

MEMORANDUM

FROM: Mike Giroux and Andrew C. Hogg
DATE: 1/19/2022
RE: Motion for Release of MTD18313 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,
- 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
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Crop Science

Entomology

Horticulture

Plant Biology

Plant Genetics

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PEDIGREE

Alkabo/Brigade//Alzada/Strongfield

- **'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'- Agriculture and Agri-Food Canada (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>

- **‘Alkabo’- North Dakota State University, 2005**

‘Alkabo’ was tested as the experimental line D96604 selected from the cross D901247/D89263 made in 1992. Alkabo is high yielding and has moderate protein strength and normal cadmium content.. The parent D901247 was derived from the cross D81154/‘Renville’ (PI 510696)/LDN(Dic-5B). The pedigree of D81154 is PI19571/‘Ward’(CI 15892). LDN(Dic-5B) is a substitution line of ‘Langdon’ (CI 13165) with chromosome 5B of *Triticum dicoccoides* accession FA-15-3 (Joppa and Cantrell, 1990). D89263 was derived from the cross ‘Fjord’/D8194.

Elias, E.M. and Manthey F.A. Registration of ‘Alkabo’ Durum Wheat. 2007. Journal of Plant Registrations, 1:10-11. <https://doi.org/10.3198/jpr2006.05.0279crc>

SELECTION HISTORY

MTD18313 is an offspring of a four-way cross between the cultivars Alzada, Strongfield, Brigade, and Alkabo. In 2015, Strongfield was crossed to Alzada and Brigade was crossed with Alkabo. In early spring of 2016, the Alzada/Strongfield x Alkabo/Brigade 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, 231 Alzada/Strongfield//Alkabo/Brigade 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, MTD18313 was included in the Bozeman Durum Preliminary Yield Trial which consisted of 550 F_{5.7} entries. Each entry was grown as 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. Relative to the semi-dwarf check, Alzada, MTD18313 had a 27% yield increase in Bozeman, MT averaged across the dryland and irrigated trials with similar protein content and maturity date. For this reason, MTD18313 was advanced for statewide testing in 2020. A bulk DNA sample from F_{5.8} greenhouse plants was genotyped for *cdul* and *lpxbl.2* and MTD18313 was determined to carry the normal cadmium accumulation allele and the low lipoxygenase activity allele. In 2020, MTD18313 (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, dryland and off-stations), CARC (dryland), and NARC (dryland and off-stations), and in Conrad, MT (2nd Nature LLC.). In 2020, MTD18313 (64.0 bu/ac) was the second highest yielding line averaged over all on-station dryland locations (including Conrad) second behind MTD18348 (64.5 bu/ac). MTD18313 was the highest yielding line at SARC, NARC and the Second Nature Research, LLC trial in Conrad, MT and had the highest test weight of all lines tested at every on-station dry location. Seed of MTD18313 (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 no private trials were planted. In 2021, MTD18313 had the highest test weight out of all the lines tested at every location, which was encouraging given the extreme drought experienced across the state this year. MTD18313 was the highest yielding line at the Chester, MT off-station trial and the second highest yielding at the Loring, MT off-station trial. Where sawfly activity was high (NARC, 2021) MTD18313 had excellent sawfly tolerance relative to currently grown cultivars (<2% cutting due to sawfly). MTD18313 was selected for varietal release for its high yield potential, particularly in Northcentral Montana, high test weight across dryland environments and under drought conditions, semi-dwarf height, early heading and maturity, tolerance to fungal leaf spot disease, and standability in sawfly areas.

PURIFICATION OF SEED STOCK

MTD18313 was developed using the single seed descent method from 2016-2018. A single F₅ head was harvested from the greenhouse and F₆ 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 in Bozeman for seed increase. Harvested F_{5:9} seed was then planted (0.2-acre) in Fall of 2020 in Yuma Arizona for increase. This F_{5:9} field was rogued throughout the growing season and was harvested using a combine that had been cleaned prior. MTD18313 (F_{5:10}) was increased as breeder's seed in 2021 in Bozeman, MT using the seed grown in Yuma, AZ. A 1-acre field of breeder's seed was planted, and the field was rogued multiple times throughout the year to remove any contaminants and off-types. Seed from the breeder's increase plot was harvested with a clean combine by MSU foundation seed. Foundation seed (F_{5:11}) 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

MTD18313 is a semi-dwarf spring durum wheat (*Triticum turgidum* ssp. *durum*) developed at MSU that is approximately 25 inches tall under dryland conditions like Alzada but is significantly shorter than full height varieties (Table 2). MTD18313 has white glumes and awns and has a heading date of June 24th similar to Alzada but 4 days earlier than Joppa and 5 days earlier than ND-Riveland (Table 2).

MTD18313 also matures approximately 5-6 days earlier than Joppa and ND-Riveland (data not shown). Averaged over all dryland locations (2020-21, 12 loc-year, no off-station) MTD18313 (52.8 bu/ac) was one of the highest yielding entries with yield comparable to ND-Riveland (52.5 bu/ac) (Table 2). Under all locations and conditions (2020-21, 16 loc-year, no off-station) MTD18313 (65.1 bu/ac) had yield equal to the top yielding cultivars Divide, Tioga, Carpio, Joppa, and ND-Riveland (Table 3). In comparison to Alzada in 2020, MTD18313 yielded almost 10% more over all dryland locations (n=6) and 6% higher than Divide, Joppa, Caprio, and Tioga (Table 3). Under irrigated conditions (n=2) MTD18313 (111.5 bu/ac) yielded 11% more than Alzada (100.0 bu ac.) in 2020. MTD18313 was the highest yielding line at the Conrad location, NARC, and SARC in 2020 (Table 4). MTD18313 was the highest yielding line at the Chester, MT off-station trial with the largest test weight (Table 5) and the second highest yielding with the largest test weight at the Loring, MT off-station trial (Table 6) in 2021. In 2021 at NARC MTD18313 showed low incidence of lodging due to wheat stem sawfly (<3%), had yield equal to top grown cultivars, and had the highest test weight (Table 7).

QUALITY CHARACTERISTICS

Average over two years and all locations, MTD18313 had grain protein content (14.8%) and grain ash (1.53%) comparable to top grown lines but had a significantly higher test weight (62.1 lb/bu) than all the lines tested (Table 8). Compared to the top grown cultivars Divide, Carpio, and ND-Riveland, MTD18313 had an average percent of large seeds (55.3%), a low percent of small seeds (11.7%), a smaller individual seed weight (37.1 mg), and the hardest seeds (80.5) (Table 9). MTD18313 had a semolina yield (61.1%) comparable to Joppa and Alzada but significantly higher than Divide and ND-Riveland (Table 10). Semolina from MTD18313 had similar protein (13.2%) and ash content (0.61%) as top grown cultivars (Table 10). MTD18313 had gluten strength (Gluten Index=72) similar to Divide (78) but not as strong as the other top grown cultivars Joppa, Alzada and ND-Riveland (Table 11). MTD18348 had semolina that is yellower (b*=29.4) than Divide but less than Joppa, Carpio, Alzada, and ND-Riveland (Table 11). MTD18313 carries a DNA marker associated with low lipoxygenase activity that enhances pasta color retention.

DISEASE EVALUATIONS

Fusarium head blight susceptibility was evaluated in 2021 at EARC and MTD18313 performed similarly as top grown cultivars in terms of severity, index, and fusarium damaged kernels having moderate susceptibility (Table 12). MTD18313 was found to be resistant to the most prevalent stem rust race in Montana TCMLK (Table 13). MTD18313 was evaluated for leaf spot caused by *Stagonospora nodorum* and *Pyrenophora tritici-repentis* and was found to be resistant to both races of Ptr and the predominant race of Sn while having sensitivity to ToxA (Table 14). MTD18313 was evaluated for resistance/susceptibility to stripe rust in 2021 at Mt. Vernon, WA and had a susceptible reaction at both the seedling stage (8) and the adult stage (8) (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.

MTD18313 Traits of Interest

- High yield potential under dryland environments
- Early heading and maturity
- Consistent very high test weight under dryland environments
- Normal cadmium content
- Fungal leaf spot tolerance
- Sawfly tolerance/straw strength
- Good semolina quality, average protein strength, pasta color retention trait

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

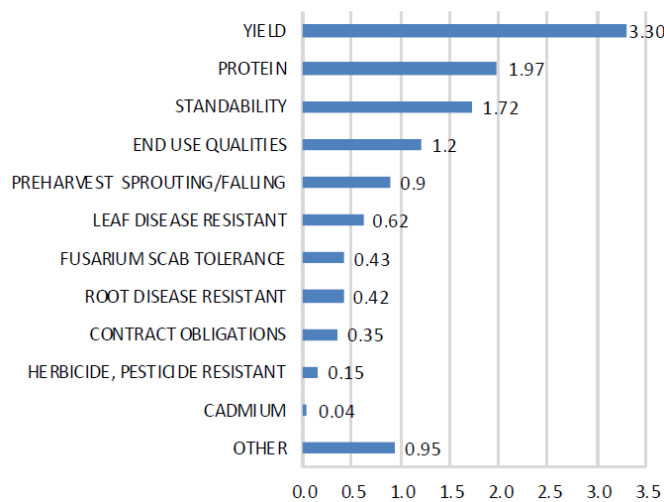


Figure 1. Durum wheat trait index where growers were asked to rank traits in order of importance when choosing a wheat variety for 2021 where 5.00 is the highest and 1.00 is the lowest (from the 2021 MWBC wheat variety survey conducted by the National Agricultural Statistics Service).

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

ID	Yield¹	Test Weight	Protein²	Plant Height	Heading Date
	bu/ac	lb/bu	%	Inches	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 (lowest for heading)

* Indicates lines equal to the highest entry based on Fisher's Protected LSD at the 0.05 probability level (lowest for heading)

Table 3. Yield Evaluations from 2020-21 State Durum Trials 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. Yield Evaluation from SARC, Conrad, and NARC 2020 State Durum Trials.

ID	Yield (bu/ac) ¹		
	SARC	Conrad	NARC
Mountrail	74.8	50.4	56.4*
Grenora	70.8	47.4	51.1
Divide	74.5	49.5	55.2*
Tioga	79.3	46.6	52.9
Carpio	74.3	43.4	48.7
Joppa	78.4	41.5	54.2
ND-Riveland	71.6	49.6	53.4
ND-Grano	77.2	41.6	50.9
Alzada	63.4	57.5*	57.3*
CDC-Vivid	68.2	47.8	54.6
Lustre	78.4	44.4	54.4
MTD18155	66.0	56.5*	58.6*
MTD16001	64.3	51.4	57.1*
MTD16002	73.6	50.5	60.5*
MTD18213	70.8	41.1	49.1
MTD18486	66.3	50.8	50.4
MTD18413	71.3	49.4	53.4
MTD18348	76.1	51.9	55.4*
MTD18091	72.9	47.5	48.5
MTD18430	68.3	49.5	48.9
MTD18179	77.0	54.3*	48.6
MTD18172	77.6	48.3	57.1*
MTD18067	74.2	43.1	57.5*
MTD18381	67.3	46.9	47.2
MTD18181	69.8	44.3	49.0
MTD18256	64.6	46.1	51.1
MTD18217	69.6	46.2	45.8
MTD18266	77.0	49.0	49.1
MTD18148	75.3	53.7	53.5
MTD18313	80.2**	62.1**	61.0**
Average	72.4	48.7	53.0
LSD (0.05)	11.8	8.1	6.4
Prob > F	0.132	<0.001	<0.001
CV (%)	9.3	9.1	7.4
Lattice RE (%)²	111	145	100

¹Grain yield reported on a 13% moisture basis

²Adjusted means provided for Lattice RE% values equal to or greater than 100%

** 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 Loring Dryland Off-station 2021 State Durum Trial.

ID	Yield¹	Test Weight	Protein²	Plant Height	Sawfly³	Falling Number
	bu/ac	lb/bu	%	inches	%	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 6. Agronomic Data Chester Dryland Off-station 2021 State Durum Trial.

ID	Yield¹	Test Weight	Protein²	Plant Height	Sawfly³	Falling Number
	bu/ac	lb/bu	%	inches	%	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 7. Agronomic Data NARC Dryland 2021 Durum Variety Trial.

ID	Yield ¹	Test Weight	Protein ²	Plant Height	Sawfly ³	Heading Date ⁴	Falling Number
	bu/ac	lb/bu	%	Inches	%	Julian	Seconds
Mountrail	23.5	57.3	17.3	25.5	30.0*	175.7	443.3
Grenora	21.4	57.1	17.3	24.8	25.0	174.3	461.4
Divide	24.4	57.6	17.4	28.2*	20.0	175.0	452.7
Tioga	21.4	57.3	18.0	28.0*	21.7	174.3	519.7*
Carpio	24.8	55.3	17.7	25.3	15.0	177.3	491.1
Joppa	24.4	57.8	17.0	26.1*	21.7	175.0	454.3
ND-Riveland	26.0	57.3	16.6	26.7*	31.7*	174.7	499.6
ND-Grano	24.5	57.0	16.9	23.6	30.0*	176.7	434.1
CDC-Vivid	22.3	56.8	18.5*	25.5	5.3	175.3	510.9*
Lustre	23.9	55.5	17.9	25.6	18.3	175.7	483.5
MTD18155	22.6	56.5	18.1	22.6	3.7	175.3	428.1
MTD16001	22.0	56.9	17.4	25.5	13.3	175.7	480.6
MTD16002	31.1**	57.4	16.1	28.3**	10.0	176.7	487.4
MTD18213	21.1	54.4	18.6*	25.8	23.3	177.7	531.3
MTD18486	22.1	59.5*	17.1	25.5	1.0	178.7	484.5
MTD18413	21.7	56.5	17.9	25.0	30.0*	174.3	422.1
MTD18348	23.9	57.0	17.5	26.2*	10.0	176.3	520.6*
MTD18091	23.8	56.0	17.9	27.5*	16.7	176.3	468.2
MTD18430	25.6	54.3	17.6	27.6*	5.0	177.0	518.1*
MTD18179	21.3	54.9	19.1**	26.0*	5.0	175.7	487.3
MTD18172	30.4*	57.5	17.7	24.5	13.3	175.3	406.2
MTD18067	23.3	56.7	17.1	26.2*	31.7*	175.7	420.9
MTD18381	19.3	56.6	18.1	24.2	38.3**	173.7	430.6
MTD18181	21.7	57.1	18.5*	25.3	5.3	177.7	484.7
MTD18256	23.4	57.9	18.1	26.0*	15.0	176.3	495.6
MTD18217	22.0	57.6	17.7	24.6	5.3	178.0	496.4
MTD18266	24.6	58.5	17.9	26.7*	3.7	177.3	495.4
MTD18148	20.0	59.5*	17.2	21.0	11.7	174.7	530.4**
MTD18313	24.6	60.4**	17.4	21.5	2.3	172.3**	468.6
Average	23.4	57.1	17.6	25.4	16.6	175.8	474.6
LSD (0.05)	3.4	1.0	0.7	2.3	8.5	1.2	27.7
Prob > F	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<.001
CV (%)	8.7	1.1	2.3	5.5	31.0	0.4	3.5
Lattice RE % ⁵	100	100	100	100	100	100	100

¹Grain yield reported on a 13% moisture basis

²Grain protein reported on a 12% moisture basis

³Lodging due to sawfly cutting

⁴>50% of heads 100% out of boot

⁵Adjusted means provided for Lattice RE% values equal to or greater than 100%

** Indicates highest numerical value within a column (lowest for heading)

* Indicates lines equal to the highest entry based on Fisher's Protected LSD at the 0.05 probability level (lowest for heading)

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
Alzada⁴	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
Alzada ³	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 Brabender Quadramat Jr. milling separated with a U.S. #35 sieve

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

³ Alzada 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	0.0002	0.16	0.0013	0.03	0.04
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

¹Infecting 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