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MEMORANDUM

TO: Wheat Cultivar Release & Recommendation Committee

FROM: Phil Bruckner and Jim Berg, Winter wheat breeders

DATE: January 7, 2019

RE: Proposal for protected MAES public cultivar release of **MTS1588**

The following motion and supporting documentation is presented for consideration at the 2019 MAES Cultivar Release and Recommendation Meeting in Bozeman:

Motion: That MTS1588 hard red winter wheat be approved for release in 2019.

Pedigree: MTS1588 derives from 2007 crosses between two solid-stem MT experimental lines [98X366E29-1 & 01X258C1] and a hollow-stem MT experimental line, MT0598 [tested 2005 to 2007 in MT trials, #1 yielder in 2006 Advanced trial].

MTS1588	selection from a composite of 2 crosses: 07X291, ((SMN82164/SMN82140//Rocky/Tiber, MT9659)/3/S87-101/4/Pronghorn, <u>MT0598</u>)/5/(<u>98X366E29-1</u> , Heyne/Rampart/(MT9513, BigSky sib)) and 07X295, (((Lew/Tiber//Redwin ,MTS92021)/3/Judith/Arapahoe, MTS0023)/4/Pryor/ Genou, <u>01X258C1</u>)/5/ <u>MT0598</u>
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Recommendation: Protected MAES Public Release.

Name: to be determined

Selection history: Following the 2007 crosses, these are steps in development of MTS1588:

- 2008 gh Individual F1 populations grown in PGC and harvested in bulk. Populations composited.
- 2009FE Composite F2 space plant population grown. Bulk of heads from solid stem plants advanced.
- 2010 NHavre F3 population grown at north Havre site. Little selection, bulk harvest.
- 2011Havre F4 population grown at Havre. Mechanical height reduction & selection for solidness, bulk advanced.
- 2012 Havre F5 population grown at Havre. WSS cutting, ~ 75 heads selected.
- 2013Post F6 headrows grown, evaluated for uniformity, stem solidness, disease, agronomics. Line 07X291cE44 selected.
- 2014-Multi. Selection 07X291cE44 and cohorts grown in Single Rep Sawfly Observation trial at Bozeman, Fort Ellis, Conrad, and Loma. 07X291cE44 [subsequently designated MTS1588] was the highest yielding line of 29 solid stem lines selected and harvested at Bozeman [118 bu/a, 64.3

lb/bu].

- 2015-Multi MTS1588 (F8) tested in MSU Sawfly trial (2015 to 2018, 19 Location-years). Milling & baking quality evaluation initiated.
- 2016-Multi MTS1588 (F9) tested in the MSU Advanced trial (7 LY). M&P heads selected.
- 2017-Multi MTS1588 (F10) tested in the Montana Intrastate (7 LY) & Off-station (16 LY) trials.
- 2018-Multi MTS1588 tested in the Montana Intrastate (9 LY) & Off-station (13 LY) trials.
- 2018-region MTS1588 entered in the USDA Northern Regional Performance Nursery (NRPN) and Wheat Quality Council (WQC) evaluations.

Purification/seed stocks: Purification and increase of MTS1588 was initiated in 2017 when 130 F9:10 headrows were evaluated for phenotypic uniformity & stem solidness. 119 linerows were bulked as Breeder seed and increased at Bozeman in 2018. Breeder seed of MTS1588 was planted fall 2018 for 2019 Foundation seed production [20+ acres Bozeman Post Farm & Lutz Farm]. MTS1588 has been genetically uniform and stable over two generations of seed increase with few visually obvious plant variants.

Table 1. Agronomic characteristics of MTS1588 vs. a set of varieties, 2015-2018^{1/}

Variety	Test weight	Winter survival	Heading date		Plant height	Protein	Stem solidness	Saw fly cutting	Stripe rust	Coleoptile length
	lb/bu	%	day of year	Calendar	in	%	5-25	%	%	in
location-years	63	1	26		62	65	29	17	5	1
Decade	60.4	69	158	7-Jun	29.8	12.8	7.5	37	52	2.9
Loma	60.1	46	161	10-Jun	28.1	12.6	19.8	25	6	2.8
Judee	61.3	49	158	7-Jun	29.8	13.0	20.1	29	6	3.7
Warhorse	60.4	52	160	9-Jun	29.2	13.2	21.7	6	4	3.2
MTS1588	61.1	52	160	9-Jun	27.6	12.6	22.9	6	6	2.9
LSD (0.05)	0.3	12	0.5		0.4	0.2	0.8	9	15	0.2

1/ = includes 2017-2018 Intrastate and 2017-2018 Off Station, and 2015-2018 Sawfly tests

bold = indicates highest (or most desirable) value within a column

Description: MTS1588 is an awned, white-glumed, solid-stemmed, semi-dwarf hard red winter wheat. MTS1588 has medium-late maturity, 160 d heading from 1 January, 2d later than Judee, the same as Warhorse, and 1d earlier than Loma (Table 1). MTS1588 is semi-dwarf (*Rht B1b*) and short (27.6 inches, n=62), significantly shorter than Loma, Warhorse, Judee, and Decade (Table 1). MTS1588 is resistant to prevalent races of stripe rust, has excellent stem solidness, and is very resistant to cutting by wheat stem sawfly. Grain protein of MTS1588 is similar to Loma and Decade, and lower than Judee and Warhorse.

Characteristics/comparisons:

Yield. In 65 location-years (LY) of testing in the Montana Winter Wheat Intrastate, Off-station, and Sawfly nurseries average yield of MTS1588 (67.9 bu/a) was similar to the yield of Loma and 4 to 5 bu/acre higher than Warhorse, Judee, and Decade (Table 2). MTS1588 is competitive with other solid stem cultivars for yield in all Districts (Table 2), but most importantly in the Havre and Conrad areas where wheat stem sawfly (WSS) is the biggest issue and yield of MTS1588 is more than 10% higher than that of Warhorse and Judee.

Yield in infested environments. Table 3 shows direct comparison of MTS1588 to a wider set of cultivars in a set of 8 environments that were heavily infested by wheat stem sawfly (average cutting by WSS>10%). In these WSS-infested environments, MTS1588 is the superior yielder and has the lowest cutting incidence by sawfly (Table 3). Warhorse, the only other cultivar providing adequate protection against WSS in these environments was not competitive for yield. Hollow stem cultivars with high yield potential were cut heavily

by WSS and generally showed reduced, non-competitive yields in these environments. These data prompted Jim Berg to state that Table 3 alone is justification for release of this line.

Table 2. Yield of MTS1588 vs. a set of varieties, 2015-2018^{1/}

Variety	Districts							All Locations
	1 Kalispell	2 Bozeman	3 Huntley ^{2/}	4 Moccasin ^{3/}	5 Conrad ^{4/}	5 Have ^{5/}	6- Sidney & Williston	
location-years	1	6	14	11	12	18	3	65
MTS1588	94.1	100.0	73.5	56.6	69.7	60.3	49.7	67.9
Loma	87.6	102.7	73.3	58.4	68.6	54.6	51.7	66.7
Warhorse	92.0	93.4	74.3	57.2	60.2	53.8	49.0	64.0
Judee	94.5	93.2	70.3	57.6	63.6	53.3	41.4	63.4
Decade	48.4	78.2	73.9	60.5	61.0	53.5	56.1	62.2
LSD (0.05)	19.2	12.1	ns	ns	3.1	3.4	ns	2.4

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)

1/ = includes 2017-2018 Intrastate and 2017-2018 Off Station, and 2015-2018 Saw fly tests

2/ includes data from Fort Smith, Hardin area, Hysham Molt, Rapelje

3/ includes data from Belt, Denton, Geraldine, Highway

4/ includes data from Choteau, Cut Bank, The Knees, Shelby

5/ includes data from Big Sandy, Gildford, Loma, Turner

Table 3. MTS1588: Yield Performance under Sawfly Pressure (test average cutting ≥10%) and % Sawfly Cutting (2017-2018)

Variety	Yield bu/a	Sawfly Cutting (%)
location-years	8	8
MTS1588	60.0	6
Loma	56.9	32
Brawl CLP	56.4	35
SY Monument	56.4	53
Northern	55.3	51
Yellowstone	55.0	57
Keldin	54.8	53
SY Clearstone 2CL	54.7	61
FourOsix	53.6	58
Judee	53.2	40
MTW1491	53.0	61
MT1265	52.9	58
SY Wolf	52.8	39
Decade	52.4	45
Ray	52.2	53
Warhorse	51.3	7
MTF1435	50.1	49
LSD (0.05)	4.4	15

Stem solidness. Stem solidness of MTS1588 over years and locations is significantly greater than Warhorse, Judee and Loma (Table 4).

Test weight. Test weight of MTS1588 (61.1 lb/bu, n=63) is similar to Judee and higher than Warhorse and Loma (Table 1).

Table 4. Stem solidness ratings of MTS1588 compared to other solid-stemmed varieties, (2015-2018)

	Stem Solidness Rating (scale 5-25, higher = more solid)					Stem Solidness by location, 2015-2018				
	2018	2017	2016	2015	2015-18	Billings	Bozeman	Conrad	Havre ^{1/}	Moccasin
location-years	9	11	6	3	29	2	6	4	14	3
Judee	22.3	18.4	20.0	19.4	20.1	22.0	17.4	21.5	20.2	21.7
Loma	22.5	19.3	17.9	17.3	19.8	22.8	16.7	20.1	20.7	19.8
MTS1588	23.8	22.8	22.3	22.0	22.9	23.0	22.6	23.0	23.1	22.5
Warhorse	22.5	21.1	21.4	21.9	21.7	22.6	20.5	21.8	22.0	22.2
LSD (0.05)	ns	1.3	2.0	ns	0.8	ns	2.3	ns	1.1	ns

bold = indicates highest value within a column

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

1/ includes Carter, Gildford, and Loma

Milling and baking quality. Based on experimental milling using a Brabender Automat Mill, flour yield of MTS1588 is relatively high with low flour ash content and intermediate flour protein (Table 5). MTS1588 has strong dough mixing characteristics with high water absorption, and relatively long mixing time. Baking qualities of MTS1588 are acceptable with intermediate loaf volume similar to Decade (Table 5).

Table 5. Mill and bake characteristics of MTS1588 vs. a set of varieties, 2015-2017

Variety	PPO ^{1/}	Kernel hardness	Flour			Mixograph			Baking		
			yield	protein	Ash	tolerance	mix time	absorption	mix time	absorption	volume
			%	%	%	(1-6)	min	%	min	%	cc
location-years	12	12	12	12	12	12	12	12	12	12	12
Judee	0.267	78.4	69.8	12.7	0.40	3.4	6.1	65.4	9.9	75.2	1161
Loma	0.167	79.1	71.4	12.3	0.40	3.1	7.6	67.7	16.3	78.3	1119
Warhorse	0.265	87.5	69.2	12.8	0.43	2.4	5.1	67.0	8.8	77.0	1117
MTS1588	0.300	69.2	71.2	12.7	0.40	3.2	7.1	68.5	17.1	78.6	1072
Decade	0.284	75.2	69.5	12.1	0.41	3.3	9.8	68.9	21.3	78.9	1068
LSD (0.05)	0.045	3.0	0.8	ns	0.01	0.6	1.1	2.1	2.5	2.0	48

bold = indicates highest value within a column

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

Disease and insect resistance. Characterization of MTS1588 for disease and insect resistance included Montana trials and cooperative evaluations at Washington State University (Pullman, WA) and the USDA Cereal Disease Laboratory (St. Paul, MN). MTS1588 has high stem solidness and high resistance to cutting by wheat stem sawfly (Tables 1, 3, & 4). In seedling evaluations at the USDA-ARS Cereal Disease Lab in 2016 and 2018 (NRPN), MTS1588 was resistant to some *Pgt* races from the United States, including QCCSM, QFCSC, MCCFC, and TPMKC, but susceptible to QTHJC, RKQQC, RKRQC, RCRSC, and TTTTF. Based on 2018 NRPN evaluation, MTS1588 is susceptible to leaf rust.

MT1588 is resistant to stripe rust based on Montana evaluations (Table 1). In addition, MTS1588 wheat was tested for reactions to natural infections of *Puccinia striiformis* f. sp. *tritici* in Pullman and Mount Vernon, WA from 2015 to 2017 and also at two more locations in Walla Walla and Lind, WA in the NRPN trial in 2018. Across locations and over years, MTS1588 had a highly resistant reaction with infection type (IT) 2 to moderate resistant reaction (IT 5) with severity 5-40%, receiving a field summary rating in 2018 of Resistant (Table 6). 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), MTS1588 was moderately resistant (IT 5) to PST races PSTv-4 and PSTv-40 and susceptible to four other races (Table 7). When tested at the high temperature cycle (10-30°C) at adult-plant stage (Zadoks 45-60), MTS1588 was resistant (IT 2, 3) to races PSTv-14, PSTv-37, and PSTv-40 (Table 8). 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 possibly have high temperature adult-plant (HTAP) resistance.

TABLE 6. STRIPE RUST INFECTION TYPE (IT^a) 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 2018b
Planting 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 ^c		LOC 06		LOC 07		Field Summary ^d	Overall rating ^e	Possible HTAP resistance ^f		
				Fks 10.53	IT %	Fks 6	IT %	Fks 11.1	IT %	Fks 10.54	IT %				Fks 11.2	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
Check	PS279 (S. Check)	CHECK	21	8	100	8	60	8	100	8	80	8	100	S	9	No
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
Check	PS279 (S. Check)	CHECK	41	8	100	8	40	8	100	8	90	8	100	S	9	No
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
Check	PS279 (S. Check)	CHECK	61	8	100	8	60	8	100	8	90	8	100	S	9	No
Check	PS279 (S. Check)	CHECK	81	8	100	8	60	8	100	8	70	8	100	S	9	No
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
END	Barley (fill)	END	100	-	-	-	-	-	-	-	-	-	-			

^a 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.

^b All locations were under natural infection.

^c 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.

^d R = resistant, MR = moderately resistant, MS = moderately susceptible, and S = susceptible.

^e 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.

^f 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 7. 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 ^a										Possible HTAP ^c resistance
				Seedling Tests ^b (4-20°C)						Adult-plant Tests ^b (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	8	3,3,3	4,3,4	3,3,3	Moderate
2	Overland	HRW	2	8	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	8	6,6,6	6,6,6	5,5,6	Low
4	Jagalene	HRW	4	8	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	8,8,8	No
CHK	Ps279 (S. Check)	CHK	21	8	8	8	8	8	8	8	8,8,8	8,8,8	8,8,8	No
35	MT1547	HRW	36	2	8	8	2	2,5	8	8	2,2,2	2,2,2	2,2,2	High
36	MT1563	HRW	37	2,8	2	5	5	2,5(1)	8	8	2,2,2	3,3,3	3,3,3	High
37	MT1564	HRW	38	2	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	8	3,3,3	3,3,3	2,2,2	High
CHK	Ps279 (S. Check)	CHK	41	8	8	8	8	8	8	8	8,8,8	8,8,8	8,8,8	No
1	Kharkof	HRW	48	8	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	8	6,6,6	5,5,5	3,3,4	Low
CHK	Ps279 (S. Check)	CHK	81	8	8	8	8	8	8	8	8,8,8	8,8,8	8,8,8	No
49	Scout 66	HRW	98	8	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	8	3,5,5	8,8,8	3,3,4	Low
END	Barley (fill)	END	100	-	-	-	-	-	-	-	-	-	-	

^a 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

^b 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.

^c 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.

MTS1588 is a high-yielding, solid-stem, semi-dwarf cultivar with excellent resistance to cutting by wheat stem sawfly. At Conrad and Havre field testing sites where wheat stem sawfly is a problem, grain yield of MTS1588 is more than 10% higher than the current, predominant solid stem cultivars Judee and Warhorse. MTS1588 combines high yield potential, acceptable test weight, grain protein content, and milling and baking quality with excellent stripe rust resistance, high stem solidness, and superior resistance to cutting by wheat stem sawfly.