



**Phil L. Bruckner, Professor**  
**Department of Plant Sciences & Plant Pathology**  
**Montana State University**  
**Bozeman, MT 59715-3140**  
**bruckner@montana.edu**  
**PHONE 406-994-5127, FAX 406-994-1848**

## **MEMORANDUM**

**FROM:** Phil Bruckner & Jim Berg, Winter wheat breeders

**DATE:** January 7, 2019

**RE:** Release of MT1564 early-maturity hard red winter wheat (cross ID 07X76cF96)

**Pedigree:** MT1564 = F4 composite of two single cross populations:

07X76 Yellowstone\*2/PI640431

07X77 Yellowstone/PI640431//06X388 [Yellowstone\*5//MT9982/MTS0222]

PI640431 is a Washington State University-developed near-isogenic backcross derivative of WA007900 HWS wheat that contains chromosome regions on 2BS from Yr5/6\*Avocet and on 1BS from Yr15/6\*Avocet that carry stripe rust seedling resistance genes Yr5 and Yr15, respectively. This genotype is expected to confer resistance to known races of stripe rust in North America.

06X388 [Yellowstone\*5//MT9982/MTS0222] is a BC5F1 population from a solid-stem molecular marker conversion project [theoretically >97% Yellowstone background].

**Recommendation:** Public, protected                      **Name:** To be determined

**Selection history:** MT1564 is a HRW wheat line developed for grain production in Montana. MT1564 derives from a WSU-developed HWS wheat germplasm line carrying two effective stripe rust resistance genes backcrossed to dominant Montana HRW wheat cultivar Yellowstone. MT1564 was selected based on multiple cycles of phenotypic selection for stripe rust resistance at Bozeman and Kalispell, MT. Yield testing from 2015 to 2018 revealed MT1564 was a high-yielding and very early in heading, significantly earlier than almost all MT winter wheat germplasm.

Following the 2007 crosses, these are steps in development of MT1564:

2008gh Individual F1 populations grown in PGC and harvested in bulk.  
2009BZ Individual F2 populations grown, bulk of selected heads advanced.  
2010BZ Individual F3 populations grown, bulk of selected heads advanced. Populations composited.  
2011W Composite F4 bulk population grown at Williston, heads from surviving plants harvested in bulk after mechanical height reduction.  
2012FE Composite F5 bulk population grown at Ft.Ellis, ~120 heads selected.  
2013K F6 hill-plots from seven populations grown at Kalispell, heavy phenotypic selection for stripe rust, 60 resistant hill plots selected and harvested [including 07X76cF96].

- 2014-Multi 60-member F7, stripe rust-resistant cohort evaluated in Single Rep Observation B nursery at Kalispell, Bozeman, and Fort Ellis. Heavy phenotypic selection for stripe rust resistance and reduced plant height. Line 07X76cF96 was selected, harvested in bulk, and designated MT1564.
- 2015-Multi MT1564 (F8) tested in Preliminary B trials at Bozeman and Kalispell. Milling & baking quality evaluation initiated.
- 2016-Multi MT1564 (F9) tested in Advanced trials at seven sites. M&P heads selected.
- 2017-Multi MT1564 (F10) tested in Montana Intrastate trials at seven locations. 130 F9:10 headrows evaluated for phenotypic uniformity, harvested individually, and 125 bulked as Breeder seed.
- 2018-Multi MT1564 tested in multi-location Intrastate (9 loc.), and Off-station trials (13 loc.).
- 2017Post MT1564 Breeder seed increased
- 2018-region MT1564 entered into NRPN regional nursery and Wheat Quality Council evaluation.

**General performance and characteristics:** MT1564 is a very early [heading 3.6 d earlier than mean heading date in the 2017 Intrastate (LSD=1.3 d) and 3.4 d earlier than mean heading date in the 2018 Intrastate (LSD=1.1 d)], semidwarf (*Rht1-B1b*), stripe rust-resistant HRW winter wheat line. MT1564 has been tested in Montana grain trials since 2015. Milling and baking quality has been evaluated from 2015 to 2017. MT1564 was also tested in the 2018 USDA Northern Regional Performance Nursery (NRPN) and WQC evaluation.

**Table 1. 2015 Preliminary B Test: 2 location Summary (Bozeman and Kalispell)**

Entry #	ID	Pedigree	Yield bu/ac	Test weight lb/bu	Heading date Julian	Plant height in	Stripe rust %	Protein %
		w = white						
1	<b>Yellowstone</b>	check	95.1	58.6	157.5	38.5	36	12.3
2	<b>Decade</b>	check	65.8	57.1	156.9	36.0	81	12.1
3	<b>Promontory</b>	check	<b>100.7*</b>	<b>63.5**</b>	156.5	37.1	14	11.2
4	<b>CDC Falcon</b>	check	71.4	57.6	157.7	33.9	56	13.0
5 a	<b>MT1561</b>	Decade*2/Radiant	<b>104.3*</b>	60.4	158.3	39.4	16	10.9
6	<b>MT1562</b>	Yellow stone*2/PI640431	85.8	59.0	155.7	35.2	20	12.7
7 a	<b>MT1563</b>	Yellow stone*2/PI640431	<b>111.5**</b>	<b>60.9*</b>	158.7	38.9	28	11.5
8 a	<b>MT1564</b>	Yellow stone*2/PI640431	<b>101.4*</b>	<b>61.6*</b>	153.3	38.2	7	12.0
9 a	<b>MT1565</b>	Decade*2//Promontory/3*Yellow stone	<b>98.9*</b>	60.1	155.7	34.6	12	11.7
10	<b>MT1566</b>	Decade*2//Promontory/3*Yellow stone	84.7	60.0	155.9	34.2	25	14.0
11	<b>MT1567</b>	Decade*2//Promontory/3*Yellow stone	91.1	59.0	156.7	34.2	31	12.7
12	<b>MT1568</b>	Decade*2//Promontory/3*Yellow stone	89.8	58.7	156.4	35.6	33	13.0
13 a	<b>MT1569</b>	MT08185/YLL*2/PI640431/3/Promont	<b>97.1*</b>	<b>60.7*</b>	156.4	37.0	9	12.3
14	<b>MT1599</b>	MT08185/YLL*2/PI640431/3/YLL*3/N	82.6	58.4	157.7	24.0	20	11.4
<b>Average</b>			<b>91.4</b>	<b>59.7</b>	<b>156.6</b>	<b>35.5</b>	<b>28</b>	<b>12.2</b>
<b>LSD (0.05)</b>			<b>16.1</b>	<b>2.2</b>	<b>1.2</b>	<b>2.4</b>	<b>25</b>	<b>ns</b>
<b>C.V. (%)</b>			<b>8.1</b>	<b>2.2</b>	<b>0.4</b>	<b>3.2</b>	<b>55</b>	<b>7.8</b>

a = lines in 2016 Advanced Test (all other MT lines dropped from testing)

\*\* = indicates highest value within a column

\* = indicates varieties with values equal to highest variety within a column based on Fisher's protected LSD (p=0.05)

The original intent of this cross was to incorporate two undefeated stripe rust resistance genes into Yellowstone. Lines were selected which had phenotypically superior stripe rust resistance in hill plots and subsequent field plots at Kalispell in 2013 and 2014. MT1564 was tested with check cultivars and other stripe rust-resistant selections in the 2015 Preliminary B trial at Kalispell and Bozeman, showing very early heading,

superior stripe rust resistance, and outstanding yield performance (Table 1).

MT1564 also had outstanding performance in the 2016 Advanced winter wheat trial at seven locations (Table 2), showing excellent yield performance overall, very early heading, and outstanding stripe rust resistance.

**Table 2. 2016 Advanced Yield Nursery: All location Summary**

Entry	ID	Pedigree	Yield bu/ac	Test weight lb/bu	Heading date Julian	Plant height in	Protein %	Stripe rust BZ %	
	w = white-seeded		locations	7	7	6	7	7	16-Jul
<b>33 i</b>	<b>MT1564</b>	Yellow stone*2/PI640431	<b>91.3</b>	<b>62.2</b>	<b>154.5</b>	<b>35.4</b>	<b>10.3</b>	<b>1</b>	
<b>2</b>	<b>Yellowstone</b>	check	<b>89.1</b>	61.0	157.7	36.1	10.6	14	
<b>32 i</b>	<b>MT1563</b>	Yellow stone*2/PI640431	<b>87.9</b>	60.9	157.9	35.3	10.3	<b>7</b>	
<b>5</b>	<b>SY Wolf</b>	check	<b>85.0</b>	62.2	155.9	33.5	10.7	12	
<b>1</b>	<b>Judee</b>	check	78.6	62.3	156.8	34.0	10.6	12	
<b>4</b>	<b>Warhorse</b>	check	78.6	61.0	158.0	34.0	<b>11.4</b>	<b>7</b>	
<b>3</b>	<b>Decade</b>	check	70.4	60.3	156.9	33.5	10.7	51	
<b>Average</b>			<b>82.4</b>	<b>61.4</b>	<b>157.2</b>	<b>34.3</b>	<b>10.6</b>	<b>16.9</b>	
<b>LSD (0.05)</b>			<b>8.2</b>	<b>0.8</b>	<b>1.0</b>	<b>1.5</b>	<b>0.6</b>	<b>9.4</b>	
<b>C.V. (%)</b>			<b>9.4</b>	<b>1.2</b>	<b>0.6</b>	<b>4.2</b>	<b>5.1</b>	<b>32</b>	

i = in 2017 Intrastate Test (all other MT lines dropped from testing)

**bold** = indicates highest value w ithin a column

**bold** = indicates varieties w ith values equal to highest variety w ithin a column based on Fisher's Protected LSD (p =0.05)

In 2017 & 2018 Montana Intrastate and the 2018 Off-station yield trials (30 location-years), MT1564 showed high grain yield potential similar to all check cultivars except Keldin and LCS Jet (higher) and Brawl CL Plus (lower) (Table 1). MT1564 was competitive for yield among early and medium maturity check cultivars.

**Table 3. Yield of MT1564 vs. a set of varieties, 2017-2018<sup>1/</sup>**

Variety	Districts							All Locations	Relative maturity
	1 Kalispell	2 Bozeman	3 Huntley	4 Moccasin	5 Conrad	5 Havre	6- Sidney & Williston		
location-years	1	2	7	5	6	6	3	30	
<b>Brawl CL Plus</b>	86.9	89.0	84.2	56.0	63.6	49.3	42.6	67.0	<b>v. early</b>
<b>MT1564</b>	<b>106.2</b>	<b>124.6</b>	<b>99.2</b>	<b>61.5</b>	<b>60.4</b>	<b>52.3</b>	<b>47.0</b>	<b>72.5</b>	<b>Early</b>
<b>SY Wolf</b>	71.5	97.4	101.1	59.4	62.0	51.5	49.3	70.0	<b>Early</b>
<b>SY Monument</b>	84.1	118.0	105.1	<b>69.3</b>	61.8	53.9	55.8	<b>75.5</b>	<b>Medium</b>
<b>Decade</b>	48.4	86.0	98.9	<b>63.5</b>	58.8	53.1	56.1	69.0	<b>Medium</b>
<b>FourOsix</b>	92.4	119.5	94.7	61.8	60.9	51.8	52.0	71.2	<b>M-L</b>
<b>Keldin</b>	101.3	121.2	<b>113.7</b>	<b>65.2</b>	66.3	56.4	55.8	<b>79.0</b>	<b>M-L</b>
<b>LCS Jet</b>	<b>122.3</b>	135.0	<b>116.1</b>	<b>65.4</b>	66.7	50.4	39.1	<b>78.4</b>	<b>Late</b>
<b>Northern</b>	78.2	119.1	102.9	61.7	63.8	53.8	55.3	73.9	<b>Late</b>
<b>LSD (0.05)</b>	<b>19.2</b>	<b>ns</b>	<b>9.6</b>	<b>6.2</b>	<b>ns</b>	<b>ns</b>	<b>ns</b>	<b>4.7</b>	

**bold** = indicates highest value w ithin a column

**bold** = indicates varieties w ith values equal to highest variety w ithin a column based on Fisher's Protected LSD (p =0.05)

<sup>1/</sup> = 2017-18 Intrastate and 2018 Off Station tests

Relative to the other check cultivars, MT1564 is early heading, relatively short, and resistant to stripe rust

(Table 4), with good test weight, intermediate winter hardiness (similar to SY Wolf, SY Monument, FourOsix, Keldin, and Northern), and average grain protein.

**Table 4. Agronomic characteristics of MT1564 vs. a set of varieties, 2017-2018<sup>1/</sup>**  
 [sorted by relative heading date, early to late]

Variety	Test	Winter	Heading date		Plant	Protein	Saw fly	Stripe
	w eight	survival			height		cutting	rust
	lb/bu	%	Julian	Calendar	in	%	%	%
location-years	30	2	15		29	30	8	2
<b>Brawl CL Plus</b>	<b>62.6</b>	36	152.7	2-Jun	28.2	<b>13.5</b>	30	70
<b>MT1564</b>	<b>61.7</b>	<b>46</b>	<b>154.7</b>	<b>4-Jun</b>	<b>29.4</b>	<b>12.8</b>	<b>47</b>	<b>3</b>
<b>SY Wolf</b>	61.7	44	155.6	5-Jun	28.5	13.0	32	<b>21</b>
<b>SY Monument</b>	60.5	<b>54</b>	156.5	6-Jun	28.5	12.2	50	<b>4</b>
<b>Decade</b>	60.9	<b>66</b>	157.6	7-Jun	30.5	<b>13.3</b>	39	74
<b>FourOsix</b>	61.1	47	158.3	7-Jun	29.2	12.9	56	<b>6</b>
<b>Keldin</b>	61.7	43	158.8	8-Jun	30.0	12.7	45	41
<b>LCS Jet</b>	58.7	13	159.5	9-Jun	27.0	12.6	50	<b>2</b>
<b>Northern</b>	60.7	43	160.9	10-Jun	29.9	13.1	51	<b>8</b>
<b>LSD (0.05)</b>	<b>0.6</b>	<b>16</b>	<b>0.9</b>		<b>0.7</b>	<b>0.2</b>	<b>13</b>	<b>23</b>

1/ = 2017-18 Intrastate and 2018 Off Station tests  
**bold** = indicates highest value w ithin a column  
**bold** = indicates varieties w ith values equal to highest variety w ithin a column based on Fisher's Protected LSD (p =0.05)

Early milling and baking quality evaluations in 2015 & 2016 (Table 5) indicated MT1564 had good milling characteristics with strong dough mixing characteristics similar to commercially-deployed cultivars Decade and Yellowstone.

**Table 5. Mill and bake characteristics of MT1564 vs. a set of varieties, including Yellowstone, 2015-2016: Combined Preliminary A (2015) and Advanced (2016) Tests**

Variety	PPO <sup>1/</sup>	Kernel hardness	Flour			Mixograph			Baking		
			yield	protein	Ash	tolerance	mix time	absorption	mix time	absorption	volume
			%	%	%	(1-6)	min	%	min	%	cc
location-years	6	6	6	6	6	6	6	6	6	6	
<b>Decade</b>	0.234	74.0	69.5	9.9	<b>0.40</b>	4.0	6.1	63.8	19.8	73.8	914
<b>MT1564</b>	0.248	69.2	<b>72.2</b>	10.3	<b>0.40</b>	<b>3.8</b>	<b>7.6</b>	<b>63.4</b>	<b>19.0</b>	<b>74.7</b>	<b>935</b>
<b>Yellowstone</b>	0.266	71.8	69.9	10.2	0.42	3.8	6.6	62.6	13.7	73.2	984
<b>LSD (0.05)</b>	<b>ns</b>	<b>ns</b>	<b>1.0</b>	<b>ns</b>	<b>0.01</b>	<b>ns</b>	<b>1.0</b>	<b>ns</b>	<b>ns</b>	<b>ns</b>	<b>ns</b>

In a wider set of cultivars tested in the 2017 Intrastate trial (Table 6), milling and baking characteristics of MT1564 appear to meet criteria for the high quality HRW wheat export market.

**Table 6. Mill and bake characteristics of MT1564 vs. a set of varieties, 2017:**

Intrastate Tests only, n=4											
Variety	PPO <sup>1/</sup>	Kernel hardness	Flour			Mixograph			Baking		
			yield %	protein %	Ash %	tolerance (1-6)	mix time min	absorption %	mix time min	absorption %	volume cc
FourOsix	0.267	77.7	<b>71.9</b>	12.4	0.43	2.5	5.6	<b>68.2</b>	10.9	<b>78.4</b>	<b>1119</b>
<b>MT1564</b>	<b>0.259</b>	<b>74.2</b>	<b>72.7</b>	11.9	<b>0.41</b>	<b>3.8</b>	10.5	<b>67.8</b>	<b>18.6</b>	<b>78.5</b>	<b>1075</b>
Northern	<b>0.092</b>	85.6	70.0	11.9	0.44	2.5	3.7	64.3	4.2	73.5	1068
Brawl CL Plus	0.283	75.5	70.4	11.9	<b>0.40</b>	3.3	4.3	64.0	6.4	73.9	1053
Decade	0.276	78.4	70.3	11.9	<b>0.41</b>	<b>3.3</b>	8.1	<b>68.4</b>	18.3	<b>79.1</b>	1053
SY Monument	0.216	80.1	<b>71.6</b>	11.4	0.43	<b>3.3</b>	8.3	<b>65.5</b>	14.0	<b>76.2</b>	1021
Keldin	0.326	68.0	69.8	11.5	0.45	<b>3.0</b>	5.3	64.0	8.0	74.0	1010
SY Wolf	0.264	78.6	70.0	11.1	<b>0.40</b>	1.5	4.3	61.6	5.8	71.4	994
LCS Jet	0.307	69.8	<b>72.2</b>	11.7	<b>0.39</b>	<b>3.0</b>	5.2	<b>65.9</b>	8.5	<b>76.0</b>	988
<b>LSD (0.05)</b>	<b>0.049</b>	<b>5.0</b>	<b>1.3</b>	ns	<b>0.03</b>	<b>1.1</b>	<b>2.4</b>	<b>3.0</b>	<b>5.0</b>	<b>3.2</b>	<b>45</b>

**bold** = indicates highest value w within a column

**bold** = indicates varieties w with values equal to highest variety w within a column based on Fisher's Protected LSD (p =0.05)

**Disease resistance:** MT1564 is resistant to stripe rust based on Montana evaluations (Tables 1, 2, & 4). In addition, MT1564 wheat was tested for reactions to natural infections of *Puccinia striiformis* f. sp. *tritici* in Pullman and Mount Vernon, Washington from 2015 to 2017 and also at two more locations in Walla Walla and Lind, Washington in the NRPN trial in 2018. Across locations and over years, MT1564 had highly resistant reaction with infection type (IT) 2 to moderate resistant reaction (IT 5) with severity 5-60%, receiving a field summary rating in 2018 of MR (Table 7). In contrast, the susceptible check (PS279) was highly susceptible (IT 8, severity 80-100%) in the late growth season.

In the seedling tests at the low temperature cycle (4-20°C), MT1564 was highly resistant (IT 2) to all tested PST races (Table 8). When tested at the high temperature cycle (10-30°C) at adult-plant stage (Zadoks 45-60), MT1564 was highly resistant (IT 1) to races PSTv-14, PSTv-37, and PSTv-40 (Table 8). The high-temperature adult-plant (HTAP) resistance data were based on greenhouse tests. Whether MT1564 has HTAP resistance or not couldn't be determined as it was resistant to all tested races in the seedling stage. Entries with *Yr5* and/or *Yr15* may not have HTAP resistance but their resistance should be highly effective as no races virulent to either of the genes are found in the US. **In summary, MT1564 has all-stage resistance effective against some races however it is not known whether MT1564 has HTAP resistance.** Marker data on the stripe rust resistance genes of MT1564 has not been consistent [Cook reported the line had *Yr15* in 2015 screening; 2018 NRPN marker screening indicated MT1564 had *Yr5* but not *Yr15*.] According to Xianming Chen, USDA stripe rust pathologist, "MT1564 is interesting. It was highly resistant to all six races in the seedling tests and the three races in the adult-plant tests in the greenhouse. These data agree with the hypothesis that the line has *Yr5* and/or *Yr15*. The field data at all locations agree with the hypothesis, except LOC 07 (Lind in central Washington) where MT1564 had IT 5 and 30% severity. If the line has *Yr5* and/or *Yr15*, it should be IT 0-2 as at other locations. So far, we do not have any stripe rust isolates in the US virulent to either *Yr5* and *Yr15*. The *Yr5* and *Yr15* single-gene lines in our nurseries at Lind were highly resistant and rust samples collected from the location are also avirulent to either *Yr5* and *Yr15*."

MT1564 is moderately resistant to stem rust based on seedling stem rust evaluations conducted by the USDA-ARS Cereal Disease Lab in 2016 and 2018 (NRPN). In seedling evaluations at St. Paul, MN, MT1564 was resistant to several *Pgt* races from the United States, including QCCSM, QFCSC, MCCFC, RCRSC, RKQQC, RKRQC, and TPMKC, but susceptible to QTHJC and TTTTF. MT1564 is not resistant to the Ug99 race group but was resistant to other races of foreign origin with broad virulence combination, including TRTTF (Yemen), TKTTF (Ethiopia), and TKKTP (Germany).

Based on screening at Logan, UT of 2018 NRPN entries, MT1564 is moderately resistant to dwarf bunt.

**Purification/seed stocks:** Purification and increase of MT1564 was initiated in 2017 when 130 F<sub>9</sub>-derived F<sub>10</sub> headrows were grown at Bozeman with evaluation for phenotypic uniformity before bulking 125 linerows as breeder seed. Breeder seed of MT1564 was increased in 2018 at Bozeman. Foundation seed is planted for 2019 harvest (~20 acres, LutzFarm).

**Summary:**

MT1564 is a unique line. It was derived from a backcross of Yellowstone to a WSU hard white spring wheat line carrying *Yr5* and *Yr15*. The line was selected based on two cycles of phenotypic selection for stripe rust resistance at Kalispell. We think MT1564 carries either *Yr5* or *Yr15*. The line is very early in heading likely due to a spring *Vrn* allele or a photoperiod insensitivity allele. MT1564 is resistant to stripe rust and has adequate end use quality for commercial production. The line performed extremely well in 2016 and 2017 trials, not so well in 2018 trials. However, the line appears to be very competitive for yield when compared to early and medium maturity lines. Currently there are no early maturity Montana-germplasm based winter wheat lines available for production. **MT1564 is proposed for release based on its unique combination of high yield potential, early heading, stripe rust resistance, and acceptable end-use qualities.**

**TABLE 7. STRIPE RUST INFECTION TYPE (IT<sup>a</sup>) AND SEVERITY (%) ON CULTIVARS AND LINES IN THE 2018 NRPN WHEAT TRIAL AT LOCATIONS IN PCFS PULLMAN (LOC 04), MT. VERNON (LOC 05), WALLA WALLA (LOC 06), AND LIND (LOC 07), WA WHEN RECORDED AT THE INDICATED DATES AND STAGES OF PLANT GROWTH UNDER NATURAL INFECTION IN 2018<sup>b</sup> Plantint dates: LOC 04, 10/24/2017; LOC 05, 10/27/2017; LOC 06, 10/10/2017; and LOC 07, 10/11/2017.**

Entry No.	Line	Putative Market Class	2018 PLOT	LOC 04		LOC 05 <sup>c</sup>		LOC 06	LOC 07	Field Summary <sup>d</sup>	Overall rating <sup>e</sup>	Possible HTAP resistance <sup>f</sup>
				6/7	4/26	6/6	5/24	6/14				
				Fks 10.53	Fks 6	Fks 11.1	Fks 10.54	Fks 11.2				
				IT %	IT %	IT %	IT %	IT %				
1	Kharkof	HRW	1	3 2	7 50	5 50	5 5	8 10	MR-MS	5	Moderate	
2	Overland	HRW	2	8 10	7 50	7 90	5 15	8 30	S	8	Low	
3	Wesley	HRW	3	8 20	8 60	7 80	5 20	8 80	S	8	Low	
4	Jagalene	HRW	4	2,8 1	8 60	7 30	5 5	8 60	MS	7	Low	
5	Jerry	HRW	5	8 20	8 60	8 90	5 15	8 80	S	9	No	
<b>Check</b>	<b>PS279 (S. Check)</b>	<b>CHECK</b>	<b>21</b>	<b>8 100</b>	<b>8 60</b>	<b>8 100</b>	<b>8 80</b>	<b>8 100</b>	<b>S</b>	<b>9</b>	<b>No</b>	
35	MT1547	HRW	36	2 1	2 20	1 1	5 10	5 20	MR	3	High	
36	MT1563	HRW	37	2,3 1	2 20	3 5	5 5	5 30	MR	4	High	
37	MT1564	HRW	38	2 1	2 20	2 2	2 5	5 30	MR	4	Unknown	
38	MTS1588	HRW	39	2,8 5	5 40	3 5	5 5	2 15	R	2	High	
<b>Check</b>	<b>PS279 (S. Check)</b>	<b>CHECK</b>	<b>41</b>	<b>8 100</b>	<b>8 40</b>	<b>8 100</b>	<b>8 90</b>	<b>8 100</b>	<b>S</b>	<b>9</b>	<b>No</b>	
1	Kharkof	HRW	48	2,5 2	3 20	1 1	5 10	0 0	MR	3	Moderate	
2	Jagalene	HRW	49	8 1	8 60	4 20	5 10	8 70	S	8	Low	
<b>Check</b>	<b>PS279 (S. Check)</b>	<b>CHECK</b>	<b>61</b>	<b>8 100</b>	<b>8 60</b>	<b>8 100</b>	<b>8 90</b>	<b>8 100</b>	<b>S</b>	<b>9</b>	<b>No</b>	
<b>Check</b>	<b>PS279 (S. Check)</b>	<b>CHECK</b>	<b>81</b>	<b>8 100</b>	<b>8 60</b>	<b>8 100</b>	<b>8 70</b>	<b>8 100</b>	<b>S</b>	<b>9</b>	<b>No</b>	
49	Scout 66	HRW	98	5 20	2 10	- -	5 15	8 100	S	9	Moderate	
50	TAM107	HRW	99	8 80	6 40	1 1	5 20	8 100	S	9	Low	
<b>END</b>	<b>Barley (fill)</b>	<b>END</b>	<b>100</b>	<b>- -</b>	<b>- -</b>	<b>- -</b>	<b>- -</b>	<b>- -</b>				

<sup>a</sup> Infection Type (IT) was recorded based on the 0-9 scale with ITs 8 and 9 combined as 8 (the most susceptible reaction) in field data. Generally IT 0-3 are considered resistant, 4-6 intermediate, and 7-9 susceptible. Heterogenous reactions of an entry were indicated by two or more ITs separated by "," for most plants with the first IT and few plants with the second IT or connected with "-" for entries containing plants with continuous ITs.

<sup>b</sup> All locations were under natural infection.

<sup>c</sup> Entries with a high IT in the first note, but a low IT in the second note at Mt. Vernon (LOC 05) may indicate that they have high-temperature, adult-plant (HTAP) resistance.

<sup>d</sup> R = resistant, MR = moderately resistant, MS = moderately susceptible, and S = susceptible.

<sup>e</sup> 1 = most resistant and 9 most susceptible.

Note: The summary and ratings are based on the highest IT and % severity to discourage use of race-specific resistance.

<sup>f</sup> The high-temperature adult-plant (HTAP) resistance data were based on greenhouse tests. Unknown = Whether the entry has HTAP resistance or not couldn't be determined as it was resistant to all tested races in the seedling stage. TBT = to be tested. Entries with Yr5 and/or Yr15 may not have HTAP resistance but their resistance should be highly effective as no races virulent to either of the genes are found in the US.

**TABLE 8. STRIPE RUST INFECTION TYPE (IT) ON SEEDLINGS AND ADULT-PLANTS OF CULTIVARS AND LINES IN THE 2018 NRPN WHEAT TRIAL TESTED WITH SELECTED *Puccinia striiformis* f. sp. *tritici* (PST) RACES UNDER CONTROLLED GREENHOUSE CONDITIONS AT LOW TEMPERATURES (DIURNAL TEMPERATURES GRADUALLY CHANGING FROM 4 TO 20°C FOR THE SEEDLING TESTS AND AT HIGH TEMPERATURES (DIURNAL TEMPERATURES GRADUALLY CHANGING FROM 10 TO 30°C) FOR THE ADULT-PLANT TESTS**

Entry No.	Line	Putative Market Class	2018 PLOT	Infection type produced by PST races <sup>a</sup>									Possible HTAP <sup>c</sup> resistance
				Seedling Tests <sup>b</sup>						Adult-plant Tests <sup>b</sup>			
				(4-20°C)						(10-30°C)			
				PSTv-4	PSTv-14	PSTv-37	PSTv-40	PSTv-51	PSTv-198	PSTv-14	PSTv-37	PSTv-40	
1	Kharkof	HRW	1	8	8	8	8	8	8	3,3,3	4,3,4	3,3,3	Moderate
2	Overland	HRW	2	8	8	8	8	8	8	6,6,6	5,5,5	5,5,5	Low
3	Wesley	HRW	3	8	8	8	8	8	8	6,6,6	6,6,6	5,5,6	Low
4	Jagalene	HRW	4	8	8	8	8	8	8	6,6,6	5,5,5	5,5,5	Low
5	Jerry	HRW	5	8	8	8	8	8	8	8,8,8	8,8,8	8,8,8	No
<b>CHK</b>	<b>Ps279 (S. Check)</b>	<b>CHK</b>	<b>21</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8,8,8</b>	<b>8,8,8</b>	<b>8,8,8</b>	No
35	MT1547	HRW	36	2	8	8	2	2,5	8	2,2,2	2,2,2	2,2,2	High
36	MT1563	HRW	37	2,8	2	5	5	2,5(1)	8	2,2,2	3,3,3	3,3,3	High
37	MT1564	HRW	38	2	2	2	2	2	2	1,1,1	1,1,1	1,1,1	Unknown
38	MTS1588	HRW	39	5	8	8	5	8	8	3,3,3	3,3,3	2,2,2	High
<b>CHK</b>	<b>Ps279 (S. Check)</b>	<b>CHK</b>	<b>41</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8,8,8</b>	<b>8,8,8</b>	<b>8,8,8</b>	No
1	Kharkof	HRW	48	8	8	8	8	8	8	3,3,5	2,3,3	2,3,3	Moderate
2	Jagalene	HRW	49	8	8	8	8	8	8	6,6,6	5,5,5	3,3,4	Low
<b>CHK</b>	<b>Ps279 (S. Check)</b>	<b>CHK</b>	<b>81</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8,8,8</b>	<b>8,8,8</b>	<b>8,8,8</b>	No
49	Scout 66	HRW	98	8	8	8	8	8	8	2,2,2	5,5,5	5,5,5	Moderate
50	TAM107	HRW	99	8	8	8	8	8	8	3,5,5	8,8,8	3,3,4	Low
<b>END</b>	<b>Barley (fill)</b>	<b>END</b>	<b>100</b>	-	-	-	-	-	-	-	-	-	

<sup>a</sup> Infection Type (IT) was recorded based on the 0-9 scale with ITs 8 and 9 combined as 8 (the most susceptible reaction) in field data. Generally IT 0-3 are considered resistant, 4-6 intermediate, and 7-9 susceptible. Heterogenous reactions of an entry were indicated by two or more ITs separated by "," for most plants with the first IT and few plants with the second IT and the number of plants for each IT is indicated in "()". For adult-plant tests, if the flag leaf has a IT different from the leaf below, the ITs are separated by "/" with the flag leaf IT first.

**Virulence/avirulence formulae (Yr genes) of the tested races:**

PSTv-4: **1,6,9,17,27,SP,Tye/5,7,8,10,15,24,32,43,44,Tr1,Exp2**

PSTv-14: **1,6,7,8,9,17,27,43,44,Tr1,Exp2,Tye/5,10,15,24,32,SP**

PSTv-37: **6,7,8,9,17,27,43,44,Tr1,Exp2/1,5,10,15,24,32,SP,Tye**

PSTv-40: **6,7,8,9,10,24,27,32,43,44,Tr1,Exp2/1,5,15,17,SP,Tye**

PSTv-51: **1,6,7,8,9,10,17,24,27,32,43,44,SP,Tr1,Exp2,Tye/5,15**

PSTv-198: **6,7,8,9,27,43,44,Exp2/1,5,10,15,17,24,32,SP,Tr1,76**

<sup>b</sup> The seedling tests were conducted in October to December 2011 for each race without replications. For adult-plant tests, seeds were planted in late November and seedlings of about 3-5 cm were vernalized at 2-4°C for 6 to 9 weeks and then transplanted into big pots and grown in the greenhouse (10 to 25°C diurnal temperature cycle, 16h light) from January to March. Plants at boot to flowering stages were inoculated (Jan to March 2012) with a mixture of urediniospores of a particular race with talc powdery at about 1:20 ratio, incubated for 20 to 24 h in a dew chamber (dark, 10°C) and then grown in a greenhouse growth chamber at the 10-30°C diurnal temperature cycle with 16 h light. IT was recorded for each plant 18 to 20 days after inoculation. The three reps for each race test were done in different time periods.

<sup>c</sup> Entries with a high IT in the seedling low-temperature test but with a low IT to all tested three races in the adult-plant tests under high temperatures have possibly high-temperature adult-plant (HTAP) resistance. Some of the entries are susceptible to all tested races in seedling stage, but resistant to one or two races and susceptible to the other race(s) in the adult-plant stage, indicating race-specificity of the adult-plant resistance.