Report of the 2023 Uniform Regional Scab Nursery for Spring Wheat Parents

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The Uniform Regional Scab Nursery for Spring Wheat Parents (URSN) was grown for the 29th year in 2023. Four locations (St. Paul, MN, Crookston, MN, Brookings, SD, and Prosper, ND) reported results.

A total of 22 entries were included in the 2023 URSN, in addition to the resistant checks ND2710, BacUp, and Rollag, the susceptible checks Wheaton, Oslo, Norm, and N10, a Norm near-isoline containing *Fhb1*. The entries were contributed by four university wheat breeding programs.

The core set of traits evaluated at the nursery locations varied, but most included Fusarium head blight (FHB) incidence, FHB severity, and disease index. In addition, visual scabby kernel ratings (VSK/tombstone/FDK) were provided for locations. Additional agronomic trait data are presented in individual location summary tables for locations where they were measured. Adult plant and seedling stem rust reactions are also presented. Molecular marker genotypes for a set of FHB resistance QTL and other traits are provided for entries.

The data of genotype means for locations (Tables 2-5) will be available online on the Triticeae Toolbox under T3/Wheat.

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Previous URSN Entries Released as New Cultivars

Unlike the Hard Red Spring Wheat Uniform Regional Nursery (HRSWURN) Annual Report, the URSN Annual Report has not included records of experimental lines becoming released varieties. Including this information is valuable to the wheat community for tracking experimental lines that were tested in this nursery under FHB-inoculated conditions and their status of becoming a released variety. Some of these varieties were also tested in the HRSWURN as well, and information on their phenotype data can be found in that Annual Report posted to the GrainGenes website: https://wheat.pw.usda.gov/GG3/

The released cultivar names along with their experimental name, PI number, years in the URSN, and a brief description are included below. Entries that have been entered in the URSN since its start in 1995 are listed below in order of year it was released.

Briggs (SD3367, PI 632970) Released in 2002 by the South Dakota Agricultural Experiment Station. It has high and stable yield potential, above average test weight and protein content. It has good disease resistance to leaf rust and stem rust, and an intermediate resistance to FHB. **URSN 1998, HRSWURN 2000-2001**

Cromwell (MN00261-4, PI 653527) Released in 2007 by Thunder Seed, license required for seed production. Moderately strong straw, good test weight, and good end-use quality. Moderately resistant to FHB. **URSN 2006, HRSWURN 2004-2005**

Tom (MN01311-A-1, PI 656383) Released in 2008 by the University of Minnesota Agricultural Experiment Station due to its high yield, moderate resistance to FHB (type 2 resistance), and adult plant resistance to Ug99 race of stem rust. **URSN 2006, HRSWURN 2004-2005,**

Sabin (MN03358-4, PI 659083) Released in 2009 by the University of Minnesota Agricultural Experiment Station due to its high yield, moderate resistance to FHB due to the Fhb1 locus, and has the Lr34 gene for adult plant resistance to leaf rust. It heads relatively later than other cultivars in the region. **URSN 2008, HRSWURN 2006-2007**

Brick (SD3851, PI 657697) Released in 2009 by the South Dakota Agricultural Experiment Station due to its high resistance to FHB and high yield potential. It has early maturity and is moderately resistant to leaf rust. **URSN 2007, HRSWURN 2005-2006**

Select (SD3948, PI 659554) Released in 2010 by the South Dakota Agricultural Experiment Station due to its high resistance to FHB with high yield potential. It is also moderately resistant to leaf rust and has an early heading date. **URSN 2009, HRSWURN 2007-2008**

Rollag (MN05214-3, PI 665250) Released in 2011 by the University of Minnesota Agricultural Experiment Station due to its good resistance to FHB and has the Fhb1 locus. It also has a competitive yield, very good straw strength, and acceptable end-use quality. **URSN resistant check 2019-2023, HRSWURN 2009-2010**

Forefront (SD3997, PI 664483) Released in 2012 by the South Dakota Agricultural Experiment Station due to its competitive high yield, and protein content. It has resistance to FHB and leaf rust, along with an early heading date. **URSN 2009, HRSWURN 2009-2010**

Lanning (MT1316, PI 676978) Released in 2016 Montana Agricultural Experiment Station due to its high yield potential in dryland conditions and superior end-use quality. It is an awned, semidwarf hard red spring wheat. It is hollow-stemmed, making it susceptible to wheat stem sawfly. **URSN 2015-2016 and 2019, HRSWURN 2015-2016**

Lang-MN (MN10261-1, PI 687038) Released in 2017 by the University of Minnesota Agricultural Experiment Station. It has high yield and grain protein, good end-use quality, and disease resistance, especially to FHB. **URSN 2016, HRSWURN 2013-2014**

ND VitPro (ND825, PI 682660) Released in 2017 by the North Dakota Agricultural Experiment Station. It has improved straw strength, end-use quality, and good disease resistance, including FHB and stem rust. It has high vitreous kernel percentage and high grain protein. **URSN 2016, HRSWURN 2016**

Dagmar (MT1621, PI 690450) Released in 2019 by Montana Agricultural Experiment Station for adaptation to drought and wheat stem sawfly regions. It has a longer green leaf stage after heading, good grain protein, and good gluten strength. It has intermediate stem-solidness providing protection against wheat stem sawfly. **URSN 2018-2019, HRSWURN 2018-2019**

ND Frohberg (NDHRS16-13-97, PI 698310) Released in 2020 by the North Dakota Agricultural Experiment Station. It has improved straw strength, yield potential, and end-use quality. It has high resistance to stem rust, moderate resistance to leaf rust, bacterial leaf streak, and FHB. **URSN 2018, HRSWURN 2018-2019**

MT Sidney (MT1716, PI 699957) Released in 2021 by the Montana Agricultural Experiment Station. It is a high yielding, early-heading, awned, and semidwarf hard red spring wheat variety. Has moderate resistance to FHB. Hollow-stem makes it susceptible to wheat stem sawfly. **URSN 2019-2021, HRSWURN 2020-2021**

MT Dutton (MT1809) Released in 2023 by the Montana Agricultural Experiment Station. It has high yield in rainfed conditions, good protein content, and moderate aluminum tolerance. It is also moderately resistant to FHB and has resistance to foliar disease. **URSN 2020, HRSWURN 2021-2022**

ND Heron (NDHRS16-14-126, PI 699926) Released in 2022 by North Dakota State University. It has competitive yield potential with good protein, test weight, and resistance to FHB and bacterial blight. It has excellent end-use qualities. **URSN 2019-2020, HRSWURN 2019-2021**

Figure 1. Map of Uniform Regional Scab Nursery Locations, 2023

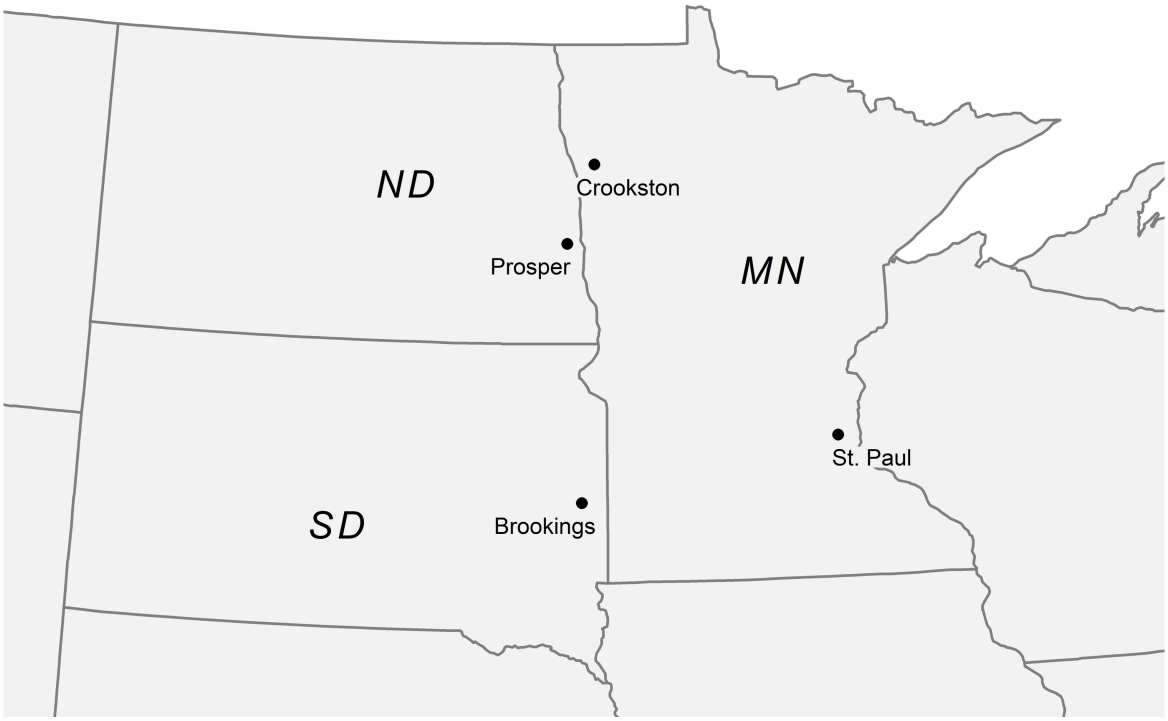

Table 1. Entries for the 2023 Uniform Regional Scab Nursery Parents.

Entry	Line	Pedigree	1st Year in URSN	Submitter	Organization
1	Bacup	CHECK			
2	ND2710	CHECK			
3	Rollag	CHECK			
4	Oslo	CHECK			
5	Wheaton	CHECK			
6	Norm	CHECK			
7	N10	CHECK (Norm Fhb1 NIL)			
8	MN18091-2	MN11116-3/MN12544-2	2023	J. Anderson	UMN
9	MN19114-3	MN13588-4/Lang-MN	2023	J. Anderson	UMN
10	MN19146-4	MN-Torgy/Lang-MN	2023	J. Anderson	UMN
11	MN19257-1	MN12345-3/MN-Washburn	2023	J. Anderson	UMN
12	MN20231-2	Shelly/MN-Torgy	2023	J. Anderson	UMN
13	SD5101	DRIVER/SD4708	2023	K. Glover	SDSU
14	SD5117	SY-VALDA/SD4748	2023	K. Glover	SDSU
15	SD5127	FOCUS/SD4710//SD4954	2023	K. Glover	SDSU
16	SD5132	SD4724/SD4719	2023	K. Glover	SDSU
17	SD5145	SD4752/SD4746	2023	K. Glover	SDSU
18	SD5159	SD4871/SD4539	2023	K. Glover	SDSU
19	NDHRS15-0037-C52	NDVITPRO/ROLLAG//GLENN	2023	A. Green	NDSU
20	NDHRS15-0006-B02	ND820/LANG-MN//DAPPS/3/GLENN/4/FALLER	2023	A. Green	NDSU
21	NDHRS15-0006-C29	ND820/LANG-MN//DAPPS/3/GLENN/4/FALLER	2023	A. Green	NDSU
22	NDHRS16RIL-0190-019	NDVITPRO/ND826	2023	A. Green	NDSU
23	NDHRS15-0405-C34	LANG-MN/ND829	2023	A. Green	NDSU
24	MT21214	DAGMAR/MT 1716	2023	J. Cook	MSU
25	MT21220	DAGMAR/MT 1716	2023	J. Cook	MSU
26	MT21222	DAGMAR/MT 1716	2023	J. Cook	MSU
27	MT21305	DAGMAR/NDHRS16-12-31	2023	J. Cook	MSU
28	MT21352	DAGMAR///MT1007//MO8/3-4	2023	J. Cook	MSU
29	MT21384	DAGMAR///MT1007//M0 09/3-4	2023	J. Cook	MSU

Table 2. 2023 Uniform Regional Scab Nursery for Spring Wheat Parents, St. Paul, MN.

Entry	Line	Incidence %	Severity %	Disease Index	VSK %	DON ppm	Heading d from 6-1	micro TWT [1] g
1	Bacup	83.3	13.0	11.1	9.0	2.5	20.0	11.4
2	ND2710	69.0	8.5	6.1	6.0	1.2	21.0	11.7
3	Rollag	83.3	16.0	14.1	9.0	2.6	21.0	11.2
4	Oslo	95.2	40.5	39.4	13.5	3.2	21.0	10.3
5	Wheaton	100.0	80.8	80.8	77.5	17.7	23.0	9.1
6	Norm	100.0	66.7	66.7	62.5	12.2	24.3	10.0
7	N10	100.0	39.7	39.7	38.5	8.3	25.7	10.4
8	MN18091-2	90.4	26.3	24.1	12.5	4.7	27.0	11.5
9	MN19114-3	100.0	20.2	20.2	12.0	2.0	24.3	11.5
10	MN19146-4	78.5	10.5	8.5	8.0	1.8	23.0	11.7
11	MN19257-1	92.8	16.7	15.6	6.0	1.3	27.0	11.7
12	MN20231-2	52.4	8.6	4.3	11.5	2.3	23.0	11.7
13	SD5101	85.7	17.1	15.5	9.0	2.7	22.0	11.6
14	SD5117	80.9	17.0	14.2	10.0	1.2	20.0	11.4
15	SD5127	83.3	25.0	20.4	16.0	3.6	21.0	10.8
16	SD5132	97.6	31.4	30.5	16.0	2.2	27.0	11.4
17	SD5145	97.6	16.5	16.1	6.0	0.8	21.0	11.7
18	SD5159	90.4	30.4	28.3	16.0	2.8	23.0	11.4
19	NDHRS15-0037-C52	95.2	24.6	23.4	12.5	3.7	23.0	11.9
20	NDHRS15-0006-B02	83.3	14.1	12.7	7.0	2.6	20.0	11.4
21	NDHRS15-0006-C29	88.1	15.0	13.2	7.0	2.5	20.0	11.7
22	NDHRS16RIL-0190-019	78.5	21.8	17.0	12.5	4.3	20.0	11.5
23	NDHRS15-0405-C34	95.2	23.2	22.4	15.0	3.6	21.0	11.2
24	MT21214	97.6	32.0	31.8	20.0	5.5	24.3	11.0
25	MT21220	100.0	34.9	34.9	12.5	3.1	25.7	11.5
26	MT21222	95.2	24.9	23.7	16.0	4.7	24.3	11.3
27	MT21305	95.2	15.2	14.3	7.0	3.4	20.0	11.6
28	MT21352	100.0	29.9	29.9	30.0	9.3	20.0	10.8
29	MT21384	95.2	30.3	29.6	16.0	7.8	20.0	11.0
*	Alsen	97.6	21.8	21.5	11.0	2.7	22.0	11.4
*	Roblin	97.6	61.3	60.3	32.5	5.1	20.0	10.9
*	MN00269	100.0	55.3	55.3	32.5	3.0	27.0	10.1
Mean		90.6	27.8	26.4	17.8	4.2	22.6	11.2
LSD		24.2	22.4	22.8	13.8	-	2.1	0.5
CV		13.0	39.3	42.1	37.8	-	5.8	2.2

[1] Weight of the VSK sample that fits in a 15.7 mL copper vessel measuring 20 mm in diameter and 50 mm in height

* Extra entries

Table 3. 2023 Uniform Regional Scab Nursery for Spring Wheat Parents, Crookston, MN.

Entry	Line	Incidence [1] %	Severity [1] %	Disease [1] Index	VSK %	DON ppm	Heading d from 6-1	micro TWT [2] g
1	Bacup	–	–	–	10.0	6.6	32.0	11.5
2	ND2710	–	–	–	8.0	6.7	36.3	11.8
3	Rollag	–	–	–	12.5	7.7	36.3	11.1
4	Oslo	–	–	–	65.0	11.5	34.0	9.7
5	Wheaton	–	–	–	70.0	26.8	38.3	9.1
6	Norm	–	–	–	47.5	21.9	38.3	10.1
7	N10	–	–	–	26.0	16.3	37.0	10.6
8	MN18091-2	–	–	–	13.5	13.1	41.3	11.4
9	MN19114-3	–	–	–	14.5	17.0	42.3	11.1
10	MN19146-4	–	–	–	7.0	8.3	37.7	11.9
11	MN19257-1	–	–	–	8.0	6.8	43.0	11.4
12	MN20231-2	–	–	–	12.5	7.9	33.0	11.2
13	SD5101	–	–	–	13.5	11.5	37.3	11.4
14	SD5117	–	–	–	13.5	5.0	35.0	11.3
15	SD5127	–	–	–	14.5	10.2	30.7	11.5
16	SD5132	–	–	–	9.0	10.4	43.0	11.4
17	SD5145	–	–	–	10.0	6.8	38.3	11.6
18	SD5159	–	–	–	9.0	5.4	38.3	11.7
19	NDHRS15-0037-C52	–	–	–	8.0	10.3	37.0	12.0
20	NDHRS15-0006-B02	–	–	–	9.0	11.7	33.3	11.4
21	NDHRS15-0006-C29	–	–	–	16.0	11.4	35.0	11.4
22	NDHRS16RIL-0190-019	–	–	–	9.0	10.1	35.0	11.7
23	NDHRS15-0405-C34	–	–	–	11.0	9.3	34.3	11.3
24	MT21214	–	–	–	35.0	26.6	39.7	10.5
25	MT21220	–	–	–	17.0	17.3	40.3	11.3
26	MT21222	–	–	–	12.0	9.1	41.3	11.3
27	MT21305	–	–	–	13.5	10.1	34.0	11.1
28	MT21352	–	–	–	37.5	22.7	35.3	10.6
29	MT21384	–	–	–	20.0	19.3	36.0	10.3
*	Alsen	–	–	–	8.0	8.3	38.7	11.8
*	Roblin	–	–	–	77.5	12.2	32.0	9.7
*	MN00269	–	–	–	40.0	25.2	45.3	9.5
Mean		–	–	–	21.2	12.6	37.2	11.0
LSD		–	–	–	14.4	-	1.4	0.6
CV		–	–	–	33.2	-	2.4	2.6

[1] Not collected- symptoms were slow to develop and by the time they worth scoring, later heading lines had senesced too far

[2] Weight of the VSK sample that fits in a 15.7 mL copper vessel measuring 20 mm in diameter and 50 mm in height

* Extra entries

Table 4. 2023 Uniform Regional Scab Nursery for Spring Wheat Parents, Brookings, SD.

Entry	Line	Incidence %	Severity %	Disease %	Tombstone %
1	Bacup	80.0	16.3	13.0	22.5
2	ND2710	76.4	9.8	7.5	7.5
3	Rollag	95.0	18.3	17.5	27.5
4	Oslo	95.0	18.5	17.7	36.7
5	Wheaton	100.0	25.3	25.3	58.3
6	Norm	87.5	15.3	13.6	20.0
7	N10	92.5	17.0	16.1	30.0
8	MN18091-2	93.3	16.2	15.2	12.3
9	MN19114-3	95.0	15.5	14.8	13.5
10	MN19146-4	80.0	11.5	9.5	16.7
11	MN19257-1	87.5	13.5	12.0	5.0
12	MN20231-2	95.0	16.3	15.5	9.7
13	SD5101	90.0	16.5	15.0	15.0
14	SD5117	96.7	18.7	18.1	13.3
15	SD5127	90.0	14.8	13.7	22.5
16	SD5132	92.2	14.4	13.3	9.0
17	SD5145	93.3	18.0	16.8	15.0
18	SD5159	91.7	17.0	16.2	13.0
19	NDHRS15-0037-C52	88.3	16.0	14.4	8.3
20	NDHRS15-0006-B02	74.5	11.4	8.5	15.0
21	NDHRS15-0006-C29	97.5	18.8	18.3	10.0
22	NDHRS16RIL-0190-019	90.0	15.0	13.6	16.7
23	NDHRS15-0405-C34	90.0	13.8	12.5	17.5
24	MT21214	90.0	17.0	15.5	26.7
25	MT21220	91.7	14.0	13.0	25.0
26	MT21222	96.7	17.3	16.9	25.0
27	MT21305	91.7	18.3	17.1	23.3
28	MT21352	90.6	22.8	20.6	27.5
29	MT21384	100.0	23.5	23.5	25.0
Mean		91	16.6	15.4	19.7
LSD 0.05		NS	6.10	7.6	10.3
CV		8.96	20	26.8	28.4

Field was very dry after planting which decreased germination. After eventual rain, weeds overtook some ro
Thirteen rows were entirely lost to weeds and ratings were collected from eight rows on fewer than 20 heads

Table 5. 2023 Uniform Regional Scab Nursery for Spring Wheat Parents, Prosper, ND.

Entry	Line	VIBE FDK [1] %	FHB 9-Jan	Flowering date DAP	DON ppm	Notes
1	Bacup	22.3	6.2	203.5	8.2	
2	ND2710	17.5	4.6	202.2	6.3	
3	Rollag	17.6	6.0	202.0	6.5	
4	Oslo	12.4	5.9	202.1	4.5	
5	Wheaton	16.3	5.1	202.5	9.2	
6	Norm	46.6	6.9	202.6	28.1	
7	N10	41.0	6.2	202.0	23.6	
8	MN18091-2 *	-	-	-	-	
9	MN19114-3	15.7	4.9	202.8	15.7	
10	MN19146-4	15.7	4.6	202.5	5.3	
11	MN19257-1	9.9	2.9	203.4	14.9	
12	MN20231-2	16.6	4.5	201.7	7.6	
13	SD5101	17.9	5.2	203.1	6.7	
14	SD5117	12.8	5.0	201.8	2.1	
15	SD5127	11.0	7.8	202.5	4.6	
16	SD5132	25.8	4.0	203.4	18.9	
17	SD5145	15.6	5.1	203.7	9.6	
18	SD5159	9.7	4.4	204.0	7.1	
19	NDHRS15-0037-C52	11.5	5.7	203.8	8.8	
20	NDHRS15-0006-B02	16.0	4.3	203.0	5.3	
21	NDHRS15-0006-C29	11.5	5.3	202.9	5.3	
22	NDHRS16RIL-0190-019	19.3	6.7	202.8	7.3	
23	NDHRS15-0405-C34	14.5	6.4	203.0	7.0	
24	MT21214	23.4	6.1	202.0	10.0	
25	MT21220	25.4	5.6	202.5	12.5	
26	MT21222	22.8	3.7	203.0	21.9	
27	MT21305	16.7	6.2	203.4	8.4	
28	MT21352	15.5	7.7	202.2	9.3	
29	MT21384	14.2	5.3	201.6	10.5	
Mean		18.5	5.5	202.7	10.7	
CV		18.3	11.6	0.2	26.8	
LSD 0.05		6.6	1.3	0.9	6.9	
**	AKFASTRO	55.4	6.7	203.6	58.4	Sus Late
**	ALSEN	17.9	4.9	201.2	8.1	Res Med
**	GLENN	10.2	3.9	201.1	3.6	Res Early
**	LINKERT	28.8	6.8	203.1	7.3	Ms Late
**	ND828	7.4	4.9	202.7	9.7	R Late
**	NDFROHBERG	13.8	6.7	203.0	7.6	MR Med
**	NDHERON	9.9	6.5	203.0	1.2	MR Early
**	NDVITPRO	9.4	6.2	202.9	6.2	MR Med
**	WBMAYVILLE	18.7	9.0	203.6	3.2	Sus Med
**	2398	36.0	5.9	202.6	32.5	Sus Early

* Did not germinate.

** Local checks

[1] Fusarium Damaged Kernels calculated from RGB image of plot grain sample using algorithim from VIBE seed analyzer.

Table 6. 2023 Uniform Regional Scab Nursery for Spring Wheat Parents - Summary of Means.

	Incidence		Severity		Disease		VSK [1, 2]		DON [2]	
	%	Rank	%	Rank	Index	Rank	%	Rank	ppm	Rank
No. of Locations >	2		2		2		4		3	
Line										
Bacup	81.7	5	14.6	5	12.0	5	15.9	18	5.8	7
ND2710	72.7	1	9.2	1	6.8	1	9.8	2	4.7	2
Rollag	89.2	10	17.2	10	15.8	11	16.7	20	5.6	5
Oslo	95.1	21	29.5	27	28.6	27	31.9	26	6.4	10
Wheaton	100.0	29	53.0	29	53.0	29	55.5	29	17.9	28
Norm	93.7	18	41.0	28	40.2	28	44.1	28	20.7	29
N10	96.2	26	28.4	26	27.9	26	33.9	27	16.1	27
MN18091-2	91.9	14	21.3	19	19.7	18	12.8	11	8.9	19
MN19114-3	97.5	27	17.9	13	17.5	16	13.9	13	11.6	22
MN19146-4	79.3	4	11.0	2	9.0	2	11.9	7	5.1	4
MN19257-1	90.2	11	15.1	6	13.8	6	7.2	1	7.7	18
MN20231-2	73.7	2	12.5	3	9.9	3	12.6	10	5.9	8
SD5101	87.8	8	16.8	8	15.3	7	13.9	12	7.0	14
SD5117	88.8	9	17.8	12	16.2	12	12.4	9	2.8	1
SD5127	86.7	7	19.9	16	17.1	14	16.0	19	6.1	9
SD5132	94.9	20	22.9	20	21.9	20	15.0	16	10.5	20
SD5145	95.4	23	17.3	11	16.5	13	11.6	5	5.7	6
SD5159	91.1	12	23.7	21	22.3	21	11.9	8	5.1	3
NDHRS15-0037-C52	91.8	13	20.3	17	18.9	17	10.1	3	7.6	17
NDHRS15-0006-B02	78.9	3	12.8	4	10.6	4	11.7	6	6.5	12
NDHRS15-0006-C29	92.8	16	16.9	9	15.8	10	11.1	4	6.4	11
NDHRS16RIL-0190-019	84.3	6	18.4	14	15.3	8	14.4	14	7.2	15
NDHRS15-0405-C34	92.6	15	18.5	15	17.5	15	14.5	15	6.6	13
MT21214	93.8	19	24.5	23	23.7	22	26.3	24	14.0	26
MT21220	95.8	24	24.4	22	23.9	23	20.0	23	11.0	21
MT21222	96.0	25	21.1	18	20.3	19	18.9	22	11.9	23
MT21305	93.5	17	16.7	7	15.7	9	15.1	17	7.3	16
MT21352	95.3	22	26.4	24	25.3	24	27.6	25	13.8	25
MT21384	97.6	28	26.9	25	26.6	25	18.8	21	12.5	24

[1] FDK and Tombstone ratings are included, these terminologies are interchangeable

[2] One fewer location was used for MN18091-2 because of poor germination

Table 7. Correlation Coefficients Between Traits, by Location.

Correlation Between	St. Paul	Brookings	Crookston	Prosper
Incidence & Severity	0.571	0.743		
Incidence & Disease Index	0.614	0.834		
Incidence & Tombstone/VSK/FDK	0.395	0.354		
Incidence & DON	0.422			
Severity & Disease Index	0.997	0.986		
Severity & Tombstone/VSK/FDK	0.924	0.629		
Severity & DON	0.878			
Disease Index & Tombstone/VSK/FDK	0.919	0.611		
Disease Index & DON	0.874			
Tombstone/VSK/FDK & DON	0.944		0.699	0.787

Table 8. Correlation coefficients among traits, using means across locations

	Incidence	Severity	Disease Index
Severity	0.497		
Disease Index	0.551	0.997	
Tombstone/VSK/FDK	0.386	0.727	0.733

Calculated using 2 locations: St. Paul and Brookings

Table 9. 2023 Uniform Regional Scab Nursery for Spring Wheat Parents, St. Paul, MN. Seedling stem rust reactions (Y. Jin, USDA-ARS).

		Race					
Entry	Line	QFCSC 06ND76C	QTHJC 75ND717C	RKRQC 99KS76A-1	TPMKC 74MN1409	TTTTF 01MN84A-1-2	Field stem rust response St. Paul
1	Bacup	0;	2	2-	0;	3	10R
2	ND2710	0	2-	;2-	;2-	1;	20R-MR
3	Rollag	0;	2-	2	2-2	1;	10R
4	Oslo	;	2	0;	2-	3	30MR
5	Wheaton	0	2-	;2-	2-	1;	5R
6	Norm	0	2-	;2-	2-	0;1	0
7	N10	0	2-	;2-	2-	1;	5R
8	MN18091-2	0;	2-	2-	2-	1	10R
9	MN19114-3	0;	2-	2	0;	1;	0
10	MN19146-4	0;	2-	2	0;	1;	5R
11	MN19257-1	0;	2-	2	2-	11+	0
12	MN20231-2	0	2-	2	0;	3-	5R
13	SD5101	;	2-C	2-	;	1+	40MR
14	SD5117	;	2-C	2-	;	11+	20MR
15	SD5127	;	2-C	2	2	3+	30MR
16	SD5132	0;	2-C	2/3	3	1;	0/30MS
17	SD5145	;	2-C	2+2	2	11+/2-	5R
18	SD5159	;	2-	2	;	;	10R
19	NDHRS15-0037-C52	;	2-	2	2-	1;	5R
20	NDHRS15-0006-B02	;	2-	2	2-	1;	5R
21	NDHRS15-0006-C29	;	2-	2	2	1;	5R
22	NDHRS16RIL-0190-019	;	2-	2	2-	1;	0
23	NDHRS15-0405-C34	;	2-	2	2-	1;	5R
24	MT 21214	;	2	22+	;2-/2	4	10R-MR
25	MT 21220	;	12-	2	;2-/2	3+	0
26	MT 21222	;	2-2	2	;2-/2	3+	5R
27	MT 21305	;2-	2-	2	2-	3+	20R-MR
28	MT 21352	;	2-	2	2	4	20R-MR
29	MT 21384	;2-	2-	2	2	3	40MR
*	Line E	33+	3	3+	4	4	90S
*	Line E	33+	3+	4	4	3+	90S
*	LMPG-6	2+2	2	2+3	3	2+3	90S
*	NA101/MqSr7a	1+1	23	1;	3+	1;	70MS-S

* checks

Explanatory notes on next page

Table 9 continued, Explanatory notes.

A. Races used in seedling evaluations:

Race	Origin	Virulence on differential genes
QFCSC	USA	5 8a 9a 9d 9g 10 17 21 McN
QTHJC	USA	5 **6** 8a **9b** 9d 9g 10 **11** 17 21 McN
RKRQC	USA	5 **6** 7b 8a 9a **9b** 9d 9g 17 21 **36** McN
TPMKC	USA	5 7b 8a 9d **9e** 9g 10 **11** 17 21 **36 Tmp** McN
TTTTF	USA	5 **6** 7b 8a 9a **9b** 9d **9e** 9g 10 **11** 17 21 **30 36 38 Tmp** McN

* **Red font** represents unique and/or significant virulence or combination of virulences to resistance genes that are important in spring wheat

B. Seedling rating scale:

0 to 4 infection type scale of Stakmen et al., 3 or 4 are considered susceptible

"/" denotes hetergeneous, the predominant type given first.

"LIF" denotes low infection frequency, or fewer number of pustules.

"C" stands for excessive chlorosis

"N" stands for excessive necrosis

"Sr2M" referred to seedling chlorosis, similar to Sr2 expression in seedling under certain environments

C. Field stem rust nursery:

Entries were planted in 1-m row plots

Nursery was inoculated with a bulk of races QFCSC, QTHJC, RCRQC, RTQQC, and TPMKC

Stem rust terminal serverity (%) and infection responses (R, MR, MS, S or combination thereof) were rated when entries were at the soft dough stage

Table 10. Markers Associated With Selected Traits/Genes (R. Nandety and J. Fiedler, USDA-ARS).

Entry	Line	Sr2	Sr6	Sr12	Sr25	Lr13	Lr16	Lr21	Lr23	Lr34	Yr7D	Tsn1	Fhb1	Fhb1-TaHRC	barc180	barc186	gwm644	GPC	GluD1	umn19	RhtB1	RhtD1	Rht24	PpdB1	PpdD1
	Trait	StemRust 3B	StemRust 6A	StemRust 3B	Stem Rust 7D	LeafRust 2B	LeafRust 2B	LeafRust 1D	LeafRust 2B	LeafRust 7D	YellowRust 2B	TanSpot 5B	Fhb 3B	Fhb 3B	Fhb 5A	Fhb 5A	Fhb 6B	GrainProt. 6B	Glutenins 1D	Glutenin 1A	Dwarfing 4B	Dwarfing 4D	Dwarfing 6A	Photoper. 2B	Photoper. 2D
1	Bacup	S	S	R	R	R	S	S	S	R	S	S	S	S	R	R	S	N	G	1	Wt	Wt	D	I	I
2	ND2710	S	S	R	S	R	S	S	R	R	R	S	R	R	R	R	S	N	G	1	Wt	Wt	Wt	S	S
3	Rollag	S	S	R	R	R	R	S	R	R	S	R	R	R	S	R	S	N	G	2	Wt	D	D	S	S
4	Oslo	S	R	R	S	R	S	S	S	S	R	R	S	S	S	S	S	N	P	1	D	Wt	D	S	I
5	Wheaton	S	S	R	S	R	S	S	R	R	R	R	S	S	S	S	S	N	G	2	Wt	D	Wt	S	I
6	Norm	S	S	R	S	R	R	S	R	R	R	R	S	S	S	S	S	N	G	2	Wt	D	Wt	S	S
7	N10	S	S	R	S	R	R	S	R	R	R	R	R	R	S	S	S	N	P	1	Wt	D	Wt	S	S
8	MN18091-2	-	S	R	S	S	S	S	R	S	S	R	R	R	S	S	S	N	G	2	D	Wt	Wt	S	S
9	MN19114-3	-	S	R	R	R	S	S	R	R	R	S	R	R	S	S	S	N	G	2	Wt	D	D	S	S
10	MN19146-4	-	S	R	R	R	S	S	R	R	R	S	R	R	S	S	S	N	G	1	Wt	Wt	D	S	I
11	MN19257-1	S	S	R	S	R	S	S	S	S	R	S	R	R	R	R	S	N	G	2	D	Wt	D	S	S
12	MN20231-2	-	S	R	R	S	S	R	R	S	R	R	R	R	S	S	S	N	G	2	Wt	Wt	D	S	S
13	SD5101	-	S	S	S	S	R	S	R	S	R	R	S	S	S	S	S	N	G	2	Wt	Wt	D	S	S
14	SD5117	S	S	S	S	S	R	S	S	R	R	S	S	S	S	S	S	N	G	2	Wt	Wt	Wt	S	S
15	SD5127	-	S	R	R	R	R	R	R	S	R	R	R	R	S	S	S	N	G	2	D	Wt	Wt	S	I
16	SD5132	S	S	R	S	S	R	R	R	S	R	R	S	S	S	S	S	N	G	2	Wt	Wt	D	S	S
17	SD5145	S	S	R	S	R	R	S	R	S	R	S	S	S	S	S	S	N	G	2	Wt	Wt	D	S	S
18	SD5159	S	S	S	S	S	S	R	S	R	R	R	R	R	S	S	S	N	G	2	Wt	Wt	D	S	I
19	NDHRS15-0037-C52	-	S	R	S	R	R	R	R	S	R	S	S	S	S	S	S	N	G	2	D	Wt	Wt	S	S
20	NDHRS15-0006-B02	-	S	R	R	S	R	S	R	S	R	S	S	S	R	R	S	N	G	2	D	Wt	Wt	S	S
21	NDHRS15-0006-C29	-	S	R	S	S	S	S	R	S	R	S	R	R	R	R	S	N	G	2	D	Wt	Wt	S	S
22	NDHRS16RIL-0190-019	-	S	R	S	R	R	R	R	S	R	S	S	S	S	S	S	N	G	2	D	Wt	Wt	S	S
23	NDHRS15-0405-C34	-	S	R	S	R	S	R	R	S	R	R	S	S	S	S	S	N	G	2	D	Wt	D	S	I
24	MT21214	-	S	R	S	S	S	S	S	S	R	R	S	S	S	S	S	N	G	2	D	Wt	Wt	S	S
25	MT21220	-	S	R	S	R	R	S	R	S	R	R	S	S	S	S	S	N	G	2	U	Wt	Wt	S	S
26	MT21222	-	S	R	S	R	S	S	R	S	R	R	S	S	S	S	S	N	G	2	D	Wt	Wt	S	S
27	MT21305	-	S	R	S	R	R	S	R	S	R	R	S	S	R	R	S	N	G	2	D	Wt	Wt	S	S
28	MT21352	S	S	R	S	S	S	S	S	S	R	R	S	S	S	S	S	N	G	1	D	Wt	Wt	S	S
29	MT21384	-	S	R	S	S	R	S	R	S	R	R	S	S	S	S	S	N	G	2	D	Wt	Wt	S	S

Information about markers on next page

Allele Code

R = Resistant (Hope allele)	S = Susceptible
R = Resistant (Harvest allele)	S = Susceptible
R = Resistant	S = Susceptible
R = Resistant (200 bp present)	S = Susceptible (no 200 bp)
R = Ne2/Lr13_ha, Lr13 resistant and hybrid necrosis (Ne2 allele)	S = Ne2/Lr13_no, Lr13 susceptible, hybrid necrosis only but still has Ne2
R = Resistant	S = Susceptible
R = Resistant	S = Susceptible
R = Resistant	S = Susceptible
R = Resistant (Thatcher allele)	S = Susceptible
R = Resistant	S = Susceptible
R = Resistant	S = Susceptible
R = Resistant	S = Susceptible
R = Resistant	S = Susceptible
R = Resistant	S = Susceptible
R = Resistant (161 bp present)	S = Susceptible (no 161 bp)
I = Increased	N = Normal
G = Good (5+10)	P = Poor (2+12)
1=359bp = Ax1 or Ax-null	2 = 341bp = Ax2
D = Dwarfing = Rht-B1b	Wt = Wild Type = Rht-B1a
D = Dwarfing = Rht-D1b	Wt = Wild Type = Rht-D1a
D = Dwarfing	Wt = Wild Type
I = Insensitive	S = Sensitive
I = Insensitive	S = Sensitive

U = No Call or Unknown = Indeterminant designation

Het = Heterozygous call

Table 10 continued, Marker information

Name	Chromosome	Alternate Name	Comment	Manuscript
Sr2	3B		Null allele	https://doi.org/10.1007/s00122-010-1482-7
Sr8	6A	kwh53		https://doi.org/10.1094/PHYTO-05-16-0186-R
Sr12	3B	NBLRR3		https://doi.org/10.1371/journal.pone.0157029
Sr25	7D		SSR	Chao, unpublished
Lr13	2B			https://www.cell.com/molecular-plant/pdf/S1674-2052(21)00171-4.pdf
Lr16	2B	kwm849		https://doi.org/10.1186/s12870-017-0993-7
Lr21	1D			https://doi.org/10.1007/s11032-012-9773-0
Lr23	2B	sunKASP_16		https://doi.org/10.1007/s11032-017-0628-6
Lr34	7D	FJ436983-T67957A		https://doi.org/10.1126/science.1166453
Yr7	2B	Yr7D		https://doi.org/10.1038/s41477-018-0236-4
Tsn	5B	Tsn1-1Ka	SNP flanking deletion	Faris Lab unpublished
Fhb1	3B	FM227		https://doi.org/10.1007/s00122-016-2727-x
TaHRC	3B			https://doi.org/10.1007/s00122-018-3159-6
barc180	5A	GENE-3371_56	equivalent to SSR	https://doi.org/10.1007/s00122-011-1573-0
barc186	5A	IWA6412	equivalent to SSR	Chao, unpublished
gwm644	6B		SSR	https://doi.org/10.1093/genetics/149.4.2007
GPC	6B	GPC-B1_DUP		https://doi.org/10.1111/j.1469-8137.2005.01627.x
GluD1	1D			https://doi.org/10.1270/jsbbs.57.243
umn19	1A		SSR	https://doi.org/10.1007/s00122-008-0886-0
RhtB1	4B			https://doi.org/10.1007/s00122-002-1048-4
RhtD1	4D			https://doi.org/10.1007/s00122-002-1048-4
Rht24	6A	Rht24-TaAP2.1		Anderson lab
PpdB1	2B			https://doi.org/10.1371/journal.pone.0079459
PpdD1	2D			https://doi.org/10.1007/s11032-012-9765-0

Table 11. 2023 Seedling and Field Stem Rust Reactions in St. Paul, Kenya, and Ethiopia

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Seedling Infection Type Key
0 - 4 infection types described by Stakman et al.
USDA-ARS Cereal Disease Laboratory 0 to 2 categorized as resistant
3 to 4 categorized as susceptible
+ = relatively larger pustules for a given infection type
- = relatively smaller pustules for a given infection type
Any combination of infection responses recorded indicates the presence of multiple infection responses with the most frequent listed first
/ = an indication of different infection types on separate plants

Infection Response Key
R = resistant
MR = moderately resistant
M = moderately resistant to modestely susceptible
MS = moderately susceptible
S = susceptible
Any combination of infection responses recorded indicates the presence of multiple infection responses with the most frequent listed first
/ = an indication of different infeciton responses on separate plants, predomiant type was given first.

Severity Key
0-100 modified Cobb scale to determine percentage of possible tissue rusted, T = trace (approximately 1%)
/ = an indication of mixture of plants, predomiant type was given first.
Peterson, RF, AB Campbell, AE Hannah (1948) A diagrammatic scale for estimating rust intensity of leaves and stem of cereals. Can. J. R

Coefficient of Infection (COI)
Coefficient of infections were calculated as the product of severity and linearized infection response
Gao et al. (2016) Genome wide association study of seedling and adult plant leaf rust resistance in elite spring wheat breeding lines. PLOS ONE 11:e0148671.
Cumulative coefficient of infection was calculated as the sum of the coefficient of infections from each rating

Wheat Line Information		Gene Postulations USDA-ARS		Field Evaluation, St. Paul, MN USDA-ARS			Field Evaluations, Njoro, Kenya KALRO- Zennah Kosgey						Field Evaluations, Debre Zeit, Ethiopia EIAR/Pablo Olivera						Seedling Evaluations, St. Paul, Minnesota USDA-ARS				Ug99 Seeding resistance to Ug99 race group highlighted in green				Ug99+Sr24+Sr7mp								Molecular Marker Evaluations, Fargo, ND USDA-ARS			Resistance-associated alleles									
				7/21/23	7/22/23	Cumulative COI	4/13/23	4/20/23	Cumulative COI	5/6/23	5/12/23	5/19/23	Cumulative COI	5/19/23	4/19/23	4/29/23	5/8/23	5/15/23	Cumulative COI	5/15/23	QFCSC	QTHJC	RKRQC	TPMKC	TTTTF	TTKSK	TTKSK	TTKTT	TTKTT	TRTTF	TRTTF	TTRTF	TTRTF	TKTTF	TKTTF	TKKTF	TKKTF	Sr11-IWB1072 4			Sr12-NBLRR3			Sr7a-IWB1214 6			Sr7a-IWB4701 6			Sr8a-kwh53		
URSN No.	Line Name	Ug99	Other	Stem rust	Stem rust	Stem rust	Stripe rust	Stripe rust	Stripe rust	Stem rust	Stem rust	Stem rust	Stem Rust	Notes	Stem Rust	Stem Rust	Stem Rust	Stem Rust	Stem Rust	Notes	95MN108	69MN399	99KS76A-	74MN1409	01MN84A-	04KEN156	04KEN156	18KEN874	18KEN874	06YEM34-	06YEM34-	4GEO189-	4GEO189-	13ETH18-	13ETH18-	19ETH323-	19ETH323-	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
check	MN06028	APR	Sr7a	5RMR	10RMR	4.08	0	5MS	4	5RMR	10MRMS	15MRMS	14.6	Soft dough	5M	40MSS	50MSS	50MSS	124.8		;1-	2-	2-	2	1 LIF	3+	3+	33+	3+	3	33+	3	33-	0;1	0;1	33+	33+	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X
check	RL6058-JK	APR		40MSMR	40MSMR	53.6	0	5MS	4	0	0	0	0	milky	TM	5M	10MR	5R,5MSS	8.6	Mixture	0;/1	0;1	1+1	1+1	;1/3-1	33+	33+	33-	3-	3+	3+	3+	33+	33+	33+	13-;	33+	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele Y	Allele Y	Allele Y	Negative	Negative	Negative	Allele X	Allele X	Allele X
check	LMPG-6		Sr30-like ?	70S	70S	140	10MS	20MS	20	60S	80S	100S	240		2SMS	50S	70S	80S	220		2+3	22+	3+	4	3	3+	3+	3+	3+	3+	3+	22-; 3+	2-;	3+	3+	3+	33+	Allele X	Allele X	Allele X	Allele Y	Allele Y	Allele Y	Allele Y	Allele Y	Allele Y	Negative	Negative	Negative	Allele X	Allele X	Allele X
check	MN15111-	Sr22	Sr7a	5RMR	5RMR	2.7	0	5MS	4	5R	5R	10RMR	4.7	soft dough	TMS	15MR	20MR	30MR	26.8		0;	1-;	;	0;	0;	;12-	;1	;1	;1	;1-	12-	2-	2-	2-	0;	0;	;1-	;12-	Allele Y	Allele Y	Allele Y	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X
check	MN15130-	Sr26	Sr7a	10RMR	10MRR	4.0	0	10MS	8	5R	5R	10RMR	4.7	soft dough	0	5MR	20MR	25MR	20		0;	2-	2-	2-	0;	0;	2-	2-	2-	2-	2-	2-	2-	2-	0;	0;	2-	22-	Allele X	Allele X	Both Alleles	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Both Alleles	Both Alleles	Both Alleles
3	Rollag	APR	Sr7a	10MRR	20MRR	9.9	0	5MS	4	15MSMR	40MSMR	40MSMR	63.65	soft dough	2SMS	40S	50MSS	80S	183.5		0;	2-	2-	2-	1 1+	33+	33+	3+		3+	3+	33+	3+		1 1+;		3 + / 1	Allele X	Allele X	Allele X	Allele X	Allele X	Negative	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X	Allele X
13	SD5101		Sr7a	2SMR	2SMR	20	1MS	5MS	4.8	80S	100S	DEAD	180		30MSS	60S	70S	100S	256.1		;	2-	2-	;	1	3+	3+	3+	3+	3+	3+	3+	33+	0;1	1;	33+	32+			Negative	Negative		Negative	Negative		Negative	Negative		Allele X		Allele X
14	SD5117		Sr7a	20MR	25MR	18	0	5MS	4	80S	100S	DEAD	180		20MS	50S	50S	80S	196		;	2-	2	;	;1	3+	3+	3+	3+	3+	3+	3+	3+	;1-	11+;	3+	32+			Negative	Negative		Negative	Negative		Negative	Negative		Allele X		Allele X
15	SD5127			35MRMS	40MRMS	39.75	10MS	15MS	20	60S	70S	80S	210		30MS	50S	70S	80S	224		;	2-	2	2-	4	3+	3+	3+	3+	3	3+	3+	3+	3+	33+	3+	3+			Negative	Negative		Negative	Negative		Negative	Negative		Allele X		Allele X
16	SD5132		Sr7a	40MRMS	40MRMS	42.4	5MR	5MR	4	30MSS	60MSS	60MSS	130.5		2SMS	3SMSS	3SMSS	60SMS	136.7		;	2-	2	2/3	1;/1	3+	3+	3+	3+	3+	3+	3+	3+	;13-	;1	3	3+			Allele X	Negative		Negative	Negative		Negative	Negative		Allele X		Allele X
17	SD5145	APR	Sr7a	15MRR	20MRR	11.55	5MS	15MS	16	15MRMS	30MRMS	50MRMS	50.35	hard dough	30MS	40S	40S	60S	164		;	2-	2-	2-	1;	3+	3+	3+	3+	3+	3+	3+	3+	13-	3-1	3	3			Negative	Negative		Negative	Negative		Negative	Negative		Allele X		Both Alleles
18	SD5159	APR	Sr7a	35MR	30MR	29.0	0	20MSMR	40	40MSMR	60MSMR	80.4	hard dough	30MSS	50S	50S	80S	206.1		0;	2-	2-	;	;1	33+	3+	33+	3+	33+	33+	3+	3+	;1	;1-	32+	33+			Negative	Negative		Negative	Negative		Negative	Negative		Allele X		Negative
27	MT21305			30MRMS	25MR	25.9	5MS	10MS	12	30MSMR	40MSMR	80MS	86.9	milky	30MS	40MSS	50S	80S	188.8		;	2-	2	2-	3	33+	3+	3+	3+	3+	3+	3+	3+	32	32+	3+	33+	Allele X		Allele X	Allele X		Allele X	Allele Y		Allele Y	Negative		Negative	Allele X		Allele X
28	MT21352			40MRMS	45MSMR	51.35	0	0	0	10MSMR	40MSMR	80S	106.9	soft dough	30MS	50S	50S	80S	204		;	2-	2	2-	3	3+	3+	3+	3+	3+	3+	3+	3+	32+	2+3	33+	32+	Allele X		Allele X	Allele X		Allele X	Allele Y		Allele Y	Negative		Negative	Allele X		Allele X
29	MT21384			35MR	35MRMS	32.55	0	0	0	40S	60S	80S	180		30SMS	50S	50S	80S	207.9		2-;	2-C	2	2-	3-	3+	3+	3+	3+	3+	3+	3+	3+	33+	32+	32+	32+	Allele X		Allele X	Allele X		Allele X	Allele Y		Allele Y	Negative		Negative	Allele X		Allele X

Due to the off-season timing between the growing season in the United States and Kenya and Ethiopia, entries must be submitted very early in order to be tested for Ug99 in the field. Not all URSN entries were selected early enough for testing.
Data from a single rep were from a pool of over 50 entries submitted by each wheat breeder in advance before deciding on final entries into the URSN.