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AAC Warman Canada Western Red Spring wheat

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CULTIVAR DESCRIPTION

AAC Warman Canada Western Red Spring wheat

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Kumar et al. 2018. AAC Warman Canada Western Red Spring Wheat.

Abstract: AAC Warman (BW1025) is a high yielding Canada Western Red Spring (CWRS) wheat adapted to production in Western Canada. AAC Warman was 3% higher yielding than Unity, the highest yielding check in the Central Bread Wheat Cooperative registration trials (2014-2016). Within the same test, AAC Warman was 11% higher yielding than Carberry, a popular CWRS wheat variety across the Canadian prairies. AAC Warman matured 3 days earlier than Carberry and a day later than Unity, the earliest maturing check. AAC Warman was shorter than Unity and had better stem strength compared to Unity, however, the lodging score for AAC Warman was higher than the mean of the checks. Over three years of testing (2014-2016), the test weight and thousand kernel weight of AAC Warman was similar to Carberry. The grain protein content of AAC Warman was 0.3% lower than both Unity and Carberry. AAC Warman was rated moderately resistant to Fusarium head blight (*Fusarium graminearum* Schwabe), and loose smut [*Ustilago tritici* (Pers.) Rostr.], resistant to leaf rust (*Puccinia triticina* Erikss.) and stem rust (*Puccinia graminis* Pers. f. sp. tritici Eriks. & E. Henn), moderately susceptible to stripe rust (*Puccinia striiformis* Westend) and common bunt [*Tilletia caries* (DC) Tul. & C. Tul.], and intermediate resistant to the leaf spot complex. AAC Warman was resistant to orange wheat blossom midge (*Sitodiplosis mosellana* Géhin). Based on the milling and baking performance over three years (2014-2016) evaluated by the Grain Research Laboratory, Canadian Grain Commission, AAC Warman was registered under the CWRS market class.

Key words: *Triticum aestivum* L., CWRS, grain yield, quality, disease resistance, orange blossom wheat midge, *Fusarium* head blight, deoxynivalenol.

Introduction

The majority of hexaploid spring wheat grown in western Canada falls under the CWRS class (www.grainscanada.gc.ca). This is predominantly because of steady yields, optimum disease resistance, and excellent milling and baking attributes. The steady market demand for exports and its suitability as a rotation crop makes wheat the desirable cereal crop for farmers. With increasing global food demand, constantly changing pathogens and diminishing farming-worthy land, there is a need to make incremental genetic gains in wheat. For agricultural sustainability, continued efforts are needed to develop improved wheat varieties.

AAC Warman is a hard red spring wheat cultivar developed by the Agriculture and Agri-Food Canada (AAFC), Brandon Research and Development Centre, Brandon, Manitoba, Canada. It was granted Plant Breeders Rights on April 28, 2017 under the registration number 8449 by the Canadian Food Inspection Agency (CFIA). AAC Warman meets the end-use quality specifications of the Canada Western Red Spring (CWRS) class and is best adapted to the Canadian prairie growing conditions.

Pedigree and Breeding Methods

AAC Warman was derived from the cross of BB07A*A637/Kane. The female parent, BB07A*A637, was a DH line derived from the cross between Alsen (Frohberg et al. 2006) and 96B42-E3C, where Alsen is a hard red spring wheat variety and 96B42-E3C is a breeding line from the AAFC, Cereal Research Centre, Winnipeg, Manitoba (CRC). Alsen (ND 674/ND 2710/ND 688), released by the North Dakota Agricultural Experiment Station in 2000, was developed by incorporating the Fusarium head blight (FHB) resistance from Sumai 3 into an

adapted background that also had good stem and leaf rust resistance, yield, and quality characteristics. The male parent Kane (BW342) was derived from a cross between AC Domain and McKenzie (Fox et al. 2007). McKenzie hard red spring wheat is the first double haploid (DH) wheat cultivar registered in Canada (Graf et al. 2003). Kane is a hard red spring wheat with good pre-harvest sprouting resistance and high flour extraction rate. This complex cross was developed to generate a high-yielding, high-protein CWRS wheat variety adapted to the eastern Canadian prairies, with broad resistance to leaf and stem rust, improved resistance to *Fusarium* head blight (FHB), and resistance to the orange wheat blossom midge. AAC Warman tested positive for markers linked to genes *Lr21*, *Lr23*, *Sr7a*, *Sr9b-2*, *Yr61*, *Fhb4B* and *Sm1*. It also tested positive for the marker linked to gene *PHS-4A*, conferring post-harvest sprouting resistance similar to AC Domain.

AAC Warman was developed using the modified pedigree breeding method. The final cross for AAC Warman was made at the AAFC, CRC in 2007. In 2007-2008, a set of 30 F₁ seeds were grown in a pair of 1.5 m rows near Leeston, New Zealand. The F₂ seeds harvested from Leeston were grown near Portage la Prairie, MB as 3 m rows with 40 seeds per row. A set of 200 spikes was collected from each of the 3 m rows and tested for sprouting tolerance in rain simulators. The F₂-derived sprouting-tolerant lines were further selected based on yield/protein, disease resistance, and grain quality up to the F₆ generation. The F₆-derived heads were then tested in advanced yield trials at multi-locations and further testing was done based on disease and grain/flour quality attributes. Finally, the line BG48A0-3-3-16 was tested in the Central Bread Wheat Cooperative (CBWC) registration trials as BW1025 for three years (2014-2016). A detailed description of the breeding history and breeder seed development is given in Table 1.

Agronomic data collection

The CBWC registration trial consisted of 30 entries tested at up to 11 locations within Manitoba and Saskatchewan using a rectangular lattice design with 6 groups with 5 entries per group and 3 replicates. The agronomic check cultivars included in the CBWC are Unity, Glenn, Carberry and AAC Viewfield. The yield data from all three replicates were collected from all locations. The final plot yields at similar moisture content were converted to yield per unit area (kg/ha). Days to maturity was recorded as days from seeding to when seeds resisted denting by fingernail (16-18% moisture), and data from all the replicates were collected multiple times per week. The plant height was measured in centimeters from the ground to top of the spikes, excluding the awns after the extension growth had ceased. Lodging was recorded on a 1-9 scale where 1 was upright and 9 was completely lodged. Test weight was measured on cleaned grain samples and reported as kilograms per hectolitre. Kernel weight was measured using a minimum of 200 undamaged kernels and recorded as milligrams per kernel.

Disease testing

The line BW1025 was evaluated for disease reaction to leaf, stem, and stripe rust, FHB, common bunt, and loose smut in CBWC trials between the years 2014-2016. Field nurseries inoculated with either a macroconidial spore suspension (University of Manitoba, Carman) or corn spawn [Morden Research and Development Centre, Manitoba (MRDC)] inoculum, with an equal proportion of 4 isolates (M1-07-2/15ADON; M3-07-2/15ADON; M7-07-1/3ADON; M9-07-1/3ADON) of *Fusarium graminearum* Schwabe, was used to evaluate tolerance to FHB. The visual rating index (VRI = % incidence x % severity/100) was recorded as described by Gilbert and Woods (2006) and the ISD (Incidence Severity DON) rating was calculated as $(0.2 * \text{mean incidence} + 0.2 * \text{mean}$

severity + 0.6*mean DON). Reactions to leaf (*Puccinia triticina* Erikss.) and stem rust (*Puccinia graminis* Pers. f.sp. tritici Eriks. & E. Henn) diseases were assessed using the modified Cobb scale (Peterson et al. 1948) in inoculated field nurseries at MRDC. Experiments were also conducted in the greenhouse to evaluate seedling reactions to four leaf rust races, MBDS (12-3), MGBJ (74-2), TJBj (77-2), and MBRJ (128-1) (McCallum and Seto-Goh 2006), and six stem rust races, TMRTF (C10), RKQSC (C63), TPMKC (C53), RTHJF (C57), QTHJF (C25), and RHTSC (C20) (Fetch 2005; Jin et al. 2008). Natural field infections were used to assess the disease severity and reaction to stripe rust (*Puccinia striiformis* Westend) near Lethbridge, Alberta (Randhawa et al. 2012). Common bunt [*Tilletia caries* (DC) Tul. & C. Tul.] resistance was recorded at the Lethbridge Research and Development Centre, Lethbridge, Alberta, Canada using a composite of races L1, L16, T1, T6, T13, and T19, and planting inoculated seed into cold soil (Gaudet and Puchalski 1989; Gaudet et al. 1993). The reaction to loose smut (*Ustilago tritici* (Pers.) Rostr.) was assessed by inoculating wheat spikes with a composite of races T2, T9, T10, and T39 (Menzies et al. 2003) and rating the progeny plants grown in a greenhouse from the infected seeds. The reaction to midge (*Sitodiplosis mosellana*) feeding damage was assessed by visually inspecting the midge damaged kernels on mature spikes. Sixty spikes (20 spikes per replicate from three replicates) were collected per entry and were analyzed under a dissecting microscope for larval feeding damage symptoms. Based on type of damage, the entries were classified as resistant, susceptible, or undamaged.

Grain and flour quality evaluation

Evaluation of end-use quality was conducted by the Grain Research Laboratory (GRL) of the Canadian Grain Commission (CGC) in Winnipeg, Manitoba. Protein content and grade of the check cultivars were used as criteria to prepare composite samples from all test locations, which

were subsequently used in tests to measure grain protein (%), flour protein (%), protein loss (%), falling number (s), α -amylase activity (amylograph; BU), clean flour yield (%), flour yield (.50 ash;%), flour ash (%), starch damage (%), farinograph properties, and dough development properties using standard analytical methods as outlined in the Prairie Recommending Committee for wheat, rye and triticale operating procedures (Prairie Recommending Committee 2015).

The PROC MIXED module (SAS, version 9.4) with years, environments, and their interactions treated as random effects, and cultivar as a fixed effect, was used to generate least significant difference (LSD) for analyzing the improvements of AAC Warman over the check cultivars.

The end-use quality data are non-replicated observations within years.

Performance

The 2014-2016 CBWC registration trials had Unity (BW362) (Fox et al. 2010), Glenn (ND747) (Mergoum et al. 2006), Carberry (BW874) (DePauw et al. 2011) and AAC Viewfield (BW965) as the recommended checks. Based on 27 site-years of testing over three years, AAC Warman was higher yielding than Carberry (10%), Glenn (11%) and Unity (3%) (Table 2). Two years (2015-2016) of comparisons (20 sites) showed that AAC Warman was 8% higher yielding than AAC Viewfield.

AAC Warman matured 3 days earlier than Carberry and was earlier than all checks except Unity (Table 3). AAC Warman was 1 cm shorter in height and had better lodging resistance compared to Unity (Table 3). The test weight and kernel weight of AAC Warman were similar to Carberry (Table 3). Grain protein content of AAC Warman was 0.3 units lower than Unity and 0.6 units lower than Carberry in 2015-2016 (Table 3).

AAC Warman had adequate resistance to diseases prevalent in the Canadian prairies. AAC Warman was rated moderately resistant to FHB by the disease evaluation team of the Prairies Grain Development Committee. Over three years of testing (2014-2016), AAC Warman expressed mostly resistant reactions to FHB at Carman and Morden (Table 4). It consistently had lower deoxynivalenol (DON) levels compared to all the agronomy checks in the inoculated nurseries (Table 4). AAC Warman was resistant to the prevalent races of leaf and stem rusts but was moderately susceptible to stripe rust. It was also rated intermediate resistant to the “Ug99” family of stem rust (Table 5). AAC Warman was moderately resistant to loose smut, susceptible to bunt, and intermediate resistant to leaf spot diseases (Table 6). AAC Warman was also resistant to orange blossom wheat midge based on phenotypic data on midge tolerance and the presence of *Sml1* gene (Table 6).

Grain protein, milling, and flour baking properties of AAC Warman were tested by the GRL in Winnipeg, Manitoba, Canada. End-use quality assessment (AACC 2002) was done on a composite sample formulated from trial locations, with grain samples representative of the best hard red spring wheat grades available. A pre-determined quantity of final grain was made up by varying the proportion of grain from each location to achieve a final protein concentration approximating the average for the crop in the given year. AAC Warman met the milling and baking performance of the CWRS class of wheat. The grain protein (%) was similar to Unity and lower than other checks (Table 7). AAC Warman had lower protein loss compared to all other checks. Flour protein (%) was similar to Glenn and falling number was similar to Carberry. Amylograph (BU), clean flour yield (%), flour ash (%), and starch damage were higher than Carberry, whereas, flour yield (.05 ash, %) was lower than Carberry (Table 7). Water absorption measured on the farinograph directly relates to the amount of bread that can be produced from a given weight of wheat flour.

The farinograph absorption was similar to or higher than Carberry within the tested years (2014-2016), and dough stability was higher than the mean of the checks in 2014 and 2016 (Table 8). Baking quality was assessed using the Canadian short process (Preston et al. 1982) for 2014 and 2015 and the Lean No Time test (Dupuis and Fu, 2016) in 2016. AAC Warman loaf volume (cm³) was higher than the mean of the checks in 2014-15 and the loaf top ratio was better than all checks in 2016 (Table 8).

Other Characteristics

The morphological characteristics were recorded using experimental field plots grown in 2016 and 2017 at Saskatoon, SK.

Seedling characteristics

Coleoptile colour: absent or very weak

Juvenile growth habit: semi-erect to intermediate

Seedling leaves: medium to dark green, glabrous

Tillering capacity (at low densities): moderately high

Adult plant characteristics

Growth habit: semi-erect to intermediate

Flag leaf attitude: intermediate

Flag leaf: light to medium green, slightly curved to recurved, glabrous sheath and blade, slightly waxy blade, long and narrow width, glabrous margins

Culm: straight, glabrous, slight waxiness

Spike characteristics

Shape: erect and oblong.

Length: short.

Density: medium.

Attitude: erect.

Colour: tan at maturity.

Awns: awned.

Spikelet characteristics

Glumes: short length and medium to narrow width; glabrous; oblique to rounded shoulder shape; beak is medium in length with acuminate shape.

Lemma: slightly curved.

Kernel characteristics

Type: hard, light to medium red in colour.

Size: medium size, medium length, narrow to medium width; oval shape; rounded cheeks; medium to long brush hairs; narrow and medium deep crease.

Embryo: medium size, round.

Maintenance and Distribution of Pedigreed Seed

Breeder Seed of AAC Warman was produced using 250 random spikes from a rogued increase plot grown at Indian Head, SK, in 2016. Spikes were analysed for signs of midge damage and were discarded based on evidence of midge feeding. Two hundred and fifty lines were grown in isolation for breeder seed in 1-m rows with a 10 m isolation distance from any other wheat near Brandon in 2015. One hundred lines were removed due to non-uniform plant phenotype, low seed amounts, or piebald kernels. One hundred and fifty Breeder Seed rows were grown as 15-m-long rows maintaining a 10 m isolation distance from other wheat at Indian Head, SK, in 2016. An additional 67 rows were further discarded. The remaining uniform plots were inspected and bulk harvested, producing 150 kg of Breeder Seed. Multiplication and distribution of all other pedigreed seed classes will be handled by SeCan, Box 30, Elstow, SK S0K 1M0, Canada (www.secan.com). AAC Warman is a midge-resistant variety and to maintain the effectiveness of the *Sm1* gene against wheat orange blossom midge, the certified seed will include AAC Tisdale as a 10% interspersed susceptible refuge.

Contributions

S. Kumar performed selections and progression of lines to finally select AAC Warman (BW1025).

S. Kumar analysed the registration trial data, generated varietal identification data for Variety

Registration and Plant Breeders' Rights including the necessary documentation, and wrote the manuscript. The other authors contributed agronomic and disease evaluation data from the registration trials.

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Table 1. Population size and activities at each generation leading to the registration of AAC Warman (BW1025) hard red spring wheat

Name	Gen.	Year	Activity – Number of lines – Locations
BG48A	F ₀	2007	Final cross made in a growth cabinet.
BG48A	F ₁	2007-8	30 F ₁ seeds grown in a pair of 1.5m rows near Leeston, NZ.
BG48A-N	F ₂	2008	F ₂ seeds grown as 50, 3m rows, ~40 seeds/row grown near Portage, MB. 200 spikes were harvested for sprouting test at Indian Head, SK.
BG48A-NP	F _{2:3}	2008-9	200 selected lines were grown in Indian Head greenhouse.
BG48A-NP-3-I	F _{2:4}	2009	15 lines were grown in a 1m row nursery near Portage la Prairie, MB. Selection for agronomics, seed appearance, resistance to rusts and common bunt, protein concentration, flour yield, and mixograph.
BG48A-NP-3-IP-3	F _{2:5}	2009-10	57 lines were grown near PN, NZ as hills. Selection for agronomics and leaf rust resistance.
BG48A-NP-3-IP-3-N	F _{2:6}	2010	15 lines were tested in a single replicate yield test at one location (MB: Portage). Selections based on agronomic and disease parameters, 30 spikes harvested per selected line and sent as 1 spike/row to PN.
BG48A-NP-3-IP-3-NP-16	F _{6:7}	2010-11	28 lines were grown near PN in 1.5m rows. Selection for agronomics and leaf rust resistance as well as quality parameters from F ₆ seeds.
BG48A-NP-3-IP-3-NP-16	F _{6:8}	2011	9 lines were tested in unreplicated yield tests at two locations (MB: Brandon; SK: Saskatoon) Selection based on agronomics, disease resistance and quality.
BG48A-NP-3-IP-3-NP-16	F _{6:9}	2012	3 lines in the Central Bread Wheat “A” test. Yield test, two replicates at five locations (MB: Glenlea, Portage la Prairie, Brandon, Morden; SK: Indian Head).
BG48A-NP-3-IP-3-NP-16	F _{6:10}	2013	1 line in the Central Bread Wheat “B” test. Yield test, three replicates at eight locations (MB: Glenlea, Brandon, Morden; SK: Saskatoon, Indian Head, Melfort, Kernen; AB: Beaverlodge).
BW1025	F _{6:11-13}	2014-2016	1 line progressed to CBWC registration test. Yield test, three replicates at various locations/year (MB: Portage la Prairie, Brandon, Souris, Dauphin; SK: Indian Head, Pense, Kamsack, Melfort, Kernen). In 2014, Glenlea site was removed.
Breeder seed production			
BW1025	F _{6:11}		Breeder seed spikes: 250 random spikes were selected from a rogued increase plot grown at Indian Head, SK
BW1025	F _{6:12}		Breeder seed isolation rows: 250 lines were grown in 1 m rows grown near Brandon, MB with a 10m isolation distance from any other wheat.
BW1025	F _{6:13}		Breeder seed rows: 15m rows grown at Indian Head, SK with 10m isolation distance from other wheat. 150 rows were grown. Lines were rogued for uniformity and 67 lines were pulled. Approximately 150 kg of breeder was produced.

Note: Breeding history of AAC Warman (BW1025).

Table 2. Yield (kg ha⁻¹) of AAC Warman (BW1025) and check cultivars in the Central Bread Wheat Cooperative (2014-2016) tests.

Cultivar	Zone 1 ^a			Zone 2 ^b			All sites			
	2014	2015	2016	2014	2015	2016	2014-2016		2015-2016	
							kg ha ⁻¹	% Unity	kg ha ⁻¹	% Unity
Unity	5275	4645	3758	4861	3377	4754	4386	100	4166	100
Glenn	4536	4285	3661	4592	3184	4129	4043	92	3848	92
Carberry	4589	4342	3646	4415	3263	4350	4066	93	3910	94
AAC Viewfield	-	4574	3331	-	3454	4450	-	-	3973	95
AAC Warman	5352	4747	4027	5058	3257	5029	4522	103	4293	103
Mean of checks	4800	4462	3599	4623	3320	4421	4165	95	3974	95
^c LSD 0.05	618	530	416	484	385	491	434		538	
No. of tests	3	4	5	4	5	6	27		20	

Note: Table comparing yield performance of AAC Warman against the check varieties.

^aZone 1 test locations: 2014 - Brandon, Dauphin, Portage la Prairie; 2015 - Dauphin, Portage la Prairie, Souris; 2016 - Brandon, Souris, Morden, Neepawa, Fort Whyte.

^bZone 2 test locations: 2014 - Kernen, Indian Head, Melfort, Pense; 2015 - Kamsack, Kernen, Indian Head, Melfort, Pense; 2016 - Kamsack, Melfort, Pense, Indian Head, Kernen, Waldheim.

^cLSD, least significant difference appropriate to make comparisons of AAC Warman to Unity, Glenn, Carberry and AAC Viewfield; $p \leq 0.05$, includes the appropriate genotype $\times$ environment interaction.

Table 3. Summary of agronomic traits of AAC Warman (BW1025) and check cultivars in the Central Bread Wheat Cooperative (2014–2016) tests.

Cultivar	Maturity (d)		Height (cm)		Lodging ^a (1-9)		Test weight (kg hL ⁻¹)		Kernel weight (mg kernel ⁻¹)		Protein (%)	
	2014-2016	2015-2016	2014-2016	2015-2016	2014-2016	2015-2016	2014-2016	2015-2016	2014-2016	2015-2016	2014-2016	2015-2016
Unity	92	92	98	94	3.0	2.9	78	77	31.5	31.5	15.0	15.1
Glenn	95	94	91	89	1.8	1.7	80	80	31.9	31.9	14.9	15.2
Carberry	96	95	84	83	1.7	1.8	78	77	31.9	31.9	15.0	15.4
AAC Viewfield	-	95	-	78	-	1.5	-	77	-	29.7	-	15.5
AAC Warman	93	93	97	95	2.6	2.6	78	78	31.9	31.8	14.7	14.8
Mean of checks	94	94	91	86	2.2	2.0	79	78	31.8	31.4	15.0	15.2
^b LSD 0.05	1.9	1.5	4.6	3.6	1.0	1.0	-	-	-	-	-	-
No. of tests	26	19	26	18	19	15	27	19	27	19	27	19

Note: Table comparing agronomic performance of AAC Warman against the check varieties.

^aLodging scale: 1 = vertical, 9 = flat.

^bAppropriate LSD to make comparisons of AAC Warman to Unity, Glenn, Carberry, and AAC Viewfield. $p \leq 0.05$, includes the appropriate genotype by environment interaction.

Table 4. *Fusarium* head blight VRI^a, DON^b and ISD^c for AAC Warman (BW1025) and check cultivars in the Central Bread Wheat Cooperative (2014-2016) tests.

Cultivar	Carman FHB									PEI FHB	
	2014			2015			2016			2014	
	VRI	DON	ISD	VRI	DON	ISD	VRI	DON	ISD	VRI	DON
Unity	25.9 I	6.6	6.1MR	31.5 I	12	9.6	23.3 I	11.2	8.8	35	17.3
Glenn	3.2 R	9.2	6.6 I	3.9 R	12	8.3	9 R	8	6.4	43.7	15.5
Carberry	20.2 I	8.6	7.2I	15.1 MR	9.5	7.6	11.8 MR	17.2	12	50	14
AAC Viewfield	-	-	-	21.5 I	15	11.1	31.8 MS	43.5	28.6	-	-
AAC Warman	3.8 R	9.5	7.0 I	6.6 R	8.6	6.5	7.4 R	7.2	5.8	42.7	14.3

Cultivar	Morden FHB									Ottawa FHB	
	2014			2015			2016			2014	
	VRI	DON	ISD	VRI	DON	ISD	VRI	DON	ISD	VRI	DON
Unity	64.0 S	43.7	29.4 MR	50.0 I	18.3	13.8MR	41.2 MR	25.5	18.0 MR	43	14.4
Glenn	47.5 I	36.9	25.0 MR	32.0 MR	23.5	16.4MR	12.9 R	17.6	12.5 R	28	15.6
Carberry	38.3 I	40.7	27.0 MR	41.0 MR	15.2	11.8MR	39.8 MR	22.1	15.9 MR	35	17.2
AAC Viewfield	-	-	-	46.0 I	22.7	16.4MR	53.0 MS	41.8	28.1 MS	-	-
AAC Warman	54.7 MS	33.6	23.2 R	30.7 MR	11.4	9.0R	15.3 R	11.5	8.9 R	33	9.9

Note: Table comparing FHB resistance of AAC Warman against the check varieties at Carman and Morden inoculated nurseries.

^aFHB visual rating index (VRI): (percentage of infected heads x percentage of diseased florets on infected heads)/100.

Disease rating class: R = resistant, MR = moderately resistant; I = intermediate; MS = moderately, susceptible, S = susceptible.

^bDON: Deoxynivalenol.

^cISD = Visual Incidence + Visual Severity + DON = (0.2*mean incidence + 0.2*mean severity + 0.6*mean DON)

Table 5. Rust disease severities and ratings of AAC Warman (BW1025) and check cultivars in the Central Bread Wheat Cooperative (2014–2016) tests.

Cultivar	Leaf Rust ^a			Stem Rust ^b			Stripe Rust ^c				UG99 ^b		
	2014	2015	2016	2014	2015	2016	2014	2015	2016	2016	2014	2015	2016
Unity	32MR	37I	30M	3MR	20I	10MR	83S	40S	60S	95S	15M	40M	80S
Glenn	20MR	6R	25MR	1R	10MR	5R	30I	2R	17MR	35I	10MS	25M	80S
Carberry	0R	4R	0.3R	3MR	5R	2R	5R	2R	10MR	25I	20S	15M	70S
5603HR	52MS	-	-	1R	-	-	25MR	-	-	-	-	-	-
AAC Viewfield	-	10R	10R	-	15MR	5R	-	15I	25I	15MR	-	3MS	30MS
AAC Warman	0R	2R	0.3R	1R	5R	15MR	25MR	30MS	50MS	75S	30M	-	40M

Note: Table comparing rust resistance of AAC Warman against the check varieties in inoculated nurseries.

^aSeverity is the percentage of leaf area affected by rust. Reaction is the descriptive classification of disease based on percent severity. Disease rating class: R, resistant (1%–10%); MR, moderately resistant (11%–30%); I, intermediate (31%–39%); MS, moderately susceptible (40%–60%); S, susceptible (>60%).

^bSeverity is the percentage of stem infected with stem rust using the modified Cobb scale. Disease response categories: R, resistant; MR, moderately resistant; I, intermediate; MS, moderately susceptible; S, susceptible.

^cSeverity is the percentage of leaf area affected by rust. Dominant pustule reaction for stripe rust. Disease response categories: R, resistant; MR, moderately resistant; I, intermediate; MS, moderately susceptible; S, susceptible.

Table 6. Bunt, smut, leaf spot and midge ratings of AAC Warman (BW1025) and check cultivars in the Central Bread Wheat Cooperative (2014–2016) tests.

Cultivar	Common bunt ^a			Loose smut ^b		Leaf spots ^c			Midge ^d	
	2014	2015	2016	2014	2015	2014	2015	2016	2015	2016
Unity	0R	0R	2R	6R	4R	7I	7.0I	10S	6:1:4	4:1:5
Glenn	21MS	8R	16I	0R	4R	7I	6.0MR	10S	0:9:1	0:7:3
Carberry	2R	0R	0R	9R	0R	7I	8.3MS	10S	0:9:1	0:8:2
AAC Viewfield	-	26MS	19I	-	2R	-	7.0I	9MS	0:10:1	0:9:1
AAC Warman	28MS	50S	29MS	24MR	16R	7.5I	7.3I	10S	3:0:7	3:0:7

Note: Table comparing bunt, loose smut, leaf spots and midge resistance of AAC Warman against the check varieties.

^aBunt data represented as severity (percentage of spikes with bunt symptoms) and ratings. Disease rating class: R = resistant, MR = moderately resistant; I = intermediate; MS = moderately susceptible, S = susceptible.

^bLoose smut data represented as severity (percentage of plants with loose smut symptoms) and ratings. Disease rating class: R = resistant, MR = moderately resistant; I = intermediate; MS = moderately susceptible, S = susceptible.

^cLeaf spot data represented as severity (percentage of leaves with leaf spot symptoms) and ratings. Disease rating class: R = resistant, MR = moderately resistant; I = intermediate; MS = moderately susceptible, S = susceptible.

^dMidge rating R:S:U (Resistant:Susceptible:Undamaged).

Table 7. Wheat and flour analytical data^a for AAC Warman (BW1025) and check cultivars from the Central Bread Wheat Cooperative (2014-2016) tests.

Cultivar	Grain protein (%)	Flour protein (%)	Protein loss (%)	Falling number (s)	Amylo-graph (BU)	Clean flour yield (%) ^b	Flour yield (.50 ash) (%)	Flour ash (%)	Starch damage (%)
2014									
Unity	13.7	12.7	1.0	380	675	76.7	77.5	0.43	7.2
Glenn	13.6	12.7	0.9	290	375	73.8	77.5	0.43	7.9
Carberry	13.8	12.8	1.1	300	215	75.3	78.0	0.42	6.7
AAC Viewfield	-	-	-	-	-	-	-	-	-
Mean of checks	13.7	12.7	1.0	323	421	75.3	77.7	0.40	7.3
AAC Warman	13.4	12.7	0.8	295	315	74.8	78.0	0.42	7.5
2015									
Unity	15.1	14.6	0.5	450	695	76.0	75.5	0.47	7.7
Glenn	15.3	14.4	0.8	320	500	75.0	77.0	0.44	8.3
Carberry	15.6	14.3	1.3	360	400	75.0	78.0	0.42	7.1
AAC Viewfield	15.9	14.8	1.1	320	420	74.9	77.0	0.44	7.1
Mean of checks	15.5	14.5	0.9	362	503	75.2	76.9	0.40	7.6
AAC Warman	15.2	14.6	0.6	300	345	76.1	75.5	0.47	7.9
2016									
Unity	13.2	12.4	0.8	405	755	76.5	77.0	0.44	8.3
Glenn	13.8	13.0	0.8	325	525	74.4	76.5	0.45	8.7
Carberry	14.3	13.3	1.0	370	350	75.4	76.5	0.45	7.4
AAC Viewfield	13.8	13.0	0.8	370	455	75.3	77.5	0.43	7.2
Mean of checks	13.8	12.9	0.9	367	521	75.4	76.9	0.40	7.9
AAC Warman	13.4	12.7	0.7	335	470	75.9	76.0	0.46	8.4

Note: Table comparing the end use quality of AAC Warman against the check varieties.. End-use quality testing was performed by the Grain Research Laboratory (GRL) of the Canadian Grain Commission (CGC) on a composite sample of each cultivar.

^aAmerican Association of Cereal Chemists methods were followed by the Grain Research Laboratory, Canadian Grain Commission for determining the various end-use quality traits on a composite of 6-10 locations each year.

^bDexter and Tipples (1987). All millings at the Canadian Grain Commission's Grain Research Laboratory are performed in rooms with environmental control maintained at 21°C and at 60% relative humidity. Common wheat is milled on an Allis-Chalmers laboratory mill using the GRL sifter flow as described by Black et al. (1980). Flour yield is expressed as a percentage of cleaned wheat on a constant moisture basis.

*AAC Viewfield data are from 2015 and 2016

Table 8. Dough properties and baking qualities for AAC Warman (BW1025) and check cultivars from the Central Bread Wheat Cooperative (2014–2016) tests.

Cultivar	Dough Properties							Baking Quality				
	Farinograph				Extensograph			CSP / Lean no time ^d				
	Abs (%) ^a	DDT (min) ^b	MTI (BU) ^c	Stability (min)	EXT Area	EXT Rmax	EXT Length	Abs (%)	Mixing time (min)	Mixing energy (whr/kg)	Loaf volume (cm ³)	Loaf top ratio
2014												
Unity	63.6	4.00	40	6.0	85	367	18.2	68	4.6	11.5	1000	-
Glenn	64.3	4.50	25	8.5	126	596	17.1	68	6.3	15.4	990	-
Carberry	61.9	5.75	45	7.5	105	415	19.8	66	4.9	10.6	960	-
AAC Viewfield	-	-	-	-	-	-	-	-	-	-	-	-
Mean of checks	63.3	4.75	37	7.3	105	459	18.4	67	5.3	12.5	983	
AAC Warman	62.9	4.25	30	8.5	109	516	18.1	67	5.9	15.0	995	-
2015												
Unity	65.3	5.75	45	6.0	87	355	19.5	69	3.4	9.1	1005	-
Glenn	65.6	8.00	30	9.5	151	691	18.5	70	5.5	13.6	980	-
Carberry	63.9	6.00	30	8.0	108	418	20.8	68	4.5	11.6	985	-
AAC Viewfield	64.5	8.25	30	9.5	117	449	20.5	69	4.5	11.4	980	-
Mean of checks	64.8	7.00	34	8.3	116	478	19.8	69	4.5	11.4	988	-
AAC Warman	64.8	7.75	40	7.5	114	463	19.8	69	4.5	11.1	1005	-
2016												
Unity	63.6	4.75	-	6.0	73	300	19.0	70	2.9	8.3	795	0.55
Glenn	65.6	5.50	-	9.5	122	624	16.4	73	3.8	10.5	910	0.67
Carberry	63.7	5.50	-	5.5	90	353	20.5	71	3.0	8.3	790	0.55
AAC Viewfield	63.6	5.75	-	7.5	91	358	20.3	71	3.1	7.8	825	0.51
Mean of checks	64.1	5.38		7.1	94	409	19.1	71	3.2	8.7	830	0.57
AAC Warman	63.4	5.50	-	8.0	93	451	16.6	70	3.6	9.6	865	0.69

Note: Table comparing the dough properties and baking quality of AAC Warman against the check varieties.

^aAmerican Association of Cereal Chemists (2000).

^bDDT: Farinograph Dough Development Time measured in minutes.

^cMTI: Farinograph Mixing Tolerance Index expressed in Brabender Units (BU)

^dCSP: Canadian short process (Preston et al. (1982) and Lean no time (Dupuis and Fu, 2016).