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CULTIVAR DESCRIPTION

AAC Network hard red winter wheat

R.J. Graf, R.J. Larsen, B.L. Beres, R. Aboukhaddour, A. Laroche, H.S. Randhawa, and N.A. Foroud

Abstract: AAC Network is a semi-dwarf hard red winter wheat (*Triticum aestivum* L.) cultivar that is well adapted across western Canada and eligible for grades of Canada Western Red Winter (CWRW) wheat. It was developed using wheat × maize pollen doubled haploid methodology. AAC Network was evaluated in the Western Canadian Winter Wheat Cooperative registration trials relative to CDC Buteo, Emerson, Moats, and AAC Elevate for 4 yr (2016–2019). Based on 44 replicated trials, AAC Network produced grain yield similar to AAC Elevate, the highest yielding check, with a protein concentration 0.9 units higher. AAC Network had fair to good winter survival, relatively late maturity, short straw with excellent lodging resistance, and high test weight. AAC Network expressed resistance to stem and stripe rust, moderate resistance to leaf rust and common bunt, and intermediate resistance to *Fusarium* head blight. In addition to increased grain protein concentration, AAC Network showed improvements in gluten strength and flour water absorption, and it maintained the excellent milling yield and low flour ash attributes of the CWRW wheat class.

Key words: Triticum aestivum L., wheat (winter), cultivar description, doubled haploid, grain yield, protein, disease resistance.

Résumé : AAC Network est une variété semi-naine de blé rouge vitreux d'hiver (*Triticum aestivum* L.) bien acclimatée à l'Ouest canadien et admissible au classement dans la catégorie du blé rouge d'hiver de l'Ouest canadien (CWRW — « Canada Western Red Winter »). Le cultivar a été obtenu par croisement de pollen de blé et de maïs grâce à la technique de la double haploïdie. AAC Network a été évalué dans le cadre des essais d'homologation de la Western Canadian Winter Wheat Cooperative et comparé pendant quatre ans (de 2016 à 2019) à CDC Buteo, Emerson, Moats et AAC Elevate. Au terme de 44 essais avec réplication, AAC Network a obtenu un rendement grainier similaire à celui de AAC Elevate, le témoin le plus productif, mais la concentration en protéines de son grain était de 0,9 unité plus élevée. AAC Network se caractérise par une résistance à l'hiver de passable à bonne, parvient à maturité relativement tard, possède une paille courte très résistante à la verse et un poids spécifique élevé. AAC Network résiste à la rouille de la tige et à la rouille jaune, résiste modérément à la rouille des feuilles et à la carie, et affiche une résistance intermédiaire à la fusariose de l'épi. Outre une concentration supérieure de protéines dans le grain, AAC Network possède un gluten plus ferme et sa farine absorbe mieux l'eau. Il conserve l'excellent rendement meunier de la classe des blés CWRW pour donner une farine renfermant peu de cendres. [Traduit par la Rédaction]

Mots-clés : Triticum aestivum L., blé (d'hiver), description de cultivar, haploïde double, rendement grainier, protéines, résistance à la maladie.

Introduction

AAC Network hard red winter wheat (*Triticum aestivum* L.) was developed at the Lethbridge Research and Development Centre (LeRDC) of Agriculture and Agri-Food Canada (AAFC) in Lethbridge, AB, Canada. Tested as LP855 and W569, AAC Network was granted registration No. 9826 by the Variety Registration Office, Plant Production Division, Canadian Food Inspection

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High grain yield, fair to good winter survival, desirable agronomic traits, excellent end-use quality, and broad-spectrum disease resistance make AAC Network Canada Western Red Winter (CWRW) wheat well suited for production in all areas of western Canada. The name "Network" acknowledges the extensive web of highly committed individuals and organizations required to develop a new cultivar, take it to market, and make it successful for the sustainability and benefit of Canadian agriculture.

Disease Resistance Breeding Milestones

Wheat in western Canada is affected by numerous pathogens that can cause widespread epidemics and devastating economic losses through reduced productivity and marketability in a single season (Aboukhaddour et al. 2020). Over the past 25 yr, considerable breeding progress has been made in the level, diversity, and combinations of disease resistance available in hard red winter wheat cultivars for western Canada. This brief chronicle does not mention all of the disease-resistant cultivars registered but rather describes the first cultivars developed in western Canada expressing resistance to a particular pathogen and when initially combined with other types of resistance.

The first winter wheat cultivars developed and supported for registration in western Canada that expressed demonstrable major resistance to recognized critical disease threats were CDC Harrier with stem rust (*Puccinia graminis* Pers.: Pers. f. sp. *tritici* Eriks. & E. Henn.) resistance in 1997 (Fowler 1999*b*), followed in 1998 by CDC Falcon with resistance to stem rust and leaf rust (*Puccinia triticina* Eriks.) (Fowler 1999*a*) and AC Bellatrix with resistance to common bunt [*Tilletia tritici* (Bjerk.) G. Wint. in Rabenh. and *Tilletia laevis* Kühn in Rabenh.] (Thomas et al. 2012*b*). Since then, most registered cultivars have carried effective stem and leaf rust resistance. Radiant (Thomas et al. 2012*a*), supported for registration in 2001, combined resistance to stripe rust (*Puccinia striiformis* Westend.) and the wheat curl mite (WCM; *Aceria tosichella* Keifer) vector of wheat streak mosaic virus. Also supported in 2001 was McClintock (Brûlé-Babel 2003), which exhibited excellent resistance to stem, leaf, and stripe rust and became a popular parent. Flourish (Graf et al. 2012), recommended in 2010, brought together resistance to stem rust, leaf rust, and common bunt but regrettably proved to be highly susceptible to *Fusarium* head blight (FHB) {caused by *Fusarium graminearum* Schwabe [teleomorph *Gibberella zeae* (Schwein.) Petch]}. In the following year, Emerson was released, which combined the excellent rust resistance from McClintock with FHB resistance (Graf et al. 2013). Emerson was the first wheat cultivar of any type in Canada to be rated "resistant" to FHB, which may account for its enduring popularity with producers in the eastern prairie region. AAC Elevate (Graf et al. 2015), which was approved in 2014, was the first winter wheat cultivar to express the minimum recommended levels of resistance to all of the aptly termed Priority 1 diseases ("intermediate resistance" or better to all rusts and common bunt; "moderate susceptibility" or better to FHB), as well as resistance to WCM. Unfortunately, the stripe rust resistance shown at the time of registration was no longer effective when AAC Elevate became commercially available in 2017. Registered in 2019, AAC Network exceeded all of these minimum recommended disease resistance guidelines. It is a clear demonstration of how collaboration among plant breeders, pathologists, and scientists of many other disciplines from numerous institutions can lead to the successful mitigation of important threats to the Canadian field crop sector.

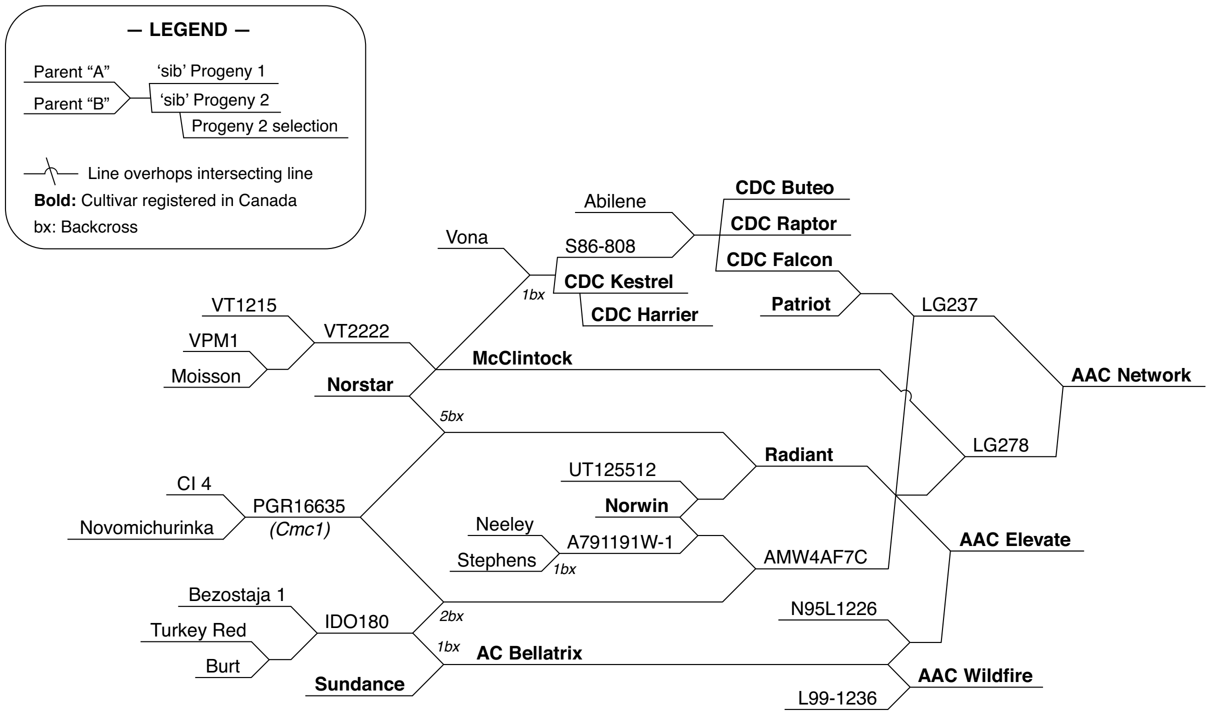
Pedigree and Breeding Method

AAC Network is an F_1-derived doubled haploid (DH) cultivar that originates from the cross LG237/LG278 made in 2008. Both LG237 and LG278 were DH lines developed at AAFC LeRDC and tested in the Western Winter Wheat Cooperative (WWWC) registration trials as W481 and W476, respectively. LG237 was selected from the cross Patriot/CDC Falcon//AMW4AF7C. LG278 has AMW4AF7C/Radiant//McClintock parentage. AMW4AF7C was derived from the cross IDO180*3/*Cmc1*//Norwin/A791191W-1 and was evaluated for registration as W334. CDC Falcon, McClintock, and Radiant are hard red winter wheat cultivars with regional registration for western Canada, whereas Patriot is a hard red winter wheat with regional registration for eastern Canada. An expanded pedigree of AAC Network illustrates ancestry to many of the original disease-resistant cultivars developed in western Canada (Fig. 1).

In 2010, wheat × maize pollination techniques were used to produce 366 DH lines from 33 F_1 plants. Ten DH lines were derived from the F_1 plant from which AAC Network originated. Evaluation of a first subset of 248 DH genotypes occurred in 2 m observation rows grown under irrigation near Lethbridge in 2011, resulting in the harvest of 64 lines based on winter survival, spring vigour, plant type, height, straw strength, stripe rust resistance, and general leaf health. In 2012, these selections were rated for disease resistance in artificially inoculated nurseries for stem and leaf rust in Winnipeg, MB, Canada, grown in collaboration with the University of Manitoba, and for stripe rust in Lethbridge. Resistance to common bunt was also evaluated in Lethbridge by planting inoculated seed into cold soil in mid-October. The remaining DH lines from this cross were evaluated in a similar manner in subsequent years.

Based on acceptable resistance to all of the diseases evaluated in 2012, 29 of the initial 64 selections were tested in single-replicate preliminary agronomic trials

Fig. 1. Expanded ancestry of AAC Network hard red winter wheat and related cultivars.



in Lethbridge in 2013. Favourable agronomic performance, continued resistance to the three rusts and bunt, and acceptable end-use quality prompted continued testing of three lines in 2014 and two lines in 2015. Evaluation for resistance to FHB and WCM colonization was also conducted for two or more years. Based on 10 site-years of replicated agronomic assessment across western Canada, LP855 entered the WWWC registration trial as W569 and was evaluated for 4 yr (2015/2016–2018/2019).

The performance of AAC Network in the WWWC registration trials was assessed relative to CDC Buteo (Fowler 2010), Emerson, Moats (Fowler 2012), and AAC Elevate. Agronomic test sites across western Canada were in Alberta (Beaverlodge, Lacombe, Lethbridge "dry land", Lethbridge "evergreen" (dry land + foliar fungicide), Lethbridge "irrigated", Olds, and Warner), Saskatchewan (Indian Head, Melfort, Saskatoon, and Swift Current), and Manitoba (Brandon, Carman, Portage la Prairie, and Winnipeg) through the collaborative efforts of AAFC, Alberta Agriculture and Forestry, and the University of Manitoba. Analyses of variance were conducted using a combined mixed effects model in which environments were considered random and genotypes were fixed. The least significant difference (LSD) test was used to identify significant differences from the check cultivars.

During registration testing, resistance to the major diseases of economic importance to winter wheat in both the eastern and western prairies was assessed by AAFC and the University of Manitoba. Supplementary checks were included in the various nurseries to aid in making accurate assessments. In addition, the agronomic trial collaborators recorded responses to various pathogens when differentials were observed. The adult plant reactions to stem and leaf rust were determined in artificially inoculated field nurseries conducted by the University of Manitoba in Winnipeg using race composites supplied by the AAFC Morden Research and Development Centre (MRDC) and reported using the modified Cobb scale (Peterson et al. 1948). The stem rust races used for one or more years included MCC (P0001), QTH (P0005), RHT (P0002), RKQ (P0003), RTH (P0007), TMR (P0006), and TPM (P0004) (Fetch et al. 2018, 2020). The leaf rust races were a representative mixture collected in western Canada during the previous field season (McCallum et al. 2019, 2020). Seedling reactions to individual races of stem and leaf rusts prevalent in Canada were also determined under controlled-environment conditions by personnel at AAFC MRDC. The races of stem rust were the same as those used in the field nurseries whereas the leaf rust races used for one or more years included MBDS (12-3), MBRJ (128-1), MGBJ (74-2), TDBG (06-1-1), TDBG (11-180-1), and TJBJ (77-2). Stripe rust ratings were determined in irrigated, inoculated nurseries at AAFC LeRDC (Puchalski and Gaudet 2011). The reaction to common bunt was also estimated in nurseries conducted at AAFC LeRDC by planting into cold soil in mid-October. All seeds were inoculated with a composite of races that included L1, L16, T1, T6, T13, and T19 (Hoffman and Metzger 1976; Gaudet and Puchalski 1989). FHB response was determined by staff at the University of Manitoba using a mist-irrigated field nursery with three replicates in Carman. Spray inoculation of each line occurred at 50% anthesis and again 3–4 d later using a suspension of *F. graminearum* macroconidia that contained equal quantities of two 3-acetyldeoxynivalenol (3-ADON) and two 15-ADON-producing chemotypes at a final concentration of 50 000 macroconidia mL^{-1}. Visual index (% incidence × % severity/100) rating typically occurred 18–21 d after anthesis or when symptoms were well developed (Gilbert and Woods 2006; Cuthbert et al. 2007). At maturity, a 50 g sample was harvested from each row to determine the percentage of fusarium-damaged kernels and to quantify the deoxynivalenol content using enzyme-linked immunosorbent assays. The response to WCM infestation was conducted each year using non-viruliferous mites under controlled-environment conditions at AAFC LeRDC (Thomas and Conner 1986). Several replicates of 10–15 plants were rated for the typical symptoms of leaf rolling and trapping of new leaves following 2–3 wk of mite exposure. The reactions to powdery mildew [*Blumeria graminis* (DC.) Speer] and unspecified leaf-spotting pathogens which may have included tan spot [*Pyrenophora tritici-repentis* (Died.) Drechsler], leaf blotch complex [*Zymoseptoria tritici* (Roberge ex Desm.) Quaedvl. & Crous and *Parastagonospora nodorum* (Berk.) Quaedvl., Verkley & Crous], and physiological leaf spot were recorded at agronomic test sites expressing differential symptoms.

End-use quality analyses were conducted annually at the Canadian Grain Commission (CGC), Grain Research Laboratory (GRL), following protocols of the American Association of Cereal Chemists (2000). Following CGC determination of grain grade and protein concentration for the check cultivars at all of the agronomic test locations, a common site blending formula for the checks and all experimental lines was provided so as to produce composite samples in which the mean protein concentration of the checks was approximately 12.5%. Grain from test sites with serious downgrading factors was not included in the quality composites.

Performance

Grain yield and agronomics

Data from across the Canadian prairies, collected at 44 sites over 4 yr, established the agronomic performance of AAC Network relative to check cultivars of the CWRW class. Comparisons with Emerson were based on 33 site-years of data collected from 2017 to 2019. Data for CDC Falcon, a well-known cultivar in the eastern prairies and a Canada Western Special Purpose wheat check, are also reported. The mean grain yield of AAC Network was 102% of the CWRW check mean (non-significant) across all sites over 4 yr. Relative to specific checks, AAC Network had significantly higher grain yield than CDC Buteo (106%) and Emerson (107%) but was similar to Moats (101%), AAC Elevate (99%), and CDC Falcon (102%). On a regional basis, AAC Network was particularly well adapted to southern Alberta (Zone 1), where it was slightly higher yielding than all of the checks and 110% of the check mean ($P \leq 0.05$). AAC Network also performed well in the eastern prairie rust area (Zone 4), where its yield was similar to AAC Elevate, the highest yielding check (Table 1).

AAC Network exhibited winter survival that was similar to the check cultivars. Heading date and maturity were later than the checks ($P \leq 0.05$). The 2 d difference in maturity between AAC Network and CDC Buteo is similar to the long-term difference between Radiant and CDC Buteo (2.3 d) when they were tested together in the WWWC registration trials between 2005 and 2015 (77 direct comparisons over 9 yr, data not presented). AAC Network was shorter than all of the CWRW checks and 3 cm taller than CDC Falcon ($P \leq 0.05$). Lodging resistance was similar to Emerson, AAC Elevate, and CDC Falcon and significantly better than CDC Buteo and Moats ($P \leq 0.05$). The test weight and seed weight of AAC Network were within the range of the CWRW checks. AAC Network expressed higher grain protein concentration than all of the checks except Emerson ($P \leq 0.05$). Grain protein yield per hectare was significantly greater than CDC Buteo, AAC Elevate, and CDC Falcon ($P \leq 0.05$), and similar to Emerson and Moats (Table 2).

Disease resistance

Upon the request for support to register W569 (AAC Network), the Prairie Recommending Committee for Wheat, Rye and Triticale (PRCWRT) Disease Evaluation Team examined 3 yr of disease ratings. Note that as AAC Network was included as a year 4 entry in the 2018/2019 WWWC registration trial, these disease resistance data are also presented. Overall, AAC Network was rated as resistant to the prevalent races of stem rust and stripe rust, moderately resistant to leaf rust and common bunt, and intermediate in resistance to FHB. Barring significant disease pressure from FHB and changes to the prevalent races of rust and common bunt in western Canada, AAC Network is unlikely to require fungicide treatment for the Priority 1 diseases. In environments where FHB infection is expected, a crop management approach integrating cultivar resistance, foliar fungicides, and escape from infection remains the best control strategy (Ye et al. 2017; Beres et al. 2018). Based on natural infection at a limited number of agronomic trial sites, the reaction to leaf spotting diseases was within the range of the checks; powdery mildew infection was somewhat lower than the best check (Tables 3 and 4). AAC Network did not express resistance to WCM (data not presented).

End-use quality

Three years of end-use suitability testing by the CGC, GRL and evaluation by the PRCWRT Quality Evaluation

Table 1. Grain yield (t ha^{-1}) of AAC Network and the check cultivars, Western Canadian Winter Wheat Cooperative registration trials (2016–2019).

					Grand mean		Alberta		Saskatchewan		Manitoba		Zone 1[a]		Zone 2[a]		Zone 3[a]		Zone 4[a]	
Cultivar	2016	2017	2018	2019	t ha^{-1}	% Ck	t ha^{-1}	% Ck	t ha^{-1}	% Ck	t ha^{-1}	% Ck	t ha^{-1}	% Ck	t ha^{-1}	% Ck	t ha^{-1}	% Ck	t ha^{-1}	% Ck
4 yr means (2016–2019)																				
CDC Buteo	4.853	4.790	4.239	4.241	4.529	96	4.528	94	4.053	99	4.888	99	4.232	92	4.753	96	3.029	98	4.798	99
Moats	4.992	5.188	4.193	4.545	4.744	101	4.874	101	4.115	100	4.966	101	4.574	99	5.079	103	3.124	101	4.869	100
AAC Elevate	5.487	5.154	4.162	4.669	4.880	103	5.117	106	4.164	101	4.962	100	5.018	109	5.018	101	3.129	101	4.891	101
CDC Falcon	5.178	5.235	4.064	4.291	4.708	100	4.967	103	3.970	97	4.766	97	4.828	105	4.922	99	3.101	100	4.675	96
CWRW check mean[c]	5.110	5.044	4.198	4.485	4.718	100	4.840	100	4.111	100	4.939	100	4.608	100	4.953	100	3.094	100	4.853	100
AAC Network	5.545	5.002	4.186	4.431	4.808	102	5.017	104	4.094	100	4.942	100	5.051	110	4.718	95	2.871	93	4.884	101
LSD ($P \leq 0.05$)	0.433	0.276	0.322	0.326	0.173	—	0.254	—	0.266	—	0.346	—	0.265	—	0.410	—	0.713	—	0.258	—
No. of tests	11	12	10	11	44	—	23	—	9	—	12	—	14	—	10	—	2	—	18	—
3 yr means (2017–2019)																				
CDC Buteo	—	4.790	4.239	4.241	4.422	98	4.401	97	3.744	100	4.988	99	4.189	94	4.455	101	3.029	102	4.794	99
Emerson	—	4.459	3.907	4.427	4.275	95	4.312	95	3.386	91	4.895	97	4.219	94	4.235	96	2.629	88	4.596	95
Moats	—	5.188	4.193	4.545	4.661	103	4.704	103	3.900	105	5.172	103	4.578	102	4.614	104	3.124	105	4.990	103
AAC Elevate	—	5.154	4.162	4.669	4.678	104	4.798	105	3.883	104	5.069	101	4.901	110	4.411	100	3.129	105	4.909	102
CDC Falcon	—	5.235	4.064	4.291	4.552	101	4.746	104	3.662	98	4.876	97	4.694	105	4.540	103	3.101	104	4.673	97
CWRW check mean[b]	—	4.897	4.125	4.471	4.509	100	4.554	100	3.728	100	5.031	100	4.472	100	4.429	100	2.977	100	4.822	100
AAC Network	—	5.002	4.186	4.431	4.562	101	4.630	102	3.772	101	5.049	100	4.873	109	4.059	92	2.871	96	4.892	101
LSD ($P \leq 0.05$)	—	0.276	0.322	0.326	0.175	—	0.250	—	0.299	—	0.353	—	0.301	—	0.337	—	0.480	—	0.283	—
No. of tests	—	12	10	11	33	—	17	—	7	—	9	—	10	—	8	—	2	—	13	—

Note: All means are weighted by the number of tests. LSD, least significant difference includes variation from the appropriate genotype × environment interaction.

[a]Zone 1: Southern Alberta sites (Lethbridge “dry land”, Lethbridge “irrigated”, Lethbridge “evergreen” (dry land + foliar fungicide), and Warner); Zone 2: Parkland sites (Beaverlodge, Lacombe, Olds, and Melfort); Zone 3: Semi-arid prairie site (Swift Current); Zone 4: Eastern prairie rust-hazard sites (Brandon, Carman, Indian Head, Portage la Prairie, Saskatoon, and Winnipeg).

[b]Percent of Canada Western Red Winter (CWRW) check mean (% Ck) (4 yr means include CDC Buteo, Moats, and AAC Elevate; 3 yr means include CDC Buteo, Emerson, Moats, and AAC Elevate). The CWRW check mean does not include CDC Falcon as it is not a CWRW check.

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Table 2. Agronomic and seed characteristics of AAC Network and the check cultivars, Western Canadian Winter Wheat Cooperative registration trials (2016–2019).

Cultivar	Grain yield		Winter survival (%)	Heading[b] (d)	Maturity[b] (d)	Height[c] (cm)	Lodging[d] (1–9)	Test weight (kg hL^{-1})	Seed weight (mg)	Grain protein[e] (%)	Grain protein yield (kg ha^{-1})
	t ha^{-1}	% Ck[a]									
4 yr means (2016–2019)											
CDC Buteo	4.529	96	90	166	211	84	4.3	81.7	33.1	12.2	568
Moats	4.744	101	89	166	211	84	3.3	80.8	32.2	12.4	606
AAC Elevate	4.880	103	89	166	210	78	2.2	79.5	37.0	11.7	587
CDC Falcon	4.708	100	88	165	208	71	2.6	79.7	30.4	12.0	587
CWRW check mean	4.718	100	89	166	211	82	3.3	80.7	34.1	12.1	587
AAC Network	4.808	102	88	167	213	74	2.1	80.1	31.2	12.6	621
LSD ($P \leq 0.05$)	0.173	—	3.1	0.5	0.7	1.4	0.65	0.43	0.71	0.19	21.7
No. of tests	44	—	20	39	38	44	15	40	40	40	40
3 yr means (2017–2019)											
CDC Buteo	4.422	98	90	168	211	82	3.8	81.7	33.2	12.3	566
Emerson	4.275	95	90	168	212	80	1.7	80.6	29.1	13.3	586
Moats	4.661	103	89	168	211	81	2.9	80.5	32.0	12.5	604
AAC Elevate	4.678	104	89	168	210	77	1.9	79.5	37.3	11.8	574
CDC Falcon	4.552	101	88	167	208	68	1.9	79.6	30.3	12.0	574
CWRW check mean	4.509	100	89	168	211	80	2.6	80.6	32.9	12.5	583
AAC Network	4.562	101	88	169	213	72	1.8	80.0	31.1	12.8	602
LSD ($P \leq 0.05$)	0.175	—	2.9	0.5	0.8	1.4	0.75	0.41	0.66	0.21	22.4
No. of tests	33	—	20	29	29	32	8	30	30	30	30

Note: LSD, least significant difference includes variation from the appropriate genotype × environment interaction.

[a]Percent of the Canada Western Red Winter (CWRW) check mean (% Ck), which includes CDC Buteo, Moats, and AAC Elevate. The CWRW check mean does not include CDC Falcon as it is not a CWRW check.

[b]Days to heading and maturity expressed as day of the year.

[c]Height measured from ground to tip of spike, excluding awns.

[d]Lodging scale: 1 = all plants vertical, 9 = all plants horizontal.

[e]Grain protein concentration determined using whole grain near-infrared reflectance analysis.

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Table 3. Disease reactions of AAC Network and the check cultivars, Western Canadian Winter Wheat Cooperative registration trials (2016–2019).

Disease	Year	CDC Buteo	Moats	AAC Elevate	Emerson	CDC Falcon	AAC Network
Stem rust	2016	40 MS-60 S	10 R	25 I	—	40 MS	10 R-MR
	2017	20 MS	5 R	tr R	tr R	5 MR	tr R
	2018	—	—	—	—	—	—
	2019	10 R-70 S	5 R	10 R-MR	5 R	10 R	tr R
Leaf rust	2016	20 MR	5 R-MR	25 MS	—	25 I	15 MR
	2017	10 I	tr R-MR	20 S	5 MR	15 I	5 R-MR
	2018	—	—	—	—	—	—
	2019	15 MR-S	5 R-MR	10-20 I	5 R-MR	5 MR	5 MR
Stripe rust	2016	75 VS	3 R	50 S	—	65 S	2 R
	2017	70 S	1 R	70 S	1 R	50 S	1 R
	2018	70 S	5 R	70 S	15 MR	60 S	5 R
	2019	90 S	2 R	90 S	—	60 S	20 MR
Common bunt	2016	35 VS	16 I	3 R	—	31 VS	11 MR
	2017	44 S	31 MS	8 MR	60 S	33 MS	4 R
	2018	30 MS	33 S	7 R	33 S	35 S	3 R
	2019	29 I	38 MS	15 MR	49 S	29 I	9 R
Leaf spots[a,b]	2016	3.2	2.6	2.9	—	3.4	3.0
	2017	2.0	2.0	1.3	1.5	1.5	2.0
	Mean	2.6	2.3	2.1	—	2.5	2.5
Powdery mildew[b]	2016	3.7	2.0	4.3	—	4.3	2.0
	2017	2.7	2.9	2.0	3.0	2.5	1.4
	2019	2.0	1.7	2.7	3.3	1.3	1.7
	Mean	2.8	2.2	3.0	—	2.7	1.7

Note: Percent infection and type of reaction: tr, trace; R, resistant; MR, moderately resistant; I, intermediate; MS, moderately susceptible; S, susceptible; VS, very susceptible.

[a]Specific leaf spotting pathogens were not determined.

[b]Rated using a 1–9 scale: 1 = disease free, 9 = very severe symptoms.

Team established that AAC Network had quality eligibility for all grades of the CWRW wheat class. AAC Network produced grain of higher protein concentration than all of the checks except Emerson and with an improvement in gluten strength, had much improved farinograph and bake absorption, and maintained the excellent milling yield and low flour ash attributes desired for the CWRW wheat class (Table 5).

Other Characteristics

Seedling: leaf sheath and blade glabrous.

Plant: juvenile growth habit semi-prostrate; flag leaf blade glabrous, medium glaucosity, mid-long, mid-wide, highly recurved; flag leaf sheath glabrous, medium glaucosity; auricle anthocyanin colouration absent or very weak; culm neck straight to weakly curved, hollow, anthocyanin intensity at maturity absent or very weak.

Spike: awned, tapering, medium dense, short to medium length, medium glaucosity, yellow, erect to slightly inclined, awns white, medium spreading; lower glume mid-wide, mid-long, glabrous; glume shoulders primarily strongly sloping, width absent or very narrow; glume beak mid-long, acuminate; resistant to shattering.

Kernel: medium red, texture medium hard, medium size.

Maintenance and Distribution of Pedigreed Seed

The development of AAC Network Breeder Seed followed a standard head-row derivation approach to preserve the purity of its DH derivation. Progeny plots originating from 66 uniform head rows, produced under isolation at Lethbridge in 2018, were grown at the AAFC Seed Increase Unit in Indian Head in 2019. Following the elimination of 12 progeny lines, the remaining 54 plots were inspected, harvested in bulk, and cleaned to form 831 kg of Breeder Seed, which was released to pedigreed seed growers in the fall of 2019. Bulking of the Breeder Seed occurred eight generations after the harvest of the original DH plant. Breeder Seed of AAC Network will be maintained by the AAFC Seed Increase Unit. All other pedigreed seed classes will be multiplied and distributed by SeedNet Inc., P.O. Box 1062, Lethbridge, AB T1J 4A2, Canada. Tel: 403-715-9771; www.seednet.ca.

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Table 4. *Fusarium* head blight (FHB) reaction of AAC Network, check cultivars and supplementary checks, Western Canadian Winter Wheat Cooperative registration trials (2016–2019).

	Visual rating[a] (index and response)					Deoxynivalenol (ppm)					Fusarium-damaged kernels[b] (%)				
	2016 Carman	2017 Carman	2019 Carman	2019 Winnipeg	Mean	2016 Carman	2017 Carman	2019 Carman	2019 Winnipeg	Mean	2016 Carman	2017 Carman	2019 Carman	2019 Winnipeg	Mean
CDC Buteo	2 MR	15 MR	1 MR	20 I	10	18	22	3	16	15	6	14	1	6	7
Moats	5 MR	17 MR	3 MR	42 S	17	17	16	5	19	14	5	8	2	11	7
AAC Elevate	14 I	19 MR	2 MR	31 MS	17	24	16	3	9	13	17	12	2	5	9
Emerson	—	1 R	2 MR	12 MR	5	—	2	1	6	3	—	2	1	3	2
CDC Falcon	7 I	16 MR	3 MR	61 S	22	20	16	2	24	16	10	9	1	17	9
AAC Network	3 MR	11 MR	2 MR	44 S	15	9	13	3	21	12	5	7	3	9	6
Supplementary checks															
DH00W32C*17	1 R	3 R	0 R	5 R	2	7	4	2	7	5	4	4	1	3	3
FHB148	2 R	2 R	2 MR	4 R	3	10	6	2	7	6	6	8	1	2	4
Freedom	9 I	15 I	5 I	22 I	13	18	23	5	16	16	9	4	2	7	6
DH01W43I*18	5 MR	9 MR	2 MR	27 I	11	14	8	4	15	10	6	17	1	6	8
Caledonia	30 S	56 S	29 S	55 S	43	46	49	10	35	35	30	14	3	12	15
Hanover	30 S	61 S	27 S	72 S	48	51	58	11	57	44	33	31	5	23	23

Note: Disease response category: R, resistant; MR, moderately resistant; I, intermediate; MS, moderately susceptible; S, susceptible. Supplementary checks were chosen to differentiate resistance levels based on long-term data collection.

[a]Visual rating index = % incidence × % severity/100.

[b]Fusarium-damaged kernels = damaged kernel weight/total weight × 100.

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Table 5. End-use quality characteristics of AAC Network and check cultivars, Western Canadian Winter Wheat Cooperative registration trials (2016–2018).

Cultivar	Test years	Wheat protein (%)	Flour protein (%)	Protein loss (%)	Hagberg falling no. (s)	Amylograph peak viscosity (BU)	Clean wheat flour yield (%)	Flour yield (0.5% ash)	Flour ash (%)	Starch damage (%)
CDC Buteo	2016–2018	12.3	11.4	1.0	415	492	76.7	81.3	0.35	6.8
Moats	2016–2018	12.5	11.7	0.8	437	692	75.4	79.3	0.39	7.4
AAC Elevate	2016–2018	11.9	10.8	1.0	417	587	76.2	81.0	0.36	7.1
Flourish[a]	2016–2017	12.3	11.5	0.8	375	455	75.5	81.0	0.36	6.3
Emerson[a]	2017–2018	13.6	12.7	0.9	405	623	76.7	81.0	0.36	6.0
CWRW check mean	2016–2018	12.5	11.6	0.9	410	570	76.1	80.7	0.37	6.7
AAC Network	2016–2018	12.6	11.7	0.9	423	493	76.4	80.3	0.37	8.4
SD[b]		0.1	0.1	0.1	15	5	0.3	0.3	0.01	0.1

	Extensograph			Farinograph			Lean No Time bake					Water dough colour (2 h)		
	Area (cm^2)	R_{max} (BU)	Length (cm)	Water absorption (%)	DDT[c] (min)	Stability (min)	Bake absorption (%)	Peak time (m)	Mixing energy (Wh kg^{-1})	Loaf volume (cm^3)	Loaf top ratio	L^*	a^*	b^*
CDC Buteo	89	434	16.5	57.9	5.75	8.0	65.3	3.1	8.0	785	0.58	81.60	2.15	22.70
Moats	110	553	16.3	57.9	6.08	10.8	65.0	3.9	10.1	753	0.56	80.75	2.45	21.95
AAC Elevate	90	498	14.7	56.3	4.25	9.0	63.3	3.3	8.9	780	0.64	80.80	2.50	21.99
Flourish[a]	116	520	18.0	57.8	5.25	8.8	65.0	3.3	8.9	798	0.61	81.24	2.50	23.46
Emerson[a]	159	910	15.1	56.0	8.13	25.0	64.5	5.0	13.0	813	0.64	80.74	2.89	23.49
CWRW check mean	113	583	16.1	57.2	5.89	12.3	64.6	3.7	9.8	786	0.61	81.03	2.50	22.72
AAC Network	137	821	13.9	59.4	3.17	26.7	68.3	5.7	15.0	782	0.66	79.18	2.99	27.39
SD[b]	4	20	6	0.2	0.4	1.4	0.0	0.1	0.3	14	0.04	NA	NA	NA

Note: American Association of Cereal Chemists methods were followed for determining the various end-use quality characteristics on a composite of several locations per year. NA, not available.

[a]Check data for Flourish and Emerson are only available for 2 yr.

[b]SD, standard deviation is based on repeated testing of Allis–Chalmers mill check samples and standard bake flour samples with replicate tests performed over time each year. Values from the Canadian Grain Commission, Grain Research Laboratory.

[c]DDT, farinograph dough development time.

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References

Aboukhaddour, A., Fetch, T., McCallum, B.D., Harding, M.W., Beres, B.L., and Graf, R.J. 2020. Wheat diseases on the prairies: a Canadian story. Plant Pathol. **69**: 418–432. doi:10.1111/ppa.13147.

American Association of Cereal Chemists. 2000. Approved methods of the AACC. 10th ed. AACC, St. Paul, MN, USA.

Beres, B.L., Brûlé-Babel, A.L., Ye, Z., Graf, R.J., Turkington, T.K., Harding, M., et al. 2018. Exploring Genotype × Environment × Management synergies to manage fusarium head blight in wheat. Can. J. Plant Pathol. **40**: 179–188. doi:10.1080/07060661.2018.1445661.

Brûlé-Babel, A.L. 2003. McClintock. Plant Var. J. **49**. [Online]. Available from http://www.inspection.gc.ca/english/plaveg/pbrpov/cropreport/whe/app00003450e.shtml.

Cuthbert, P.A., Somers, D.J., and Brûlé-Babel, A. 2007. Mapping of *Fhb2* on chromosome 6BS: a gene controlling Fusarium head blight field resistance in bread wheat (*Triticum aestivum* L.). Theor. Appl. Genet. **114**: 429–437. doi:10.1007/s00122-006-0439-3. PMID:17091262.

Fetch, T., Mitchell Fetch, J., Zegeye, T., and Xue, A. 2018. Races of *Puccinia graminis* on barley, oat, and wheat in Canada, in 2011 and 2012. Can. J. Plant Pathol. **40**: 11–21. doi:10.1080/07060661.2017.1396499.

Fetch, T., Mitchell Fetch, J., Zegeye, T., and Xue, A. 2020. Races of Races of *Puccinia graminis* on barley, oat, and wheat in Canada, in 2013 and 2014. Can. J. Plant Pathol. doi:10.1080/07060661.2020.1745892.

Fowler, D.B. 1999*a*. CDC Falcon winter wheat. Can. J. Plant Sci. **79**: 599–601. doi:10.4141/P99-024.

Fowler, D.B. 1999*b*. CDC Harrier winter wheat. Can. J. Plant Sci. **79**: 603–605. doi:10.4141/P99-025.

Fowler, D.B. 2010. CDC Buteo hard red winter wheat. Can. J. Plant Sci. **90**: 707–710. doi:10.4141/CJPS09170.

Fowler, D.B. 2012. Moats hard red winter wheat. Can. J. Plant Sci. **92**: 191–193. doi:10.4141/cjps2011-115.

Gaudet, D.A., and Puchalski, B.L. 1989. Races of common bunt (*Tilletia caries* and *T. foetida*) in western Canada. Can. J. Plant Pathol. **11**: 415–418. doi:10.1080/07060668909501089.

Gilbert, J., and Woods, S. 2006. Strategies and considerations for multi-location FHB screening nurseries. Pages 93–102 in T. Ban, J.M. Lewis, and E.E. Phipps, eds. The global fusarium initiative for international collaboration: a strategic planning workshop, CIMMYT, El Batàn, Mexico. 14–17 Mar. 2006. CIMMYT, Mexico, D.F.

Graf, R.J., Thomas, J.B., Beres, B.L., Gaudet, D.A., Laroche, A., and Eudes, F. 2012. Flourish hard red winter wheat. Can. J. Plant Sci. **92**: 183–189. doi:10.4141/cjps2011-084.

Graf, R.J., Beres, B.L., Laroche, A., Gaudet, D.A., Eudes, F., Pandeya, R.S., et al. 2013. Emerson hard red winter wheat. Can. J. Plant Sci. **93**: 741–748. doi:10.4141/cjps2012-262.

Graf, R.J., Beres, B.L., Randhawa, H.S., Gaudet, D.A., Laroche, A., and Eudes, F. 2015. AAC Elevate hard red winter wheat. Can. J. Plant Sci. **95**: 1021–1027. doi:10.4141/cjps-2015-094.

Hoffman, J.A., and Metzger, R.J. 1976. Current status of virulence genes and pathogenic races of the wheat bunt fungi in the northwestern USA. Phytopathology, **66**: 657–660.

McCallum, B.D., Seto-Goh, P., Reimer, E., Foster, A., and Xue, A. 2019. Physiological specialization of *Puccinia triticina*, the causal agent of wheat leaf rust, in Canada in 2013. Can. J. Plant Pathol. doi:10.1080/07060661.2019.1653376.

McCallum, B.D., Reimer, E., McNabb, W., Foster, A., and Xue, A. 2020. Physiological specialization of *Puccinia triticina*, the causal agent of wheat leaf rust, in Canada in 2014. Can. J. Plant Pathol. doi:10.1080/07060661.2020.1723705.

Peterson, R.F., Campbell, A.B., and Hannah, A.E. 1948. A diagrammatic scale for estimating rust intensity on leaves and stems of cereals. Can. J. Res. **26c**: 496–500. doi:10.1139/cjr48c-033.

Puchalski, B., and Gaudet, D.A. 2011. 2010 southern Alberta stripe rust survey. Can. Plant Dis. Surv. **91**: 69–70.

Thomas, J.B., and Conner, R.L. 1986. Resistance to colonization by the wheat curl mite in *Aegilops squarrosa* and its inheritance after transfer to common wheat. Crop Sci. **26**: 527–530. doi:10.2135/cropsci1986.0011183X002600030019x.

Thomas, J.B., Conner, R.L., and Graf, R.J. 2012*a*. Radiant hard red winter wheat. Can J. Plant Sci. **92**: 169–175. doi:10.4141/cjps2011-082.

Thomas, J.B., Gaudet, D.A., and Graf, R.J. 2012*b*. AC Bellatrix hard red winter wheat. Can. J. Plant Sci. **92**: 163–168. doi:10.4141/cjps2011-091.

Ye, Z., Brûlé-Babel, A.L., Graf, R.J., Mohr, R., and Beres, B.L. 2017. The role of genetics, growth habit, and cultural practices in the mitigation of Fusarium head blight. Can. J. Plant Sci. **97**: 316–328. doi:10.1139/cjps-2016-0336.