 2019.

Update on Snow Mold, Stripe Rust, and Eyespot Diseases of Wheat. Highline Grain Growers Annual Meeting, Waterville, WA, February 25, 2019.

Soil Acidity – Its causes and Impacts on Wheat Diseases. Management Matter for Soil Health, WSU Farmers Network, Pullman, WA, February 21, 2019.

Biology and Management of Winter Wheat Diseases. Spokane Ag Expo, Spokane, WA, February 5, 2019.

Update on Snow Mold, Stripe Rust, and Eyespot Diseases of Wheat, and Hessian Fly. 2019 Syngenta Cereal & Pulse School, Spokane, WA, February 4, 2019.

Cultural Management of Soil-borne Plant Diseases. Management Matters for Soil Health, WSU Farmers Network, Pullman, WA, January 22, 2019.

Biology and Management of Winter Wheat Diseases. Walla Walla Cereal Seminar, Walla Walla, WA, January 15, 2019.

WGC project number: 3682
WGC project title: Control of Eyespot and Cephalosporium Stripe in Winter Wheat
Project PI(s): T. Murray, A. Carter, K. Garland-Campbell
Project initiation date: 7/1/19
Project year (X of 3-yr cycle): 2 of 2

Objective	Deliverable	Progress	Timeline	Communication
1. Evaluate advanced breeding lines and new varieties for resistance to eyespot and Cephalosporium stripe in field plots	Provide unbiased data on the resistance reactions of advanced selections and new varieties to eyespot and Cephalosporium stripe.	<p>2020: Forty-two winter wheat cultivars and breeding lines were evaluated for their resistance/tolerance to eyespot and Cephalosporium in inoculated field trials in June 2019. Another 60 lines were planted in September for evaluation in 2020.</p> <p>2021: Sixty winter wheat cultivars and breeding lines were evaluated for resistance/tolerance to eyespot and Cephalosporium stripe in inoculated field trials in June 2020.</p>	<p>2020: This was the third year of testing in collaboration with the WSU Variety Testing program and WSU Winter Wheat Breeding.</p> <p>2021: This was the fourth and final year of testing varieties and advanced lines for resistance to eyespot and Cephalosporium stripe in collaboration with the WSU Variety Testing program.</p>	Results from these plots are presented at field days, variety plot tours, and other talks to grower and industry groups, and available online at the Extension Small Grains Team website. Data are used to update variety ratings in the Washington State Crop Improvement Seed Buyer's Guide, the WSU Extension Small Grains Variety Selection tool, and published online in Plant Disease Management Reports so they are available to the larger wheat research community.
2. Screen wild wheat relatives and other genetic populations to identify and map potential new eyespot resistance genes	Identify potential new eyespot resistance genes for use by breeders to improve effectiveness of resistant varieties.	<p>2020: Conducted two experiments to screen 135 lines from a Cappelle Desprez x Whetstone population for eyespot resistance; one study each with Oy and Oa was completed and data have been summarized. A third experiment was setup in December for the second round of screening. DNA was collected from all lines and submitted for genotyping. We anticipate completing the screening experiments in late spring and then follow with analysis of the data.</p> <p>2021: Three growth chamber experiments were conducted to determine whether the same genes control resistance to both species of the eyespot pathogen. Phenotyping and genotyping was completed, data analysis is nearly done and a manuscript is in progress.</p>	<p>2020: We anticipate beginning work on populations of the wheat relative <i>Dasypyrum villosum</i> in collaboration with Chinese wheat breeders in early summer or fall 2020.</p> <p>2021: Seed of the <i>Dasypyrum</i> population was not received as a result of COVID-19 restrictions on research in China. We hope to receive the seed to evaluate in the future.</p>	Results of this research will be shared with breeders, presented at field days, variety testing plot tours, and other talks to grower and industry groups. Data also will be published in appropriate scientific journals.
3. Evaluate fungicides currently registered for eyespot control for effectiveness and determine the potential for development of fungicide resistance	Provide data that will help growers and field consultants make decisions about whether and which fungicide to use in controlling eyespot by testing fungicides registered for eyespot control in multiple locations in eastern WA.	<p>2020: Two field trials were planted in September 2019; one for the evaluation of eight seed treatments and another for spring-applied foliar fungicides for eyespot control.</p> <p>2021: Disease and yield evaluation of two fungicide trials, one for seed treatment and the other for foliar fungicides, was completed during summer 2020</p>	2020: Fungicides will be tested annually depending on interest and support from industry. Work on resistance has not begun.	Results from this research will be presented at field days, variety plot tours, and other talks to grower and industry groups, and available online at the Extension Small Grains Team website. Results also will be published in Plant Disease Management Reports so they are available to the larger small grains pathology community.
Prepare an article for Wheat Life during the three-year project.	Prepare an article for Wheat Life during the three-year project.	2020: Management options for wheat diseases in the Inland PNW published in January Wheat Life	2020: One article published in January	