CULTIVAR DESCRIPTION

AAC Tenacious red spring wheat

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Key words: *Triticum aestivum* L., cultivar description, Canada Prairie Spring wheat, grain yield, quality, disease resistance, preharvest sprouting, orange blossom wheat midge

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Mots clés: *Triticum aestivum* L., description de cultivar, blé de printemps Canada Prairie, rendement grainier, qualité, résistance à la maladie, germination sur pied, cédidomyie du blé

AAC Tenacious is a hard red spring wheat (*Triticum aestivum* L.) cultivar developed by the Agriculture and Agri-Food Canada (AAFC), Cereal Research Centre (CRC), Winnipeg, Manitoba and released in 2013. It was assigned registration number 7627 by the Variety Registration Office, Canadian Food Inspection Agency on 2014 Dec. 18. AAC Tenacious is adapted to western Canada and fits into the Canada Prairie Spring Red (CPSR) wheat market class.

Pedigree and Breeding Methodology

AAC Tenacious was derived from the cross HY665/BW346 made at AAFC-CRC during the winter of 2003–2004. The primary objective of this cross was to develop a CPSR wheat variety adapted to the eastern Canadian prairies by combining orange wheat blossom midge (*Sitodiplosis mosellana* Géhin) and *Fusarium* head blight (FHB) resistance and excellent quality along with good leaf rust resistance, stem rust resistance and adequate yield potential. The female parent, HY665, was a first year line in the 2002 High Yield Wheat Cooperative (HYWC) Registration tests and was high yielding, midge and FHB resistant, which was derived from the cross 96W137//Howell/HY617BSR. The male parent, BW346, was a first year line in the 2003 Central Bread Wheat Cooperative (CBWC) Registration tests that was early

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Abbreviations: **CPS**, Canada Prairie Spring; **DO**, deoxynivalenol; **FHB**, *Fusarium* head blight

Table 1. Least square means for grain yield of AAC Tenacious compared with the check cultivars in the High Yielding Wheat Co-operative Registration Trials, 2010–2012

Line	Zone 1	Zone 2	Zone 3	Zone 4	Mean	% of 5700PR	Maturity	Height	Lodging	TW	TKWT
5700PR	3451	4576	4816	3697	4222	100	106.5	80.7	1.5	77.2	37.2
5701PR	3969	4959	4863	5339	4655	110	104.9	82.3	1.8	75.6	37.8
AAC Tenacious	3870	4527	4826	4818	4441	105	104.4	102.3	2.7	78.1	39.3
LSD	681	597	911	1232	435		3.3	2.4	0.5	1.0	7.7
Site years	14	12	11	3	40	40	34	41	19	34	34

Table 2a. Reaction to various diseases[z] of AAC Tenacious compared with the check cultivars in the High Yielding Wheat Co-operative Registration Trials, 2010–2012

	Leaf rust			Stem rust – Winnipeg			Stem rust – Kenya			Stripe rust		
Line	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
5700PR	–	10R	25MR	20R	20I	20I	15RMR	15MR	10R	5R	30I	68S
5701PR	0R	1R	0.3R	7R	5R	5R	15M	–	20M	5R	17I	25I
AAC Tenacious	0R	0R	0R	15MR	15MR	15I	5RMR	10MR	5R	0R	20I	11R

Table 2b. Reaction to various diseases and wheat midge of AAC Tenacious compared with the check cultivars in the High Yielding Wheat Co-operative Registration Trials, 2010–2012

	Common bunt			Loose smut			Leaf spot – Glenlea[y]			Midge (S/R/U)[x]		
Line	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
5700PR	2R/MR	10MR	3R	16MR	25MR	11R	28I	37MS	12I	20/0/4S	22/0/8S	30/0/0S
5701PR	21MS	18I	17MR	48I	38I	49I	22MR	48S	21MS	20/0/4S	18/0/12S	29/0/1S
AAC Tenacious	1R/MR	1MR	2.3R	7.9R	12R	12.5R	39MS	49S	43S	0/14/12R	0/3/27R	0/10/20R

Table 2c. *Fusarium* head blight (FHB) reaction of AAC Tenacious compared with the check cultivars in the High Yielding Wheat Co-operative Registration Trials, 2010–2012

	Glenlea – index			Carman – index			Ottawa – index			PEI – index		
Line	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
5700PR	24I	14I	20MS	52S	50MS	56S	18.3	42	41	25.7	36.0	41.0
5701PR	26MS	21S	9MR	49S	43MS	45MS	16.7	55	38	25.0	32.0	40.0
AAC Tenacious	5.7R	2.6R	2.5R	1.3R	4.9R	4.3R	26.7	3	23	43.3	27.7	52.0

Table 2d. Deoxynivalenol (DON) Level of AAC Tenacious compared with the check cultivars in the High Yielding Wheat Co-operative Registration Trials, 2010–2012

	DON – Glenlea (ppm)			DON – Ottawa (ppm)			PEI – DON (ppm)		
Line	2010	2011	2012	2010	2011	2012	2010	2011	2012
5700PR	25.7	4.1	7.78	–	19.3	9.2	–	24.8	2.2
5701PR	18.7	5.5	9.13	–	17.8	4.2	–	17.7	1.6
AAC Tenacious	1.9	0.2	0.57	–	0.6	0.5	–	22.7	0.2

[z]Disease rating class: VR = very resistant, R = resistant, RMR = resistant to moderately resistant, MR = moderately resistant, I = intermediate rating, MRMS = moderately resistant to moderately susceptible, MSS = moderately susceptible to susceptible, S = susceptible (% incidence × % severity/100, rating).
[y]Caused by main leaf spotting pathogens: *P. tritici-repentis, P. nodorum, M. graminicola*, and *C. sativus*.
[x]Wheat midge caused by *Sitodiplosis mosellana* (Géhin): S = susceptible, R = resistant, U = undamaged.

maturing, midge resistant with good yield potential and had the pedigree RL4802//(96MHN5295-1)BW174*2/Clark. A modified pedigree breeding method was used to develop AAC Tenacious. Seventeen F_1 plants were grown in the greenhouse during the winter of 2003–2004. The F_2 seeds derived from individual F_1 plants were space-planted in four-row 1.2-m^2 plots in the early generation disease nursery at Glenlea, MB, in 2004. The nursery was established on land where the previous crop was corn mulched to provide *Fusarium graminearum* inoculum. Prior to planting, the F_2 seeds were inoculated with common bunt [*Tilletia laevis* Kuhn in Rabenh. and *T. tritici* (Bjerk.) (Bjerk.) R. Wolff] spores. Susceptible spreader rows on either side of each plot were inoculated with leaf (*Puccinia triticina* Eriks. = *P. recondita* Roberge ex Desmaz.), and stem rust (*Puccinia graminis* Pers.: Pers. f. sp. *tritici* Eriks. & e. Henn.). The F_2 plants that were rust, bunt and/or FHB susceptible, tall or prone to lodging, late maturing were discarded. Seeds from the remaining plants were harvested in bulk. After cleaning and sizing, F_3 seeds were space planted in six 40-m-long rows near Palmerston North, New Zealand, during the winter of 2004–2005. After discarding plants that were susceptible to leaf rust, and/or tall or weak straw, and/or late, 1050 heads were selected from agronomically desirable plants. These were threshed individually, resulting seed was visually inspected and 272 F_4 head rows were planted in 2005 near Portage la Prairie, MB, in a disease nursery that was artificially inoculated with common bunt, leaf and stem rust. The F_4 nursery was also inoculated with FHB-infested corn spawn to permit screening for FHB resistance/tolerance, as described by Gilbert and Woods (2006). Mist irrigation was used every second day to encourage good disease incidence. Based on visual disease resistance and midge resistance, plant type, yield and kernel appearance, seed from 18 head rows was advanced to the next generation. The F_5 generation was planted in 1-m rows near Palmerston North, New Zealand (2005–2006). These lines were concurrently screened for bunt resistance in the AAFC-CRC greenhouses and for basic quality (protein content, kernel hardness and sedimentation) at the CRC Cereal Quality Laboratory. Based on bunt resistance and quality data plus agronomic performance and disease resistance in New Zealand, eight F_5 rows were harvested. Out of these, only lines yielding more than 176 g in New Zealand were advanced to the 2006 F_6 Yield Trial. The selected four F_6 lines were planted in single-replicate yield trials with alternating checks every 10th plot at Glenlea and Brandon, MB, and Saskatoon, SK, and in rust/common bunt/FHB disease nurseries planted at Glenlea and Portage la Prairie. All four of these lines were selected for advancement based on good yield, agronomic performance, leaf rust, stem rust, common bunt, midge, and especially FHB resistance. Fifteen heads were randomly collected from each selected F_6 line and five heads from each line were advanced for further purification and selection in New Zealand in 2006–2007. Twenty F_7 head rows were planted near Palmerston North, New Zealand, and eight lines were selected based on selection criteria similar to those in the F_4 generation including concurrent greenhouse and quality laboratory screening. These $F_{6:8}$ lines were planted in the 2007 F_8 Yield Trial planted at Glenlea, Brandon and Saskatoon. Two F_9 lines were advanced to the 2008 Eastern Prairie Wheat (EPW) 'A' trial, a replicated yield trial grown at five locations and in disease nurseries. Based on agronomic performance, disease resistance and quality analysis, one F_{10} line was advanced to the EPW 'B' tests grown at seven locations in 2009. One entry, EPWB09-235, was advanced to the High Yield Wheat Cooperative (HYWC) Registration tests as HY1615 in the 2010 to 2012. As part of these tests, artificially inoculated field nurseries were used to determine reactions to leaf rust and stem rust at AAFC-CRC (Winnipeg) using the modified Cobb scale (Peterson et al. 1948). Seedling reactions were determined in the greenhouse for leaf rust races MBDS (12-3), MGBJ (74-2), TJBJ (77-2) and MBRJ (128-1) (McCallum and Seto-Goh 2006) and to stem rust races TMRTK (C10), RKQSR (C63), TPMKR (C53), RTHJT (C57), QTHST (C25) and RHTSK (C20) (Roelfs and Martens 1988; Fetch 2005). Severity reaction to stripe rust (*Puccinia striiformis* Westend) was recorded based on natural field infection in stripe rust nurseries near Lethbridge (Randhawa et al. 2012). *Fusarium* head blight tolerance was evaluated at Glenlea and Carman, MB, in field nurseries spray inoculated with a macroconidial suspension and rated using a visual index (% incidence × % severity/100) as described by Gilbert and Woods (2006). Resistance to loose smut [*Ustilago tritici* (Pers.) Rostr.] was estimated as described by Menzies et al. (2003) using a composite of races T2, T9, T10 and T39. Evaluation of common bunt resistance was conducted at the AAFC Lethbridge Research Centre using a composite of races L1, L16, T1, T6, T13 and T19, and planting into cold soil (Gaudet and Puchalski 1989; Gaudet et al. 1993).

End-use quality was evaluated by the Grain Research Laboratory, Canadian Grain Commission, Winnipeg, MB, based on composite samples for each test entry prepared from test locations selected on the basis of protein content and grade of the check cultivars.

Analyses of variance were conducted on data from the registration tests using a combined mixed effects model for agronomic data with years, environments and their

Table 3. Artificial falling number and visual sprouting rating of AAC Tenacious compared with the check cultivars in the High Yielding Wheat Co-operative Registration Trials, 2010–2012

	Artificial (falling number)			Visual sprout (1–9)		
Line	2010	2011	2012	2010	2011	2012
5700PR	62	87	86	4.6	7.3	5.3
5701PR	62	109	90	4.4	5.7	7.6
AAC Tenacious	250	292	303	1.9	1.4	2.2

Table 4a. Grain and milling characteristics of AAC Tenacious compared with the check cultivars in the High Yielding Wheat Co-operative Registration Trials, 2010–2012

	Grain			Milling									
	Test wt.	Kernel wt.	Wheat pro	Flour pro	Pro loss	Falling number	Amylograph peak	Flour yield	Flour yield 0.50 ash	Flour ash	Flour color	Starch dmg	Particle size index
2010													
5700PR	80.1	41.2	12.4	11.7	0.7	280	325	76.1	77.0	0.44	78	8.3	52
5701PR	77.4	38.5	13.1	12.2	0.9	330	370	75.5	78.5	0.41	79	7.10	55
AAC Tenacious	81.1	50.2	13.1	12.4	0.7	405	610	75.6	79.0	0.40	77	8.1	54
2011													
5700PR	82.1	38.0	12.5	11.7	0.8	385	775	75.8	78.5	0.43	94.6	7.9	57
5701PR	81.0	38.8	12.6	11.9	0.7	435	905	76.0	79.5	0.41	94.9	6.8	60
AAC Tenacious	82.8	36.3	13.2	12.5	0.7	440	995	76.5	80.5	0.39	93.8	7.4	58
2012													
5700PR	81.1	38.1	13.2	12.2	1.0	405	770	75.2	77.0	0.44	94.9	7.7	58
5701PR	78.7	38.1	13.6	12.7	0.9	435	760	76.1	78.0	0.42	94.9	6.7	61
AAC Tenacious	82.3	35.0	13.2	12.2	1.0	485	1060	76.1	79.5	0.39	94.2	7.6	59

Table 4b. Dough mixing and baking characteristics of AAC Tenacious compared with the check cultivars in the High Yielding Wheat Co-operative Registration Trials, 2010–2012

	Farinograph				Remix baking							
	Absorption	Dough development time	Mixing tolerance index	Stability	Absorption	Peak time	Energy Whr/kg	Loaf volume	Loaf volume/ unit protein	Loaf appearance	Crumb structure	Color
2010												
5700PR	66.8	8.75	–	9.5	62	2.8	6.7	943	80.6	8.8	5.4	6.0
5701PR	62.7	10.25	–	23.5	62	2.7	4.6	945	77.5	8.8	5.2	5.4
AAC Tenacious	68.8	7.50	–	11.0	68	3.5	6.5	883	71.2	8.8	6.0	5.7
2011												
5700PR	65.5	8.50	30	10.0	64	3.5	6.1	935	79.9	8.5	5.4	6.0
5701PR	62.2	15.50	10	29.0	61	2.8	5.1	965	81.1	8.8	5.5	6.0
AAC Tenacious	67.2	6.00	15	10.5	63	3.4	6.1	915	73.2	8.8	5.8	6.0
2012												
5700PR	64.4	9.25	15	13.5	60	2.3	4.5	990	81.1	7.8	5.6	8.0
5701PR	61.3	13.00	10	26.0	59	1.8	3.7	1025	80.7	7.7	5.8	8.0
AAC Tenacious	65.4	7.00	20	14.0	61	2.7	4.7	915	75.0	7.5	5.5	7.7

interactions treated as random effects and cultivar treated as a fixed effect. The least significant difference ($LSD_{0.05}$) test was used to identify significant differences of the means for AAC Tenacious from those of the check cultivars. For end-use quality data there were no replicated observations within years.

Performance and Adaptation

Based on 40 station years of data in the HYWC test from 2010 to 2012, the yield of AAC Tenacious was intermediate as compared with checks, 5700PR and 5701PR, in all the zones within western Canada (Table 1). Overall, AAC Tenacious yielded about 5% higher than 5700PR ($P > 0.05$) and 5% lower than 5701PR ($P > 0.05$). AAC Tenacious (Table 1) was equal in maturity and 2 d earlier than 5701PR and 5700PR, respectively. AAC Tenacious had acceptable straw strength, was 21.6 cm taller ($P \leq 0.05$) than 5700PR and 20 cm taller ($P \leq 0.05$) than 5701PR. AAC Tenacious had higher test weight than both check cultivars. It had slightly heavier kernels than both 5701PR and 5700PR.

AAC Tenacious was resistant to western Canadian races of leaf rust and moderately resistant to stem rust, common bunt and loose smut. It had an intermediate reaction to stripe rust (Table 2a). AAC Tenacious had excellent resistance to *Fusarium* head blight with resistant reaction and lower production of DON as compared with check varieties (Table 2c and 2d). Based on 3 yr of screening in the HYWC registration tests, AAC Tenacious was resistant to or undamaged by the wheat midge, conferred by the presence of the gene, *Sm1* (Table 2b) and confirmed by the presence of the molecular marker (Thomas et al. 2005). AAC Tenacious expressed excellent resistance to preharvest sprouting under 3 yr of testing in an artificial rain simulator (Table 3). End-use quality (milling and baking) assessment by the Canadian Grain Commission showed that AAC Tenacious had excellent quality with improved test weight, flour protein, flour yield, Farinograph absorption and lower ash for the CPSR class (Table 4a and 4b).

Other Characteristics

Plant characteristics were recorded from experimental field plots grown in 2014 at Lethbridge, AB.

Seedling characteristics

Coleoptile colour: Absent.
Juvenile growth habit: Erect.
Seedling leaves: Medium green, glabrous.
Tillering capacity (at low densities): Moderately high.

Adult plant characteristics

Growth habit: Erect.
Flag leaf: Medium green, slightly curved, glabrous, slightly waxy blade, medium length and width, leaf auricle with weak anthocyanin and slightly pubescent margin.
Flag leaf attitude: Upright.
Culm colour: Glabrous.

Spike characteristics

Shape: Tapering.
Length: Medium.
Density: Medium.
Attitude: Erect.
Colour: White.
Awns: Awned; shorter than spike.

Spikelet characteristics

Glumes: White at maturity; medium length and width; glabrous; medium width, square shoulder, long length beak with acuminate shape.

Kernel characteristics

Type: Hard; red in colour.
Size: Medium, long, medium width; elliptical shape; rounded cheeks; medium length brush hairs, shallow crease depth.
Embryo: Broad elliptical.

Maintenance and Distribution of Pedigreed Seed

Breeder seed was produced by collecting F_6-derived F_{11} random heads from a rogued increase of AAC Tenacious grown at Regina in 2010 and growing about 250 heads as F_{12} 1-m-long head rows in isolation at Glenlea in 2011. Two hundred and four single-plant progeny F_{13} lines were grown as single 15-m rows at Indian Head in 2012. One hundred and eighty-two uniform breeder lines produced 347 kg of breeder seed. The breeder seed of AAC Tenacious will be maintained by the AAFC Seed Increase Unit, Indian Head, Saskatchewan, Canada S0G 2K0. Multiplication and distribution of the pedigreed seed will be handled by Alliance Seeds 2400 333 Main St., Winnipeg, Manitoba, Canada R3C 4E2 (www.allianceseed.com). To preserve the effectiveness of the *Sm1* gene, as detailed in the Midge Tolerant Wheat Stewardship Plan (www.midgetolerantwheat.ca), Certified Seed of AAC Tenacious will include a 10% interspersed susceptible wheat refuge of AAC Crusader and designated as AAC Tenacious VB (varietal blend).

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