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Authors: Graf, R.J., Beres, B.L., Laroche, A., Aboukhaddour, R., Humphreys, D.G., et al.

Source: Canadian Journal of Plant Science, 102(3) : 785-795

Published By: Canadian Science Publishing

URL: https://doi.org/10.1139/CJPS-2022-0043

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CULTIVAR DESCRIPTION

AAC Coldfront hard red winter wheat

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

Abstract: AAC Coldfront is a hard red winter wheat (*Triticum aestivum* L.) cultivar with broad adaptation and excellent performance in all production areas of western Canada. Eligible for grades of Canada Western Red Winter (CWRW) wheat, AAC Coldfront was evaluated in the Western Canadian Winter Wheat Cooperative registration trials relative to CDC Buteo, Emerson, Moats, and AAC Elevate. Based on 32 replicated trials over 3 years (2017/2018–2019/2020), AAC Coldfront produced significantly more grain than all of the checks (108–115%) at a protein concentration similar to the check mean, suggesting an improved capacity to convert soil moisture and nutrients into grain under a wide range of western Canadian field conditions. AAC Coldfront expressed very good winter survival, medium to late maturity, short to moderate height, excellent lodging resistance, and high test weight. AAC Coldfront was rated resistant to stem, leaf, and stripe rust, intermediate in resistance to *Fusarium* head blight, and susceptible to common bunt. It became a check for western Canadian winter wheat registration trials in 2021/2022.

Key words: Triticum aestivum L., wheat (winter), cultivar description, grain yield, cold tolerance, disease resistance.

Résumé : AAC Coldfront est une variété de blé roux d'hiver (*Triticum aestivum* L.) largement adaptée aux régions de l'Ouest canadien consacrées à la culture du blé, où elle donne une excellente performance. Le cultivar est admissible à la catégorie « blé rouge d'hiver de l'Ouest canadien » (CWRW). Lors des essais d'homologation coopératifs pour le blé d'hiver de l'Ouest canadien, AAC Coldfront a été comparé à CDC Buteo, Emerson, Moats et AAC Elevate. Au terme des 32 essais répétés réalisés en 3 ans (de 2017/2018 à 2019/2020), le cultivar a produit sensiblement plus de grain que les autres témoins (de 108 à 115 %). La teneur en protéines du grain était similaire à la moyenne des témoins et la variété a illustré une meilleure capacité à transformer l'eau et les oligoéléments en grain dans les nombreuses conditions particulières à l'Ouest canadien. AAC Coldfront se caractérise par une très bonne rusticité, une maturité allant de moyenne à tardive, une paille de taille courte à moyenne, une excellente résistance à la verse et un poids spécifique élevé. La variété résiste à la rouille de la tige, à la rouille des feuilles et à la rouille jaune, oppose une résistance intermédiaire à la brûlure de l'épi causée par Fusarium et est sensible à la carie. AAC Coldfront est devenu une variété témoin pour les essais d'homologation du blé d'hiver dans l'Ouest canadien en 2021/22. [Traduit par la Rédaction]

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

Received 25 February 2022. Accepted 11 April 2022.

R.J. Graf, B.L. Beres,* A. Laroche, R. Aboukhaddour, H.S. Randhawa, N.A. Foroud,* and H.S. Sidhu. Lethbridge Research and Development Centre, Agriculture and Agri-food Canada, 5403-1st Avenue South, Lethbridge, AB T1J 4B1, Canada.

D.G. Humphreys. Ottawa Research and Development Centre, Agriculture and Agri-food Canada, 960 Carling Avenue, Ottawa, ON K1A 0C6, Canada.

R.J. Larsen. Harrow Research and Development Centre, Agriculture and Agri-food Canada, 2585 Country Road 20, Harrow, ON N0R 1G0, Canada.

Corresponding author: R.J. Graf (emails: robert.graf@agr.gc.ca; grafwheat@hotmail.com).

*B.L. Beres served as Editor-in-Chief and N.A. Foroud served as an Associate Editor at the time of manuscript review and acceptance; peer review and editorial decisions regarding this manuscript were handled by Yuefeng Ruan.

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Introduction

AAC Coldfront 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. Tested as LR535 and W601, AAC Coldfront was granted registration No. 9507 by the Variety Registration Office, Plant Production Division, Canadian Food Inspection Agency on 25 Feb. 2022. Plant Breeders' Rights application No. 22-10774 was accepted for filing on 12 Jan. 2022.

AAC Coldfront showed broad adaptation across western Canada, expressing very high grain yield and winter survival combined with desirable agronomic traits, very good resistance to all species of wheat rust, intermediate resistance to *Fusarium* head blight, and end-use quality acceptable for the Canada Western Red Winter (CWRW) wheat class. AAC Coldfront replaced CDC Buteo (Fowler 2010) as a CWRW registration trial check in 2021/2022.

Pedigree and Breeding Method

AAC Coldfront was selected from the three-way cross Norstar/CDC Falcon//LF1318, completed in 2008. Norstar (Grant 1980) and CDC Falcon (Fowler 1999) are registered Canadian cultivars developed at AAFC LeRDC and the University of Saskatchewan Crop Development Centre, respectively. LF1318 was an experimental line developed at AAFC LeRDC, selected from a McClintock/Radiant doubled-haploid population and tested in the Western Canadian Winter Wheat Cooperative (WWWC) registration trial as W455 (Brûlé-Babel 2003; Thomas et al. 2012). An expanded ancestry of AAC Coldfront is presented in Fig. 1.

Following growth of 60 F_1 seeds in a greenhouse, about 6000 F_2 plants were grown in a large, sparsely seeded bulk plot at Lethbridge in 2010, from which 138 spikes were selected and planted as F_3 head rows. In 2011, approximately 250 spikes were selected from rows expressing good winter survival and spring vigour, attractive plant type with short to moderate plant height and stiff straw, and resistance to stripe rust (*Puccinia striiformis* Westend.). These spikes were threshed in bulk and seeded as several plots in Saskatoon, SK; in 2012, 153 spikes were selected based on winter survival and plant type. Each spike was planted as a row in an inoculated stem rust (*Puccinia graminis* Pers.: Pers. f.sp. *tritici* Eriks. & E. Henn.) and leaf rust (*Puccinia triticina* Eriks.) nursery on the University of Manitoba campus in Winnipeg, MB; 115 spikes were selected from among the resistant rows in 2013 and planted as $F_{5:6}$ observation rows in Lethbridge. In 2014, 40 of the 115 rows were harvested and seeded in single replicate irrigated preliminary trials in Lethbridge, as well as the stem and leaf rust nursery in Winnipeg, and an inoculated stripe rust nursery in Lethbridge. Based on the resistance expressed by parent LF1318, wheat curl mite (WCM, *Aceria tosichella* Keifer) reaction was also evaluated. Promising agronomic characteristics, resistance to all wheat rusts, and acceptable end-use quality prompted replicated, multi-location testing of 13 lines in 2016 and three lines in 2017. Further examination of the resistance to stem rust, leaf rust, stripe rust, *Fusarium* head blight (FHB) {caused by *Fusarium graminearum* Schwabe [teleomorph *Gibberella zeae* (Schwein.) Petch]}, common bunt [*Tilletia tritici* (Bjerk.) G. Wint. in Rabenh. and *Tilletia laevis* Kühn in Rabenh.], and wheat curl mite were also conducted in both years. Following 14 site-years of replicated field tests across western Canada and 2 years of full end-use quality analysis, a line designated LR535 entered the WWWC registration trial as W601 and was evaluated for 3 years (2017/2018 to 2019/2020). It was retained in the trial in 2020/2021 to provide contiguous annual data as it transitioned to become a check, starting in 2021/2022. For additional details, please see Table 1.

Performance

Grain yield and agronomics

The performance of AAC Coldfront was assessed in the WWWC registration trials relative to CDC Buteo, Emerson (Graf et al. 2013), Moats (Fowler 2012), and AAC Elevate (Graf et al. 2015). Agronomic test sites across western Canada were in Alberta (Beaverlodge, Lacombe, Lethbridge, Olds, Warner), Saskatchewan (Indian Head, Melfort, Saskatoon, Swift Current), and Manitoba (Brandon, Carman, Portage la Prairie, 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 where environments were treated as random effects and genotypes were fixed. The least significant difference (LSD) generated from the analysis of variance was used to identify significant differences from the check cultivars.

Data collected from 32 sites over 3 years established the agronomic performance of AAC Coldfront in western Canada. The overall mean grain yield of AAC Coldfront was 11% higher than the CWRW check mean ($P \leq 0.05$). Relative to specific checks, AAC Coldfront was significantly higher yielding than CDC Buteo (+13%), Emerson (+15%), Moats (+9%), AAC Elevate (+8), and CDC Falcon (+14%) ($P \leq 0.05$). CDC Falcon is not a CWRW check but is reported because of its familiarity to Manitoba and eastern prairie producers. On a provincial basis, AAC Coldfront had significantly higher grain yield than all of the checks in Alberta and Saskatchewan. In Manitoba, AAC Coldfront was significantly higher yielding than CDC Buteo and Moats ($P \leq 0.05$), and marginally higher than Emerson and AAC Elevate ($P \leq 0.06$) (Table 2).

AAC Coldfront expressed winter survival similar to the CWRW check cultivars and equal to CDC Buteo, the best check. The heading and maturity dates for AAC Coldfront were earlier and later than the CWRW check

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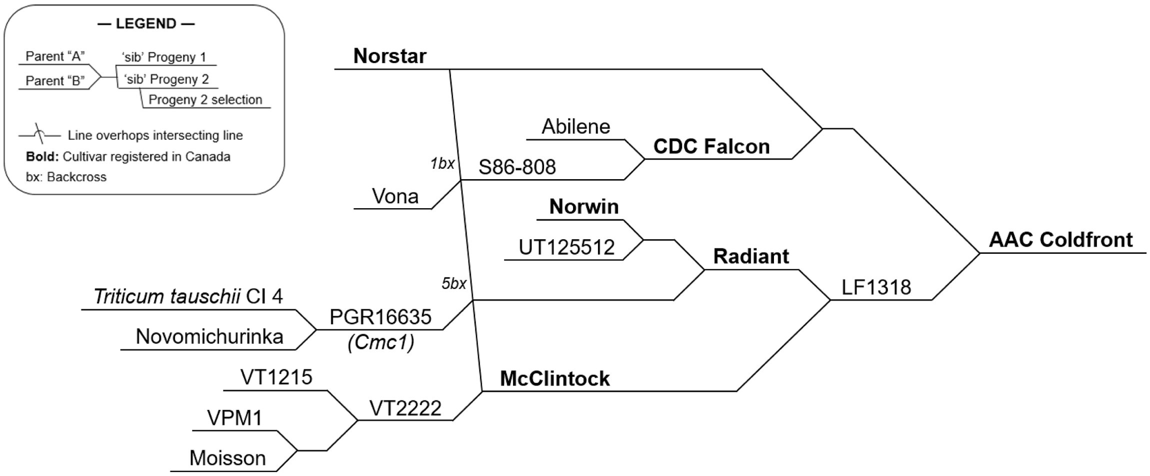
Fig. 1. Expanded ancestry of AAC Coldfront hard red winter wheat.



means, respectively ($P \leq 0.05$), which reflects a 2 day longer grain-filling period. AAC Coldfront was similar to AAC Elevate for heading date and to Emerson for maturity date. The plant height of AAC Coldfront was equal to AAC Elevate and shorter than the remaining CWRW checks ($P \leq 0.05$). Lodging resistance was superior to CDC Buteo and Moats ($P \leq 0.05$). The test weight and seed weight of AAC Coldfront were within the range of the CWRW checks. AAC Coldfront produced grain with a protein concentration similar to the check mean and equal to CDC Buteo and Moats. Grain protein yield, measured by multiplying grain yield × grain protein concentration at each site, was 10% higher than the check mean and 7% higher than Emerson, the best check ($P \leq 0.001$), suggesting that AAC Coldfront has a much improved capacity to convert soil moisture and nutrients into grain under a wide range of western Canadian field conditions (DePauw et al. 1989; Ortiz-Monasterio et al. 2001) (Table 3). Research into the nature of this improvement may be valuable as plant breeders and other scientists strive to improve the productivity, climate resilience, and profitability of the Canadian agriculture sector.

Disease resistance

During registration testing, resistance to the wheat diseases of major economic importance in the eastern and western prairies (Aboukhaddour et al. 2020) was assessed by AAFC and the University of Manitoba using methodologies described in the Operating Procedures (Appendix E) of the Prairie Recommending Committee for Wheat, Rye, and Triticale (PRCWRT; www.pgdc.ca). Supplementary checks were included in the various nurseries to aid in making accurate assessments. 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 1 or more years included MCC (P0001), QTH (P0005), RHT (P0002), RKQ (P0003), RTH (P0007), TMR (P0006), and TPM (P0004) (Fetch et al. 2021). The leaf rust races were a representative mixture collected in western Canada during the previous field season (McCallum et al. 2021). Seedling reactions to individual races of stem and leaf rust 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 1 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, using races prevalent in southern Alberta during the previous year (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 seed was mixed with a blend of bunt spores that included races 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 in Carman and Winnipeg, and at the AAFC Ottawa Research and Development Centre in Ottawa, using mist-irrigated field nurseries with three replicates. Each line was spray-inoculated with an *F. graminearum* macroconidial suspension at 50% anthesis and again 3–4 days later. The inoculum had a concentration of 50 000 macroconidia·mL^{-1} and contained equal amounts of two 3-acetyldeoxynivalenol (3-ADON) and two 15-acetyldeoxynivalenol (15-ADON) producing chemotypes. Visual index (% incidence × % severity / 100) was typically recorded 18 to 21 days after anthesis or when symptoms were well developed (Gilbert and Woods 2006; Cuthbert et al. 2007). At maturity in Carman and Winnipeg, a 50 g sample from each row was used to determine the percentage of *Fusarium*-damaged kernels (FDK)

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Table 1. AAC Coldfront hard red winter wheat selection and evaluation history.

Year	Gen.	Identity	Status	No. seeds, plants, lines	Selection or agronomic evaluation locations	Selection criteria, handling
2008	F_0	J118	Final cross completed: Norstar/CDC Falcon//LF1318	153 seeds	—	—
2009	F_1	J118	F_1 seed grown in greenhouse	60 plants	—	Harvested in bulk.
2009/2010	F_2	J118	F_2 bulk population	Approx. 6000 plants	Lethbridge (irrigated)	Spikes selected from plants based on survival, spring vigour, plant type, height, straw strength. Threshed individually.
2010/2011	$F_{2:3}$	J118-2x	Head rows	138 families	Lethbridge (irrigated)	Spikes selected from families based on winter survival, spring vigour, plant type, height, straw strength, stripe rust resistance. Threshed in bulk.
2011/2012	F_4	J118-3x	Modified bulk plots	Approx. 3200 plants	Saskatoon	Spikes selected from plants with good winter survival, plant type, height, straw strength. Threshed individually.
2012/2013	$F_{4:5}$	J118-4x	Head rows	153 families	Winnipeg	Spikes selected from rows based on stem and leaf rust resistance, absence of disease, survival, plant type, height, straw strength. Threshed individually.
2013/2014	$F_{5:6}$	J118-5ED	Head rows	115 lines	Lethbridge (irrigated)	Rows selected based on winter survival, vigour, plant type, height, straw strength, stripe rust resistance, overall leaf health.
2014/2015	$F_{5:7}$	LR535	Preliminary trial (1 location × 1 replicate); disease screening: stem, leaf and stripe rust, wheat curl mite (WCM).	40 lines	Lethbridge (irrigated)	Advancement based on yield, agronomics, disease resistance, grain protein, test weight, basic milling and rheology.
2015/2016	$F_{5:8}$	LR535	A-level trial (5 sites × 3 replicates); screening: all rusts, FHB, bunt, WCM, survival.	13 lines	Lethbridge (dry land and evergreen), Warner, Indian Head, Brandon	Advancement based on yield, agronomics, disease resistance, grain protein, test weight, milling, rheology, baking.
2016/2017	$F_{5:9}$	LR535	B-level trial (9 sites × 3 replicates), screening: all rusts, FHB, bunt, WCM, survival.	3 lines	As above plus: Lacombe, Swift Current, Saskatoon, Carman	Advancement based on yield, agronomics, disease resistance, grain protein, test weight, milling, rheology, baking.

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Table 1. (*concluded*).

Year	Gen.	Identity	Status	No. seeds, plants, lines	Selection or agronomic evaluation locations	Selection criteria, handling
2017/2018 to 2019/2020	$F_{5:10\text{-}12}$	W601	Western Canadian Winter Wheat Cooperative (WWWC) Registration trial (15 sites × 3 replicates); screening: all rusts, FHB, bunt, WCM.	2 lines in Year 1 (W600 and W601); 1 line in Years 2 and 3	As above plus: Lethbridge (irrigated), Olds, Beaverlodge, Melfort, Portage la Prairie, Winnipeg.	Advanced based on excellent yield, agronomics, disease resistance and acceptable end-use quality.
Breeder Seed Production						
2018/2019	F_{11}	W601	Rogued seed increase plot	Approx. 175 spikes	Lethbridge (irrigated)	Spikes threshed individually. Head rows seeded in isolation.
2019/2020	F_{12}	W601	Head rows (potential breeder lines)	116 potential rows; 75 with reasonable establishment.	Lethbridge (irrigated)	Poor establishment due to late seeding into wet soil and spring soil erosion. Selected 45 of 75 rows based on uniformity within and among rows. Rows harvested individually, treated with fungicide, sent to Indian Head Seed Increase Unit.
2020/2021	F_{13}	W601	Breeder line plots	45 breeder lines	Indian Head	5 lines eliminated due to extreme drought and gopher damage. 3 lines discarded based on height variability. Remaining 37 breeder lines harvested in bulk to form Breeder Seed.

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Table 2. Grain yield (t·ha^{-1}) of AAC Coldfront and the check cultivars, Western Canadian Winter Wheat Cooperative registration trial (2018–2020).

				Grand mean		Alberta		Saskatchewan		Manitoba		Zone 1[a]		Zone 2[a]		Zone 3[a]		Zone 4[a]	
Cultivar	2018	2019	2020	t·ha^{-1}	% Ck[b]	t·ha^{-1}	% Ck[b]	t·ha^{-1}	% Ck[b]	t·ha^{-1}	% Ck[b]	t·ha^{-1}	% Ck[b]	t·ha^{-1}	% Ck[b]	t·ha^{-1}	% Ck[b]	t·ha^{-1}	% Ck[b]
CDC Buteo	4.239	4.241	5.357	4.605	98	4.943	97	3.929	101	4.733	100	4.451	93	5.081	102	3.740	100	4.552	99
Emerson	3.907	4.427	5.181	4.517	97	4.835	95	3.748	96	4.788	101	4.494	94	4.758	96	3.613	97	4.525	99
Moats	4.193	4.545	5.577	4.778	102	5.316	104	3.944	101	4.709	99	5.077	106	5.016	101	3.959	106	4.551	99
AAC Elevate	4.162	4.669	5.593	4.814	103	5.338	105	3.971	102	4.780	101	5.113	107	5.013	101	3.578	96	4.675	102
CDC Falcon	4.064	4.291	5.343	4.567	98	5.107	100	3.753	96	4.472	94	4.897	102	4.870	98	3.582	96	4.305	94
CWRW check mean[b]	4.125	5.082	5.427	4.679	100	5.108	100	3.898	100	4.752	100	4.784	100	4.967	100	3.722	100	4.576	100
AAC Coldfront	4.526	4.680	5.996	5.209	111	5.753	113	4.400	113	5.100	107	5.574	117	5.402	109	4.151	112	5.001	109
LSD ($P \leq 0.05$)	0.322	0.326	0.406	0.187	—	0.310	—	0.303	—	0.325	—	0.361	—	0.422	—	0.527	—	0.253	—
No. of tests	10	11	11	32	—	15	—	9	—	8	—	9	—	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), Warner); Zone 2, Parkland sites (Beaverlodge, Lacombe, Olds, Melfort); Zone 3, Semi-arid prairie site (Swift Current); Zone 4, Eastern prairie rust-hazard sites (Brandon, Carman, Indian Head, Portage la Prairie, Saskatoon, Winnipeg).
[b]Percent of CWRW check mean (CDC Buteo, Emerson, Moats, AAC Elevate). CDC Falcon is a CWSP check.

Table 3. Agronomic and seed characteristics of AAC Coldfront and the check cultivars, Western Canadian Winter Wheat Cooperative registration trial (2018–2020).

	Grain Yield										
Cultivar	t·ha^{-1}	% Ck[a]	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})
CDC Buteo	4.605	98	89	170.9	215.9	81	4.0	82.6	33.3	12.4	596
Emerson	4.517	97	88	171.1	217.4	79	1.8	81.4	29.4	13.3	621
Moats	4.778	102	88	171.7	216.3	81	3.0	81.1	32.2	12.4	617
AAC Elevate	4.814	103	87	170.7	216.0	76	2.0	80.2	37.6	11.9	600
CDC Falcon	4.567	98	87	169.7	213.4	68	2.0	80.4	30.4	12.2	586
CWRW check mean[a]	4.679	100	88	171.1	216.4	79	2.7	81.3	33.1	12.5	608
AAC Coldfront	5.209	111	89	170.2	217.8	76	1.7	81.9	32.8	12.4	670
LSD ($P \leq 0.05$)	0.187		3.4	0.6	0.85	1.2	0.72	0.43	0.68	0.22	23.7
No. of tests	32		18	27	29	32	10	29	29	29	29

Note: LSD, least significant difference includes variation from the appropriate genotype × environment interaction.
[a]Percent of the CWRW check mean (CDC Buteo, Emerson, Moats, AAC Elevate). CDC Falcon is a CWSP check.
[b]Days to heading and maturity expressed as day of the year.
[c]Height measured from soil surface 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.

Table 4. Disease reactions of AAC Coldfront and the check cultivars, Western Canadian Winter Wheat Cooperative registration trials (2018–2020).

Disease	Year	CDC Buteo	Emerson	Moats	AAC Elevate	CDC Falcon	AAC Coldfront
Stem rust	2018[a]	—	—	—	—	—	—
	2019	10 R-70 S	5 R	5 R	10 R-MR	10 R	tr R
	2020	30 I	tr R	tr MR	10 MR	5 MR	10 MS-S
Leaf rust	2018[a]	—	—	—	—	—	—
	2019	15 MR-S	5 R-MR	5 R-MR	10-20 I	5 MR	tr R
	2020	15 MR	5 R-MR	5 R-MR	5 MR	5 MR	5 R-MR
Stripe rust	2018	70 S	15 MR	5 R	70 S	60 S	15 MR
	2019	90 S	—	2 R	90 S	60 S	0 R
	2020	60 S	15 R	1 R	80 S	30 I	2 R
Common bunt	2018	30 MS	33 S	33 S	7 R	35 S	36 S
	2019	29 I	49 S	38 MS	15 MR	29 I	43 MS
	2020	33 MS	—	23 I	1 R	15 MR	40 S

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]Despite repeated inoculations, 2018 data were not available due to environmental conditions that prevented adequate infection and spread of the pathogens.

and to quantify the deoxynivalenol (DON) content using enzyme-linked immunosorbent assays (ELISA). The response to WCM infestation was conducted annually at AAFC LeRDC by exposing several replicates of 10 to 15 seedlings to non-viruliferous mites for 2 to 3 weeks under controlled-environment conditions, with ratings based on pronounced leaf rolling and looping of newly emerging leaves (Thomas and Conner 1986).

The PRCWRT Disease Evaluation Team summarized 3 years of disease ratings for AAC Coldfront as resistant to the prevalent races of stem rust, leaf rust, and stripe rust, intermediate in resistance to FHB, and susceptible to common bunt (Tables 4 and 5). AAC Coldfront did not express wheat curl mite resistance (data not presented).

End-use quality

End-use quality analyses were conducted annually at the Canadian Grain Commission, Grain Research Laboratory, following protocols of the American Association of Cereal Chemists (2000). Following Canadian Grain Commission 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 where the mean protein concentration of the checks was approximately 12.5%. Grain from test sites with serious down-grading factors was not included in the quality composites.

Following 3 years (2018–2020) of end-use suitability testing, the PRCWRT Quality Evaluation Team considered AAC Coldfront eligible for grades of CWRW wheat. Based on the 3-year means, AAC Coldfront was within tolerances relative to the check means for most characteristics. Notably, AAC Coldfront had superior flour yield (0.5% ash), with improved (lower) ash content. AAC Coldfront was flagged for lower farinograph absorption but was within the range of the checks (Table 6).

Other Characteristics

Seedling

Leaf sheath and blade glabrous.

Plant

Juvenile growth habit prostrate; flag leaf blade glabrous, medium to strong glaucosity, mid-long, mid-wide, absent or very low frequency of recurved leaves; flag leaf sheath glabrous, strong glaucosity; absent or very weak auricle anthocyanin colouration; culm neck straight to weakly curved, hollow, upper most node pubescence absent or very sparse, weak glaucosity, anthocyanin intensity at maturity absent or very weak.

Spike

Awned, tapering, medium density, medium length, medium glaucosity, yellow, inclined, awns white, medium spreading to spreading; lower glume mid-long, mid-wide, glabrous; glume shoulders primarily strongly sloping, width very narrow to narrow; glume beak short to medium long; resistant to shattering.

Kernel

Medium red, texture medium hard, medium size.

Maintenance and Distribution of Pedigreed Seed

A standard head-row derivation approach was used to produce Breeder Seed of AAC Coldfront. In fall 2019, spikes were collected from rogued $F_{5:11}$ increase plots, threshed individually, and planted in Lethbridge under isolation. Unfortunately, an intense blizzard on

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Table 5. *Fusarium* head blight (FHB) reaction of AAC Coldfront, check cultivars and supplementary checks, Western Canadian Winter Wheat Cooperative registration trials (2018–2020).

	Visual rating[a] (index and response)									Deoxynivalenol (ppm)					*Fusarium*-damaged kernels[b] (%)				
	Carman[c]		Winnipeg[c]		Ottawa			MB Mean ($n=4$)	Grand Mean ($n=7$)	Carman[c]		Winnipeg[c]		Mean ($n=4$)	Carman[c]		Winnipeg[c]		Mean ($n=4$)
	2019	2020	2019	2020	2018	2019	2020			2019	2020	2019	2020		2019	2020	2019	2020	
CDC Buteo	1 MR	68 MS	20 I	6 MR	21	11	13	24	20	3	24 MS	16	3 MR	12	1	13	6	2	6
Emerson	2 MR	38 MR	12 MR	11 I	11	8	9	16	13	1	14 MR	6	2 R	6	1	6	3	2	3
Moats	3 MR	61 I	42 S	37 S	15	10	19	36	27	5	22 I	19	10 I	14	2	9	11	5	7
AAC Elevate	2 MR	56 I	31 MS	16 I	16	15	13	26	21	3	19 I	9	4 MR	9	2	7	5	3	4
CDC Falcon	3 MR	80 S	61 S	37 S	57	31	14	45	40	2	28 MS	24	11 I	16	1	26	17	6	13
AAC Coldfront	1 R	53 I	31 MS	19 I	13	13	11	26	20	1	21 I	16	4 MR	11	0	9	9	3	5
Supplementary checks																			
DH00W32C*17	0 R	20 R	5 R	1 R	—	—	—	7	—	2	11 MR	7	1 R	5	1	4	3	1	2
FHB148	2 MR	22 R	4 R	2 R	—	—	—	8	—	2	9 R	7	2 R	5	1	2	2	1	2
Freedom	5 I	37 MR	22 I	7 I	—	—	—	18	—	5	18 I	16	7 I	12	2	7	7	5	5
DH01W43I*18	2 MR	35 MR	27 I	3 MR	—	—	—	17	—	4	18 I	15	3 MR	10	1	11	6	2	5
Caledonia	29 S	83 S	55 S	16 MS	—	—	—	46	—	10	30 S	35	16 MS	23	3	22	12	9	12
Hanover	27 S	37 MR	72 S	25 S	—	—	—	40	—	11	13 MR	57	25 S	27	5	5	23	19	13

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.

[c]Data from Carman were not available in 2018 due to severe winterkill; an additional Manitoba nursery was initiated in Winnipeg in 2019.

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Table 6. End-use quality characteristics of AAC Coldfront and the check cultivars, Western Canadian Winter Wheat Cooperative registration trials (2018–2020).

Cultivar	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 (%)	Water dough colour (2 h)[a]		
										L*	a*	b*
CDC Buteo	13.0	12.1	1.0	425	570	77.0	80.8	0.36	6.6	79.99	2.51	22.41
Emerson	13.7	12.8	0.9	400	633	76.8	81.0	0.36	5.9	79.24	2.66	23.76
Moats	12.9	12.1	0.8	448	768	76.0	79.2	0.40	7.4	79.74	2.40	22.57
AAC Elevate	12.4	11.4	1.0	415	608	77.2	80.3	0.37	7.1	79.56	2.54	22.75
Check mean	13.0	12.1	0.9	422	645	76.7	80.3	0.37	6.8	79.63	2.53	22.87
AAC Coldfront	12.8	11.7	1.1	392	535	76.3	82.0	0.34	6.2	79.55	2.19	23.69
SD[b]	0.1	0.1	0.1	15	5	0.3	0.3	0.01	0.1	NA	NA	NA
N[c]	3	3	3	3	3	3	3	3	3	3	3	3

	Extensograph			Farinograph[d]			Lean No Time (LNT) bake				
	Area (cm²)	R_{max} (BU)	Length (cm)	Water absorption (%)	DDT (min)	Stability (min)	Bake absorption (%)	Peak time (m)	Mixing energy (Wh·kg^{-1})	Loaf volume (cm³)	Loaf top ratio
CDC Buteo	88	388	17.9	59.2	5.75	7.2	66.5	2.9	7.7	738	0.53
Emerson	164	886	15.9	56.7	7.92	22.3	64.5	4.7	12.7	803	0.66
Moats	104	510	16.5	59.0	6.58	8.5	66.0	3.6	9.5	728	0.56
AAC Elevate	94	494	15.4	57.7	5.50	7.2	65.0	3.1	8.2	740	0.59
Check mean	113	570	16.4	58.2	6.44	11.3	65.5	3.5	9.5	753	0.58
AAC Coldfront	83	404	16.3	56.9	5.77	6.8	64.0	3.2	8.3	736	0.57
SD[b]	4	20	6	0.2	0.4	1.4	0.0	0.1	0.3	14	0.04
N[c]	3	3	3	3	3	3	2	2	2	2	2

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

[a]CIELAB colour scale: L*, a*, and b* represent lightness, red-green, and yellow-blue values, respectively.

[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]*N*, number of evaluation years.

[d]Farinograph parameters: DDT, farinograph dough development time.

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28–29 Sept. 2019 necessitated late seeding into wet soil, resulting in uneven emergence and poor establishment of the rows, which was further exacerbated by intense winds and soil erosion in early spring. These unfavourable conditions reduced the number of available rows from 116 to 75 with reasonable growth. In the interest of developing uniform Breeder Seed, 30 of the 75 head rows were eliminated due to what appeared to be minor height and maturity differences, some of which were likely the result of variable times to emergence, often within the same row. The remaining 45 rows were harvested individually and sent to the AAFC Seed Increase Unit at Indian Head for planting. In 2021, 5 of the 45 potential breeder lines were eliminated due to extreme drought and gopher damage. Three lines were eliminated based on variable height. The remaining 37 breeder lines at the F_{13} generation were inspected, harvested in bulk, and cleaned to produce 395 kg of Breeder Seed, which was distributed to pedigreed seed growers in fall 2021. Breeder Seed of AAC Coldfront will be maintained by the AAFC Seed Increase Unit. All other pedigreed seed classes will be multiplied and distributed by SeCan Association, 400–300 Terry Fox Drive, Ottawa, ON, K2K 0E3, Canada. Tel: 1-800-764-5487; Fax: 613-592-9497; e-mail: seed@secan.com.

Acknowledgements

Sincere appreciation is expressed to the dedicated staff at the AAFC LeRDC who contributed to the development of AAC Coldfront winter wheat, in particular: B. Postman, D. Quinn, J. Prus, M. Fast, L. Kneeshaw, D. Pearson, E. Amundsen, T. Despins, C. Parent, S. Pahl, M. Cradduck, and the many summer students over the years. The authors also recognize the support provided by numerous AAFC personnel working at research sites in Lethbridge, Beaverlodge, Swift Current, Saskatoon, Indian Head, Melfort, Brandon, Portage la Prairie, Winnipeg, and Ottawa; the provision of inoculated stem/leaf rust and FHB nurseries by A. Brûlé-Babel at the University of Manitoba; and all contributors to the Western Canadian Winter Wheat Cooperative registration trials. Thanks are also extended to H. Naeem and staff of the AAFC Seed Increase Unit at Indian Head for their care and attention in producing and maintaining the Breeder Seed of AAC Coldfront. In addition to funding from AAFC, financial assistance from the following producer and industry groups is gratefully acknowledged: the Western Grains Research Foundation producer check-off on wheat, the Ducks Unlimited Canada administered Western Winter Wheat Initiative, the Canadian Wheat Research Coalition, the Alberta Wheat Commission, the Saskatchewan Winter Cereals Development Commission, Winter Cereals Manitoba, and the Alberta Crop Industry Development Fund.

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 Path. **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.

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.

DePauw, R.M., Clarke, J.M., McCaig, T.N. and Townley-Smith, T.F. 1989. Opportunities for the improvement of western Canadian wheat protein concentration, grain yield and quality through plant breeding. Pages 75–93 in D.B. Fowler, W.E. Geddes, A.M. Johnston, and K.R. Preston, eds. Wheat protein production and marketing. Wheat Protein Symposium, Saskatoon, SK. 9–10 March 1998. Univ. Extension Press, University of Saskatchewan, Saskatoon, SK.

Fetch, T., Fetch, J.M., Zegeye, T., and Xue, A. 2021. Races of *Puccinia graminis* on barley, oat, and wheat in Canada from 2015 to 2019. Can. J. Plant Pathol. **43**: 463–471. doi:10.1080/07060661.2020.1829066.

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

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., 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.

Grant, M.N. 1980. Registration of Norstar wheat. Crop Sci. **20**: 552. doi:10.2135/cropsci1980.0011183X002000040042x.

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. doi:10.1094/Phyto-66-657.

McCallum, B.D., Reimer, E., McNabb, W., Foster, A., Rosa, S., and Xue, A. 2021. Physiologic specialization of *Puccinia triticina*, the causal agent of wheat leaf rust, in Canada in 2015–2019. Can. J. Plant Pathol. **43**: S333–S346. doi:10.1080/07060661.2021.1888156.

Ortiz-Monasterio, J.I., Manske, G.G.B., and van Ginkel, M. 2001. Chapter 17: Nitrogen and phosphorus use efficiency. Pages 200–207 in M.P. Reynolds, J.I. Ortiz-Monasterio, and A. McNab, eds. Application of physiology in wheat breeding. CIMMYT, Mexico, D.F.

Peterson, R.F., Campbell, A.B., and Hannah, A.E. 1948. A diagrammatic scale for estimating rust intensity on leaves

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and stems of cereals. Can. J. Res. **26**(sec C): 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. Radiant hard red winter wheat. Can J. Plant Sci. **92**: 169–175. doi:10.4141/cjps2011-082.

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