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MEMORANDUM

TO: Wheat Cultivar Release & Recommendation Committee

FROM: Phil Bruckner and Jim Berg, Winter wheat breeders

DATE: January 28, 2016

RE: Proposal for protected MAES public (F.2.b) cultivar release of **MTS1224**

The following motion and supporting documentation is presented for consideration at the 2016 MAES Cultivar Release and Recommendation Meeting in Bozeman:

Motion: That MTS1224 hard red winter wheat be approved for release in 2016, that MTS1224 be named 'x,' and that x be recommended for all cropping districts.

Pedigree: MTS1224 derives from the cross: Yellowstone//MTS0112/MTS0125. Experimental line MTS0112 has the pedigree Lew/Tiber//Redwin/3/2*Erhardt; MTS0125 is an experimental line with high stem solidness derived from a composite of 4 crosses all made between Lew/Tiber//Redwin derivatives and Idaho germplasm.

Recommendation: Protected MAES Public Release (F.2.b).

Name: Name to be determined.

Selection history: MTS1224 derives from the 2003 cross: Yellowstone//MTS0112/MTS0125 as described above. The F₁ population was grown at Bozeman in 2004 and the F₂ population at Fort Ellis in 2005. The F₃, F₄, and F₅ bulk populations were grown at a selection nursery north of Havre from 2006 to 2008. Segregating populations were advanced using a modified bulk breeding method, with mass selection for stem solidness, survival, reduced plant height, favorable head morphology, disease resistance, and kernel plumpness. Sixty-two heads which were selected from the F₅ population in 2008 were grown as F₆ headrows at Bozeman in 2009. Headrow 03X137E41 and eight other population cohorts were selected based on visual criteria for uniformity, stem solidness, stripe rust resistance, productivity, and acceptable agronomic type, and heads harvested for a 2nd round of headrow selection. F₇ headrows were evaluated in 2010 and headrow 03X137E41-3 was selected and harvested in bulk. 03X137E41-3 was subsequently tested and selected from the 2011 Sawfly Observation Nursery (SFO) grown at Bozeman, Havre, and Fort Ellis. In 2012, 03X137E41-3 was designated MTS1224 and subsequently tested in in the Sawfly yield trial (15 LY) from 2012-2015, in the Advanced trial planted in 2013 (6 LY), in the Montana Intrastate trial from 2014 to 2015 (12 LY), and in the Off-station nursery planted in 2015 (15 LY). Quality has been evaluated in multi-location Montana trials since 2012. For 2016, MTS1224 is an entry in the USDA Northern Regional Performance Nursery (NRPN) planted at approximately 20 sites across the Northern Great Plains.

Purification/seed stocks: Purification and increase of MTS1224 was initiated in 2014 when 120 F₆-derived F₁₀ headrows were grown at Bozeman with selection for stem solidness and visual uniformity, retaining 83 linerows. Individual linerows were bulked as breeder seed and increased at Bozeman in 2015. Breeder seed of MTS1224 was planted fall 2015 for 2016 Foundation seed production [5 acres Bozeman Post Farm; 10 acres Moccasin]. MTS1224 has been genetically uniform and stable over two generations of seed increase with few visually obvious plant variants.

Description: MTS1224 is an awned, white-glumed, semi-solid stemmed, semi-dwarf hard red winter wheat. MTS1224 has medium-late maturity, 164 d heading from 1 January, slightly later than currently deployed Montana cultivars (Table 1). MTS1224 is semi-dwarf (*Rht* allele unknown) and short (29.8 inches, n=42), most similar to ‘CDC Falcon’ and ‘SY Wolf’ (data not shown) and ‘Bearpaw’ (Table 1). Winter hardiness of MTS1224 needs further evaluation but appears to be superior to that of ‘Judee’ and ‘Rampart’ (Table 1). MTS1224 is resistant to prevalent races of stem rust, including UG99, and stripe rust, but susceptible to leaf rust. Preliminary evaluation indicates MTS1224 may be resistant to *Cephalosporium* stripe.

Table 1. Agronomic characteristics of MTS1224 vs. a set of recommended varieties, 2012-2015^{1/}

Variety	Test weight lb/bu	Winter survival %	Heading date		Plant height in	Lodging %	Protein %	Saw fly cutting %	Stripe rust %
			Julian	Calendar					
location-years	42	2	29		42	4	42	7	4
Bearpaw	58.8	84*	161.2	10-Jun	30.6	37	12.9	10*	39
Decade	59.0	86*	160.6	10-Jun	31.7	12	13.0	21	46
Genou	59.1	88*	162.0	11-Jun	34.6	27	13.2	8*	40
Judee	59.5**	40	161.4	10-Jun	31.0	21	13.2	8*	5*
MTS1224	58.9	89*	163.9	13-Jun	29.8	17	12.7	11*	5*
Rampart	59.2*	69	162.2	11-Jun	34.5	20	13.7**	4*	19*
Warhorse	59.0	79*	162.6	12-Jun	31.2	15	13.1	2*	3**
WB-Quake	59.0	80*	163.4	12-Jun	31.4	17	12.8	6*	10*
Yellowstone	58.9	94**	162.6	12-Jun	33.4	11	12.5	21	10*
LSD (0.05)	0.4	17	0.5		0.5	ns	0.3	13	23

^{1/} = includes 2012-14 Saw fly , 2010-14 Intrastate and 2011-14 Off Station tests

** = 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)

Table 2. Yield of MTS1224 vs. a set of recommended varieties, 2012-2015^{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	2	6	6	11	4	11	2	42
Yellowstone	140.5	89.5**	69.8**	56.8**	82.9**	54.6	57.1**	69.2**
MTS1224	142.3	89.2*	66.1*	53.7*	79.3*	53.0	48.1*	66.8*
Decade	91.2	74.1	64.3*	53.6*	76.9*	54.1	48.0*	61.9
Warhorse	130.9	80.8*	63.8*	48.7	63.2	50.5	38.6	60.7
Bearpaw	100.1	73.5	65.7*	49.6	71.6	51.9	41.7	60.0
Judee	130.9	78.0	61.5	44.1	68.3	52.8	29.6	59.5
WB-Quake	125.1	80.1	59.3	46.7	63.5	51.0	43.0	59.5
Rampart	113.5	74.1	56.4	39.9	63.2	49.6	35.3	55.2
Genou	92.2	66.3	55.7	41.6	71.8	50.7	47.6*	55.1
LSD (0.05)	ns	9.2	5.3	4.1	8.3	ns	9.0	3.1

** = 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)

^{1/} = includes 2012-15 Saw fly , 2014-15 Intrastate and 2015 Off Station tests

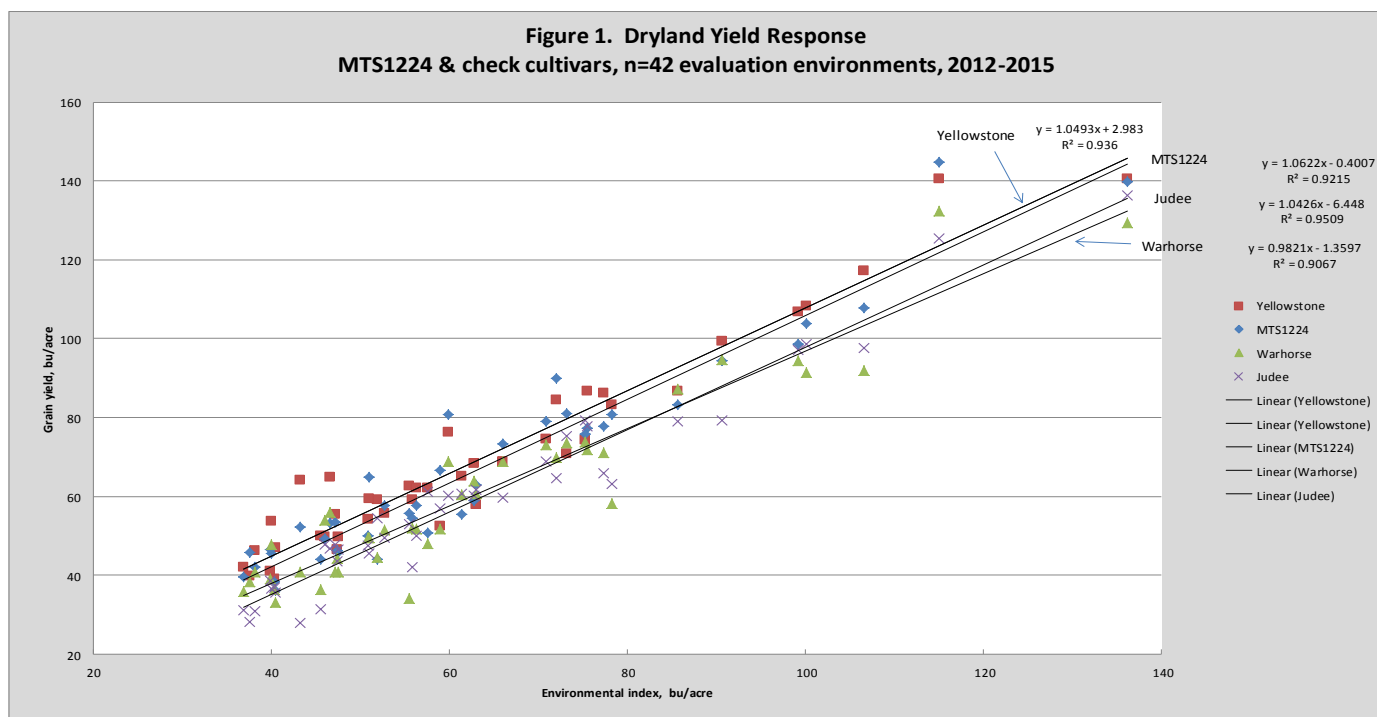
^{2/} includes data from Hardin area, Hysham, Molt, Rapelje

^{3/} includes data from Belt, Denton, Geraldine, Winifred

^{5/} includes data from Choteau, Cut Bank, The Knees, Shelby

^{6/} includes data from Loma, Turner

Figure 1. Dryland Yield Response
MTS1224 & check cultivars, n=42 evaluation environments, 2012-2015



Characteristics/comparisons:

Yield. In 42 location-years (LY) of testing in the Montana Winter Wheat Intrastate, Off-station, and Sawfly nurseries average yield of MTS1224 (69.2 bu/a) was similar to the yield of ‘Yellowstone’ and higher than that of all other tested cultivars (Table 2). Yield superiority over deployed solid-stem cultivars exceeds 10% across environments. MTS1224 is competitive for yield in all Districts (Table 2). Analyses by regression shows MTS1224 and Yellowstone have a similar yield response across changing dryland environments (Fig. 1).

Test weight. Test weight of MTS1224 (58.9 lb/bu, n=42) is lower than that of Judee and similar to the remaining check cultivars (Table 1).

Grain protein content of MTS1224 is medium high, lower than that of Rampart, ‘Genou’, Judee, and ‘Warhorse’ (Table 1).

Disease and insect resistance. Characterization of MTS1224 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). MTS1224 has intermediate stem solidness (19.1, n=23), similar to that of Genou and Judee, but less than the stem solidness of Rampart, Bearpaw, and Warhorse (Table 3). As expected based on stem solidness, cutting of MTS1224 by wheat stem sawfly is intermediate to that of hollow-stem checks and the most solid solid-stem check cultivars (Tables 1 and 4). MTS1224 is resistant to stem rust based on field and seedling evaluations conducted at Bozeman, MT using race TLMKD and seedling stem rust evaluations conducted by the USDA Cereal Disease Lab in 2013. In seedling evaluations at St. Paul, MN, MTS1224 was moderately resistant or resistant to all tested stem rust races, including Ug-99 and its derivatives and is postulated to carry *Sr36* + unknown gene(s) (Table 5). Field adult-plant evaluations in 2013 at St. Paul, MN indicated MTS1224 was resistant to a bulk of prevalent North American stem rust races including MCCFC, QFCSC, QTHJC, RCRSC, RKQQC, and TPMKC. MTS1224 is resistant to stripe rust based on field observations in Montana (Table 1) and screening at Pullman and Mount Vernon, WA over multiple years. Based on one trial in Washington, MTS1224 may have excellent resistance to Cephalosporium Stripe (Table 6).

Table 3. Stem solidness ratings of MTS1224 compared to other solid-stemmed varieties, (2012-2015)

	Stem Solidness Rating (scale 5-25, higher = more solid)					Stem Solidness by location, 2012-2015				
	2015	2014	2013	2012	2012-15	Bozeman	Conrad	Havre	Loma	Moccasin
location-years	7	8	4	4	23	6	2	6	3	6
Bearpaw	19.9	21.5*	22.2	20.4*	20.9*	18.9*	22.0*	22.2	21.3	21.2*
Genou	15.5	19.6	20.5	17.5	18.1	13.9	19.1	20.0	19.9	19.3
Judee	19.3	20.8	21.1	17.9	19.9	17.9*	21.5*	21.0	20.0	20.2
MTS1224	17.2	21.1*	20.1	17.3	19.1	16.8	19.6	21.8	19.2	18.5
Rampart	18.7	21.4*	22.0	20.4**	20.5	16.8	22.0*	22.6	21.0	21.5*
Warhorse	22.0**	22.1**	21.4	19.3*	21.4**	20.0**	23.1**	22.0	20.9	22.1**
WBQuake	19.2	21.0	20.5	17.5	19.7	16.5	21.4*	21.4	20.3	20.5
LSD (0.05)	1.8	1.1	ns	1.6	0.9	2.2	2.3	ns	ns	1.2

** = indicates highest yielding variety w ithin a column

* = indicates varieties yielding equal to highest yielding variety w ithin a column based on Fisher's protected LSD (p=0.05)

Table 4. MTS1224: Yield Performance under Sawfly Pressure (test average cutting >10%) and % Sawfly Cutting (2012-2015): Loma

Variety	Yield bu/a	Sawfly Cutting (%)
location-years	3	3
Decade	54.3**	39
MTS1224	54.1*	22
WB-Quake	52.7*	8
Bearpaw	51.4*	20
Warhorse	49.9*	3
Yellowstone	49.5*	39
Judee	49.3*	15
Rampart	45.7*	7
Genou	43.8	14
LSD (0.05)	9.4	ns

Table 5. Seedling stem rust evaluation of MTS1224 by the USDA Cereal Disease Laboratory in 2013.

CDL			QFCSC	QTHJC	MCCFC	RRCSC	RKQCC	TPMKC	TTTTF	SCCSC	QCCSM	TKSK	TKSK	TKST	TTTSK	TRTTF	NOTES 1	NOTES 2
			06ND76C	75ND717C	59KS19	77ND82A	99KS76A-1	74MN1409	01MN84A-1:2	09ID73-2	75WA165-2A	04KEN156/04	04KEN156/04	06KEN19V3	07KEN24-4	06YEM34-1		Gene postulation
12/13#	Nursery	Line																
805	Local ck 1	McNair 701	4	4			4	4	4		4	4						
806	Local ck 2	Red Chief	2+3	2+3			2+3	4	4		2+3	2+3	2+3	2+3	2+3	4		
807	MT 1	Genou	4	4			4	4	3-3		4	4	3+	3	3	3+		
808	MT 2	Yellowstone	4/2	4			4	4/2	4		2	4	3+	3+	3+	3+		
809	MT 3	Jagalene	1-;	;			:1-/-/4	2/;	2		:1/13-;	2-	2-	3	2-	2-		Sr24
810	MT 4	Decade	;	2			2	;	2		:1-	2-	2-	3	2	2-		Sr24
811	MT 5	Judee	4	4/2			4/2	4/2	4/2		4/2-	4						
820	MT 14	MTS1224	0;	0			2-LIF	2	2		0;	:2-?	;	;	2-	2-		Sr36+

Table 6.

Cephalosporium Stripe Disease Index, Yield, and Test Weight of Winter Wheat Varieties and Breeding Lines, 2014-15 Palouse Conservation Field Station

Dr. Tim Murray and Zachary Sexton, Washington State University

Variety	Disease Index	Yield, bu/acre	Test wt, lbs/bu	Variety	Disease Index	Yield, bu/acre	Test wt, lbs/bu
Eltan	21.0	100.3	54.9	ARS010263-10-3C	56.7	106.0	55.3
MDM	23.3	94.1	55.7	WA8232	58.0	97.8	53.7
4J071366-1	36.2	125.4	55.8	MT1257	58.9	92.9	54.8
UIS Silver	36.5	102.5	59.8	OR2090473	59.1	97.8	52.3
MTS1224	36.6	104.8	57.6	DAS004	60.1	82.6	50.4
UIS RG	37.3	94.0	57.0	OR2100081H	61.7	86.1	56.1
WA8169	40.2	120.2	53.5	ARS20060123-31C	62.3	96.5	57.4
IDO1101	41.5	112.0	58.9	IDO1005	62.6	73.7	54.1
MT1078	42.4	109.7	57.6	WA8177	63.6	90.5	55.5
Bruehl	42.4	105.1	55.2	Madsen	63.9	86.1	54.2
SY71-4	42.5	123.2	55.5	MT1265	64.0	88.7	55.1
Bauermeister	43.6	87.6	57.0	OR2100940	65.6	96.0	52.9
IDO1108DH	45.1	107.9	53.5	OR2080637	65.6	64.3	50.6
IDO1209DH	46.0	107.6	59.8	WA8233	67.5	105.7	52.8
MTCS1204	48.1	68.1	57.0	OR2080641	67.5	89.0	51.7
WA8212	49.7	94.1	53.4	WA8234	68.7	82.2	52.0
OR2101043	52.9	97.0	53.3	SY62-21	69.3	85.8	56.2
WA8187	52.9	100.8	54.7	WA8206	69.6	78.3	52.9
Brundage 96	53.0	97.4	54.3	SY96-2	71.7	90.1	56.6
SY13#38	53.2	106.7	58.0	Stephens	77.7	61.4	48.2
MT1286	53.6	83.0	55.9				
ARS010669-2C	53.9	92.9	56.5	Mean	53.5	94.9	55.0
ARS06135-9C	54.0	98.6	58.3	LSD 0.05	18.7	15.5	2.9
ARS20060126-35C	54.4	92.8	56.4	P>F	<0.0001	<0.0001	<0.0001
DAS003	55.3	91.2	52.7	CV	25.0	10.1	3.3

This experiment was planted on 11 Sept. 2014 and inoculated on 8 Nov. 2014 by spreading *Cephalosporium gramineum* infested oats evenly over the field site.

Plants were evaluated for disease incidence and severity on 18-23 June 2015 by visually rating plants for disease symptoms. Disease index combines incidence and severity into a single rating ranging from 0-100, where 0=all healthy plants and 100=all plants with dead, "white" heads.

Experiment was harvested on 23 July 2015.

Yield was negatively correlated with Disease Index ($R = -0.296$, $P = 0.0005$).

Test wt. was negatively correlated with Disease Index, but not significantly ($R = -0.136$, $P = 0.116$).

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Table 7. Mill and bake characteristics of MTS1224 vs. recommended varieties, 2012-2014:

Combined Sawfly Tests (2012-2014) and 2014 Intrastate Test											
Variety	PPO ^{1/}	Kernel hardness	Flour			Mixograph			Baking		
			yield %	protein %	Ash %	tolerance (1-6)	mix time min	absorption %	mix time min	absorption %	volume cc
location-years	13	13	13	13	13	13	13	13	13	13	13
Bearpaw	0.230	82.3	69.7	12.4	0.41	2.9	4.3	62.2	7.0	72.3	1066
Decade	0.272	77.0	68.8	12.5	0.40**	4.8**	8.3	66.0**	19.0	76.5**	1120
Genou	0.296	79.3	70.1*	12.5	0.40*	3.8	5.4	64.6	13.2	74.6	1143
Judee	0.254	80.2	68.7	12.6	0.41*	4.2	5.6	63.2	9.5	73.2	1200**
MTS1224	0.161**	82.1	70.5**	12.2	0.41*	4.4*	6.4	64.8	16.1	75.2*	1188*
Warhorse	0.258	91.5	68.5	12.5	0.43	3.2	4.9	63.1	7.5	73.6	1118
Yellowstone	0.189*	81.5	69.7	12.0	0.42	4.8*	8.4	64.1	15.4	74.6	1117
LSD (0.05)	0.029	2.5	0.6	ns	0.01	0.6	0.9	1.3	2.0	1.3	33

** = 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)

^{1/} low is best for noodles

Milling and baking quality. Based on experimental milling using a Brabender Automat Mill, flour yield of MTS1224 is relatively high with intermediate flour ash content and flour protein (Table 7). MTS1224 has strong dough mixing characteristics with high water absorption, and relatively long mixing time. Baking qualities of MTS1224 are acceptable with good loaf volume similar to Judee and superior to remaining check cultivars (Table 7). MTS1224 has relatively low polyphenol oxidase (PPO) activity but not exceptional Asian noodle brightness (L24) or color stability (data not shown).

MTS1224 is proposed as a supplement to the current high-yielding, semi-dwarf, stripe rust-resistant, solid-stem cultivar set that includes Bearpaw, Judee, and Warhorse, adding diversity to the cultivars available for production in Montana and with potential to replace Judee on major acreage. MTS1224 combines high yield potential, acceptable test weight, grain protein content, and milling and baking quality with stem and stripe rust resistance, Cephalosporium stripe resistance, reduced plant height, and intermediate stem solidness.

2015 Winter Wheat Quality Drill Strips, Northern Agricultural Research Center								
Entry	ID	Yield*	Test Weight	Moisture	Protein	Head Date	Plant Ht	Sawfly
		bu/ac	lb/bu	%	%	day	in	% cut
1	Yellowstone	52.3	60.9	11.0	13.4	6/2/15	31.8	9.3
2	Jagalene	44.4	62.2	11.3	14.2	5/29/15	28.1	10.8
3	MTS0826-63	47.1	60.1	10.7	13.9	6/7/15	28.3	0.7
4	MTS1224	52.1	60.3	11.6	13.8	6/6/15	25.7	1.0
5	MT1265	46.8	61.2	11.2	13.0	6/4/15	30.4	8.7
6	MT1286	47.3	61.2	11.1	12.8	6/3/15	30.5	12.8
*Yield adjusted to 12% moisture.				plot size~ 18 rows x 132 feet, 2376 ft ²				
Seeded September 22, 2014								
Harvested July 21, 2015								