AC Bellatrix hard red winter wheat

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Thomas, J. B., Gaudet, D. A. and Graf, R. J. 2012. **AC Bellatrix hard red winter wheat**. Can. J. Plant Sci. **92**: 163–168. AC Bellatrix is a winter-hardy, reduced-height cultivar of hard red winter wheat (*Triticum aestivum* L.) developed by Agriculture and Agri-Food Canada at the Lethbridge Research Centre. Based on evaluation in the Western Winter Wheat Cooperative Registration trials from 1995 to 1997, the average grain yield of AC Bellatrix was higher than Norstar and AC Readymade and similar to CDC Clair and CDC Osprey. AC Bellatrix was shorter than the standard height cultivar Norstar and had moderate lodging resistance, equivalent to CDC Osprey but with stiffer straw than Norstar and CDC Clair. AC Bellatrix exhibited moderate resistance to common bunt but was susceptible to leaf diseases including stem, leaf and stripe rust. Since its registration, AC Bellatrix is eligible for the enhanced-quality grades of the Canada Western Red Winter wheat market class.

Key words: *Triticum aestivum* L., wheat (winter), cultivar description, cold tolerance, stress tolerance, common bunt

Thomas, J. B., Gaudet, D. A. et Graf, R. J. 2012. **Le blé d'hiver roux vitreux AC Bellatrix**. Can. J. Plant Sci. **92**: 163–168. AC Bellatrixest un cultivar de blé d'hiver (*Triticum aestivum* L.) roux vitreux à paille courte et tolérant au froid créé par Agriculture et Agroalimentaire Canada à son centre de recherche de Lethbride. Selon les évaluations réalisées de 1995 à 1997 dans le cadre des essais coopératifs d'homologation des variétés de blé d'hiver dans l'Ouest, AC Bellatrix a un rendement grainier moyen supérieur à ceux de Norstar et de AC Readymade, et semblable à ceux de CDC Clair et CDC Osprey. Plus court que Norstar, AC Bellatrix résiste modérément à la verse, soit aussi bien que CDC Osprey, mais sa paille est plus robuste que celle de Norstar ou de CDC Clair. AC Bellatrix résiste modérément à la carie, tout en étant sensible aux affections foliaires, dont la rouille de la tige, la rouille des feuilles et la rouille jaune. Depuis son homologation, la variété est devenue admissible aux classes de qualité supérieure de la catégorie « Blé rouge d'hiver de l'Ouest canadien ».

Mots clés: *Triticum aestivum* L., blé (d'hiver), description de cultivar, tolérance au froid, tolerance au stress, carie

AC Bellatrix hard red winter wheat (*Triticum aestivum* L.) is a winter-hardy, reduced-height, common bunt resistant cultivar developed by Agriculture and Agri-Food Canada (AAFC) at the Lethbridge Research Centre (LRC), in Lethbridge, AB. It is well suited for production in Alberta and western Saskatchewan and meets the end-use quality attributes of the Canada Western Red Winter (CWRW) wheat class. AC Bellatrix was granted regional registration No. 5005 from the Variety Registration Office, Plant Production Division, Canadian Food Inspection Agency on 1999 Nov. 03 for all provinces except Ontario and Quebec. The name Bellatrix was chosen for this cultivar as it is the star that marks the right shoulder in the constellation Orion and is thus a prominent star in the winter sky.

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Pedigree and Breeding Method

AC Bellatrix was selected from the cross IDO 180*2/Sundance made in 1984 at AAFC, LRC, in Lethbridge. IDO180 is a hard red winter wheat selection from the United States Department of Agriculture (USDA) breeding program at Aberdeen, ID, with the pedigree Turkey Red/Burt//Bezostaya 1. It was introduced into the AAFC program through participation in the USDA Western Winter Wheat Performance Nursery in 1979. The principle merits of IDO180 were high grain yield potential, reduced plant height, improved straw strength and partial resistance to common bunt [*Tilleti atritici* (Bjerk.) G. Wint. in Rabenh. and *T. laevis* Kühn in Rabenh.]. Principle defects of IDO180 were poor winter hardiness, low test weight, low grain protein content, low flour yield, weak rheological properties, and a proportion of kernels that resembled those of the Canada Western Red Spring wheat class. Sundance was a CWRW wheat cultivar developed at AAFC, LRC from the cross Cheyenne/Kharkov 22MC (Grant 1972).

Abbreviations: **AAFC**, Agriculture and Agri-Food Canada; **LRC**, Lethbridge Research Centre; **USDA**, United States Department of Agriculture; **CWRW**, Canada Western Red Winter

It was registered for production from 1971 to 1991. The main advantages of Sundance were good winter hardiness, partial resistance to common bunt, and kernels conforming to the parameters that defined other CWRW wheat cultivars. The primary defects of Sundance were relatively low grain yield, tall straw, poor lodging resistance, overly hard kernels and weak rheological properties. The expanded parentage of AC Bellatrix is therefore (Turkey Red/Burt//Bezostaya 1)*2/(Cheyenne/Kharkov 22MC).

The BC_1F_1 hybrids were grown in the greenhouse, with the resulting seed grown in bulk under field conditions for two generations. Approximately 2000 heads were selected from a large F_3 plot, threshed individually, and examined for kernel characteristics. Selections with kernels that resembled other CWRW cultivars (plump kernels, medium red, elongate to ovate or elliptical, narrow germ, elliptical scutellum) were subjected to a dark-hardened freezing test for seedlings (Thomas et al. 1988) to identify lines with improved winter hardiness. Gaines (Vogel 1964) and Norstar (Grant 1980) were included as non-hardy and hardy checks, respectively. Five weeks of cold stress at $-10^{\circ}C$, following 8 wk of vernalization and hardening at $0.5^{\circ}C$, provided sufficient stress to kill all the seedlings of Gaines while permitting substantial survival of the Norstar seedlings. Four F_4 plants from the best surviving F_3 families were transplanted into pots, grown to maturity and harvested F_5 seed was planted as hill plots under irrigation. Attractive F_4-derived F_5 lines were harvested and replanted as F_4-derived F_6 rows under rain-fed conditions in Lethbridge. Reserve seed from each line was tested concurrently to identify lines with acceptable protein content and sodium dodecyl sulphate sedimentation volume. Lines with short, stiff straw and satisfactory quality were advanced to progressively stringent multi-location replicated trials for 4 yr (1991–1994), in which grain yield, agronomic traits, common bunt resistance and end-use quality were evaluated. An F_4-derived F_{10} selection designated AMF4AL was tested as W300 in the Western Winter Wheat Cooperative (WWWC) registration trials from 1995 to 1997.

Evaluation of suitability for registration in the WWWC trials was relative to Norstar, AC Readymade (Thomas and Graf 2012), CDC Clair (Fowler 1997a) and CDC Osprey (Fowler 1997b); Winalta was a long-term check during the first 2 yr of merit testing (Andrews and Grant 1962). Agronomic trials were grown in Alberta (Beaverlodge, Lacombe, Lethbridge ''dry land'', Lethbridge ''irrigated'', Olds, Vauxhall, Warner, Wilson Siding), Saskatchewan (Indian Head, Saskatoon, Swift Current), and Manitoba (Carman, Neepawa, Rosebank) through the collaborative efforts of AAFC, Alberta Agriculture and Rural Development, the University of Manitoba, the University of Saskatchewan and United Grain Growers. Disease resistance was assessed by AAFC plant pathologists and the agronomic trial collaborators when differential reactions for various pathogens were observed. End-use quality analysis was performed by the Canadian Grain Commission (CGC). MINITAB was used for the combined mixed model statistical analysis, in which the effects of environment were considered random and genotypes were fixed (MINITAB Inc. 2007).

During registration testing, resistance to the major diseases of economic importance to winter wheat was assessed. Seedling reactions to stem rust (*Puccinia graminis* Pers.: Pers. f. sp. *tritici* Eriks. & E. Henn.) and leaf rust (*P. triticina* Eriks.) were determined by pathologists at the AAFC Cereal Research Centre in Winnipeg, MB. The stem rust races used were: QCCJ, TMRT, TPMK, RKQS and QTHJ (Roelfs and Martens 1988). The leaf rust races used were: MBRJ, MCDS, TGBJ, TJBJ and MBDS (Long and Kolmer 1989). Adult reactions to stem rust were determined in an inoculated epiphytotic at Lethbridge under irrigated conditions, using races recovered from the AAFC rust nursery at Winnipeg in 1994 (Harder et al. 1996). Field reactions to leaf rust were based on natural infection at Indian Head in 1996 (Kolmer and Lui 1997). The reaction to common bunt was estimated annually by inoculating the seed with a composite of races that included L1, L16, T1, T6, T13 and T19 (Hoffman and Metzger 1976; Gaudet and Puchalski 1989) and planting into cold soil at Lethbridge in October. The reactions to powdery mildew [*Blumeria graminis* (DC.) E.O. Speer] and unspecified leaf spotting pathogens were recorded by trial collaborators at naturally infected test sites expressing differential symptoms.

End-use quality was evaluated at the Canadian Grain Commission, Grain Research Laboratory (GRL), following protocols of the American Association of Cereal Chemists. The grain composite sample used for the end-use quality analyses consisted of unequal quantities of grain from those test sites where the check cultivars met top grades and produced a mean protein concentration of approximately 12.5%, which is a desired target for the marketing of CWRW wheat. Grain from test sites with serious down-grading factors was not included in the quality composite. Kernel visual distinguishability attributes from each test site were examined by the Canadian Grain Commission, Grain Inspection Division, to determine eligibility into the CWRW wheat class.

Performance

Based on data collected from 27 sites over 3 yr (1995–1997) from across the Canadian prairies, AC Bellatrix yielded significantly more grain than Norstar and AC Readymade and was similar in grain yield to CDC Clair and CDC Osprey (Table 1). Regional yield comparisons also confirmed that AC Bellatrix did not differ significantly from that of the high-yielding checks, CDC Clair and CDC Osprey. In Zone 1 (southern Alberta) and Zone 3 (semi-arid prairie), AC Bellatrix was higher yielding than all of the checks; in Zone 2 (parkland), it

Table 1. Mean grain yield (t ha^{-1}) of AC Bellatrix compared with the check cultivars, Western Winter Wheat Cooperative registration trials (1995–1997)

Cultivar	1995[z]	1996	1997	1995–1996	1995–1997	Zone 1[y,x]	Zone 2	Zone 3	Zone 4
Winalta	3.84	3.33	–	3.65	–	–	–	–	–
Norstar	4.29	3.67	3.70	4.06	3.95	3.53	6.38	2.54	3.44
AC Readymade	3.92	3.73	3.60	3.85	3.78	3.48	6.22	2.40	3.04
CDC Clair	4.52	3.86	3.93	4.28	4.18	3.78	7.30	2.57	3.22
CDC Osprey	4.63	3.83	3.93	4.34	4.22	3.84	6.97	2.73	3.43
AC Bellatrix	4.51	3.77	4.02	4.24	4.18	3.86	7.14	2.77	3.14
LSD ($P \leq 0.05$)[w]	0.33	0.48	0.40	0.27	0.22	0.32	0.53	0.60	0.33
No. of tests	12	7	8	19	27	12	5	2	8

[z]All means are weighted by the number of tests.
[y]All zone means are for the 1995–1997 period.
[x]Zone 1: Southern Alberta sites (Lethbridge "dry land", Lethbridge "irrigated", Vauxhall, Warner, Wilson Siding).
Zone 2: Parkland sites (Beaverlodge, Lacombe, Olds).
Zone 3: Semi-arid prairie site (Swift Current).
Zone 4: Eastern prairie rust hazard sites (Carman, Indian Head, Neepawa, Rosebank, Saskatoon).
[w]Least significant difference includes variation from the genotype by environment interaction.

ranked second, behind CDC Clair. Regression analysis of all available yield data from registration and regional trials revealed that the yield performance of AC Bellatrix relative to other cultivars was highest when yields were low, suggesting that the anecdotal reputation for drought tolerance is well deserved (J. Thomas, unpublished research).

AC Bellatrix exhibited no statistical difference ($P \leq 0.05$) in winter survival compared with the winter-hardy checks Norstar, CDC Clair and CDC Osprey (Table 2), and had better survival ($P \leq 0.10$) than AC Readymade. The days to heading and maturity of AC Bellatrix were within the range of the checks – Norstar was significantly later to head than AC Bellatrix; AC Readymade was significantly later to reach maturity. AC Bellatrix was significantly shorter than Norstar, a standard height cultivar. AC Bellatrix had moderate lodging resistance; straw strength was lower than AC Readymade but significantly higher than Norstar and CDC Clair.

AC Bellatrix was comparable with the check cultivars for test weight and kernel mass (Table 3). The grain protein content of AC Bellatrix was significantly higher than all of the checks except AC Readymade. Protein yield per hectare showed a similar trend. The higher grain protein content was corroborated with a 48–61% lower incidence of piebald kernels compared with the high-yielding check cultivars, CDC Clair and CDC Osprey. AC Bellatrix displayed inferior black point incidence relative to the check cultivars.

AC Bellatrix was resistant to moderately resistant to common bunt, but lacked effective resistance to stem and leaf rust, which limits its adaptation to Alberta and western Saskatchewan (Table 4). Seedling tests for stem rust reaction to specific races revealed that AC Bellatrix has resistance to some races. The reaction to races QCCJ, RKQS and QTHJ is noteworthy, as it suggests that AC Bellatrix has *SrTmp*, making it a potential parent for the development of future cultivars with resistance to the new African stem rust races (Ug99 and its variants) (Jin and Singh 2006). This resistance was likely inherited from IDO180, which has Turkey Red as a parent (Roelfs and McVey 1979). In addition, the heterogeneous reaction to race TMRT indicates that a second stem rust resistance gene is also present (T. Fetch, personal communication, AAFC Cereal Research Centre, Winnipeg, MB). AC Bellatrix had reactions to powdery mildew and leaf spotting diseases that were similar to the check cultivars. In 2006 and 2010, widespread epidemics of stripe rust (*Puccinia striiformis*

Table 2. Agronomic performance of AC Bellatrix compared with the check cultivars, Western Winter Wheat Cooperative registration trials (1995–1997)

Cultivar	Winter survival (%)	Heading[z] (d)	Maturity[z] (d)	Height (cm)	Lodging[y] (1–9)
Norstar	50	174.7	219.9	104.2	3.9
AC Readymade	34	172.8	220.7	85.3	1.5
CDC Clair	38	173.4	218.6	84.9	3.9
CDC Osprey	59	172.5	217.1	86.5	3.2
AC Bellatrix	48	174.1	219.0	85.1	2.8
LSD ($P \leq 0.05$)[x]	16	0.6	1.0	2.0	0.7
No. of tests	6	14	14	21	13

[z]Days to heading and maturity expressed as day of year.
[y]Lodging scale: 1=all plants vertical, 9=all plants horizontal.
[x]Least significant difference includes variation from the genotype by environment interaction.

Table 3. Seed characteristics of AC Bellatrix compared with the check cultivars, Western Winter Wheat Cooperative registration trials (1995–1997)

Cultivar	Test weight (kg hL^{-1})	Kernel mass (mg)	Grain protein[z] (%)	Protein yield (kg ha^{-1})	Black point (%)	Piebald (%)
Norstar	80.1	33.6	12.4	476	7.0	15.4
AC Readymade	79.6	35.6	14.2	523	7.3	9.8
CDC Clair	79.2	33.9	12.4	498	7.3	23.1
CDC Osprey	78.8	31.6	12.5	506	6.3	31.1
AC Bellatrix	79.4	35.4	12.9	519	11.8	12.1
LSD ($P \leq 0.05$)[y]	0.4	0.8	0.3	26	2.4	6.7
No. of tests	28	26	28	27	26	24

[z]Grain protein content determined using whole grain NIR analysis.
[y]Least significant difference includes variation from the genotype by environment interaction.

Westend.) in the Canadian prairies demonstrated that AC Bellatrix was highly susceptible to the prevalent race combinations (McCallum et al. 2007; Puchalski and Gaudet 2011).

The three years of registration testing established that AC Bellatrix was equal to the check cultivars in end-use quality (Table 5). It is eligible for all grades of CWRW wheat and became eligible for price premiums under the Canadian Wheat Board's CWRW "Select" identity preserved contract program when it was launched in the 2002/2003 marketing year. AC Bellatrix replaced CDC Clair as a check cultivar in the WWWC trials in fall 1999, with demonstrated improvements in grain protein content (Table 3), flour yield, dough strength and water absorption (Table 5). AC Bellatrix became commercially available to producers in fall 2000 and was the predominant CWRW wheat cultivar in Alberta from 2004 to 2006 (Canadian Wheat Board 2005 Board 2007). In 2005 it became the predominant cultivar in western Canada, planted on 25.6% of the CWRW wheat acreage.

Other Characteristics

Seedling Characteristics

Anthocyanin colouration of coleoptile: absent (green).
Juvenile growth habit: prostrate.
Pubescence of lower leaf sheath: glabrous.
Pubescence of lower leaf blade: glabrous.
Colour of lower leaf blade: medium green.
Tillering capacity (at low densities): moderate.

Plant Characteristics at Booting

Flag leaf colour: medium green.
Pubescence of flag leaf blade: glabrous.
Waxiness of lower side of flag leaf blade: slightly waxy.
Waxy bloom of flag leaf sheath: pronounced.
Pubescence of flag leaf sheath: glabrous.
Flag leaf width: moderately narrow.
Flag leaf length: medium long.
Flag leaf curvature: recurved (drooping).
Flag leaf attitude: intermediate.
Anthocyanin colouration of flag leaf auricles: white to slightly pink.
Pubescence of flag leaf auricle margins: slight.

Plant Characteristics After Heading

Shape of culm neck: straight.
Waxiness of culm upper internode: slight.
Pubescence of culm upper internode: glabrous.
Pubescence of rachis margins: slight.
Anthocyanin colouration of straw at maturity: absent.
Pith in cross-section of straw (at middle of internode below the neck): hollow.
Stem colour at maturity: yellow.

Spike Characteristics

Shape: tapering to oblong.
Attitude at maturity: strongly inclined at 80 to 90 degrees.
Density: medium.
Length: medium.
Waxy bloom: moderately pronounced.
Colour at maturity: white.
Awnedness: awned.
Length of awns at tip of spike: shorter than spike.
Awn colour: white.
Awn attitude: slightly spreading.
Supernumary spikelets: absent.

Lower Glume Characteristics

Width: moderately narrow.
Length: long.
Pubescence: slight.
Shape of shoulder: rounded.
Shoulder width: narrow.
Shape of beak: acuminate.
Beak length: medium long.
Internal imprint: absent.
Colour at maturity: white.

Kernel Characteristics

Class eligibility: CWRW Wheat.
Type: hard red.
Colour: medium red.
Size: mid-size.
Length: mid-long to short.
Width: mid-wide.
Shape: elliptical to ovate.
Cheek shape: slightly rounded to angular.

Table 4. Disease reactions of AC Bellatrix compared with the check cultivars, Western Winter Wheat Cooperative registration trials (1995–1997)

	Stem rust						Leaf rust														
	Seedling race reaction[z]					Adult reaction[y]	Seedling race reaction[z]					Adult reaction[x]	Common bunt[w]			Leaf spots (1–6)[v,u]			Powdery mildew (1–6)		
Cultivar	QCCJ	TMRT	TPMK	RKQS	QTHJ		MBRJ	MCDS	TGBJ	TJBJ	MBDS		1995	1996	1997	1995	1996	1997	1995	1996	1997
Norstar	4	4	4	4	4	4.0	4	4	4	4	4	4.0	46 S	21 S	64 VS	5.6	2.9	2.2	4.4	4.1	3.7
AC Readymade	4	4	4	4	4	4.0	4	4	4	4	4	3.5	20 MS	6 MR	43 S	5.5	2.6	3.1	3.8	4.6	6.3
CDC Clair	11(0;1–) 2(2)	7(;1–) 7(4)	9(;4) 5(4)	4	4	4.0	4	3+	4	4	4	3.4	53 S	24 S	55 S	5.5	2.6	3.3	4.2	4.7	4.8
CDC Osprey	13(1±) 1(4)	7(23) 5(4)	4	4	4	4.0	4	4	4	4	4	2.7	58 S	32 S	78 VS	4.8	3.1	3.2	4.0	5.0	6.2
AC Bellatrix	2±	7(12+) 4(4)	4	12+	22+	3.9	4	4	4	4	4	3.0	9 MR	0 R	3 R	5.5	2.6	2.5	3.9	4.8	5.8

[z]Stem and leaf rust ratings to specific races (Stakman et al. 1962).
[y]Rated using a 1–4 scale: 1 = resistant, 4 = susceptible. Based on an inoculated stem rust epiphytotic at Lethbridge under irrigated conditions.
[x]Rated using a 1–4 scale: 1 = resistant, 4 = susceptible. Based on natural infection at Indian Head in 1996.
[w]Percent infection and rating: R = resistant, MR = moderately resistant, I = intermediate, MS = moderately susceptible, S = susceptible, VS = very susceptible.
[v]Rated using a 1–6 scale: 1 = disease free, 6 = very severe symptoms.
[u]Specific leaf spotting pathogens were not determined.

Table 5. Mean end-use quality characteristics[z] of AC Bellatrix and check cultivars, Western Winter Wheat Cooperative registration trials (1995–1997)

											Farinograph				Remix-to-peak bake		
Cultivar	Wheat protein (%)	Flour protein (%)	Protein loss (%)	Hagberg falling no. (s)	Amylograph peak viscosity (B.U.)	Flour yield (%)	Flour ash (%)	Flour colour (Agtron)	Starch damage (%)	Particle size index	Absorption (%)	DDT[y] (min)	MTI[y] (B.U.)	Stability (min)	Absorption (%)	Peak time (min)	Loaf volume (cm^3)
Norstar	12.7	12.0	0.7	345	383	76.7	0.39	74.0	4.0	59.1	58.1	5.8	49	9.4	59.3	2.0	822
AC Readymade	14.2	13.5	0.7	383	465	74.7	0.39	68.5	4.4	60.1	64.9	7.4	24	12.9	66.7	2.3	923
CDC Clair	12.8	11.7	1.1	367	442	75.0	0.40	71.0	4.1	62.5	60.1	5.7	53	8.9	61.3	2.0	853
CDC Osprey	12.9	12.2	0.7	395	717	77.2	0.39	77.5	3.9	61.6	57.7	6.3	32	12.7	59.3	2.0	872
AC Bellatrix	12.9	11.9	1.0	388	548	76.0	0.43	72.0	5.1	59.9	63.2	5.4	29	10.6	64.0	1.6	850
SD[x]	0.1	0.1	0.1	15	5	0.3	0.01	0.9	0.1	0.9	0.2	0.4	3	1.4	0.0	0.1	14

[z]American Association of Cereal Chemists methods were followed by the CGC, GRL for determining the various end-use quality characteristics on a composite of several locations per year.
[y]Farinograph parameters: DDT = dough development time, MTI = mixing tolerance index.
[x]Standard deviation is based on repeated testing of Allis 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.

Length of brush hairs: short to mid-long.
Size of brush: mid-size to small
Germ shape: ovate to oval.
Germ size: mid-size to small
Crease width: mid-wide.
Crease depth: shallow to mid-deep.

Maintenance and Distribution of Breeder Seed

Breeder seed development was initiated in early 1997 by vernalizing about 200 F_4-derived F_{13} seeds and growing them to maturity in 15 cm pots in a greenhouse. Off-type and weak plants were discarded, leaving 164 plants. Individual harvest of each plant resulted in 144 families with sufficient seed for planting as long, spaced plant rows (one plant per 23 cm) under irrigation in fall 1997. An isolation buffer was created by surrounding the rows with a bulk of the original seed source for the registration trials. Following removal of rogues within and between the rows, about 120 F_4-derived F_{14} Breeder Lines were inspected by the Canadian Food Inspection Agency and harvested in bulk to produce the initial Breeder Seed in 1998. The AAFC Seed Increase Unit at Indian Head, SK will maintain the Breeder Seed of AC Bellatrix. All other classes of seed will be multiplied and distributed by FP Genetics, 426 McDonald Street, Regina, SK, Canada S4N 6E1.

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