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MEMORANDUM

FROM: Arpit Gaur, Ronald Proctor, Ronald Ramsfield and Suchismita Mondal, Winter Wheat Breeders

DATE: January 24th, 2024

RE: Proposal for public cultivar release of MTS2068

Pedigree: MTS2068 = MTS0819//08x350-A6/Warhorse

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

Contributors:

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Mr. Doug Holen and Ms Brandee Johnston, MSU Foundation Seed, Bozeman, MT

Dr. Dale Clark and Mr. Trevor Schafer, Nutrien Ag Solutions, Bozeman, MT

Dr. Xianming Chen, USDA-ARS, Pullman, WA

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Selection history: MTS2068 is a semi-solid stem hard red winter wheat line developed from a threeway cross of MTS0819//08x350-A6/Warhorse. One of the parent varieties “Warhorse” is a popular solid stem variety grown in Montana, while MTS0819 a sister line of another solid stem winter wheat variety “Judee”. The first cross was done in 2010 and top cross in 2011, F1 and next generations were selected and advanced through the following steps:

- 2010 Cross conducted in greenhouse in 2010, 08x350-A6/Warhorse
- 2011 F1 is backcrossed to MTS0819 in greenhouse 2011
- 2012 BCF1 grown at Post research farm in Bozeman, MT
- 2013 F2 population grown at Ft Ellis, selected bulk
- 2014 F3 population grown at Ft Ellis and Loma, MT, selected bulk
- 2015 F4 population grown at Ft Ellis, MT, selected bulk
- 2016 F5 population grown at Ft Ellis, MT, selected bulk
- 2017 F6 population grown at Post Farm, MT, 120 heads selected
- 2018 Re-selection of headrows at Ft Ellis, MT.
- 2019 MTS2068 evaluated in Sawfly Observation Nursery
- 2020 MTS2068 tested in multi-location preliminary yield trial
- 2021 MTS2068 tested in multi-location advanced yield trial
- 2022 MTS2068 tested in multi-location Intrastate
- 2023 MTS2068 tested in multi-location Intrastate and Off-station yield trial

General performance and characteristic:

MTS2068 is an awned, semi-solid stemmed, medium-late maturing semi-dwarf hard red winter wheat. Days to heading for MTS2068 was 1 or 2 days later than check varieties Warhorse, Bobcat and Judee across years and locations of evaluations (Table1,2 &3). Plant height is similar to Warhorse and about an inch taller than Bobcat.

In 33 location-years of grain yield evaluations in the Advanced, Intrastate, Off-station yield trials conducted across location in Montana the average yield of MTS2068 has been around 10% or higher compared to Warhorse. In the advanced yield trial conducted in 2021, MTS2068 performed well across most locations, with significant yields than Warhorse in Havre and Ft. Benton. A similar trend was observed in the Intrastate and Off-station trials conducted in 2022 and 2023, with MTS2068 having grain yields higher than Bobcat and Warhorse in the wheat stem fly areas of Havre and

Conrad (Table 2 & 3). In multiple years of evaluation physiological leaf spot was not observed visually.

MTS2068 was selected under sawfly pressure across multiple years. Solidness scores of MTS2068 were on average 20.5, lower than Bobcat and Warhorse, however, sawfly cutting scores ranged between 4-9% which was similar to check varieties Warhorse and Bobcat and lower than MT WarCat.

Test weight of MTS2068 ranged between 58.4-60.6 (lb/bu) across trial years, which was similar to Warhorse or Bobcat (Table 1, 2 & 3). MTS 2068 has a high flour yield and average protein content. MTS2068 has strong dough mixing characteristics with high water absorption, and relatively long mixing time. MTS2068 has low PPO and expected to have good noodle quality (1 year available data waiting 2023 data).

MTS2068 was characterized for stripe rust resistance at Washington State University (Pullman, WA) and the USDA Cereal Disease Laboratory (St. Paul, MN). MTS2068 has very good stripe rust resistance in multiple years of evaluations. MTS2068 is highly susceptible to leaf rust and moderately susceptible to stem rust (2023 NRPN evaluations)

Purification/ Seed stock: Increase of MTS2068 was initiated in 2021 when 130 individual heads were collected from a phenotypically-uniform plot. Multiplication and purification plots were grown at Post Farm in 2022. Selected uniform rows were bulked and sown at Post Farm for Breeder's seed increase in 2023. Breeder seed of MTS2068 was planted in Fall 2023 for 2024 Foundation seed production.

Summary: MTS2068 is a high yielding, semi-solid stem line that has low cutting by wheat stem sawfly. MTS2068 has done particularly well in field testing sites at Ft Benton and Havre with average yields 10% or higher than Warhorse. In multiple years of testing, it has not shown the physiological leaf spot symptoms related to chloride deficiency in soils. It has excellent stripe rust resistance though susceptible to stem and leaf rust. MTS2068 combines high yield, test weight, low PPO with excellent stripe rust resistance and resistance to sawfly by low stem cutting.

Figure 1. Grain yield and agronomic performance of MTS2068 and check varieties in 2021 Advanced Yield Trial across seven locations in Montana.

Variety/Line	Grain Yield (bu/ac)							Across Locations					
	Bozeman	Havre	Williston	Moccasin	Huntley	Conrad	Ft Benton	Combined Yield (bu/ac)	Test Weight (lb/bu)	Heading date (Julian)	Plant Height (in)	Sawfly Cutting (%)	Protein (%)
Locations(n)								n=7	n=7	n=7	n=7	n=2	n=7
Yellowstone	71.2	37.8	25.3	35.5	67.3	56.0	48.6	52.1	57.6	168	30.4	38.3	13.6
Warhorse	60.2	30.8	27.4	27.4	55.3	48.4	43.1	43.4	58.2	168	28.9	10.2	14.3
SY Monument	71.9	35.5	28.0	30.3	61.1	52.4	50.4	49.8	57.0	165	28.6	39.2	13.3
Bobcat	66.6	42.1	26.3	32.8	54.2	63.8	43.8	47.9	58.3	169	27.3	8.9	14.2
MTS2068	69.3	34.8	29.5	29.6	62.1	43.7	51.8	49.5	58.4	170	28.0	9.2	13.5
Mean (n=36)	67.6	34.5	26.0	31.2	56.1	53.9	44.5	46.8	58.0	168.6	28.6	31.2	14.1
LSD (0.05)	6.96	4.45	ns	5.41	12.47	ns	7.17	4.57	1.0	1.5	1.8	23.1	0.5
C.V. (%)	5.9	7.4	9.1	9.8	12.7	21.6	9.9	7.8	1.6	0.6	5.6	36.4	3.2
Gen significance	<.0001	<.0001	0.4702	0.0323	0.0359	0.1408	<.0001	<.0001	<.0001	<.0001	<.0001	0.0002	<.0001

***BOLD** data values indicate significantly different

Figure 2. Grain yield (bu/ac) and agronomic performance of MTS2068 and check varieties in 2022 and 2023 Intrastate trials.

Varieties/lines	Grain Yield (2022-2023, bu/ac)								Across Locations (2022-2023)						
	Bozeman	Ft Benton	Havre	Huntley	Kalispell	Moccasin	Sidney	Williston	Grain Yield (bu/ac)	Days to Heading (Julian)	Plant Height (in)	Test Weight (lb/bu)	Protein (%)	Stem solidness (5-25)	Sawfly (%) Only 2022
Locations years (n)									n=15	n=15	n=15	n=15	n=15	n=4	n=2
Warhorse	117.0	47.2	40.2	72.5	127.9	45.5	76.4	37.4	71.4	166	32.6	57.5	13.2	21.7	5.3
Yellowstone	130.9	32.4	49.6	58.0	137.2	50.5	83.7	34.3	73.6	166	33.9	57.9	12.6	7.9	92.1
Judee	119.8	43.5	41.4	79.7	137.7	43	71.7	35.8	73.8	165	32.5	59.4	13.1	22.7	62.0
Loma	131.2	42.1	44.0	69.2	140.3	44.5	80.7	37.7	75.7	167	30.5	57.7	13.0	21.9	41.8
Bobcat	116.9	45.3	50.4	60.1	139.3	44.3	80.3	35.2	72.5	165	29.9	59.2	13.0	23.0	3.9
StandClear CLP	127.8	43.9	45.2	64.5	137.6	40.9	81.0	31.7	73.2	165	32.2	59.0	12.9	20.2	27.2
MT WarCat	126.1	48.5	44.5	75.7	136.3	41.6	80.9	35.2	75.4	168	30.0	58.2	12.9	22.1	11.9
MTS2068	128.7	51.7	48.2	76.4	142.4	39.8	81.3	42.6	76.8	167	32.1	58.6	12.8	20.1	7.1
Mean (n=49)	128.5	40.8	45.5	73.5	13.1	43.7	78.1	35.2	74.2	164.2	31.3	58.4	12.7	20.2	66.9
LSD (0.05)	15.20	17.30	7.30	27.70	26.30	14.14	9.70	8.07	4.28	0.69	2.61	1.07	0.34	1.82	19.05
CV (%)	5.6	26.7	9.8	8.5	11.7	16.7	8.2	14.0	13.7	0.9	17.8	4.3	5.9	9.62	14.7
Gen significance	0.00	0.25	0.02	0.15	0.18	0.12	0.00	0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

***BOLD** data values indicate significantly different statistically

Figure 3. Grain yield (bu/ac) and agronomic performance of MTS2068 and check varieties in 2023 Off-Station Yield Trial across nine locations in Montana

Variety/Line	Grain Yield (bu/ac), Individual locations									Across Locations			
	Loma	Loring	Huntley Irrigated	Hysham	Molt	Repelje	Flycreek	Ethridge	Valier	GrainYield (bu/ac)	TestWeight (lb/bu)	Sawfly(%)	Protein(%)
Locations										n=9	n=9	n=1	n=9
Yellowstone	84.6	57.4	106.2	64.1	82.9	90.7	108.3	62.9	99.9	82.1	59.6	50.8	12.4
Warhorse	73.6	42.2	117.8	45.9	95.9	88.7	104.4	53.2	96.5	77.7	60.1	3.8	13.4
Loma	85.8	61.4	111.4	60.3	108.9	91.7	98.2	83.9	114.4	87.7	60.8	33.3	12.9
Bobcat	74.8	55.6	123.9	66.9	90.8	85.8	103.5	57.2	98.9	82.3	60.7	3	12.9
StandClear CLP	80.7	45.7	119.2	55.2	97.7	86.4	106	53	109.8	80.5	61.2	33	13
MT WarCat	88	59.6	128.4	60	114.6	91.1	107.2	67.6	109.9	89.5	59.9	23.3	13.2
MTS2068	83.3	60.7	122.9	60.6	91.8	97.1	106.7	58.1	104.2	85.1	60.4	4.5	12.5
Mean (n=25)	80.1	48.5	118.7	58.3	96.4	89.5	104.7	63.7	103.9	82.5	60.4	32.1	12.8
LSD (0.05)	7.25	11.5	11.3	10.5	13.7	9.35	8.45	8.50	3.68	6.2	0.57	27.2	0.33
CV (%)	7.2	16.3	7.1	13.9	9.8	6.9	6.77	18.3	13.5	10.0	1.2	41.1	3.62
Gen. Significance	0.008	<0.001	<0.001	0.005	<0.001	<0.001	0.029	0.52	0.94	<0.001	<0.001	<0.001	<0.001

***BOLD** data values indicate significantly different statistically

Table 4. Quality analysis of MTS2068 and check varieties across three locations between 2022-2023.

Variety/Line	PPO	Single Kernel Hardness	Wheat protein, % (12 m.b.)	Flour Yield %	Flour Protein%(14% m.b)	Wheat Ash, %	Flour Ash, %	Mixograph			Test Bake		
								Tolerance	Mixing Time Min	Water Absorption%	Mixing Time Min	Water Absorption%	Loaf Volume
Yellowstone	0.237	72.06	13.7	69.0	12.4	1.61	0.46	3.83	8.18	64.8	14.6	75.3	1001
Warhorse	0.264	78.33	14.6	67.8	13.3	1.54	0.46	1.83	4.18	64.2	7.5	73.9	1075
StandClearCLP	0.264	68.16	13.8	70.3	12.6	1.51	0.42	3.50	4.68	63.0	9.8	73.4	1015
Bobcat	0.262	68.25	14.1	70.1	13.0	1.56	0.43	3.83	5.65	64.4	13.0	75.2	1073
MTWarCat	0.150	74.21	14.1	70.9	12.9	1.56	0.46	3.33	8.43	64.8	16.6	75.1	1088
MTS2068	0.118	70.19	13.6	70.4	12.6	1.50	0.45	3.17	7.58	66.0	17.2	76.2	1080
Grand Mean	0.206	71.86	13.9	69.9	12.7	1.53	0.45	3.33	6.96	64.8	13.9	75.2	1055
LSD	0.057	7.11	0.66	1.64	0.61	ns	0.028	0.97	3.94	ns	6.78	2.45	56.46
CV	16.4	6.9	3.1	1.0	3.4	8.1	3.0	24.5	44.7	3.5	29.6	2.9	3.9
Gen significance	<0.001	0.08	0.20	0.06	0.09	ns	0.01	0.04	0.06	ns	0.004	0.54	0.29

***BOLD** data values indicate significantly different statistically

Table5. Stripe rust infection type (It ^{a,b}) an severity (%) of MTS2068 and check varieties in 2022 and 2023 at Pullman, Mt Vernon and Central Ferry in Washington.

Varieties/Lines	2022								2023							
	Pullman		Mt. Vernon				Central Ferry		Pullman				Mt. Vernon			
	24-Jun		13-Apr		19-May		23-Jun		16-Jun		22-Jun		27-Apr		6-Jun	
	IT	%	IT	%	IT	%	IT	%	IT	%	IT	%	IT	%	IT	%
Yellowstone	2	15	2	5	2	20	5	30	5	10	3	20	3	30	2	10
Warhorse	2	10	2	5	2	10	2	5	5	15	2	5	5	50	2	10
Judee	3	30	2	10	2	20	2	5	3	15	2	10	7	70	3	10
Loma	2	15	8	20	2	20	2	5	3	10	2	10	7	60	3	10
Brawl CL Plus	8	100	8	40	8	60	5	60	7	40	8	80	8	70	5	30
Bobcat	3	15	5	10	2	10	2	5	3	5	2	5	2	20	2	10
StandClear CLP	2	15	2	5	2	10	2	5	2	5	3	20	2	20	3	30
MT WarCat	2	10	8	10	3	15	2	5	3	10	2	5	5	40	2	20
MTS2068	2	5	2	5	2	10	2	5	2	5	2	5	2	10	2	10

^aInfection Type (IT) was recorded based on the 0-9 scale with ITs 8 and 9 combined as 8 (the most susceptible reaction) in field. Generally, IT 0-3 are considered resistant, 4-6 intermediate and 7-9 susceptible

^bEntries with a high IT in the first note, but a low IT in the second note may indicate that they have high-temperature adult plant (HTAP) resistance