CULTIVAR DESCRIPTION

AAC Elevate hard red winter wheat

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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. AAC Elevate is a hard red winter wheat (*Triticum aestivum* L.) cultivar that is well adapted across western Canada and eligible for all grades of the Canada Western Red Winter (CWRW) wheat class. It was developed using wheat × maize-pollen doubled haploid methodology. AAC Elevate was evaluated in the Western Winter Wheat Cooperative Registration trials relative to CDC Osprey, AC Bellatrix, Radiant and CDC Buteo for 3 yr (2011–2013), with Flourish and Moats added as checks in the latter 2 yr. Based on these 35 replicated trials, AAC Elevate produced higher grain yield than all of the checks (103.3–114.4%) and exhibited good winter survival, medium height with excellent straw strength, large kernels, acceptable end-use quality, and broad disease resistance. AAC Elevate expressed moderate resistance to stem rust and common bunt, intermediate resistance to leaf rust, stripe rust and Fusarium head blight, and resistance to colonization by the wheat curl mite vector for wheat streak mosaic virus.

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

Graf, R. J., Beres, B. L., Randhawa, H. S., Gaudet, D. A., Laroche, A. et Eudes, F. 2015. **Le blé de force rouge d'hiver AAC Elevate**. Can. J. Plant Sci. **95**: 1021–1027. AAC Elevate est une variété de blé de force rouge d'hiver (*Triticum aestivum* L.) bien adaptée à l'Ouest canadien. Ce cultivar est admissible à toutes les classes du blé rouge d'hiver de l'Ouest canadien (CWRW). Il a été créé par la technique de l'haploïdie double avec du pollen de blé et de maïs. AAC Elevate a été évalué aux essais d'homologation coopératifs de l'Ouest sur le blé d'hiver et comparé à CDC Osprey, AC Bellatrix, Radiant et CDC Buteo pendant trois ans (2011–2013), les variétés Flourish et Moats ayant été rajoutées aux autres variétés témoins les deux dernières années. D'après les résultats des 35 essais répétés, le rendement grainier d'AAC Elevate dépasse celui de tous les témoins (de 103,3 à 114,4 %). La variété se caractérise par une bonne rusticité, a une taille moyenne et une paille très robuste, produit de gros grains de qualité acceptable selon l'usage final, et jouit d'une large résistance à la maladie. AAC Elevate exprime une résistance modérée à la rouille de la tige et à la carie commune et résiste de façon intermédiaire à la rouille des feuilles, à la rouille jaune et à la brûlure de l'épi causée par Fusarium. Enfin, elle résiste à la colonisation par *Aceria tosichella,* insecte vecteur de la mosaïque-bigarrure.

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

AAC Elevate hard red winter wheat (*Triticum aestivum* L.) was developed at the Lethbridge Research Centre (LRC) of Agriculture and Agri-Food Canada (AAFC) in Lethbridge, AB. Tested as LJ083 and W495, AAC Elevate was granted registration no. 7669 by the Variety Registration Office, Plant Production Division, Canadian Food Inspection Agency on 2015 Feb. 09. Plant Breeders' Rights application no. 15-8512 was accepted for filing on 2015 Jan. 26.

High grain yield, good winter survival, desirable agronomic traits, acceptable end-use quality, and broad-spectrum disease resistance make AAC Elevate Canada Western Red Winter (CWRW) wheat well-suited for production in all areas of western Canada. AAC Elevate is the first Canadian winter wheat cultivar to combine useful levels of resistance to stem, leaf and stripe rust, Fusarium head blight, common bunt and the wheat curl mite vector of wheat streak mosaic virus. The name "Elevate" was chosen for this cultivar with optimism that it will raise producer expectations and confidence in western Canadian winter wheat production.

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Pedigree and Breeding Method

AAC Elevate originates from the three-way cross Radiant// AC Bellatrix/N95L1226 completed in 2003 at the AAFC LRC. Radiant (Thomas et al. 2012a) and AC Bellatrix (Thomas et al. 2012b) are registered CWRW wheat cultivars developed by AAFC LRC. N95L1226 is a sib of the hard red winter wheat cultivar Wesley, which was accessed through participation in the 1998 and 1999 Northern Regional Performance Nurseries and used in crosses under the provisions of the Wheat Workers Code of Ethics. It was developed by the United States Department of Agriculture,

Abbreviations: **AAFC**, Agriculture and Agri-Food Canada; **CWRW**, Canada Western Red Winter; **DH**, doubled haploid; **FHB**, fusarium head blight; **LRC**, Lethbridge Research Centre; **WCM**, wheat curl mite; **WWWC**, Western Winter Wheat Cooperative

Agricultural Research Service (USDA-ARS) at Lincoln, NE. The ancestry of N95L1226 is KS831936-3/NE86501, where KS831936-3 is a sib of Sumner with Plainsman V/Odeskaja 51 parentage and NE86501 is a selection from the cross Colt/Cody (Peterson et al. 2001).

In late 2003, 72 F_1 seeds were vernalized and later needle inoculated with a mixture of prevalent races of stem rust (*Puccinia graminis* Pers.: Pers. f.sp. *tritici* Eriks. & E. Henn.) and leaf rust (*P. triticina* Eriks.) when the main stem was at the early boot stage (Z45) (Zadoks et al. 1974). These plants were placed in a greenhouse outfitted with misting nozzles to maintain 95% relative humidity at 25°C for 3 d. About 10 d after removal from the high humidity conditions and growth in a greenhouse set at 22/16°C, stem and leaf rust ratings identified 12 resistant plants that were used to produce 84 doubled haploid (DH) lines by employing wheat × maize-pollen hybridization techniques (Fedak et al. 1997; Knox et al. 2000). Eight DH lines were derived from the F_1 plant from which AAC Elevate originates.

Evaluation of a first subset of 68 DH genotypes occurred in 2 m observation rows grown under irrigation near Lethbridge in 2006, resulting in the harvest of 23 lines based on winter survival, vigour, plant type, height and straw strength. The remaining 16 DH lines were evaluated in a similar manner in either 2007 or 2008. All selections were then rated in an artificially inoculated stem and leaf rust nursery, grown in collaboration with the University of Manitoba in Winnipeg, MB. Resistance to common bunt [*Tilletia tritici* (Bjerk.) G. Wint. in Rabenh. and *T. laevis* Kühn in Rabenh.] was also estimated at Lethbridge by planting inoculated seed into cold soil in mid-October. Based on acceptable resistance to all three diseases in 2007, 10 of the initial 23 selections were tested in single replicate preliminary agronomic trials in Lethbridge. Favourable agronomic performance, continued resistance to the rusts and bunt, resistance to colonization by the wheat curl mite (WCM) (*Aceria tosichella* Keifer) vector for wheat streak mosaic virus, and acceptable end-use quality prompted the advancement of two lines into replicated trials across western Canada in 2009 and 2010. Following 12 site-years of pre-registration testing, line LJ083 was designated as W495 and evaluated in the Western Winter Wheat Cooperative (WWWC) registration trial for 3 yr (2011–2013).

The performance of AAC Elevate in the WWWC registration trials was assessed relative to CDC Osprey (Fowler 1997), AC Bellatrix, Radiant and CDC Buteo (Fowler 2010) for 3 yr, with Flourish (Graf et al. 2012) and Moats (Fowler 2012) added as checks in the latter 2 yr. Agronomic test sites across western Canada were in Alberta (Beaverlodge, Lacombe, Lethbridge "dry land", Lethbridge "irrigated", Morrin, Olds, Warner), Saskatchewan (Indian Head, Kamsack, Melfort, Saskatoon, Swift Current), and Manitoba (Brandon, Carman, Winnipeg), through the collaborative efforts of AAFC, Alberta Agriculture and Rural Development, the University of Saskatchewan, the University of Manitoba, and Canterra Seeds Ltd. Analyses of variance were conducted using a combined mixed effects model where 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, the University of Manitoba, and the agronomic trial collaborators when differential responses for various pathogens were observed. Supplementary checks were added as required to aid in making accurate assessments. 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 Cereal Research Centre, and reported using the modified Cobb scale (Peterson et al. 1948). The stem rust races used for 1 or more years included: MCCFR (P0001), QTHJT (P0005), RHTSK (P0002), RKQSR (P0003), RTHJT (P0007), TMRTK (P0006) and TPMKR (P0004) (Fetch 2005; Jin et al. 2008). The leaf rust races were a representative mixture collected in western Canada during the previous field season (McCallum et al. 2011, 2013). Seedling reactions to infection by individual races of stem and leaf rust prevalent in Canada were also determined under controlled-environment conditions. 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), TJBJ (77-2) and TDBJ (11-180-1). Stripe rust (*P. striiformis* Westend.) ratings were determined in nurseries under conditions of natural infection in Lethbridge (Puchalski and Gaudet 2011). The reaction to common bunt was estimated in nurseries conducted at AAFC LRC by inoculating seed with a composite of races that included L1, L16, T1, T6, T13, and T19 (Hoffman and Metzger 1976; Gaudet and Puchalski 1989) prior to planting into cold soil at two locations in mid-October. Fusarium head blight (FHB) {caused by *Fusarium graminearum* Schwabe [teleomorph *Gibberella zeae* (Schwein.) Petch]} response was determined in a three-replicate, mist-irrigated field nursery in Carman, conducted by the University of Manitoba. Each line was spray-inoculated with a suspension of *F. graminearum* macroconidia at 50% anthesis and again 3 to 4 d later. Equal quantities of two 3-acetyldeoxynivalenol (3-ADON) and two 15-acetyldeoxynivalenol (15-ADON) producing chemotypes were used to prepare the spore suspension at a final concentration of 50 000 macroconidia mL^{-1}. Rating was done using a visual index (% incidence × % severity/100), typically 18 to 21 d after anthesis or when symptoms were well developed (Gilbert and Woods 2006; Cuthbert et al. 2007). A 50-g grain sample harvested from each inoculated row was used to determine the percentage of fusarium-damaged kernels and to quantify the deoxynivalenol content using enzyme-linked immunosorbent assays (ELISA) at the AAFC Eastern Cereal and Oilseed Research Centre

in Ottawa, ON (Sinha et al. 1995; Sinha and Savard 1996). Characterization of the response to WCM infestation was conducted each year using non-viruliferous mites under controlled-environment conditions at AAFC LRC (Thomas and Conner 1986). Several replicates of 10 to 15 plants each were rated for the typical symptoms of leaf rolling and trapping of new leaves following 2 to 3 wk of mite exposure. The reactions to powdery mildew [*Blumeria graminis* (DC.) E.O. Speer] and unspecified leaf spotting pathogens were recorded at test sites expressing differential symptoms based on natural infection.

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.

Performance

Data from across the Canadian prairies, collected at 35 sites over 3 yr, established the agronomic performance of AAC Elevate relative to check cultivars of the CWRW class. Data for CDC Falcon (Fowler 1999), a registration trial check for the Canada Western General Purpose wheat class, are also reported as it has been a predominant winter wheat cultivar in the eastern prairies since the early 2000s. The description of AAC Elevate performance will focus on comparisons relative to the CWRW checks.

The mean grain yield of AAC Elevate was 108.9% of the CWRW check mean ($P \leq 0.05$) across all sites over 3 yr (Table 1). Relative to specific checks, AAC Elevate had significantly higher grain yield than CDC Osprey (109.1%), AC Bellatrix (114.4%), CDC Buteo (109.3%), and Moats (105.5%), but the yield advantage over Radiant (103.3%) and Flourish (103.9%) was not significant ($P \leq 0.05$). On a regional basis, AAC Elevate demonstrated a significant yield advantage ($P \leq 0.05$) over all of the checks (109.4 to 121.1%) in southern Alberta (Zone 1), but the generally higher numerical yields for AAC Elevate in other zones or on a provincial basis were not necessarily significant. Based on yield performance across western Canada relative to the checks, the production of AAC Elevate was most advantageous in Alberta and Saskatchewan, although the differences from the highest-yielding checks (Radiant in Alberta, Radiant or Flourish in Saskatchewan) were not significant ($P \leq 0.05$). In Manitoba, Flourish and Moats were numerically higher yielding than AAC Elevate (NS).

AAC Elevate exhibited winter survival, heading and maturity characteristics that were similar to the check cultivars (Table 2). AAC Elevate produced straw that was 4 cm taller than Flourish ($P \leq 0.05$) but was 7–11 cm

Table 1. Grain yield (t ha^{-1}) of AAC Elevate and the check cultivars, Western Winter Wheat Cooperative registration trials (2011–2013)

				Grand mean		Alberta		Saskatchewan		Manitoba		Zone 1[y]		Zone 2		Zone 3		Zone 4	
Cultivar	2011[z]	2012	2013	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr
CDC Osprey	4.70	5.40	5.63	5.51	5.25	5.52	5.20	5.31	5.22	5.96	5.44	5.72	5.38	4.87	4.55	5.75	–	5.63	5.48
AC Bellatrix	4.42	5.45	5.07	5.28	5.01	5.13	4.68	5.21	5.15	5.82	5.43	5.39	4.94	4.28	4.01	5.88	–	5.58	5.47
Radiant	5.08	5.66	5.88	5.76	5.55	5.97	5.63	5.50	5.50	5.87	5.46	5.79	5.39	5.56	5.26	5.85	–	5.82	5.76
CDC Buteo	4.80	5.46	5.42	5.44	5.24	5.32	5.09	5.37	5.25	5.93	5.54	5.25	5.12	5.03	4.62	5.44	–	5.78	5.63
Flourish	–	5.63	5.82	5.72	–	5.77	–	5.53	–	6.06	–	5.75	–	4.96	–	5.61	–	6.10	–
Moats	–	5.62	5.64	5.63	–	5.60	–	5.41	–	6.23	–	5.27	–	5.32	–	5.45	–	6.07	–
CDC Falcon	5.08	5.63	5.42	5.53	5.39	5.61	5.50	5.37	5.18	5.72	5.54	5.63	5.41	4.87	4.84	5.90	–	5.72	5.60
CWRW check mean[x]	4.75	5.54	5.58	5.56	5.26	5.55	5.15	5.39	5.28	5.98	5.47	5.53	5.21	5.00	4.61	5.66	–	5.83	5.58
AAC Elevate	5.27	5.95	5.93	5.94	5.73	6.10	5.81	5.78	5.73	5.94	5.56	6.29	5.98	5.21	4.93	6.35	–	5.98	5.90
LSD ($P \leq 0.05$)[w]	0.51	0.35	0.52	0.30	0.23	0.45	0.39	0.44	0.31	0.73	0.42	0.53	0.48	0.66	0.51	0.88	–	0.44	0.30
No. of tests	11	13	11	24	35	10	15	10	13	4	7	7	10	5	8	2	–	10	15

[z]All means are weighted by the number of tests.
[y]Zone 1: Southern Alberta sites (Lethbridge "dry land", Lethbridge "irrigated", Morrin, 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, Kamsack, Saskatoon, Winnipeg).
[x]CDC Falcon is not a CWRW check and is therefore not included in the CWRW check mean.
[w]Least significant difference includes variation from the genotype by environment interaction.

Table 2. Agronomic and seed characteristics of AAC Elevate and the check cultivars, Western Winter Wheat Cooperative registration trials (2011–2013)

	Winter survival (%)		Heading[z] (%)		Maturity[z] (%)		Height[y] (%)		Lodging[x] (1–9)		Test weight (kg hL^{-1})		Seed mass (mg)		Grain protein[w] (%)		Grain protein yield (kg ha^{-1})	
Cultivar	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr	2 yr	3 yr
CDC Osprey	84	83	174	175	217	218	101	100	2.9	2.8	78.1	77.9	30.4	29.5	11.8	11.5	640	595
AC Bellatrix	79	78	176	177	219	220	98	98	4.0	3.6	79.3	79.0	33.1	32.2	12.5	12.2	649	601
Radiant	81	80	174	176	220	221	97	96	2.0	2.0	78.8	78.7	33.8	33.1	11.6	11.3	658	620
CDC Buteo	80	78	173	175	218	219	98	97	3.2	3.0	80.6	80.6	32.3	31.4	11.8	11.6	632	601
Flourish	82	–	172	–	215	–	86	–	2.3	–	78.2	–	34.3	–	12.2	–	685	–
Moats	80	–	174	–	218	–	99	–	3.0	–	79.7	–	32.1	–	12.4	–	686	–
CDC Falcon	81	80	172	174	215	216	81	80	2.8	2.6	78.0	78.0	28.9	28.4	11.6	11.4	624	602
CWRW check mean[v]	81	80	174	176	218	220	96	97	2.9	2.8	79.2	79.1	32.7	31.6	12.0	11.6	658	604
AAC Elevate	80	79	174	175	218	220	90	89	2.3	2.1	78.5	78.2	36.9	36.3	11.8	11.6	687	654
LSD ($P \leq 0.05$)[u]	4.8	3.2	0.6	0.4	1.1	0.9	1.7	1.6	0.5	0.5	0.6	0.6	0.9	0.9	0.3	0.2	41	30
No. of tests	13	19	20	29	22	32	24	35	16	21	21	32	21	32	21	32	21	32

[z]Days to heading and maturity expressed as day of the year.
[y]Height measured from ground to tip of spike, excluding awns.
[x]Lodging scale: 1 = all plants vertical, 9 = all plants horizontal.
[w]Grain protein concentration determined using whole grain near infrared reflectance analysis.
[v]CDC Falcon is not included in the CWRW check mean.
[u]Least significant difference includes variation from the genotype by environment interaction.

Table 3. Disease reactions of AAC Elevate and the check cultivars, pre-registration (2008–2010) and Western Winter Wheat Cooperative registration trial (2011–2014) data

Disease	Year	CDC Osprey	AC Bellatrix	Radiant	CDC Buteo	Flourish	Moats	CDC Falcon	AAC Elevate
Stem rust[z]	2009	30 S	70 S	60 S	20 MR/30 S	–	–	30 I	5 R
	2010	S	S	S	R/S	–	–	MR	R-MR
	2011	50 S	50 S	70 S	60 I	–	5 R-MR	30 MR	30 MS
	2012	50 MS-S	50 S	70 S	50 S/10 MR	5 R	tr R	30 I	tr R
	2013	50 S	80 S	80 S	40 MS/20 S	20 MR	5 R	20 MR	10 I
	2014	–	–	20 MS-S	40 MS-S	20 MR	tr R	10 R-MR	tr R
Leaf rust[z]	2011	60 MS-S	40 MS-S	70 MS-S	20 MR	–	5 R	5 MR	60 MS-S
	2012	20 MS	senesced	30 MS	20 MR	senesced	tr R-MR	5 MR	5 I
	2013	15 MS-S	10 MS-S	20 MS-S	5 I	5 I	tr R-MR	tr R-MR	10 I
	2014	–	–	25 MS-S	tr MR-5 MS	tr R-MR	tr R	10 I	15 MS-S
Stripe rust[z]	2010	50 S	80 S	30 I	35 I	–	–	25 I	0 R
	2011	40 S	38 S	32 MS	32 MS	–	–	50 S	24 MS
	2012	48 S	33 I	33 I	28 I	18 R	3 VR	43 S	13 R
	2013	45 S	63 I	60 S	13 I	2 R	0 VR	4 R	13 MR
	2014	–	–	60 S	70 S	40 MS	0 R	40 MS	25 I
Common bunt[zy]	2008	63 VS	12 MR	62 VS	–	–	–	58 VS	MR
	2009	66 VS	16 MR-I	52 VS	58 VS	–	–	34 MS	7 VR
	2010	51 VS	20 MR	46 VS	54 VS	–	–	34 VS	11 VR
	2011	68 VS	12 MR	57 VS	63 VS	–	31 MS	57 S	16 MR
	2012	46 VS	16 MR	31 S	43 VS	17 MR	26 I-MS	35 VS	19 MR-I
	2014	54 VS	14 MR	30 MS	29 MS	8 R	24 I	29 MS	22 I
Leaf spots[xw]	2011	3.3	2.7	5.7	5.7	–	–	5.7	4.3
	2012	3.1	2.9	4.9	5.3	3.5	5.0	5.0	4.2
	2013	2.1	2.4	4.2	4.1	2.8	2.2	2.2	2.6
	2014	–	–	2.0	2.2	3.2	2.8	3.0	2.0
Powdery mildew[w]	2011	3.8	3.5	3.7	3.0	–	–	2.9	3.3
	2012	4.0	4.7	4.0	4.3	3.7	2.3	2.3	3.7
	2013	4.7	4.3	3.0	4.0	2.7	3.0	3.0	3.3
	2014	–	–	3.2	3.0	2.8	2.3	2.0	2.5

[z]Percent infection and type of reaction: tr = trace, R = resistant, MR = moderately resistant, I = intermediate, MS = moderately susceptible, S = susceptible, VS = very susceptible.
[y]Common bunt infection was extremely variable in 2013 and did not provide a reliable differential based on long-term check responses.
[x]Specific leaf spotting pathogens were not determined.
[w]Rated using a 1–9 scale: 1 = disease free, 9 = very severe symptoms.

Table 4. Fusarium head blight (FHB) reaction of AAC Elevate, check cultivars and supplementary checks, Western Winter Wheat Cooperative registration trials (2011–2013)

	Visual rating[z] (index and response[y])					Deoxynivalenol (ppm)					Fusarium-damaged kernels[x] (%)				
	2011	2012	2013	2 yr	3 yr	2011	2012	2013	2 yr	3 yr	2011	2012	2013	2 yr	3 yr
CDC Osprey	29 I	18 I	29 I	24	25	25.4	6.8	22.0	14.4	18.1	11.0	4.2	10.3	7.3	8.5
AC Bellatrix	35 I	11 MR	43 MS	27	30	42.2	6.7	16.3	11.5	21.7	12.2	3.4	13.0	8.2	9.5
Radiant	54 S	40 MS	54 MS	47	49	47.0	6.8	37.9	22.3	30.5	20.0	3.2	27.5	15.4	16.9
CDC Buteo	17 MR	8 MR	31 I	20	19	26.8	4.7	39.5	22.1	23.7	8.4	1.5	27.0	14.3	12.3
Flourish	–	51 S	79 S	54	–	–	9.1	53.0	31.1	–	–	5.2	40.7	23.0	–
Moats	–	40 MS	48 MS	44	–	–	13.1	29.7	21.4	–	–	2.8	20.0	11.4	–
CDC Falcon	50 S	26 MS	49 MS	38	42	49.5	5.5	42.3	23.9	32.4	15.2	3.0	28.8	15.9	15.7
AAC Elevate	29 I	36 MS	23 MR	30	29	12.9	6.4	27.3	16.8	15.5	9.4	1.8	19.7	10.7	10.3
Supplementary checks[w]															
FHB148	10 R	6 R	16 MR	11	11	13.8	4.2	11.1	7.6	9.7	1.8	0.6	5.4	3.0	2.6
Freedom	57 S	37 MS	34 I	36	43	29.4	2.3	24.1	13.2	18.6	14.0	1.7	14.0	7.8	9.9
DH01W43I*45	28 I	19 I	34 I	27	27	28.7	4.6	18.3	11.4	17.2	6.2	1.5	14.3	7.9	7.3
Caledonia	67 S	49 S	63 S	56	60	80.0	10.9	42.8	26.9	44.6	16.3	6.2	32.5	19.3	18.3
Hanover	72 S	54 S	68 S	61	65	81.7	11.3	48.8	30.0	47.3	26.6	7.8	40.0	23.9	24.8

[z]Visual rating index = % incidence × % severity/100.
[y]Disease response category: R = resistant, MR = moderately resistant, I = intermediate, MS = moderately susceptible, S = susceptible.
[x]Fusarium-damaged kernels = damaged kernel weight/total weight × 100.
[w]Supplementary checks were chosen to differentiate resistance levels based on long term data collection.

shorter than the other CWRW checks ($P \leq 0.05$). Lodging resistance was similar to Radiant and Flourish and significantly better than the remaining checks ($P \leq 0.05$). The test weight of AAC Elevate was similar to the checks. AAC Elevate had significantly higher seed mass than all of the checks ($P \leq 0.05$). The grain protein concentration of AAC Elevate was within the range of the CWRW checks and equal to that of CDC Buteo. Grain protein yield per hectare was significantly greater than all of the check cultivars where 3-yr means were available ($P < 0.05$); 2-yr means indicated that AAC Elevate was similar to Flourish and Moats.

The Prairie Recommending Committee for Wheat, Rye and Triticale Disease Evaluation Team summarized the disease ratings for AAC Elevate as moderately resistant to the prevalent races of stem rust and common bunt, and intermediate in resistance to leaf rust, stripe rust and FHB (Tables 3 and 4). The reactions to powdery mildew and leaf spotting diseases were within the range of the check cultivars. AAC Elevate was included in the 2013/2014 WWWC registration trial to provide an uninterrupted dataset in anticipation of its use as a check in 2014/2015; therefore, these disease resistance data are also presented. Based on screening with non-viruliferous mites (Table 5), AAC Elevate is the second Canadian wheat cultivar that exhibits protection against wheat streak mosaic virus through resistance to colonization by the WCM vector. This resistance is conferred by *Cmc1* via its Radiant parentage (Thomas et al. 2012a).

Three years of end-use suitability testing by the Canadian Grain Commission, Grain Research Laboratory and evaluation by the Prairie Recommending Committee for Wheat, Rye and Triticale Quality Evaluation Team established that AAC Elevate had quality eligible for all grades of the CWRW wheat class (Table 6). The overall quality of AAC Elevate was generally similar to Radiant, with slightly higher wheat and flour protein concentration, amylograph peak viscosity and farinograph water absorption. Combined with the

Table 5. Response of AAC Elevate to infestation by non-viruliferous wheat curl mite

	Resistant:Susceptible	Response
Susceptible check[z]		
2011	1:43	S
2012	0:58	S
2013	11:45	S
Resistant check[z]		
2011	45:2	R
2012	58:0	R
2013	58:0	R
AAC Elevate		
2011	53:0	R
2012	59:0	R
2013	50:0	R

[z]Resistant and susceptible checks are various previously characterized lines.

Table 6. End-use quality[z] characteristics of AAC Elevate and check cultivars, Western Winter Wheat Cooperative registration trials (2011–2013)

Cultivar	Test years	Wheat protein (%)	Flour protein (%)	Protein loss (%)	Hagberg falling no. (s)	Amylograph peak viscosity (BU)	Flour yield (0.5% ash)	Flour ash (%)	Starch damage (%)
CDC Osprey	2011–2013	12.1	11.3	0.8	393	580	81.2	0.39	6.1
AC Bellatrix	2011–2013	12.5	11.6	1.0	400	393	79.0	0.43	7.0
Radiant	2011–2013	11.8	10.9	0.9	400	502	80.7	0.40	6.6
CDC Buteo	2011–2013	12.2	11.3	0.9	415	532	81.7	0.38	6.6
Flourish	2012–2013	12.7	12.0	0.7	440	763	81.0	0.40	6.1
Moats	2012–2013	12.9	12.3	0.6	435	663	80.5	0.41	7.1
Check mean (2 yr)[y]	2012–2013	12.5	11.8	0.8	410	564	81.1	0.39	6.4
AAC Elevate (2 yr)[y]	2012–2013	12.3	11.5	0.9	398	538	81.5	0.39	6.6
Check mean (3 yr)[x]	2011–2013	12.2	11.3	0.9	402	502	80.6	0.40	6.6
AAC Elevate (3 yr)[x]	2011–2013	12.1	11.2	0.9	398	550	80.8	0.39	6.8
SD[w]		0.05	0.05	0.05	15	5	0.34	0.005	0.08

	Farinograph[v]				Remix-to-peak bake				
	Water absorption (%)	DDT (min)	MTI (BU)	Stability (min)	Baking absorption (%)	Peak time (min)	Mixing energy (Wh kg^{-1})	Loaf volume (cm^3)	Loaf volume/ unit flour protein
CDC Osprey	57.5	6.7	32	10.0	56.0	2.1	4.1	837	74.0
AC Bellatrix	62.5	5.4	28	8.3	59.3	2.2	4.1	843	72.9
Radiant	58.1	8.0	33	9.5	57.0	2.5	4.7	820	75.1
CDC Buteo	59.6	5.6	33	8.7	57.0	2.5	4.8	833	73.7
Flourish	59.8	7.8	18	19.0	58.5	1.8	3.6	958	79.8
Moats	60.6	7.9	23	11.0	59.0	2.2	4.1	960	78.4
Check mean (2 yr)[y]	59.8	7.1	26	11.7	57.8	2.0	3.8	900	76.5
AAC Elevate (2 yr)[y]	58.6	6.5	35	10.8	55.5	2.1	3.9	835	73.0
Check mean (3 yr)[x]	59.4	6.4	32	9.1	57.3	2.3	4.4	833	73.9
AAC Elevate (3 yr)[x]	58.8	6.2	37	9.7	56.0	2.5	4.9	812	72.2
SD[w]	0.2	0.4	2.6	1.4	0.0	0.1	0.3	14	–

[z]American Association of Cereal Chemists (AACC) methods were followed for determining the various end-use quality characteristics.
[y]Mean of 2012 and 2013 values. Check mean includes CDC Osprey, AC Bellatrix, Radiant, CDC Buteo, Flourish and Moats.
[x]Mean of 2011, 2012 and 2013 values. Check mean includes CDC Osprey, AC Bellatrix, Radiant and CDC Buteo.
[w]Standard deviation 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 Canadian Grain Commission, Grain Research Laboratory.
[v]Farinograph parameters: DDT = farinograph dough development time; MTI = farinograph mixing tolerance index.

demonstrated improvements in agronomic performance and disease resistance, AAC Elevate was considered to be a suitable replacement for Radiant as a check in all western Canadian winter wheat registration trials starting with tests grown in 2014/2015.

Other Characteristics

SEEDLING: Coleoptile anthocyanin pigmentation absent.

PLANT: Juvenile growth semi-prostrate, leaves medium green; tillering capacity medium, intermediate to semi-erect at tillering; flag leaf dark green, glabrous, slightly waxy, mid-long, mid-wide, slightly curved, upright; flag leaf sheath glabrous, strongly waxy; auricle anthocyanin colouration absent, margins very slight pubescence; culm neck straight, hollow, glabrous, medium waxy, yellow at maturity.

SPIKE: Awned, tapering, medium dense, medium length, white to yellow, nodding at maturity; awns white to light yellow, slightly spreading; glumes mid-wide, mid-long, glabrous, yellow; glume shoulders rounded, narrow to mid-wide; glume beak mid-long, acuminate; rachis margins strongly pubescent; resistant to shattering.

KERNEL: Medium red, texture medium hard, medium to large size.

Maintenance and Distribution of Pedigreed Seed

To preserve the high level of genetic purity inherent in DH genotypes, the creation of AAC Elevate Breeder Seed followed a standard head-row derivation approach. Progeny plots originating from 79 uniform head rows, produced under isolation at Lethbridge in 2013, were grown at the AAFC Seed Increase Unit in Indian Head in 2014. Following the elimination of 14 progeny lines (some due to glyphosate drift), the remaining 65 plots were inspected, harvested in bulk and cleaned to form 491 kg of Breeder Seed, which was released to pedigreed seed growers in fall 2014. As expected of a DH line, AAC Elevate was uniform and stable during all years of evaluation. Bulking of the Breeder Seed occurred nine

generations after the creation of the original DH plant. Based on observations made during the final stages of Breeder Seed production in 2014, a very low frequency of plants that are slightly taller or express bronze chaff at maturity may be present and should be removed to the extent possible. AAC Elevate Breeder Seed will be maintained at the facilities in Indian Head. All other pedigreed seed classes will be multiplied and distributed by SeCan Association, 501–300 March Road, Kanata, Ontario, Canada K2K 2E2. Tel: 1.800.764.5487; Fax: 613.592.9497; e-mail: seed@secan.com.

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

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.

Fedak, G., Burvill, M. and Voldeng, H. 1997. A comparison of anther culture and maize pollination for haploid production in wheat. J. Appl. Genet. **38**: 407–414.

Fetch, T. G. 2005. Races of *Puccinia graminis* on wheat, barley, and oat in Canada, in 2002 and 2003. Can. J. Plant Pathol. **27**: 572–580.

Fowler, D. B. 1997. CDC Osprey winter wheat. Can. J. Plant Sci. **77**: 665–667.

Fowler, D. B. 1999. CDC Falcon winter wheat. Can. J. Plant Sci. **79**: 599–601.

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

Fowler, D. B. 2012. Moats hard red winter wheat. Can. J. Plant Sci. **92**: 191–193.

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.

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. 2006 Mar. 14–17. 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.

Knox, R. E., Clarke, J. M. and DePauw, R. M. 2000. Dicamba and growth condition effects on doubled haploid production in durum wheat crossed with maize. Plant Breed. **119**: 289–298.

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.

Jin, Y., Szabo, L. J., Pretorius, Z. A., Singh, R. P., Ward, R. and Fetch Jr., T. 2008. Detection of virulence to resistance gene *Sr24* within race TTKS of *Puccinia graminis* f. sp. *tritici*. Plant Dis. **92**: 923–926.

McCallum, B. D., Seto-Goh, P. and Xue, A. 2011. Physiologic specialization of *Puccinia triticina*, the causal agent of wheat leaf rust, in Canada in 2008. Can. J. Plant Pathol. **33**: 541–549.

McCallum, B. D., Seto-Goh, P. L. and Xue, A. 2013. Physiologic specialization of *Puccinia triticina*, the causal agent of wheat leaf rust, in Canada in 2009. Can. J. Plant Pathol. **35**: 338–345.

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. **26**: sec C: 496–500.

Peterson, C. J., Shelton, D. R., Baenziger, P. S., Baltensperger, D. D., Graybosch, R. A., Worrall, W. D., Nelson, L. A., McVey, D. V., Watkins, J. E. and Krall, J. 2001. Registration of 'Wesley' wheat. Crop Sci. **41**: 260–261.

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

Sinha, R. C. and Savard, M. E. 1996. Comparison of immunoassay and gas chromatography methods for the detection of the mycotoxin deoxynivalenol in grain samples. Can. J. Plant Pathol. **18**: 233–236.

Sinha, R. C., Savard, M. E. and Lau, R. 1995. Production of monoclonal antibodies for the specific detection of deoxynivalenol and 15-acetyldeoxynivalenol by ELISA. J. Agric. Food Chem. **43**: 1740–1744.

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.

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

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

Zadoks, J. C., Chang, T. T. and Konzak, C. F. 1974. A decimal code for the growth stages of cereals. Weed Res. **14**: 415–421.