



**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:** Licensed release of MTCS1601 Clearfield hard red winter wheat (cross ID 07X349D10-1)

**Pedigree:** MTCS1601 resulted from a 2007 cross of MTS0531 [HW winter experimental line with intermediate stem solidness] to a BC5F1 (equivalent) herbicide-resistant plant selected in the 2007 gh from Clearfield population 06X435 (segregating for two *als* genes conveying tolerance to imidazolinone herbicides) after application of an 18oz/acre rate of Beyond herbicide + UAN +NIS by Ed Davis.

The expanded pedigree for MTCS1601 is  
**MTS0531/7/MTS0532/6/96X17E69/3/MTCL0309/CDC Teal 11A//MTW01143/4/MTCL0510/5/MTS0531**

Herbicide resistant trait donors for this population are MTCL0309 (*als1*) and CDC Teal 11A (*als2*). The intent of this cross was a solid-stem line with 2 gene herbicide resistance.

**Recommendation:** Licensed release. [Rationale: contains patented traits]      **Name:** To be determined

**Selection history:** Following the 2007 cross, these are steps in development of MTCS1601:

2008BZ      F1 populations grown in field and harvested in bulk.

2009FE      All Fort Ellis Clearfield breeding nurseries from 2009 to 2018 were sprayed with Beyond herbicide at a 2X rate (12 oz./acre) + 1% MSO and 1.5% v/v UAN in the spring prior to jointing. Phenotypic selection against herbicide susceptibility was applied in each year. F2 population grown, harvested in bulk. After seed sieving, plump seed fraction advanced.

2010Post      F3 populations grown, herbicide screened, bulk advanced.

2011W      F4 bulk population grown at Williston, heads from surviving plants harvested in bulk after mechanical height reduction.

2012FE      F5 bulk population grown at Ft.Ellis, ~110 heads selected.

2013FE      F6 headrow at Ft.Ellis, phenotypic selection for stem solidness, disease and herbicide resistance, agronomics. 07X349D10 selected, four heads collected, plot harvested in bulk.

2014FE      F7 headrow reselection families grown at Ft.Ellis. 07X349D10-1 solid stem headrow selected and harvested.

2015-Multi      F8 solid-stem, herbicide-resistant selections grown at five sites in Single Row Observation Sawfly and Clearfield nurseries. Based on visual evaluation and selection across all sites,

07X349D10-1 was selected and designated MTCS1601.

2016-Multi MTCS1601 (F9) tested in the MSU Sawfly trial from 2016 to 2018 (16 location years) and the MSU Clearfield Qualification trial from 2016 to 2018 (7 LY). Milling & baking quality evaluation initiated.

2017-Multi MTCS1601 (F10) tested in MSU Advanced trials (6 LY). M&P heads selected from FE bulk.

2018-Multi Breeder seed from 2017 FE bulk increased at Ft.Ellis.

MTCS1601 (F11) tested in Montana Intrastate (9 LY) and Off-station (13LY) trials.

126 F10:11 headrows evaluated for phenotypic uniformity and stem solidness, harvested individually, and 96 bulked as Breeder seed (R).

2019-Multi Breeder seed increased under MTA with Northern Seed.

**Table 1. Agronomic characteristics of MTCS1601 vs. a set of solid-stem varieties, 2016-2018<sup>1/</sup>**

Variety	Test weight lb/bu	Winter survival %	Heading date		Plant height in	Protein %	Stem solidness 5-25	Saw fly cutting %	Stripe rust %
			Julian	Calendar					
location-years	37	1	15		38	39	21	13	2
<b>Judee</b>	<b>61.5</b>	49	159.6	9-Jun	30.3	13.1	20.8	33	7
<b>Loma</b>	60.1	46	162.8	12-Jun	28.3	12.8	20.5	26	9
<b>MTCS1601</b>	<b>61.6</b>	<b>61</b>	<b>159.8</b>	<b>9-Jun</b>	<b>29.8</b>	<b>12.8</b>	<b>19.3</b>	<b>35</b>	<b>10</b>
<b>MTS1588</b>	61.2	52	160.9	10-Jun	28.0	12.8	<b>23.2</b>	<b>6</b>	7
<b>Warhorse</b>	60.6	52	161.4	10-Jun	29.6	<b>13.4</b>	21.8	<b>6</b>	4
<b>LSD (0.05)</b>	<b>0.3</b>	<b>12</b>	<b>0.5</b>		<b>0.6</b>	<b>0.2</b>	<b>1.0</b>	<b>11</b>	<b>ns</b>

1/ = includes 2018 Intrastate and 2018 Off Station, and 2016-2018 Saw fly tests

**bold** = indicates highest (or most desirable) 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)

**Table 2. Stem solidness ratings of MTCS1601 compared to other solid-stemmed varieties, (2016-2018)**

	Stem Solidness Rating (scale 5-25, higher = more solid)				Stem Solidness by location, 2016-2018				
	2018	2017	2016	2016-18	Billings	Bozeman	Conrad	Havre <sup>1/</sup>	Moccasin
location-years	9	6	6	21	2	4	3	11	1
<b>Judee</b>	22.3	19.1	20.0	20.8	22.0	18.5	<b>22.5</b>	20.6	<b>24.4</b>
<b>Loma</b>	22.5	20.1	17.9	20.5	22.8	18.5	20.5	20.9	20.6
<b>MTCS1601</b>	<b>20.1</b>	<b>18.4</b>	<b>19.0</b>	<b>19.3</b>	<b>18.4</b>	<b>18.3</b>	<b>19.4</b>	<b>19.8</b>	<b>19.9</b>
<b>MTS1588</b>	<b>23.8</b>	<b>23.2</b>	<b>22.3</b>	<b>23.2</b>	23.0	<b>23.1</b>	<b>23.3</b>	<b>23.2</b>	<b>23.4</b>
<b>Warhorse</b>	22.5	<b>21.3</b>	<b>21.4</b>	21.8	22.6	<b>21.0</b>	<b>22.2</b>	<b>21.9</b>	<b>22.3</b>
<b>LSD (0.05)</b>	<b>1.2</b>	<b>2.2</b>	<b>1.7</b>	<b>1.0</b>	<b>ns</b>	<b>2.7</b>	<b>2.4</b>	<b>1.4</b>	<b>2.5</b>

**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

**General performance and characteristics:** MTCS1601 was selected as a solid-stem Clearfield line, and was targeted into the MSU Sawfly trial for initial evaluations. MTCS1601 is a medium-maturity, semi-dwarf, semi-solid stem HRW wheat line with average grain protein content, and good test weight (Table 1). Testing from 2016 to 2018 has shown that stem solidness of MTCS1601 over years and locations is significantly lower than predominant solid-stem cultivars Loma, Judee, and Warhorse (Table 2) and cutting of MTCS1601 by wheat stem sawfly has been relatively high, significantly greater than Warhorse and MTS1588 (Table 1).

Grain yield performance of MTCS1601 has been good in comparison to solid-stem lines (Table 3) and a larger set of cultivars, including Clearfield lines, SY Clearstone 2CL and Brawl CL Plus (Table 4). Currently, no solid-stem Clearfield winter wheat cultivars are available in Montana. Relative to SY Clearstone 2CL, MTCS1601 is similar in yield (Table 4), 2 lb./bu. higher in test weight, 2 days earlier in heading, 3.5 inches shorter, and has better resistance to cutting by wheat stem sawfly) (Table 5). Relative to Brawl CL Plus, MTCS1601 is 5.3 bu./acre higher in yield (Table 4), 1 lb./bu. lower in test weight, 6 days later in heading, 2.1 inches taller, and 0.6% lower in grain protein (Table 5). In 6 heavily-infested wheat stem sawfly environments, MTCS1601 yielded similarly to Brawl CL Plus and SY Clearstone 2CL and had significantly lower sawfly cutting damage than SY Clearstone 2CL (Table 6).

**Table 3. Yield of MTCS1601 vs. a set of solid-stem varieties, 2016-2018<sup>1/</sup>**

Variety	Districts							All Locations
	1 Kalispell	2 Bozeman	3 Huntley <sup>2/</sup>	4 Moccasin <sup>3/</sup>	5 Conrad <sup>4/</sup>	5 Have <sup>5/</sup>	6- Sidney & Williston	
location-years	1	4	8	4	7	13	2	39
<b>MTS1588</b>	94.1	108.5	74.6	63.1	<b>66.8</b>	<b>64.0</b>	55.7	<b>71.5</b>
<b>MTCS1601</b>	<b>85.4</b>	<b>113.5</b>	<b>77.9</b>	<b>63.7</b>	<b>64.7</b>	<b>60.6</b>	<b>56.4</b>	<b>71.1</b>
<b>Loma</b>	87.6	109.9	76.0	66.1	<b>66.4</b>	58.1	59.3	<b>70.2</b>
<b>Warhorse</b>	92.0	99.5	79.0	62.8	55.1	57.7	57.2	67.3
<b>Judee</b>	94.5	102.3	72.5	64.3	60.8	56.7	55.3	67.0
<b>LSD (0.05)</b>	<b>ns</b>	<b>ns</b>	<b>ns</b>	<b>ns</b>	<b>4.3</b>	<b>4.9</b>	<b>ns</b>	<b>2.6</b>

**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 2018 Intrastate and 2018 Off Station, and 2016-2018 Saw fly tests

2/ includes data from Fort Smith, Hardin area, 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 4. Yield of MTCS1601 vs. a set of varieties (including Clearfield varieties), 2018<sup>1/</sup>**

Variety	Districts							All Locations
	1 Kalispell	2 Bozeman	3 Huntley <sup>2/</sup>	4 Moccasin <sup>3/</sup>	5 Conrad <sup>4/</sup>	5 Have <sup>5/</sup>	6- Sidney & Williston	
location-years	1	1	6	4	5	4	2	23
<b>Loma</b>	87.6	<b>139.7</b>	92.7	66.1	<b>67.6</b>	55.2	59.3	<b>75.0</b>
<b>MTS1588</b>	94.1	<b>134.5</b>	91.6	63.1	<b>68.9</b>	58.1	55.7	<b>74.7</b>
<b>SY Clearstone 2CL</b>	89.6	<b>142.4</b>	93.9	67.4	<b>65.3</b>	55.8	55.3	<b>74.4</b>
<b>MTCS1601</b>	<b>85.4</b>	<b>135.3</b>	<b>95.4</b>	<b>63.7</b>	<b>66.4</b>	<b>49.6</b>	<b>56.4</b>	<b>73.3</b>
<b>Yellowstone</b>	83.6	<b>137.3</b>	92.6	62.0	<b>65.6</b>	56.7	59.8	<b>73.3</b>
<b>Warhorse</b>	92.0	120.7	96.8	62.8	57.2	51.1	57.2	<b>71.7</b>
<b>Judee</b>	94.5	128.2	87.9	64.3	60.7	52.0	55.3	71.1
<b>Brawl CL Plus</b>	86.9	115.3	90.6	53.6	60.1	51.1	49.7	68.0
<b>LSD (0.05)</b>	<b>ns</b>	<b>11.6</b>	<b>ns</b>	<b>ns</b>	<b>7.2</b>	<b>ns</b>	<b>ns</b>	<b>3.6</b>

1/ = includes 2018 Intrastate and 2018 Off Station tests

2/ includes data from Fort Smith, Hardin area, 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 5. Agronomic characteristics of MTCL1601 vs. a set of varieties (including Clearfield varieties), 2018**

Variety	Test	Winter	Heading date		Plant	Protein	Stem	Saw fly
	weight	survival			height		solidness	cutting
	lb/bu	%	Julian	Calendar	in	%	5-25	%
location-years	23	1	9		23	23	5	7
<b>Brawl CL Plus</b>	<b>63.0</b>	45	154.5	4-Jun	27.5	<b>13.7</b>		26
<b>Judee</b>	61.9	49	160.4	9-Jun	30.5	<b>13.5</b>	<b>23.3</b>	39
<b>Loma</b>	60.4	46	163.4	12-Jun	28.3	13.1	22.3	29
<b>MTCS1601</b>	<b>62.0</b>	<b>61</b>	<b>160.5</b>	<b>10-Jun</b>	<b>29.6</b>	<b>13.1</b>	<b>20.7</b>	<b>34</b>
<b>MTS1588</b>	61.8	52	161.8	11-Jun	27.9	13.0	<b>24.2</b>	<b>3</b>
<b>SY Clearstone 2CL</b>	60.0	48	162.6	12-Jun	33.1	12.9		60
<b>Warhorse</b>	61.0	52	161.9	11-Jun	29.6	<b>13.7</b>	22.7	<b>5</b>
<b>Yellowstone</b>	60.2	62	163.0	12-Jun	31.7	12.8	6.0	57
<b>LSD (0.05)</b>	<b>0.5</b>	<b>12</b>	<b>0.9</b>		<b>0.8</b>	<b>0.3</b>	<b>1.5</b>	<b>19</b>

1/ = includes 2018 Intrastate and 2018 Off Station tests

**bold** = indicates highest (or most desirable) 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)**Table 6. MTCL1601: Yield Performance under Sawfly Pressure (test average cutting ≥10%) and % Sawfly Cutting (2018)**

Variety	Yield bu/a	Sawfly Cutting (%)
location-years	6	6
<b>Brawl CL Plus</b>	60.6	29
<b>Judee</b>	58.7	45
<b>Loma</b>	62.7	33
<b>MTCS1601</b>	<b>60.0</b>	<b>39</b>
<b>MTS1588</b>	66.0	<b>3</b>
<b>SY Clearstone 2CL</b>	59.7	68
<b>Warhorse</b>	55.6	<b>6</b>
<b>Yellowstone</b>	59.4	65
<b>LSD (0.05)</b>	<b>ns</b>	<b>20</b>

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

**Crop tolerance to herbicide.** Prior to cultivar release, data demonstrating adequate crop tolerance to Beyond® herbicide must be submitted to BASF and approved. To this end, Crop Qualification data from seven MT trials over three years has been submitted to BASF for evaluation and potential approval. A summary of crop yield data [control & 2X herbicide rate] in comparison to the genetic standard [SY Clearstone 2CL] is shown in Table 7.

**Milling and Baking Quality.** End-use quality of MTCS1601 has been evaluated over a three-year period (n=10) in Montana trials. In the 2016 & 2017 Sawfly trials, MTCS1601 had good milling qualities, intermediate dough mixing characteristics, and acceptable loaf volume (Table 8). In the 2017 Advanced trial, end-use qualities of MTCS1601 also appeared acceptable for commercial production (Table 9).

**Table 7. Yield of MTCS1601 vs. SY Clearstone 2CL, 2016-2018 Clearfield Qualification Tests**

Variety	Districts			All Locations
	1 Kalispell	2 Bozeman <sup>1/</sup>	3 Huntley	
location-years	1	4	2	7
SY Clearstone 2CL 2X Beyond	103.9	112.9	114.6	112.1
MTCS1601 2X Beyond	90.5	101.2	120.1	107.7
SY Clearstone 2CL untreated	109.4	104.3	116.5	105.8
MTCS1601 untreated	91.5	100.4	120.3	104.8
<b>LSD (0.05)</b>	<b>ns</b>	<b>ns</b>	<b>ns</b>	<b>ns</b>

1/ = includes Fort Ellis and Northern Seeds Gallatin Valley tests

**Table 8. Mill and bake characteristics of MTCS1601 vs. a set of varieties, 2016-2017 Sawfly Trials**

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
location-years	6	6	6	6	6	6	6	6	6	6	6
Judee	0.274	77.4	69.9	12.6	<b>0.39</b>	<b>3.3</b>	6.4	66.5	10.7	76.4	<b>1168</b>
Warhorse	0.262	84.6	69.3	13.0	0.43	2.2	5.5	68.8	9.9	78.5	<b>1143</b>
Loma	0.151	79.2	<b>71.4</b>	12.6	<b>0.40</b>	3.0	8.0	69.4	18.1	79.8	<b>1134</b>
Yellowstone	0.271	75.2	70.4	12.1	0.41	<b>4.2</b>	9.0	66.8	17.2	77.3	1080
MTS1588	0.330	68.4	<b>71.5</b>	12.6	<b>0.39</b>	<b>3.2</b>	7.4	69.3	18.6	79.2	1074
<b>MTCS1601</b>	<b>0.317</b>	<b>70.0</b>	<b>71.7</b>	12.1	<b>0.39</b>	<b>3.0</b>	<b>5.4</b>	<b>66.0</b>	<b>10.6</b>	<b>76.3</b>	<b>1033</b>
<b>LSD (0.05)</b>	<b>0.048</b>	<b>4.2</b>	<b>1.2</b>	<b>ns</b>	<b>0.01</b>	<b>1.1</b>	<b>1.6</b>	<b>ns</b>	<b>3.7</b>	<b>ns</b>	<b>84</b>

**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)

<sup>1/</sup> low is best for noodles

**Table 9. 2017 Advanced Winter Wheat Nursery Mill & Bake (Exp. 14) 4 locations  
Location: Means Across Locations**

Sample No.	Variety	PPO	Single kernel hardness	Wheat Protein, % (12% m.b.)	Flour Yield, %	Flour Protein, % (14% m.b.)	Wheat Ash, %	Flour Ash, %	Mixing Tolerance	Bake Mixing Time, min	Bake Water Absorption, %	Loaf Volume
11	MT1642	0.137	76.1	13.4	70.2	12.4	1.40	<b>0.40</b>	<b>3.8</b>	14.2	<b>79.6</b>	<b>1191</b>
1	Judee	0.235	82.8	<b>13.6</b>	70.1	<b>12.8</b>	1.42	<b>0.41</b>	<b>3.5</b>	7.8	76.3	<b>1176</b>
3	Warhorse	0.250	90.0	<b>14.1</b>	69.2	<b>12.9</b>	1.38	0.43	1.5	7.7	79.0	1103
13	MT1683	0.281	76.6	13.2	70.4	12.1	1.39	0.43	2.8	14.9	79.0	1074
5	<b>MTCS1601</b>	<b>0.341</b>	<b>73.6</b>	<b>13.4</b>	<b>71.3</b>	<b>12.5</b>	<b>1.41</b>	<b>0.40</b>	<b>2.8</b>	<b>10.6</b>	<b>77.3</b>	<b>1071</b>
2	Decade	0.291	81.1	13.3	69.6	12.3	1.36	<b>0.41</b>	2.8	20.0	<b>82.6</b>	1054
4	SY Wolf	0.303	77.0	13.2	69.9	12.2	1.38	<b>0.41</b>	0.8	7.9	74.2	1031
	<b>Average</b>	<b>0.234</b>	<b>78.7</b>	<b>13.4</b>	<b>70.3</b>	<b>12.4</b>	<b>1.37</b>	<b>0.42</b>	<b>2.8</b>	<b>11.0</b>	<b>78.2</b>	<b>1080</b>
	<b>LSD (0.05)</b>	<b>0.052</b>	<b>4.4</b>	<b>0.5</b>	<b>1.0</b>	<b>0.5</b>	<b>ns</b>	<b>0.01</b>	<b>0.9</b>	<b>3.6</b>	<b>3.0</b>	<b>63</b>
	<b>C.V.</b>	<b>15.4</b>	<b>3.9</b>	<b>2.6</b>	<b>0.9</b>	<b>2.6</b>	<b>4.2</b>	<b>2.4</b>	<b>22.4</b>	<b>22.7</b>	<b>2.7</b>	<b>4.1</b>

**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 resistance:** MTCS1601 is moderately resistant to stripe rust based on Montana evaluations (Table 1). In addition, MTCS1601 wheat was tested for reactions to natural infections of *Puccinia striiformis* f. sp. *tritici* in Pullman and Mount Vernon, WA from 2016 to 2018. Across locations and over years, MTCS1601 had highly resistant reaction with infection type (IT) 2 to moderate resistant reaction (IT 5) with severity 2-40%. In contrast, the susceptible check (PS279) was highly susceptible (IT 8, severity 80-100%) in the late growth season.

MTCS1601 is moderately susceptible to stem rust based on seedling stem rust evaluations conducted by the USDA-ARS Cereal Disease Lab in 2016. In seedling evaluations at St. Paul, MN, MTCS1601 was resistant to several *Pgt* races from the United States, including QCCSM, QFCSC, and TPMKC, but susceptible to QTHJC, RKRQC, and TTTTF. MTCS1601 is not resistant to the Ug99 stem rust race group.

**Purification/seed stocks:** Increase of MTCS1601 was initiated in 2017 when a phenotypically-uniform, herbicide-treated fill plot of MTCS1601 (F10) was hand harvested and threshed after collection of 130 individual heads. Breeder seed was increased at Fort Ellis in 2018 using Clearfield seed increase protocols. As a backup seed purity option, 126 F<sub>10</sub>-derived F<sub>11</sub> headrows were grown at Bozeman, evaluated for phenotypic uniformity and stem solidness, harvested individually, and 96 bulked as breeder seed (R =redundant). Breeder seed of both lots is being increased by Northern Seed under a Material Transfer Agreement in 2019.

**Summary:**

**MTCS1601 is a medium-maturity, semi-dwarf, semi-solid stem HRW wheat line with two gene-resistance to Beyond® herbicide, average grain protein content, and good test weight (Table 1). MTCS1601 has intermediate stem solidness but relatively poor resistance to cutting by wheat stem sawfly in heavily-infested environments. MTCS1601 does have good yield potential and has performed well in Montana relative to other Clearfield lines in environments not heavily infested with sawfly. MTCS1601 has moderate resistance to stripe rust and adequate end-use qualities for commercial production.**