

MEMORANDUM

FROM: Mike Giroux and Andrew C. Hogg
DATE: 1/19/2022
RE: Motion for Release of MTD18348 spring durum wheat with supporting documentation.

RECOMMENDATION Public, protected **NAME** To be determined

CONTRIBUTORS

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- Ms. Peggy Lamb and Ms. Kyla McNamara, MSU-NARC, Havre, MT
- Dr. Ken Kephart and Ms. Valerie Smith, MSU-SARC, Huntley, MT
- Dr. Justin Vetch and Ms. Elizabeth Simmons, MSU-WTARC, Conrad, MT
- Mr. Doug Holen, MSU Foundation Seed, Bozeman, MT
- Mr. Craig Cook, 2nd Nature Research, LLC, Bozeman, MT
- Dr. Linda Dykes, USDA-ARS, Fargo, ND
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Crop Science

Entomology

Horticulture

Plant Biology

Plant Genetics

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PEDIGREE

Alzada/Strongfield//Brigade/Carpio

- **'Alzada'-Westbred, LLC, 2004**

'Alzada' was developed from the cross Mohawk/Kofa and released by Westbred, LLC, Bozeman, MT. Alzada is a semi-dwarf, spring durum wheat adapted to drier climates with excellent end-use quality traits (high yellowness, high gluten strength, and good color stability) and normal cadmium content. Alzada heads and matures ~5 days early than other commonly grown durum cultivars. Alzada has been the most widely grown durum wheat in the "Golden Triangle" of Montana the last 15 years.

- **'Strongfield'- Agriculture and Agri-food Canada (AAC), 2004**

'Strongfield' spring durum wheat (Reg. no. CV-1000, PI 641223) was developed by the AAC, Swift Current, SK. It has high yield, good end-use quality traits, and carries the low cadmium trait. Strongfield was selected from the cross 'AC Avonlea'/DT665 made in 1994 and developed using a modified pedigree breeding method. AC Avonlea (Clarke et al., 1999) is from the AAC program and DT665 derives from the cross 'Kyle'/'Nile'. Nile was obtained from the International Centre for Agricultural Research in the Dry Areas, Aleppo, Syria and Kyle (TownleySmith et al., 1987) is from AAC.

Clarke, J.M., McCaig, T.N., DePauw, R.M., Knox, R.E., Clarke, F.R., Fernandez, M.R., and Ames, N.P. 2006. Registration of 'Strongfield' Durum Wheat. *Crop Science*, 46(5), 2306-2307.

<https://doi.org/10.4141/P04-119>

- **'Brigade'- AAC, 2008**

'Brigade' was selected from the cross DT513/DT696 made in 1999. Brigade has good yield, high gluten strength, good straw strength and fusarium resistance better than many Canadian durum varieties and carries the low cadmium trait. DT513 (DT625/DT612) was developed at the Crop Development Centre, University of Saskatchewan, and DT696 (DT618/DT 637//Kyle) derives from the AAC breeding program.

Clarke, J.M., Knox, R.E., DePauw, R.M., Clarke, F.R., Fernandez, M.R., McCaig, T.N., Singh, A.K. 2009. Brigade Durum Wheat. *Canadian Journal of Plant Science*, 89(3)

<https://doi.org/10.4141/CJPS08168>

- **‘Carpio’- North Dakota State University (NDSU), 2012**

‘Carpio’ was developed by NDSU using the pedigree breeding method from the cross D95580/D95595 made in fall 1999. Carpio has high gluten index, equal to Alzada, high grain yield potential, disease resistance, and excellent end-use qualities. Carpio has normal cadmium content.

Elias, E.M., Manthey, F.A., and AbuHammad, W.A. 2015. Registration of ‘Carpio’ Durum Wheat. *Journal of Plant Registrations* 9(1):78.

<https://doi.org/10.3198/jpr2014.05.0030crc>

SELECTION HISTORY

MTD18348 was developed from a four-way cross between Alzada, Strongfield, Brigade, and Carpio. In 2015, Strongfield was crossed with Alzada and Brigade was crossed with Carpio. In early spring of 2016, the Alzada/Strongfield x Brigade/Carpio F₁s were crossed. The F₁ offspring from this cross was then advanced in the greenhouse and field by single seed descent to the F₅ generation at which point a whole head was harvested. In 2018, 214 Alzada/Strongfield//Brigade/Carpio F_{5.6} lines were planted in spaced head-rows (15 seeds/5 ft row) in Bozeman, MT at the Post Agronomy Farm and the best agronomic rows were visually selected and threshed using a Vogel thresher. Visual selection focused on selecting plots with high productive tillers, high straw strength, moderate height, low disease symptoms, large heads, high vigor, and normal or early maturity. Harvested grain was assessed for protein content and lines with protein below 13.5% were discarded. In 2019, MTD18348 was included in the Bozeman Durum Preliminary Yield Trial which consisted of 550 F_{5.7} entries. Each entry was grown as a single non-replicated 2-row plot (2 x 10 ft) with check entries Joppa and Alzada included every 25 rows at the Post Agronomy Farm under dryland and irrigated conditions. Lines were evaluated for agronomic traits (height, heading date, maturity date, and grain yield) and quality traits (protein, seed size, and yellowness) and plots from the irrigated trial were harvested with a binder and Vogel thresher for seed stock. Based on yield performance (4th highest average yield), protein content and maturity date, MTD18348 was advanced for statewide testing in 2020. A bulk DNA sample from F_{5.8} greenhouse plants was genotyped for *cdul* using published protocols and MTD18348 was determined to carry the low cadmium accumulation allele. In 2020, MTD18348 (F_{5.8}) was grown at eight locations across the state to evaluate agronomics and quality traits were assessed by the USDA quality lab in Fargo, ND. Locations tested were Bozeman Post Agronomy Farm (irrigated and dryland), SARC (dryland), EARC (irrigated and dryland), CARC (dryland), and NARC (dryland), and in Conrad, MT (dryland, 2nd Nature LLC). In 2020, MTD18348 was the highest yielding line averaged over all on-station dryland locations (64.5 bu/ac, $p=0.043$) and at EARC dryland (55.4 bu/ac, $p=0.304$). MTD18348 had the highest percentage of large

seeds (76.7), high yellowness ($b^*=31.5$), and high gluten strength (Gluten Index=96) in 2020. MTD18348 (F_{5:9}) was tested again in the Montana 2021 State Durum Trials at the same locations as 2020 with the exception that the trial in Conrad was planted at WTARC, and four off-station trials were planted at Loring, Turner, Chester, and Dagmar. In 2021, MTD18348 was the second highest yielding line across all on-station dryland locations (45.2 bu/ac, $p=0.063$) and the highest yielding line at EARC dryland (45.6 bu/ac, $p<0.001$). In 2021, MTD18348 again had a high percent of large seeds (52.1%), high semolina yellowness ($b^*=32$), and high gluten strength (Gluten Index=96). MTD18348 was selected for varietal release due to its high yield potential in the durum growing regions of the state, its excellent quality characteristics, low grain cadmium accumulation, and tolerance to fungal leaf spot disease.

PURIFICATION OF SEED STOCK

MTD18348 was developed using the single seed descent method from 2016-2018. A single F₅ head was harvested from the greenhouse and F_{5:6} seed was planted in a head-row in spring 2018. In 2018, a F_{5:6} head-row was selected and harvested by binder and threshed with a Vogel for seed stock. In 2019, a 2'x10' plot of F_{5:7} was planted under irrigation and harvested by binder and threshed with a Vogel. In 2020, a 4 x 30 ft plot of F_{5:8} was planted for initial seed increase. This plot was rogued for off types throughout the growing season and harvested using a clean Wintersteiger plot combine. MTD18348 (F_{5:9}) was increased as breeders seed in 2021 in Bozeman, MT. A 0.2-acre increase was grown under irrigation and the field was rogued multiple times throughout the year to remove contaminants and off-types. Seed from the breeder's increase plot was harvested with a clean Wintersteiger plot combine by MSU foundation seed. Foundation seed (F_{5:10}) will be raised in 2022 in Bozeman, MT, followed by registered seed in 2023 and certified seed in 2024. Expected availability to the public in 2025.

AGRONOMIC CHARACTERISTICS

MTD18348 is a standard height spring durum wheat (*Triticum turgidum* ssp. *durum*) developed at MSU that carries the *cdul* allele for low cadmium accumulation. MTD18348 is approximately 33 inches tall under all dryland conditions, similar to NDSU varieties such as Tioga and ND-Riveland (Table 2) and has white glumes and black awns. MTD18348 has a heading date (June 28th) a day later than Tioga and ND-Riveland, two days later than Joppa, and six days later than Alzada under dryland conditions (Table 2). Under only dryland conditions (2020-21, 12 loc-year, no off-station) MTD18348 (54.8 bu/ac) was the top yielding entry and yielded significantly higher than Divide (50.3 bu/ac), Joppa (50.4 bu/ac), and Tioga (50.1 bu/ac) (Table 2). In 2020, MTD18348 (64.5 bu/ac) yielded significantly more than Alzada (58.4 bu/ac) under all dryland locations (n=6). Under all locations and conditions (2020-21, 16 loc-year, no off-station) MTD18348 (67.4 bu/ac) yielded more than the top grown cultivars Divide (64.0 bu/ac), and

Tioga (63.5 bu/ac) (Tables 3). Over two years at EARC dryland (2020-21) MTD18348 was the highest yielding line, though not significantly, with an average yield (50.5 bu/ac) higher than Divide (41.8 bu/ac), Joppa (41.4 bu/ac), Tioga (41.3 bu/ac), and ND-Riveland (45.4 bu/ac) (Table 4). At the off-station Dagmar 2021 trial MTD18348 was the highest yielding line by 3 bu/ac, though not statistically so (Table 5). At the Loring off-station trial in 2021 MTD18348 was the highest yielding line and significantly higher than the top grown cultivars (Table 6). MTD18348 was the third highest yielding line in the Chester off-station trial which was equal to the highest yielding line (Table 7).

QUALITY CHARACTERISTICS

Averaged over two years and all locations (16 loc-years), MTD18348 had grain protein content (14.8%), test weight (60.5 lb/bu), and grain ash (1.56%) comparable to top grown lines but had a significantly higher falling number (481.6 sec) (Table 8). Compared to the top grown cultivars Divide, Joppa, and ND-Riveland, MTD18348 had a significantly higher percent of large seeds (65.3%), the lowest percent of small seeds (8%), and one of the largest individual seed weights (41 mg) (Table 9). MTD18348 had a semolina yield (60.9%) comparable to Joppa and Alzada but significantly higher than Divide and ND-Riveland (Table 10). Semolina from MTD18348 had similar protein (13.1%) and ash content (0.66%) as top grown cultivars (Table 10). MTD18348 has excellent gluten strength (Gluten Index=96) like Alzada, ND-Riveland, and Carpio which is higher than Divide (78) and Joppa (88) (Table 11). MTD18348 has yellower ($b^*=31.8$) semolina than Divide and Joppa but equal to Carpio, Alzada, and ND-Riveland (Table 11).

DISEASE EVALUATIONS

Fusarium head blight susceptibility was evaluated in 2021 at EARC and MTD18348 performed similarly as top grown cultivars in terms of severity, index, and fusarium damaged kernels having moderate susceptibility (Table 12). MTD18348 was found to be resistant to the most prevalent stem rust race in Montana TCMLK (Table 13). MTD18348 was evaluated for leaf spot caused by *Stagonospora nodorum* and *Pyrenophora tritici-repentis* and was resistant to the predominant race of both pathogens while having sensitivity to ToxA and moderate susceptibility to Ptr race 5 (Table 14). MTD18348 was evaluated for resistance/susceptibility to stripe rust in 2021 at Mt. Vernon, WA and had an intermediate reaction at the seedling stage (5) similar to top grown cultivars but had an intermediate reaction (5) at the adult stage, indicating this line may not have high-temperature adult plant resistance (HTAP) to stripe rust as seen in other lines (Tables 15).

STATISTICAL ANALYSIS

For yield data across years and locations, the entry mean from each location/year was considered a replicate and was analyzed as a randomized complete block design (RCBD) using PROC GLIMMIX (SAS v9.4). For data from individual on-station locations in one year, 3 replicates per entry were analyzed as an alpha lattice design using PROC GLIMMIX (SAS v9.4). For data from individual off-station locations in one year, 3 replicates per entry were analyzed as a RCBD using PROC GLIMMIX (SAS v9.4). For quality data, each location-year was considered as a replicate and analyzed as a RCBD using PROC GLIMMIX (SAS v9.4). A protected LSD was used to determine significant differences between entries at the $\alpha=0.05$ level. For the entry Alzada only data from 2020 was used in the quality analysis. Environmental conditions were much drier and hotter in 2021 compared to 2020.

MTD18348 Traits of Interest

- Very high yield potential
- Low grain cadmium accumulation
- Very high protein strength
- Excellent semolina quality
- Fungal leaf spot tolerance
- Good test weight and large seed size
- High grain protein

Table 1. 2021 Montana Variety Share of Planted Acres³ (2021 MWBC Durum Variety Survey conducted by the National Agricultural Statistics Service).

Cultivar	2021 % ¹	2020 % ¹
Divide	16.9	8.8
Alzada	16.0	35.2
ND-Riveland	13.4	1.0
Joppa	12.3	22.5
Transcend	10.7	5.3
Carpio	3.3	1.0
Other²	27.4	26.2

¹Percentage may not add to 100 due to rounding

²Includes varieties with less than 1% of acreage in 2021 and unknown varieties

³1,000 acres (1 acre = 0.405 hectares), 2021 = 670,000 acres, 2020 = 695,000 acres

Durum Wheat Trait Index Montana: 2021

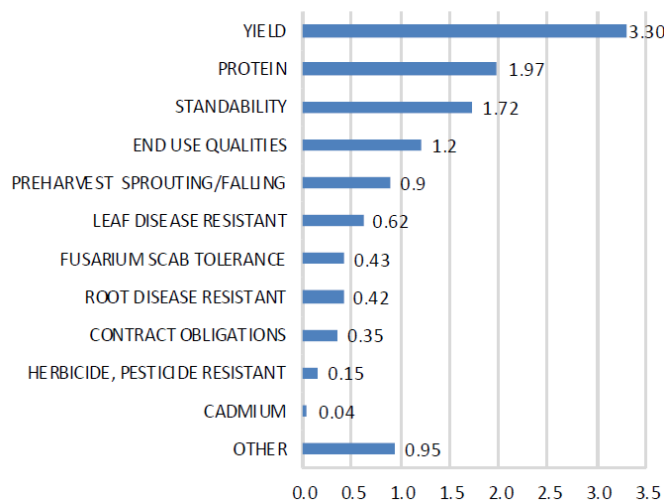


Figure 1. Durum wheat trait index where growers were asked to rank traits in order of importance when choosing a wheat variety for 2021 where 5.00 is the highest and 1.00 is the lowest (from the 2021 MWBC wheat variety survey conducted by the National Agricultural Statistics Service).

Table 2. Agronomic Evaluation All Dryland State Durum Trials 12 location-years (2020-21).

ID	Yield ¹ bu/ac	Test Weight lb/bu	Protein ² %	Plant Height Inches	Heading Date Julian
Mountrail	51.9*	59.5	15.3	30.5	179.0
Grenora	51.6*	59.7	15.1	29.7	178.5
Divide	50.3	60.2	15.3	31.8	178.9
Tioga	50.1	60.3	15.5	33.2	179.0
Carpio	51.8*	59.0	15.5	31.2	180.4
Joppa	50.4	60.4	15.0	31.8	178.9
ND-Riveland	52.5*	59.8	15.4	32.5	179.3
ND-Grano	51.6*	60.4	15.4	30.7	180.2
CDC-Vivid	50.2	60.0	16.1*	31.2	179.1
Lustre	51.8*	58.8	15.6	31.1	179.3
MTD18155	50.9	59.6	15.6	28.8	179.0
MTD16001	48.9	59.2	15.0	31.2	179.0
MTD16002	53.0*	59.6	15.2	32.7	180.3
MTD18213	49.6	58.0	15.9	32.5	181.1
MTD18486	49.5	59.9	15.3	32.1	183.0**
MTD18413	52.5*	59.8	15.7	31.0	178.2
MTD18348	54.8**	59.9	15.3	32.8	180.3
MTD18091	49.4	59.3	15.7	31.3	180.4
MTD18430	47.9	57.8	15.7	34.7**	182.7*
MTD18179	48.6	57.8	16.4**	29.9	178.6
MTD18172	54.1*	60.8	15.8	31.1	180.3
MTD18067	50.8	59.2	15.3	31.3	179.7
MTD18381	46.0	59.5	15.5	29.6	177.3
MTD18181	46.5	59.5	16.2*	32.3	181.9
MTD18256	52.0	59.8	15.8	32.1	181.0
MTD18217	50.2	59.4	15.4	32.6	182.5*
MTD18266	51.6*	60.7	16.0*	31.7	181.0
MTD18148	50.9	60.3	15.2	23.5	178.0
MTD18313	52.8*	62.0**	15.2	24.7	175.6
Average	50.8	59.7	15.5	30.8	179.6
LSD (0.05)	3.5	0.5	0.4	1.2	0.7
Prob > F	<0.001	<0.001	<0.001	<0.001	<0.001
CV (%)	8.7	1.0	3.2	4.7	0.4

¹Grain yield reported on a 13% moisture basis

²Grain protein reported on a 12% moisture basis

** Indicates highest numerical value within a column

* Indicates lines equal to the highest entry based on Fisher's Protected LSD at the 0.05 probability level

Table 3. Yield Evaluations State Durum Trials 2020-21 16 location-years (2020-21).

ID	All Locations Yield (bu/ac) ¹			Dryland Yield (bu/ac) ¹		
	2 Year	2020	2021	2 Year	2020	2021
Mountrail	66.4*	77.3*	55.6*	51.9*	62.3*	41.5
Grenora	65.3*	72.8*	57.9*	51.6*	60.0*	43.2
Divide	64.0	74.3*	53.8	50.3	59.8*	40.7
Tioga	63.5	74.2*	52.9	50.1	60.2*	39.9
Carpio	66.0*	76.0*	56.0*	51.8*	60.4*	43.3
Joppa	65.2*	74.7*	55.8*	50.4	60.1*	40.8
ND-Riveland	66.9*	75.0*	58.7*	52.5	61.2*	43.9
ND-Grano	67.1*	77.1*	57.1*	51.6*	60.6*	42.6
Alzada	-	68.8	-	-	58.4	-
CDC-Vivid	63.5	73.6*	53.3	50.2	61.2*	39.3
Lustre	65.3*	77.1*	53.5	51.8*	63.6*	40.1
MTD18155	64.2	74.0*	54.4	50.9	61.4*	40.4
MTD16001	62.8	72.8*	52.8	48.9	58.2	39.6
MTD16002	66.6*	77.5**	55.8*	53.0*	64.0**	42.0
MTD18213	65.0	75.5*	54.5	49.6	59.0	40.3
MTD18486	64.2	77.1*	51.4	49.5	61.9*	37.2
MTD18413	66.3*	74.8*	57.8*	52.5	60.9*	44.0
MTD18348	67.4*	77.4*	57.5*	54.8**	64.5*	45.2
MTD18091	64.0	74.1*	53.9	49.4	59.4*	39.4
MTD18430	60.3	71.1	49.4	47.9	58.2	37.7
MTD18179	62.5	73.0*	52.1	48.6	59.9	37.2
MTD18172	68.6**	76.8*	60.4**	54.1*	62.4	45.9**
MTD18067	66.7*	75.7*	57.7*	50.8	60.3	41.4
MTD18381	57.9	66.4	49.5	46	54.5	37.6
MTD18181	58.2	66.9	49.4	46.5	55.4	37.6
MTD18256	66.0*	75.4*	56.6*	52.0**	61.6*	42.4
MTD18217	64.8	74.6*	55.1	50.2	58.6	41.8
MTD18266	65.7*	76.7*	54.8	51.6*	61.7*	41.6
MTD18148	63.9	74.2*	53.6	50.9	61.8*	40.0
MTD18313	65.1*	75.9*	54.3	52.8*	64.0*	41.6
Average	64.4	74.4	54.7	50.8	60.5	41.0
LSD (0.05)	3.6	5.1	4.9	3.5	5.1	5.2
Prob > F	<0.001	<0.001	<0.001	<0.001	0.043	0.063
CV (%)	7.8	7.0	9.1	8.7	7.4	11.1
n	16	8	8	12	6	6

¹Grain yield reported on a 13% moisture basis

** Indicates highest numerical value within a column

* Indicates lines equal to the highest entry based on Fisher's Protected LSD at the 0.05 probability level

Table 4. Agronomic Data EARC Dryland On-station 2 Year 2020-21.

ID	Yield¹ bu/ac	Test Weight lb/bu	Protein² %	Plant Height Inches
Mountrail	48.1	60.3	15.4	25.7
Grenora	44.1	61.1	15.0	25.6
Divide	41.8	61.6	15.5	27.1
Tioga	41.3	61.9	15.6	28.4*
Carpio	44.0	61.4	15.7	26.4
Joppa	41.4	61.7	15.4	27.0
ND-Riveland	45.4	61.6	15.7	28.6*
ND-Grano	41.5	62.0	15.7	26.4
CDC-Vivid	44.0	61.1	16.3*	25.8
Lustre	43.2	60.0	16.2*	26.5
MTD18155	44.0	61.2	15.7	25.0
MTD16001	42.1	60.7	15.0	27.2
MTD16002	44.9	61.6	15.4	28.1*
MTD18213	42.3	60.0	16.2*	27.4
MTD18486	40.4	62.2	15.9*	26.8
MTD18413	45.0	61.6	15.7	26.7
MTD18348	50.5**	61.3	15.2	28.8*
MTD18091	40.3	61.0	16.3*	26.4
MTD18430	39.7	59.3	16.3*	29.7**
MTD18179	38.7	58.7	16.8**	26.1
MTD18172	44.5	62.4*	16.2*	26.6
MTD18067	42.7	60.7	15.7	26.3
MTD18381	39.3	60.5	15.0	25.4
MTD18181	36.6	61.5	16.4*	27.3
MTD18256	46.6	61.0	15.8	28.3*
MTD18217	43.0	61.2	16.3*	27.3
MTD18266	44.0	62.0	16.7*	26.8
MTD18148	44.0	61.3	15.1	21.2
MTD18313	43.1	63.2**	15.2	21.2
Average	43.0	61.2	15.8	26.6
LSD (0.05)	6.2	0.9	1.0	2.1
Prob > F	0.070	<0.001	0.013	<0.001
CV (%)	7.1	0.7	3.0	3.9

¹Grain yield reported on a 13% moisture basis

²Grain protein reported on a 12% moisture basis

** Indicates highest numerical value within a column

* Indicates lines equal to the highest entry based on Fisher's Protected LSD at the 0.05 probability level

Table 5. Agronomic Data EARC Dagmar Dryland Off-station 2021 Durum Variety Trial.

ID	Yield¹ bu/ac	Test Weight lb/bu	Protein² %	Plant Height inches
Mountrail	16.1	63.1	17.3	19.8*
Grenora	19.3	63.2	16.5	18.8
Divide	19.5	63.6	16.6	21.0*
Tioga	19.1	63.6	17.2*	22.4**
Carpio	17.8	63.1	16.5	19.3*
Joppa	18.5	64.0*	16.5	20.3*
ND-Riveland	22.1	63.8	16.4	22.2*
ND-Grano	16.2	63.8	17.4*	19.8*
CDC-Vivid	18.4	63.9*	18.2**	22.0*
Lustre	16.1	62.4	17.9*	17.2
MTD16001	18.6	63.2	16.2*	19.4*
MTD16002	20.5	62.9	16	20.9*
MTD18348	24.8**	63.5	16	22.6*
MTD18313	16.1	64.9**	17.2*	17.3
Average	18.7	63.5	16.8	20.1
LSD (0.05)	6.6	1.0	1.0	3.0
Prob > F	0.371	0.016	0.002	0.008
CV (%)	21.0	1.0	3.6	9.0

¹Grain yield reported on a 13% moisture basis

²Grain protein reported on a 12% moisture basis

** Indicates highest numerical value within a column

* Indicates lines equal to the highest entry based on Fisher's Protected LSD at the 0.05 probability level

Table 6. Agronomic Data Loring Dryland Off-station 2021 State Durum Trial.

ID	Yield ¹ bu/ac	Test Weight lb/bu	Protein ² %	Plant Height inches	Sawfly ³ %	Falling Number seconds
Mountrail	26.6	58.4	16.2	20.3	2.3	415.4
Grenora	26.3	58.9	15.6	20.8	8.3*	389.7
Divide	22.9	59.6	16.0	21.3	8.3*	406.4
Tioga	25.5	59.6	16.1	23.1*	2.3	395.4
Carpio	27.0	58.7	15.5	21.6	1.0	429.4
Joppa	24.7	59.9	15.9	22.3*	2.3	428.5
ND-Riveland	24.8	59.1	16.0	23.2*	1.0	467.2*
ND-Grano	27.3*	59.8	16.3	20.9	2.3	443.0
CDC-Vivid	23.9	59.5	16.9**	22.1	8.3**	457.3*
Lustre	24.1	58.0	16.3	21.7	3.7	471.5**
MTD-16001	23.7	59.4	15.9	19.9	2.3	440.0
MTD16002	22.8	59.4	16.1	23.8**	3.7	459.8*
MTD18348	29.3**	59.1	15.5	21.9	2.3	462.5*
MTD18313	28.1*	62.0**	15.8	19.9	3.7	461.5*
Average	25.7	59.4	16.0	21.5	3.7	436.9
LSD (0.05)	2.0	0.4	0.3	1.6	3.5	18.7
Prob > F	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CV (%)	4.7	0.4	1.2	4.5	57.2	2.6

¹Grain yield reported on a 13% moisture basis

²Grain protein reported on a 12% moisture basis

³Lodging due to sawfly cutting visually estimated at maturity

** Indicates highest numerical value within a column

* Indicates lines equal to the highest entry based on Fisher's Protected LSD at the 0.05 probability level

Table 7. Agronomic Data Chester Dryland Off-station 2021 State Durum Trial.

ID	Yield ¹ bu/ac	Test Weight lb/bu	Protein ² %	Plant Height inches	Sawfly ³ %	Falling Number seconds
Mountrail	22.3	55.4	17.1	23.0	5.3	189.1
Grenora	26.3*	55.0	16.3	22.6	3.7	106.5
Divide	24.6	56.3	16.7	25.2*	1.0	209.3
Tioga	20.2	56.1	17.4*	25.7**	5.3	92.3
Carpio	23.2	54.4	17.1	24.1	0.7	201.4
Joppa	21.8	56.4	16.9	24.0	5.3	163.2
ND-Riveland	24.0	56.8	16.9	24.5*	1.0	224.1*
ND-Grano	22.1	56.1	16.8	22.2	10.0**	168.7
CDC-Vivid	25.2*	56.7	17.0	22.9	2.3	142.5
Lustre	21.1	55.0	17.6**	25.2	1.0	185.8
MTD-16001	26.9*	56.1	16.4	24.3*	1.0	205.9
MTD16002	19.9	55.5	17.4*	24.0	1.8	202.9
MTD18348	26.3*	57.4	16.2	25.0*	2.3	150.2
MTD18313	27.9**	58.6**	16.4	20.6	0.5	242.1**
Average	23.8	56.1	16.8	23.7	3.2	171.6
LSD (0.05)	2.7	0.6	0.4	1.6	4.2	24.4
Prob > F	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
CV (%)	6.3	0.6	1.2	3.7	74.9	7.9

¹Grain yield reported on a 13% moisture basis

²Grain protein reported on a 12% moisture basis

³Lodging due to sawfly cutting visually estimated at maturity

** Indicates highest numerical value within a column

* Indicates lines equal to the highest entry based on Fisher's Protected LSD at the 0.05 probability level

Table 8. Durum Seed Quality Evaluation I 16 location-years (2020-21).

ID	Test Weight ¹	Grain Protein ²	Grain Ash ³	Falling Number
	lb/bu	%	%	seconds
Mountrail	59.9	14.7	1.55	458.9
Grenora	60.3	14.5	1.57	464.9
Divide	60.5	14.5	1.50	450.4
Tioga	60.6	15.0	1.56	419.6
Carpio	59.7	14.9	1.55	454.5
Joppa	60.8	14.3	1.52	434.0
ND-Riveland	60.2	14.8	1.55	479.7
ND-Grano	60.9	14.7	1.54	444.1
Alzada ⁴	60.1	14.3	1.56	556.2**
CDC-Vivid	60.5	15.5*	1.54	458.2
Lustre	59.2	15.0	1.51	472.0
MTD18155	60.1	15.1	1.56	413.9
MTD16001	59.5	14.2	1.51	458.2
MTD16002	60.1	14.5	1.48	480.1
MTD18213	58.7	15.0	1.59*	498.1
MTD18486	60.8	14.6	1.56	447.2
MTD18413	60.3	15.1	1.52	415.6
MTD18348	60.5	14.8	1.56	481.6
MTD18091	60.1	14.8	1.55	446.9
MTD18430	58.6	15.1	1.60*	492.6
MTD18179	58.2	15.6*	1.56	455.7
MTD18172	61.4	15.1	1.52	414.2
MTD18067	59.9	14.5	1.55	411.3
MTD18381	59.9	14.9	1.57	459.5
MTD18181	60.3	15.6**	1.54	448.5
MTD18256	60.2	15.2	1.61**	463.8
MTD18217	60.1	14.7	1.56	454.7
MTD18266	61.1	15.3*	1.57	462.4
MTD18148	60.3	14.9	1.55	526.2
MTD18313	62.1**	14.8	1.53	449.9
Average	60.2	14.9	1.55	459.1
LSD (0.05)	0.5	0.4	0.04	21.7
Prob > F	<0.001	<0.001	<0.001	<0.001
CV (%)	1.2	3.7	3.2	6.5

¹n=15

²Grain protein reported on a 12% moisture basis

³Grain ash reported on a 14% moisture basis

⁴Alzada data n=8 (2020 only)

** Indicates highest numerical value within a column

* Indicates lines equal to the highest entry based on Fisher's Protected LSD at the 0.05 probability level

Table 9. Durum Seed Quality Evaluation II 16 location-years (2020-21).

ID	Large Seeds ¹	Small Seeds ¹	Hardness ^{1,2}	Individual Seed Weight ^{1,2}	Individual Seed Diameter ^{1,2}
	%	%		mg	mm
Mountrail	39.4	18.7*	72.4	38.3	2.76
Grenora	48.3	15.0	75.6	39.4	2.80
Divide	51.1	13.8	73.7	39.0	2.79
Tioga	54.9	12.7	71.8	40.4*	2.86
Carpio	50.9	14.3	73.3	37.9	2.76
Joppa	44.1	16.6*	73.9	39.3	2.78
ND-Riveland	56.1	10.9	71.9	40.9*	2.83
ND-Grano	44.0	17.5*	74.4	37.8	2.76
Alzada³	64.0*	10.3	70.8	41.8**	2.96**
CDC-Vivid	55.0	12.2	77.2	38.1	2.77
Lustre	37.7	17.6*	74.0	37.7	2.74
MTD18155	56.7	10.9	76.5	38.3	2.85
MTD16001	41.1	17.9*	75.7	37.6	2.74
MTD16002	40.9	17.5*	80.1*	35.6	2.73
MTD18213	52.1	15.0	70.2	39.4	2.74
MTD18486	64.5*	9.2	76.4	39.0	2.83
MTD18413	59.2	10.2	73.0	39.4	2.81
MTD18348	65.3**	8.1	73.3	41.0*	2.89
MTD18091	42.8	19.0**	75.8	36.3	2.72
MTD18430	47.7	14.5	75.0	37.8	2.74
MTD18179	43.2	17.3*	77.8	35.8	2.71
MTD18172	62.1*	8.9	75.2	40.3	2.87
MTD18067	48.9	13.7	73.3	40.6*	2.83
MTD18381	49.8	13.0	75.8	37.8	2.81
MTD18181	49.0	13.2	77.3	37.9	2.79
MTD18256	53.0	12.5	75.7	38.9	2.82
MTD18217	62.0*	9.7	71.4	40.0	2.83
MTD18266	55.3	10.6	77.0	39.8	2.83
MTD18148	47.3	14.3	79.8*	37.5	2.79
MTD18313	55.3	11.7	80.5**	37.1	2.83
Average	51.4	13.6	75.0	38.7	2.80
LSD (0.05)	4.7	2.7	1.8	1.1	0.04
Prob > F	<0.001	<0.001	<0.001	<0.001	<0.001
CV (%)	12.7	27.6	3.3	4.1	2.2

¹n=15

²Determined using the single kernel characterization system

³Alzada data n=8 (2020 only)

** Indicates highest numerical value within a column

* Indicates lines equal to the highest entry based on Fisher's Protected LSD at the 0.05 probability level

Table 10. Durum Semolina Quality Evaluation I 16 location-years (2020-21).

ID	Bran ¹	Shorts ¹	Semolina ¹	Semolina Protein ²	Semolina Ash ²
	%	%	%	%	%
Mountrail	26.7	12.1	61.2*	13.6	0.66
Grenora	27.8	12.7	59.5	13.1	0.65
Divide	27.0	12.1	60.8	13.2	0.62
Tioga	26.4	12.1	61.5*	13.6	0.63
Carpio	27.1	12.9	60.0	13.5	0.66
Joppa	26.6	12.2	61.2*	13.0	0.63
ND-Riveland	28.7**	13.4	57.9	13.2	0.64
ND-Grano	26.6	12.0	61.4*	13.3	0.63
Alzada³	25.0	14.1**	60.9*	13.0	0.68**
CDC-Vivid	27.0	13.5	59.5	14.0*	0.68*
Lustre	27.0	12.8	60.2	13.7	0.65
MTD18155	27.2	12.7	60.1	13.7	0.63
MTD16001	26.9	12.4	60.7	12.9	0.62
MTD16002	27.6	12.5	59.8	13.3	0.61
MTD18213	28.5*	12.5	59.0	13.7	0.67
MTD18486	27.9	13.1	58.9	13.2	0.68
MTD18413	28.3*	12.2	59.5	13.6	0.63
MTD18348	26.6	12.5	60.9*	13.1	0.66
MTD18091	27.2	12.3	60.5	13.6	0.67*
MTD18430	28.0	13.3	58.7	13.9*	0.68*
MTD18179	28.5*	13.0	58.5	14.2**	0.64
MTD18172	26.3	12.4	61.2*	13.7	0.60
MTD18067	26.6	11.9	61.5*	13.3	0.65
MTD18381	25.9	12.6	61.5**	13.5	0.66
MTD18181	27.7	12.0	60.3	14.0*	0.58
MTD18256	27.4	13.0	59.6	13.7	0.67*
MTD18217	26.3	12.5	61.2*	13.3	0.65
MTD18266	26.7	13.5	59.7	13.9*	0.66
MTD18148	26.6	13.7*	59.7	13.7	0.67*
MTD18313	26.0	12.9	61.1*	13.2	0.61
Average	27.1	12.7	60.2	13.5	0.65
LSD (0.05)	0.5	0.3	0.7	0.4	0.07
Prob > F	<0.001	<0.001	<0.001	<0.001	<0.001
CV (%)	2.8	3.6	1.6	4.1	3.9

¹Milling fractions from Quadramat Brabender Jr. milling separated with a U.S. #35 sieve

²Semolina protein and ash reported on a 14% moisture basis

³Alzada n=8 (2020 only)

** Indicates highest numerical value within a column

* Indicates lines equal to the highest entry based on Fisher's Protected LSD at the 0.05 probability level

Table 11. Durum Semolina Quality Evaluation II 16 location-years (2020-21).

ID	CIELAB Color Space ¹			Mix Time	Max Integral Peak ²	Gluten Index ³
	L*	b*	a*	Minutes	%TQ	
Mountrail	85.0	26.9	-2.65**	2.2	102.5	34.2
Grenora	85.0	30.2	-3.04	3.0	142.3	64.7
Divide	84.9	28.8	-2.82	3.3	154.6	78.5
Tioga	84.7	30.5	-2.94	3.7	175.9	84.0
Carpio	84.7	31.7	-3.23	4.2	217.0	97.2*
Joppa	84.8	31.2	-3.02	3.9	177.3	88.7
ND-Riveland	84.8	31.4	-3.16	4.0	201.7	92.5*
ND-Grano	84.9	31.6	-3.25	3.3	159.0	82.7
Alzada ⁴	84.2	31.8	-2.84	4.0	206.6	97.9**
CDC-Vivid	84.2	32.8	-2.97	5.1**	228.8*	90.0*
Lustre	84.6	29.7	-2.70*	3.2	150.7	64.2
MTD18155	84.8	28.5	-2.80	3.9	172.0	72.0
MTD16001	84.9	29.4	-2.87	3.2	157.9	69.2
MTD16002	84.7	28.8	-2.83	2.8	132.3	48.7
MTD18213	84.4	33.7**	-3.27	3.3	167.0	82.5
MTD18486	84.5	32.9	-3.18	4.7	232.9**	94.2*
MTD18413	84.9	28.5	-2.83	3.5	169.7	86.2
MTD18348	84.7	31.8	-3.16	4.6	228.8*	96.0*
MTD18091	84.9	30.8	-3.19	3.3	164.7	87.0
MTD18430	84.7	31.0	-3.22	3.8	197.9	90.5*
MTD18179	84.3	32.2	-3.03	4.5	209.7	85.2
MTD18172	85.3**	27.1	-2.84	2.8	126.1	59.0
MTD18067	85.0	29.2	-2.94	3.4	163.1	86.0
MTD18381	84.8	30.6	-3.09	3.4	154.7	68.7
MTD18181	84.6	31.9	-3.05	3.9	193.7	89.0
MTD18256	84.5	31.1	-3.00	4.3	203.5	82.7
MTD18217	84.8	31.7	-3.25	4.5	222.9*	95.5*
MTD18266	84.8	29.8	-2.99	3.3	158.2	69.7
MTD18148	84.2	31.9	-2.86	4.3	204.0	95.0*
MTD18313	84.6	29.4	-2.77	3.9	172.2	71.8
Average	84.7	30.6	-2.99	3.7	178.3	80.1
LSD (0.05)	0.2	0.5	0.089	0.2	12.5	7.7
Prob > F	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CV (%)	0.3	2.5	4.2	8.4	9.9	6.7

¹CIELAB color space L*=whiteness, b*=yellowness, a* =redness

²Mixograph midline analysis

³Data from two environments only

⁴Alzada n=8 (2020 only)

** Indicates highest numerical value within a column

* Indicates lines equal to the highest entry based on Fisher's Protected LSD at the 0.05 probability level

Table 12: Durum Fusarium Head Blight Evaluation 2021 (Dr. Frankie Crutcher, EARC, Sidney, MT).

ID	Severity ¹ %	Incidence ² %	Index ³	FDK ⁴ %	Yield bu/ac
Mountrail	34.8 AB	92.2	32.3 AB	16.7 AB	31.4 AB
Grenora	21.6 B	72.2	15.8 B	10.0 B	32.0 AB
Divide	28.4 AB	88.9	25.3 AB	21.7 AB	33.7 AB
Tioga	21.6 B	85.6	18.8 AB	15.0 AB	36.0 AB
Carpio	26.7 AB	83.3	22.3 AB	25.0 AB	37.5 AB
Joppa	19.9 B	81.1	16.3 B	18.3 AB	43.0 AB
ND-Riveland	15.1 B	83.3	12.6 B	16.7 AB	46.0 A
ND-Grano	18.9 B	82.2	16.2 B	13.3 AB	36.1 AB
CDC-Vivid	33.9 AB	94.4	32.1 AB	26.7 AB	32.8 AB
Lustre	27.4 AB	75.6	21.9 AB	16.7 AB	31.9 AB
MTD18155	25.8 AB	90	23.9 AB	16.7 AB	35.3 AB
MTD16001	26.3 AB	82.2	22.3 AB	11.7 AB	35.5 AB
MTD16002	28.6 AB	78.9	22.9 AB	18.3 AB	33.6 AB
MTD18213	22.9 B	80	18.7 AB	23.3 AB	40.3 AB
MTD18486	20.0 B	78.9	16.3 B	33.3 AB	27.2 AB
MTD18413	17.1 B	78.9	13.7 B	21.7 AB	40.6 AB
MTD18348	23.4 B	86.7	20.3 AB	26.7 AB	35.2 AB
MTD18091	24.0 B	88.9	21.4 AB	21.7 AB	37.1 AB
MTD18430	23.0 B	71.1	16.5 B	36.7 AB	31.1 AB
MTD18179	34.7 AB	90	31.4 AB	26.7 AB	35.6 AB
MTD18172	34.3 AB	90	31.1 AB	30.0 AB	24.5 AB
MTD18067	23.6 B	88.9	20.9 AB	35.0 AB	27.6 AB
MTD18381	49.0 A	88.9	43.4 A	20.0 AB	23.4 AB
MTD18181	28.8 AB	86.7	25.0 AB	25.0 AB	23.6 AB
MTD18256	20.6 B	82.2	16.9 B	16.7 AB	33.9 AB
MTD18217	13.5 B	70	9.7 B	23.3 AB	36.1 AB
MTD18266	17.9 B	76.7	14.0 B	25.0 AB	38.6 AB
MTD18148	27.8 AB	86.7	25.1 AB	28.3 AB	21.5 B
MTD18313	27.2 AB	90	24.8 AB	43.3 A	32.4 AB
Average	25.2	83.5	21.6	22.5	33.5
Prob > F	<0.001	0.160	0.001	0.030	0.040
CV (%)	37	12	44.1	50.9	25.2
HSD (5%)⁵	23.5	N/A	25.1	32.7	24.4

¹Pest Severity: Average percent area of head covered by disease. Thirty heads were evaluated per plot

²Pest Incidence: Percent of thirty plants per plot that had visible FHB symptoms

³Index: Severity X Incidence / 100

⁴Percent of Fusarium diseased kernels

⁵Letters in common did not differ significantly using a Tukey's HSD test at a significance level of 5%

Table 13. Durum Stem Rust Evaluation 2021 (Dr. Li Huang, MSU, Bozeman, MT).

ID	Infection Type¹	Level of Reaction
Mountrail	;	R
Grenora	;1=	R
Divide	1=1C	R
Tioga	1=	R
Carpio	;	R
Joppa	1=~2C	R~MR
ND-Riveland	1=	R
ND-Grano	;	R
CDC-Vivid	1=1+C	R
Lustre	1=1+C	R
MTD18155	1=2C	R
MTD16001	1=	R
MTD16002	2-C	MR
MTD18213	;1+C	R
MTD18486	1=	R
MTD18413	1=C	R
MTD18348	1-	R
MTD18091	1=	R
MTD18430	1-C~2C	R~MR
MTD18179	1=C	R
MTD18172	1 2 C	R
MTD18067	1=C	R
MTD18381	1-2+C	R
MTD18181	2C	MR
MTD18256	2 3-C	MS
MTD18217	1-C	R
MTD18266	1 2 C	MR
MTD18148	1-C	R
MTD18313	1-C	R

¹Inoculated with *Puccinia graminis* isolate TPMKC on 4/19/2021 scored 5/3/2021. 0 = immune (R), “;” = Very Resistant (VR), 1=Resistant (R), 2 = Moderately resistant (MR), 3 = Moderately susceptible (MS), 4 = Susceptible (S), Chlorosis (C). Variations are given by + and = to indicate more or less than usual

Table 14. Durum Fungal Leaf Spot Evaluation 2021 (Dr. Zhaohui Liu, NDSU, Fargo, ND).

ID	Ptr ToxA ¹	Ptr Race 1 ²	Ptr Race 5 ²	Sn4
Mountrail	ND	3.0	2.0	2.0
Grenora	1	3.0	2.0	2.0
Divide	1	2.5	1.5	3.0
Tioga	1	1.5	1.5	1.0
Carpio	1	2.0	1.5	2.5
Joppa	1	3.5	3.5	3.0
ND-Riveland	0	2.5	2.5	2.0
ND-Grano	1	2.5	2.0	3.0
CDC-Vivid	1	1.5	1.0	3.5
Lustre	1	1.0	1.0	2.5
MTD18155	1	2.0	1.0	2.0
MTD16001	0	3.5	2.5	1.5
MTD16002	0	1.5	2.5	1.5
MTD18213	1	2.0	1.0	2.5
MTD18486	1	3.5	3.0	1.0
MTD18413	ND	1.5	1.5	2.5
MTD18348	1	1.0	3.0	2.0
MTD18091	1	2.5	2.5	2.0
MTD18430	0	1.0	ND	1.0
MTD18179	ND	1.0	ND	1.0
MTD18172	1	3.0	3.0	2.5
MTD18067	1	2.0	1.5	2.5
MTD18381	1	1.5	3.0	2.0
MTD18181	ND	ND	ND	3.0
MTD18256	1	2.5	2.5	3.0
MTD18217	1	2.5	1.5	3.0
MTD18266	0	2.0	2.5	1.0
MTD18148	1	2.0	3.5	2.0
MTD18313	1	1.0	2.0	1.0
Salamouni (check)	0	1.5	1.0	1.0
Glenelea (check)	1	4.0	2.5	4.0

¹*P. tritici-repentis* (Ptr) ToxA: 0=insensitive; 1=sensitive, ND=no data. ToxA sensitivity is conferred by wheat *Tsn1*

²Evaluation with Ptr races 1 (predominant in North Dakota) and 5 using a 0-5 scale, 1,2=resistant, 3=moderately susceptible, 4, 5=highly susceptible, ND=no data

³Evaluation with *Septoria nodorum* isolate Sn4 (predominant in North Dakota) using 0-5 scale, 0-2=resistant, 3=moderately susceptible, 4,5=highly susceptible

Table 15. Durum Stripe Rust Evaluation 2021 (Dr. Xianming Chen, USDA-ARS, Pullman, WA).

ID	MOUNT VERNON ²			
	5/26		6/22	
	Fks 3 ³		Fks 10.53 ³	
	IT ¹	%	IT ¹	%
Mountrail	8	80	2	15
Grenora	8	70	2	10
Divide	5	40	2	10
Tioga	5	40	2	15
Carpio	5	40	2	15
Joppa	8	70	3	20
ND-Riveland	5	40	3	20
ND-Grano	5	40	2	10
CDC-Vivid	5	40	2	10
Lustre	5	40	2	10
MTD18155	8	70	3	20
MTD16001	8	70	3	20
MTD16002	5	30	2	10
MTD18213	5	40	2	10
MTD18486	5	40	2	5
MTD18413	8	70	5	30
MTD18348	5	40	5	30
MTD18091	8	70	5	30
MTD18430	8	70	2	10
MTD18179	5	40	2	5
MTD18172	5	40	2	5
MTD18067	5	40	3	20
MTD18381	5	30	3	20
MTD18181	5	30	2	5
MTD18256	8	70	2	5
MTD18217	8	70	2	5
MTD18266	8	70	2	10
MTD18148	8	80	3	20
MTD18313	8	80	8	80
Alzada (2018)	5	40	2	15
Alzada (2019)	5	40	2,8	5,80
Check	9	80	9	100
Check	9	80	9	100

¹Infected with naturally occurring *Puccinia striiformis*. 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, 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

²Entries with a high IT in the first note, but a low IT in the second note at Mt. Vernon may indicate that they have high-temperature, adult-plant (HTAP) resistance

³Feekes (Fks) scale for wheat growth stages. 3=late tillering, 10.53=flowering