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CULTIVAR DESCRIPTION

AAC Wildfire hard red winter wheat

R.J. Graf, B.L. Beres, D.A. Gaudet, J.B. Thomas, and R.A. Butts

Abstract: AAC Wildfire is a hard red winter wheat (*Triticum aestivum* L.) cultivar eligible for grades of Canada Western Red Winter (CWRW) wheat. It was developed using a modified pedigree breeding method. AAC Wildfire was evaluated across western Canada for four years in the Western Winter Wheat Cooperative registration trials, where it yielded significantly more grain than all of the checks (Radiant, CDC Buteo, Flourish, Moats) and expressed very good winter survival, relatively late maturity, medium height straw with very good lodging resistance, large kernels, acceptable end-use quality, and disease resistance appropriate for the western region of the Canadian prairies. AAC Wildfire was resistant to the prevalent races of stripe rust, moderately resistant to *Fusarium* head blight and common bunt, showed improved leaf spot reaction, and tolerance to the original biotype of Russian wheat aphid (*Diuraphis noxia* Mordvilko) in North America. In the absence of effective fungicides, production of AAC Wildfire in the eastern Prairies is not recommended due to stem rust susceptibility.

Key words: Triticum aestivum L., wheat (winter), cultivar description, grain yield, stripe rust, common bunt, *Fusarium* head blight, Russian wheat aphid, *Diuraphis noxia* Mordvilko.

Résumé : AAC Wildfire un cultivar de blé (*Triticum aestivum* L.) roux vitreux d'hiver admissible à la catégorie « blé rouge d'hiver de l'Ouest canadien » (CWRW). La variété a été créée par une technique d'amélioration généalogique modifiée. AAC Wildfire a été évalué pendant quatre ans lors des essais d'homologation coopératifs sur le blé d'hiver de l'Ouest canadien et a donné sensiblement plus de grains que les témoins (Radiant, CDC Buteo, Flourish, Moats). La variété se caractérise par une très bonne survie à l'hiver, parvient à maturité relativement tard, a une paille de taille moyenne qui résiste très bien à la verse, produit de gros grains de qualité acceptable selon l'usage final et résiste de façon adéquate à la maladie dans la partie ouest des Prairies canadiennes. AAC Wildfire résiste aux races courantes de la rouille jaune, est modérément résistante à la brûlure de l'épi causée par *Fusarium* et à la carie, réagit mieux à la tache foliaire et tolère le biotype original du puceron russe du blé (*Diuraphis noxia* Mordvilko) en Amérique du Nord. Faute de fongicides efficaces, on ne recommande pas la culture d'AAC Wildfire dans la partie est des Prairies, où sévit la rouille de la tige. [Traduit par la Rédaction]

Mots-clés : Triticum aestivum L., blé (d'hiver), description de cultivar, rendement grainier, rouille jaune, carie, brûlure de l'épi causée par *Fusarium*, puceron russe du blé, *Diuraphis noxia* Mordvilko.

Introduction

AAC Wildfire hard red winter wheat (*Triticum aestivum* L.) was developed at the Agriculture and Agri-Food Canada (AAFC) Lethbridge Research and Development Centre (LeRDC) in Lethbridge, AB. Tested as LK1064 and W512, registration No. 7857 was granted by the Variety Registration Office, Plant Production Division, Canadian Food Inspection Agency on 27 Nov. 2015. Application No. 15-8742 for Plant Breeders' Rights has been accepted for filing under the provisions of the 1991 Convention of the *Union internationale pour la protection des obtentions végétales* (UPOV91).

AAC Wildfire is well adapted to Alberta and western Saskatchewan, the non-hazard region for stem rust in

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Abbreviations: **AAFC**, Agriculture and Agri-Food Canada; **CGC**, Canadian Grain Commission; **CWRW**, Canada Western Red Winter; **DON**, deoxynivalenol; **FHB**, *Fusarium* head blight; **GRL**, Grain Research Laboratory; **LeRDC**, Lethbridge Research and Development Centre; **PRCWRT**, Prairie Recommending Committee for Wheat, Rye and Triticale; **RWA**, Russian wheat aphid.

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western Canada. The end-use quality profile of AAC Wildfire meets the specifications of the Canada Western Red Winter (CWRW) wheat class.

Pedigree and Breeding Method

Early generation development and evaluation

AAC Wildfire originates from the cross L99-1236/AC Bellatrix made in 2003 at the AAFC, LeRDC in Lethbridge. AC Bellatrix is a registered CWRW wheat cultivar with IDO180*2/Sundance parentage, developed at AAFC, LeRDC and released in 1998 (Thomas et al. 2012*b*). L99-1236, which was evaluated as W381 in the Western Winter Wheat Cooperative (WWWC) registration trials from 2002 to 2004, is a doubled haploid line developed from the cross AMN4LV/RWA53//IDO337-R1/CDC Kestrel. AMN4LV was tested as W304 and has Norstar*5/PGR16635 parentage; it expresses a high level of cold tolerance and wheat curl mite resistance conferred by *Cmc1* (Thomas and Conner 1986). RWA53 represents a complex cross that incorporated Russian wheat aphid (RWA) (*Diuraphis noxia* Mordvilko) tolerance into adapted germplasm: PI294994/3/I3C//Norwin/Blizzard/4/2*AC Readymade/5/Norstar*5/PGR16635//2*Redwin/3/AC Readymade. PI294994 is a heterogeneous accession from Bulgaria reported to carry *Dn5* and several other uncharacterized RWA resistance genes (Zhang et al. 1998). IDO337-R1 is a selection from IDO337 that expresses excellent common bunt [*Tilletia tritici* (Bjerk.) G. Wint. in Rabenh. and *T. laevis* Kühn in Rabenh.] and dwarf bunt (*T. controversa* Kühn in Rabenh) resistance; it has A7257W-71-2-1/A77695 parentage (J. Chen, personal communication, University of Idaho, Aberdeen, ID) and was obtained through participation in the Western Regional Uniform Hard Winter Wheat Nursery. CDC Kestrel is a Canada Western Special Purpose (CWSP) cultivar selected from the cross Norstar*2/Vona (Fowler 1997*a*). An expanded ancestry of AAC Wildfire is shown in Figure 1.

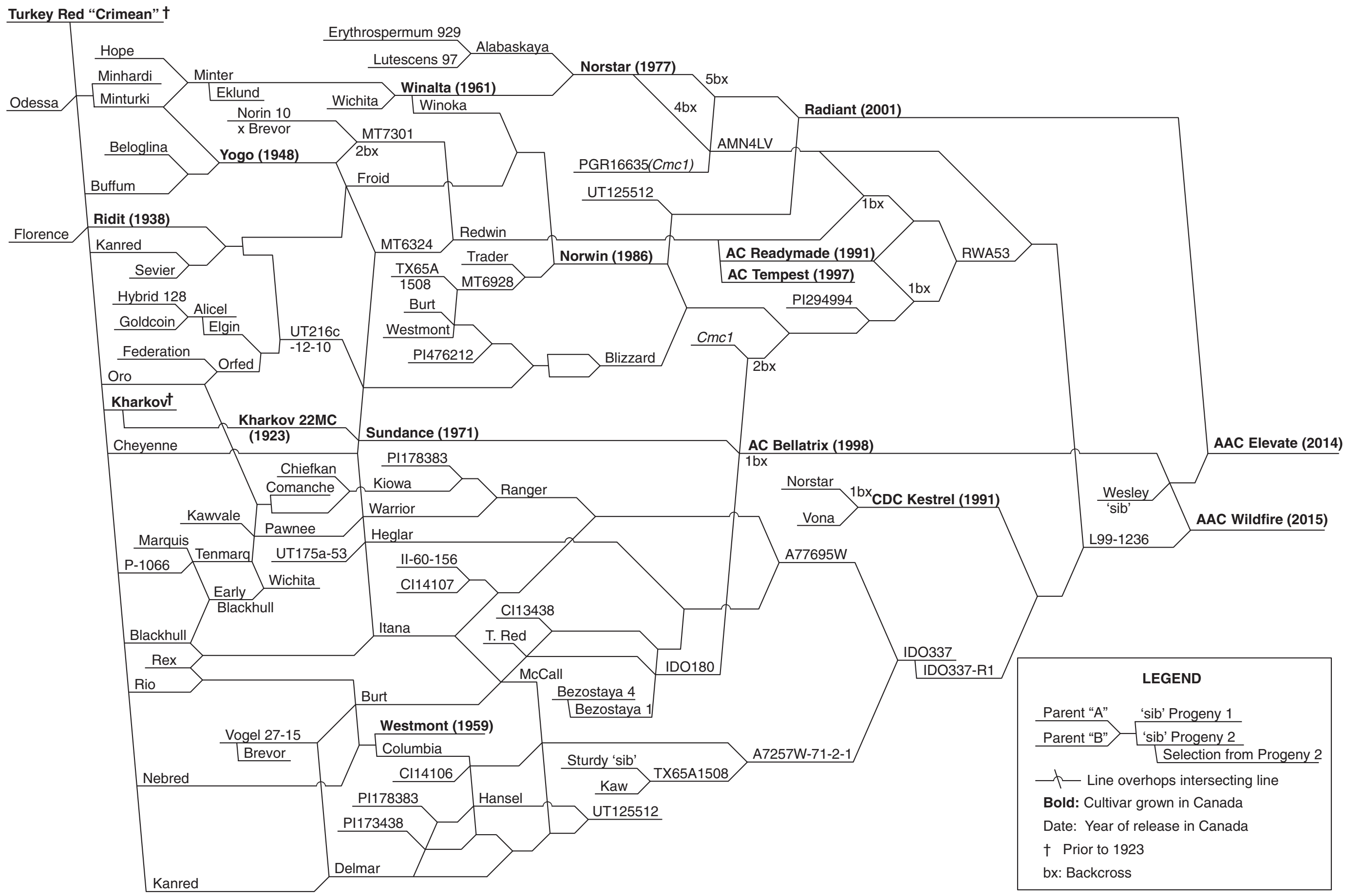
Following growth of the F_1 seeds in a greenhouse, several F_2 bulk plots were grown in Lethbridge in 2005, from which 78 spikes were selected and planted as F_3 rows. In 2006, 84 spikes were selected from desirable rows based on winter survival, plant type and vigour, plant height, straw strength, and stripe rust resistance. Seed from each spike was inoculated with common bunt and seeded as a row into cold soil in Lethbridge in mid-October. In 2007, 43 of the 84 rows showed bunt infection rates of 0% to 6%, whereas the remaining rows ranged in infection from 10% to 55%. Common bunt infection in the nursery was high, as revealed by AC Bellatrix (the long-term moderately resistant check) with an infection rate of 18%, versus CDC Osprey (Fowler 1997*b*) (the long-term susceptible check) which showed an infection rate of 49%. From the rows expressing low infection (6% or under), 76 spikes were selected and seeded in an observation nursery in Lethbridge. In 2008, 30 desirable F_4-derived F_5 lines were harvested and seeded in single replicate preliminary trials and an inoculated bunt nursery. In 2009, promising agronomic characteristics, resistance to common bunt, improved leaf spot reaction, and acceptable end-use quality prompted the advancement of four lines into replicated multi-location trials across western Canada in 2010 and 2011. Concurrently, resistance to stem rust (*Puccinia graminis* Pers.: Pers. f.sp. *tritici* Eriks. & E. Henn.) and leaf rust (*P. triticina* Eriks.) were assessed in collaboration with the University of Manitoba in Winnipeg, MB; stripe rust (*Puccinia striiformis* Westend.), common bunt, and Russian wheat aphid reactions were determined at AAFC, LeRDC. Following 11 site-years of pre-registration testing and two years of detailed end-use quality analysis, LK1064 entered the WWWC registration trial as W512 and was evaluated over three years for registration purposes (2011/2012 to 2013/2014), plus one additional year (2014/2015).

Assessment for cultivation and processing

The suitability of AAC Wildfire for registration in western Canada was considered relative to Radiant (Thomas et al. 2012*a*), CDC Buteo (Fowler 2010), Flourish (Graf et al. 2012), and Moats (Fowler 2012). CDC Osprey and AC Bellatrix were also used as end-use quality checks in 2012 and 2013. Agronomic trial sites 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, reactions to the major winter wheat diseases of economic importance in both the eastern and western prairies were assessed. 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 (CRC), and reported using the modified Cobb scale (Peterson et al. 1948). The stem rust races used for one or more years included: MCCFR (P0001), QTHJT (P0005), RHTSK (P0002), RKQSR (P0003), RTHJT (P0007), TMRTK (P0006), and TPMKR (P0004) (Fetch et al. 2015). The leaf rust races were a representative mixture collected in western Canada during the previous field season (McCallum et al. 2013, 2016). Seedling reactions to individual races of stem and leaf rust prevalent in Canada were also determined under controlled-environment conditions. The races of stem

Fig. 1. Detailed genealogy of AAC Wildfire hard red winter wheat and related cultivars.



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), TJBJ (77-2), and TDBJ (11-180-1). Stripe rust and common bunt reactions were rated in nurseries at AAFC, LeRDC. Both natural infection and artificial inoculation using spores collected in the previous year were used to promote localized stripe rust epiphytotics (Puchalski and Gaudet 2011). Common bunt resistance was estimated 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 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 conducted by the University of Manitoba in Carman. Each line was spray-inoculated with a suspension of *F. graminearum* macroconidia at 50% anthesis and again 3–4 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 18–21 d after anthesis or when symptoms were well developed (Gilbert and Woods 2006; Cuthbert et al. 2007). Harvested grain from each inoculated row was used to prepare a 50 g sample to determine the percentage of *Fusarium* damaged kernels (FDK). This sample was also used to quantify the deoxynivalenol (DON) content using enzyme-linked immunosorbent assays (ELISA) at the AAFC Ottawa Research and Development Centre (ORDC) in Ottawa, ON (Sinha et al. 1995; Sinha and Savard 1996). 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.

Russian wheat aphid reaction was determined annually under controlled environment conditions by infesting two or three replicates of 15 or more seedlings with 20–25 aphids per plant and assessing feeding damage approximately 21 d later. Susceptibility to infestation included typically observed symptoms of chlorophyll loss, longitudinal leaf curling, and white or yellow streaking along the entire leaf blade (Linscott et al. 2001).

Table 1. Grain yield of AAC Wildfire and the check cultivars (t ha^{-1} and percent of check mean) over 4 y of Western Winter Wheat Cooperative registration trials (2012–2015).

Cultivar	2012	2013	2014	2015	Grand mean		Alberta		Saskatchewan		Manitoba		Zone 1[a]		Zone 2		Zone 3		Zone 4	
					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
Radiant	5.656	5.880	5.231	4.463	5.311	100	5.294	101	5.076	101	5.821	96	5.045	98	5.301	106	5.148	102	5.559	98
CDC Buteo	5.462	5.419	5.614	4.311	5.155	97	4.953	94	4.943	99	6.059	100	4.904	95	4.760	95	4.960	98	5.601	99
Flourish	5.628	5.821	5.764	4.494	5.383	101	5.430	103	5.002	100	6.034	100	5.463	106	4.741	95	5.105	101	5.727	101
Moats	5.620	5.639	5.721	4.767	5.403	102	5.381	102	5.023	100	6.218	103	5.146	100	5.157	103	5.048	100	5.814	102
Check mean[b]	5.592	5.690	5.583	4.509	5.313	100	5.264	100	5.011	100	6.033	100	5.139	100	4.990	100	5.065	100	5.675	100
AAC Elevate	5.948	5.928	5.476	4.513	5.466	103	5.446	103	5.291	106	5.861	97	5.544	108	4.954	99	5.523	109	5.663	100
AAC Wildfire	6.158	6.195	5.964	4.963	5.803	109	5.808	110	5.701	114	5.991	99	5.729	111	5.546	111	5.728	113	6.012	106
LSD ($P \leq 0.05$)	0.351	0.517	0.279	0.410	0.222		0.350		0.362		0.386		0.419		0.466		0.924		0.413	
No. of tests	13	11	7	12	43		19		16		8		13		9		4		17	

Note: All means are weighted by the number of tests. Least significant difference includes variation from the appropriate genotype by environment interaction.
[a]Zone 1: Southern Alberta sites (Lethbridge "dry land", Lethbridge "irrigated", Morrin, Warner). Zone 2: Parkland sites (Beaverlodge, Lacombe, Melfort). Zone 3: Semi-arid prairie site (Swift Current). Zone 4: Eastern prairie rust-hazard sites (Brandon, Carman, Indian Head, Kamsack, Saskatoon, Winnipeg).
[b]AAC Elevate was not a check during registration testing and is therefore not included in the mean. AAC Elevate replaced Radiant as a check in 2015.

In 2012 and 2013, end-use quality analyses were conducted 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 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. In 2014, quality analyses were not conducted due to severe preharvest sprouting and insufficient quantities of grain from acceptable sites to create sufficiently large composite samples of reliable quality. Data from preregistration trials generated in 2010 and 2011 by the AAFC Cereal Quality Laboratory relative to several common checks were considered as part of the request for registration in early 2015.

Performance

Grain yield and agronomics

The agronomic performance of AAC Wildfire, relative to the prescribed check cultivars for the CWRW wheat class (Radiant, CDC Buteo, Flourish, Moats) was established from data collected at 43 sites over four years across the Canadian prairies. Ancillary data for AAC Elevate (Graf et al. 2015), which was not a check during the evaluation of AAC Wildfire, are also considered because it replaced Radiant as a registration check in 2014/2015.

AAC Wildfire expressed significantly higher ($P \leq 0.05$) grain yield than the CWRW check mean (109.2%) and all of the CWRW checks: Radiant (+9.3%), CDC Buteo (+12.6%), Flourish (+7.8%), and Moats (+7.4%) (Table 1). It was also 6.2% higher yielding than AAC Elevate ($P \leq 0.05$). On a regional basis, AAC Wildfire demonstrated numerically higher yields than all of the checks in all zones, with significance ($P \leq 0.05$) shown relative to Radiant and CDC Buteo in southern Alberta (Zone 1); CDC Buteo and Flourish in the parkland region (Zone 2); and Radiant in the eastern prairie rust-hazard region (Zone 4). Provincially, AAC Wildfire was significantly higher yielding ($P \leq 0.05$) than all of the checks in Alberta and Saskatchewan, but no significant differences were shown in Manitoba.

AAC Wildfire exhibited excellent winter survival that was within the range of the check cultivars (Table 2). Heading date was 5 d later than Flourish and 3 d later than Radiant, CDC Buteo, Moats, and AAC Elevate ($P \leq 0.05$). Maturity was later than all of the checks ($P \leq 0.05$), ranging from 6 d later than Flourish to 2 d later than Radiant. AAC Wildfire was 5–6 cm shorter than Radiant, CDC Buteo, and Moats, 6 cm taller than Flourish, and 2 cm taller than AAC Elevate ($P \leq 0.05$). Lodging resistance was significantly better than CDC

Table 2. Agronomic and seed characteristics of AAC Wildfire and the check cultivars over 4 yr of Western Winter Wheat Cooperative registration trials (2012–2015).

Cultivar	Winter survival (%)	Heading[a] (d)	Maturity[a] (d)	Height (cm)	Lodging[b] (1–9)	Test weight (kg hL^{-1})	Kernel weight (mg)	Grain protein[c] (%)	Grain protein yield (kg ha^{-1})
Radiant	85	172	217	94	2.2	77.9	33.3	11.7	615
CDC Buteo	83	172	216	94	3.7	79.8	32.0	12.0	610
Flourish	85	170	213	83	2.5	77.6	34.1	12.4	661
Moats	83	172	216	95	3.3	79.1	31.7	12.5	673
Check mean[d]	84	171	215	91	2.9	78.6	32.8	12.1	639
AAC Elevate	85	172	216	87	2.4	77.5	36.0	11.8	639
AAC Wildfire	84	175	219	89	2.6	78.6	34.5	12.0	687
LSD ($P \leq 0.05$)	4.1	0.4	0.8	1.2	0.40	0.54	0.73	0.20	29
No. of tests	27	37	37	41	30	38	38	38	38

Note: Least significant difference includes variation from the appropriate genotype by environment interaction.
[a]Days to heading and maturity expressed as day of the year.
[b]Lodging scale: 1 = all plants vertical, 9 = all plants horizontal.
[c]Grain protein concentration determined using whole grain NIRS analysis.
[d]AAC Elevate was not a check during registration testing and is therefore not included in the mean.

Buteo and Moats, similar to Flourish and AAC Elevate, but inferior to Radiant ($P \leq 0.05$). The test weight of AAC Wildfire was within the range of the check cultivars; kernel weight was higher than Radiant, CDC Buteo, and Moats ($P \leq 0.05$), similar to Flourish, and lower than AAC Elevate ($P \leq 0.05$). The grain protein concentration of AAC Wildfire was within the range of the checks and equal to that of CDC Buteo. Grain protein yield per hectare was significantly greater than Radiant, CDC Buteo, and AAC Elevate ($P \leq 0.05$), and similar to Flourish and Moats.

Disease and pest resistance

Three years of disease ratings (2012–2014) for AAC Wildfire were summarized by the Prairie Recommending Committee for Wheat, Rye and Triticale (PRCWRT) Disease Evaluation Team as follows: resistant to stripe rust, moderately resistant to FHB and common bunt, intermediate in resistance to leaf rust, and susceptible to stem rust. The data from 2015 confirmed these assessments (Tables 3 and 4). AAC Wildfire had a mean leaf spot rating that was better than the best check and showed powdery mildew infection within the range of the checks. The combination of disease resistance exhibited by AAC Wildfire is well-suited for Alberta and western Saskatchewan, the non-hazard area for stem rust, and should facilitate reduced usage of seed- and foliar-applied fungicides in this region.

Five years of rating relative to susceptible and resistant checks indicated that AAC Wildfire expresses good tolerance to RWA feeding (Table 5). This resistance is likely to the RWA1 biotype that was prevalent in North America in the mid-1980s, when the local colony was established for screening. Efforts to develop winter wheat cultivars with RWA tolerance were initiated at AAFC, LeRDC shortly after its isolation in southern Alberta, since fall feeding on young seedlings reduces vigour and increases the likelihood of cold injury (Thomas and Butts 1990). Although RWA populations in western Canada are normally eradicated or severely reduced during the winter (Butts 1992), and western Canadian monitoring ended in 2007 following several years of low but stable wheat infestation levels in southwestern Saskatchewan (Anonymous 2007), the threat to winter wheat remains. Significant fall infestations are likely to reoccur in the future via summer migrations from high-density areas of the United States as crops ripen successively northward (Burd et al. 1998), or through climate-change induced overwintering. In 2003, nine years after the successful deployment of RWA tolerant cultivars incorporating *Dn4*, a new biotype (RWA2) virulent on all but one source of resistance was isolated in Colorado (Haley et al. 2004). Additional biotypes (RWA3/7, RWA6, RWA8) were subsequently identified (Puterka et al. 2014). Despite rapid dispersal of RWA2, such that it dominated populations in Northern and Central Plains states in 2005 (Puterka et al. 2007), a recent shift towards the *Dn4* avirulent RWA6 emphasizes that the population dynamics of the biotype complex are not well understood (Puterka et al. 2015). It also suggests that the uncharacterized tolerance of AAC Wildfire may provide some protection against RWA when it is required.

End-use quality

Four years of end-use suitability testing, two years (2010–2011) at the AAFC Cereal Quality Laboratory (data not presented) and two years (2012–2013) at the CGC, GRL allowed the PRCWRT Quality Evaluation Team to establish that AAC Wildfire had milling and baking quality suitable for grades of the CWRW wheat class (Table 6). AAC Wildfire milling characteristics were similar to the checks and demonstrated the high flour yield/low flour

Table 3. Disease reactions of AAC Wildfire and the check cultivars, Western Winter Wheat Cooperative registration trials (2012–2015).

	Year	Radiant	CDC Buteo	Flourish	Moats	AAC Elevate	AAC Wildfire
Stem rust	2012	70 S	50 S/10 MR	5 R	tr R	tr R	50 S
	2013	80 S	40 MS/20 S	20 MR	5 R	10 I	80 S
	2014	20 MS-S	10 I	20 MR	tr R	tr R	70 MS-S
	2015	80 S	50 I	30 MR	tr R	20 MR	80 MS-S
Leaf rust	2012	30 MS	20 MR	—	tr R-MR	5 I	5 R-MR
	2013	20 MS-S	5 I	5 I	tr R-MR	10 I	20 S
	2014	25 MS-S	tr MR-5 MS	tr R-MR	tr R	15 MS-S	5 MS
	2015	60 S	10 MR	tr R	tr R-MR	5 R-MR	15 MS
Stripe rust	2012	33 I	28 I	18 R	3 VR	13 R	tr VR
	2013	60 S	13 I	2 R	0 VR	13 MR	tr VR
	2014	60 S	70 S	40 MS	0 R	25 I	5 R
	2015	80 S	60 S	20 I	2 R	70 S	12 MR
Common bunt	2012	31 S	43 VS	17 MR	26 I-MS	19 MR-I	6 VR
	2013	—	—	—	—	—	—
	2014	30 MS	29 MS	8 R	24 I	22 I	19 MR-I
	2015	35 MS	30 MS	17 MR	18 MR	19 MR-I	11 MR
Leaf spots[a,b]	2012	4.9	5.3	3.5	5.0	4.2	3.9
	2013	4.2	4.1	2.8	2.2	2.6	2.1
	2014	2.0	2.2	3.2	2.8	2.0	1.5
	2015	5.6	4.8	4.6	4.1	5.2	3.8
	Mean	4.2	4.1	3.5	3.5	3.5	2.8
Powdery mildew[b]	2012	4.0	4.3	3.7	2.3	3.7	3.7
	2013	3.0	4.0	2.7	3.0	3.3	4.7
	2014	3.2	3.0	2.8	2.3	2.5	2.2
	2015	2.7	3.0	4.2	2.7	3.2	2.7
	Mean	3.2	3.6	3.3	2.6	3.2	3.3

Note: Percent infection and type of reaction: tr, trace; VR, very resistant; 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.

Table 4. *Fusarium* head blight (FHB) reaction of AAC Wildfire, check cultivars, and supplementary checks; Western Winter Wheat Cooperative registration trials (2012–2015).[a]

	Visual rating[b] (index and response)							DON[c] (ppm)		FDK[d] (%)	
	2012		2013		2015		Mean	2012	2013	2012	2013
Radiant	40	MS	54	MS	58	MS	51	6.8	37.9	3.2	27.5
CDC Buteo	8	MR	31	I	28	MR	22	4.7	39.5	1.5	27.0
Flourish	51	S	79	S	87	S	72	9.1	53.0	5.2	40.7
Moats	40	MS	48	MS	42	I	43	13.1	29.7	2.8	20.0
AAC Elevate	36	MS	23	MR	47	I	35	6.4	27.3	1.8	19.7
AAC Wildfire	5	R	21	MR	23	MR	16	7.2	25.5	3.9	13.8
Supplementary checks[e]											
DH00W32C*17	—		12	R	4	R	8	—	3.9	—	1.9
FHB148	6	R	16	MR	19	MR	14	3.7	11.1	0.6	5.4
DH01W43I*18	19	I	34	I	19	MR	24	6.4	18.3	1.5	14.3
Freedom	37	MS	34	I	34	I	35	2.7	24.1	1.7	14.0
Caledonia	49	S	63	S	79	S	64	13.3	42.8	6.2	32.5
Hanover	54	S	68	S	92	S	71	9.9	48.8	7.8	40.0

Note: Disease response category: R, resistant; MR, moderately resistant; I, intermediate; MS, moderately susceptible; S, susceptible.

[a]2014 data were unavailable due to winterkill of the nursery.

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

[c]Deoxynivalenol content.

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

[e]Supplementary checks were chosen to differentiate resistance levels based on long-term data collection.

Table 5. Response of AAC Wildfire and checks to artificial infestation with Russian wheat aphid (RWA) under controlled environment conditions (2010–2015).

	2010		2011		2012		2013		2014		Total	
	R[a]	S	R	S	R	S	R	S	R	S	R	S
CDC Kestrel												
Rep 1	0	7	0	7	0	12	1	12	0	27		
Rep 2	0	7	0	15	0	16	0	15	0	18		
Rep 3	—	—	0	26	0	8	0	13	—	—		
Total	0	14	0	48	0	36	2	40	0	45	2	183
LA2034[a]												
Rep 1	11	0	13	0	7	0	12	0	—	—		
Rep 2	9	0	13	0	10	0	11	0	—	—		
Rep 3	—	—	23	0	—	—	12	0	—	—		
Total	20	0	49	0	17	0	35	0	—	—	121	0
Stanton[b]												
Rep 1	—	—	15	0	8	0	13	0	26	3		
Rep 2	—	—	14	0	8	0	14	1	16	0		
Rep 3	—	—	26	0	—	—	15	0	—	—		
Total	—	—	55	0	16	0	42	1	42	3	155	4
AAC Wildfire												
Rep 1	15	0	15	0	16	0	25	0	26	3		
Rep 2	15	0	15	0	15	0	25	0	27	3		
Rep 3	—	—	13	1	8	0	25	0	—	—		
Total	30	0	43	1	39	0	75	0	53	6	240	7

Note: Response category: R, resistant (absence of symptoms); S, susceptible (seedling chlorosis, longitudinal leaf curling, whitish streaking along entire leaf blade).

[a]Tested as W398 in the WWWC registration trials (2004–2006) with demonstrated resistance to RWA.

[b]Resistant to RWA (Martin et al. 2001).

ash attributes of the CWRW wheat class. The farinograph indicated strong mixing properties, and similar or better water absorption than most of the checks except AC Bellatrix. Remix-to-peak bake attributes for AAC Wildfire were similar to Radiant and CDC Buteo, but with improved baking absorption.

Other characteristics

Seedling: coleoptile anthocyanin pigmentation absent.

Plant: juvenile growth prostrate, leaves medium green; tillering capacity medium high, semi-prostrate to intermediate at tillering; flag leaf medium to dark green, glabrous, slightly waxy, medium long, medium wide, strongly recurved, upright; flag leaf sheath glabrous, medium to strong waxiness; auricle anthocyanin colouration absent to very weak with a low frequency of purple, margins slightly pubescent; culm neck straight to very slightly curved, hollow, glabrous, slightly waxy, yellow at maturity.

Spike: awned, tapering, medium dense, medium length, weak to medium waxiness, reddish brown, inclined at maturity; awns tan, slight to moderate spreading; glumes medium to long, medium wide, glabrous, light brown to brown; glume shoulders square, narrow; glume beak medium long, acuminate; rachis margins strongly pubescent; resistant to shattering.

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

Pedigreed Seed Development and Maintenance

Breeder Seed production of AAC Wildfire was initiated in 2013 by planting random spikes taken from rogued F_4-derived F_{10} increase plots grown in Lethbridge. In 2014, seed was harvested from 86 of these 110 head-rows grown in isolation from other wheat. Elimination of 24 rows was based on minor differences in plant appearance. The AAFC Seed Increase Unit at Indian Head planted 84 of the 86 pre-breeder seed lines in fall 2014. During the winter of 2014/2015, each potential breeder seed line was screened for RWA resistance, resulting in the elimination of three lines because of inconsistent results. Fifteen additional lines were discarded prior to harvest due to the presence of a low frequency of plants of similar height with white chaff at maturity. The remaining 66 F_{12} breeder lines were inspected, harvested in bulk, and cleaned to form 439 kg of Breeder Seed, which was released to pedigreed seed growers in fall 2015. AAC Wildfire Breeder Seed is maintained at the AAFC Seed Increase Unit in Indian Head. All other pedigreed seed classes derive from this initial lot of Breeder Seed, with multiplication and distribution coordinated

Table 6. End-use quality characteristics of AAC Wildfire and check cultivars; Western Winter Wheat Cooperative registration trials (2012–2013).

Cultivar	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	12.4	11.7	0.7	390	585	81.8	0.38	5.9
AC Bellatrix	12.8	11.9	1.0	390	378	79.8	0.42	6.8
Radiant	12.2	11.3	0.8	398	490	81.3	0.39	6.4
CDC Buteo	12.4	11.6	0.8	410	523	82.3	0.37	6.3
Flourish	12.7	12.0	0.7	440	763	81.0	0.40	6.1
Moats	12.9	12.3	0.6	435	663	80.5	0.41	7.1
Check mean[b]	12.5	11.8	0.8	410	567	81.1	0.39	6.4
AAC Elevate	12.3	11.5	0.9	398	538	81.5	0.39	6.6
AAC Wildfire	12.1	11.6	0.6	398	563	82.0	0.38	6.7
SD[c]	0.1	0.1	0.1	15	5	0.3	0.01	0.1

	Farinograph[a]				Remix-to-peak bake				
	Water absorption (%)	DDT (min)	Stability (min)	MTI (min)	Baking absorption (%)	Peak time (min)	Mixing energy (Wh kg^{-1})	Loaf volume (cm^3)	Loaf volume unit flour protein^{-1}
CDC Osprey	57.4	6.9	11.3	27.5	55.5	1.9	3.4	870	74.7
AC Bellatrix	62.6	5.8	8.3	30.0	59.0	1.9	3.1	878	74.1
Radiant	58.2	8.6	10.8	30.0	57.5	2.4	4.4	868	77.1
CDC Buteo	60.0	5.9	10.0	27.5	57.0	2.3	4.1	868	75.1
Flourish	59.8	7.8	19.0	17.5	58.5	1.8	3.6	958	79.8
Moats	60.6	7.9	11.0	22.5	59.0	2.2	4.1	960	78.4
Check mean[b]	59.8	7.1	11.7	25.8	57.8	2.0	3.8	900	76.5
AAC Elevate	58.6	6.5	10.8	35.0	55.5	2.1	3.9	835	72.9
AAC Wildfire	60.1	11.3	24.8	20.0	58.5	2.2	4.4	873	75.6
SD[c]	0.2	0.4	1.4	2.6	0.0	0.1	0.3	14	na[d]

Note: American Association of Cereal Chemists (AACC) methods were followed by the CGC, GRL for determining the various end-use quality characteristics on a composite of several locations per year.

[a]Farinograph parameters: DDT, dough development time; MTI, mixing tolerance index.

[b]AAC Elevate was not a check during registration testing and is therefore not included in the mean.

[c]Standard deviation is based on repeated testing of Allis-Chalmers mill check samples and standard bake flour samples with replicate tests performed over an extended period of time each year. Values provided by the CGC, GRL.

[d]Not available.

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References

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

Anonymous. 2007. Western forum on pest management, western committee on crop pests 2007 minutes. [Online]. Available: http://www.westernforum.org/WCCP%20Minutes.html.

Burd, J.D., Butts, R.A., Elliott, N.C., and Shufran, K.A. 1998. Seasonal development, overwintering biology, and host plant interactions of Russian wheat aphid (Homoptera: Aphididae) in North America. Pages 65–99 *in* S.S., Quisenberry and F.B., Peairs, eds. A response model for an introduced pest — the Russian wheat aphid. Thomas Say Publications in Entomology, Entomological Society of America, Lanham, MD.

Butts, R.A. 1992. Cold hardiness and its relationship to overwintering of the Russian wheat aphid (Homoptera: Aphididae) in southern Alberta. J. Econ. Entomol. **85**: 1140–1145. doi:10.1093/jee/85.4.1140.

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. 2015. Races of Puccinia graminis on wheat, oat and barley in Canada in 2009 and 2010. Can. J. Plant Pathol. **37**: 476–484. doi:10.1080/07060661.2015.1119735.

Fowler, D.B. 1997*a*. CDC Kestrel winter wheat. Can. J. Plant Sci. **77**: 673–675. doi:10.4141/P96-193.

Fowler, D.B. 1997*b*. CDC Osprey winter wheat. Can. J. Plant Sci. **77**: 665–667. doi:10.4141/P96-191.

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. 2006 Mar. 14–17. CIMMYT, Mexico, DF.

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.

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.

Haley, S.D., Peairs, F.B., Walker, C.B., Rudolph, J.B., and Randolph, T.L. 2004. Occurrence of a new Russian wheat aphid biotype in Colorado. Crop Sci. **44**: 1589–1592. doi:10.2135/cropsci2004.1589.

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.

Linscott, T.M., Bosque-Pérez, N.A., Schotzko, D.J., Kidwell, K.K., and Zemetra, R.S. 2001. Genetic control of Russian wheat aphid (*Diuraphis noxia*) resistance in wheat accession PI47545. Euphytica, **121**: 31–35. doi:10.1023/A:1012003332713.

Martin, T.J., Fritz, A., and Shroyer, J.P. 2001. Stanton hard red winter wheat. Kansas State Univ. Agric. Exp. Stn. and Coop. Ext. Serv. Publication L-921. Kansas State Univ. Manhattan, KS.

McCallum, B.D., Hiebert, C.W., Cloutier, S., Bakkeren, G., Rosa, S.B., Humphreys, D.G., Marais, G.F., McCartney, C.A., Panwar, V., Rampitsch, C., Saville, B.J., and Wang, X. 2016. A review of wheat leaf rust research and the development of resistant cultivars in Canada. Can. J. Plant Pathol. **38**: 1–18. doi:10.1080/07060661.2016.1145598.

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. doi:10.1080/07060661.2013.810669.

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. 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.

Puterka, G.J., Burd, J.D., Porter, D., Shufran, K., Baker, C., Bowling, B., and Patrick, C. 2007. Distribution and diversity of Russian wheat aphid (Hemiptera: Aphididae) biotypes in North America. J. Econ. Entomol. **100**: 1679–1684. doi:10.1093/jee/100.5.1679. PMID:17972648.

Puterka, G.J., Giles, K.L., Brown, M.J., Nicholson, S.J., Hammon, R.W., Peairs, F.B., Randolph, T.L., Michaels, G.J., Bynum, E.D., Springer, T.L., Armstrong, J.S., and Mornhinweg, D.W. 2015. Change in biotypic diversity of Russian wheat aphid (Hemiptera: Aphididae) in the United States. J. Econ. Entomol. **108**: 798–804. doi:10.1093/jee/tov008. PMID:26470192.

Puterka, G.J., Nicholson, S.J., Brown, M.J., Cooper, W.R., Peairs, F.B., and Randolph, T.L. 2014. Characterization of eight Russian wheat aphid (Hemiptera: Aphididae) biotypes using two-category resistant-susceptible plant responses. J. Econ. Entomol. **107**: 1274–1283. doi:10.1603/EC13408. PMID:25026693.

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. doi:10.1080/07060669609500617.

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. doi:10.1021/jf00054a061.

Thomas, J.B., and Butts, R.A. 1990. Effect of Russian wheat aphid on cold hardiness and winterkill of overwintering winter wheat. Can J. Plant Sci. **70**: 1033–1041. doi:10.4141/cjps90-126.

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.

Zhang, Y., Quick, J.S., and Liu, S. 1998. Genetic variation in PI 294994 wheat for resistance to Russian wheat aphid. Crop Sci. **38**: 527–530. doi:10.2135/cropsci1998.0011183X003800020042x.