

AC Readymade and AC Tempest, selections from Redwin hard red winter wheat

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Thomas, J. B. and Graf, R. J. 2012. AC Readymade and AC Tempest, selections from Redwin hard red winter wheat. *Can. J. Plant Sci.* **92**: 355–361. AC Readymade and AC Tempest are hard red winter wheat (*Triticum aestivum* L.) cultivars selected from the Montana cultivar 'Redwin' to conform to the kernel visual distinguishability requirements of the Canada Western Red Winter (CWRW) wheat class. AC Readymade and AC Tempest were registered in 1991 and 1999, respectively, following 3 yr of testing in the Western Winter Wheat Cooperative registration trials relative to various checks including Winalta, Norstar, CDC Clair and CDC Osprey. The survival characteristics of these cultivars demonstrated that they were well-suited to the relatively mild winter climate of southern Alberta. In this region of the prairies, AC Tempest had 4% higher grain yield than AC Readymade and was not significantly different from the other checks except Winalta, which was lower yielding. Both cultivars displayed relatively late maturity, moderate height, exceptional straw strength, high test weight, large kernels, high grain protein content and moderate resistance to common bunt. AC Tempest had significantly higher flour yield than AC Readymade.

Key words: *Triticum aestivum* L., wheat (winter), cultivar description, high grain protein, farinograph absorption, milling quality

Thomas, J. B. et Graf, R. J. 2012. Les sélections AC Readymade et AC Tempest du blé rouge vitreux d'hiver Redwin. *Can. J. Plant Sci.* **92**: 355–361. AC Readymade et AC Tempest sont des cultivars du blé rouge vitreux d'hiver (*Triticum aestivum* L.) Redwin du Montana sélectionnés pour se conformer aux paramètres visuels particuliers du grain de la classe « blé rouge d'hiver de l'Ouest canadien » (CWRW). AC Readymade et AC Tempest ont été respectivement homologués en 1991 et 1999, après trois années d'essais dans le cadre des tests d'homologation coopératifs sur le blé d'hiver de l'Ouest, durant lesquels ils ont été comparés à divers témoins, dont Winalta, Norstar, CDC Clair et CDC Osprey. Les caractéristiques de survie montrent que ces cultivars sont bien acclimatés aux hivers doux du sud de l'Alberta. Dans cette région des Prairies, le rendement grainier de AC Tempest dépassait celui de AC Readymade de 4 % et ressemblait sensiblement à celui des autres témoins, hormis Winalta, dont le rendement était plus faible. Les deux variétés se caractérisent par une maturité assez tardive, une taille moyenne, une paille exceptionnellement robuste, un poids spécifique élevé, de gros grains, une forte teneur en protéines et une résistance modérée à la carie du blé. AC Tempest a un rendement en farine sensiblement plus élevé que celui de AC Readymade.

Mots clés: *Triticum aestivum* L., blé (d'hiver), description de cultivar, forte teneur en protéines, absorption au farinographe, qualité meunière

AC Readymade and AC Tempest are hard red winter wheat (*Triticum aestivum* L.) cultivars selected at the Lethbridge Research Centre (LRC) of Agriculture and Agri-Food Canada (AAFC) in Lethbridge, AB. Both were derived from Redwin, a cultivar developed cooperatively by Montana State University and the United States Department of Agriculture, Agricultural Research Service (Taylor et al. 1983). Shortly after its release to Montana growers in 1979, Redwin was identified as a desirable cultivar for producers along

the foothills of the southern Alberta Rocky Mountains. The principle advantages of Redwin were higher grain yield and protein content, shorter straw and excellent lodging resistance compared with western Canadian cultivars of the time. Lower winter hardiness than Norstar (Grant 1980) was the main agronomic disadvantage. In 1983, the Expert Committee on Grain discussed the merits of Redwin but requested that additional data be collected prior to considering a recommendation for registration. Following 3 yr of replicated multi-location testing, Redwin was deemed

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Abbreviations: AAFC, Agriculture and Agri-Food Canada; LRC, Lethbridge Research Centre; CWRW, Canada Western Red Winter; CGC, Canadian Grain Commission; GRL, Grain Research Laboratory

unsuitable for registration in 1986 due to kernel visual distinguishability (KVD) attributes that resembled an admixture of the Canada Western Red Winter (CWRW) and Canada Western Red Spring wheat classes. A search for lines that were consistent in producing homogeneous CWRW kernels was therefore initiated.

AC Readymade received national registration No. 3490 from the Seed Division, Plant Health Directorate, Food Production and Inspection Branch, Agriculture Canada on 1991 Dec. 06. AC Tempest, a selection with improved grain and milling yield over AC Readymade, was granted national registration No. 4962 on 1999 July 28 by the Variety Registration Office, Canadian Food Inspection Agency.

Like Redwin, AC Readymade and AC Tempest are well-adapted to southern Alberta, where the winter climate is relatively mild and there is a high risk of soil erosion. Production outside of this traditional winter wheat region was not recommended because of variable winter survival, and poor resistance to stem rust (*Puccinia graminis* Pers.: Pers. f.sp. *tritici* Eriks. & E. Henn.) and leaf rust (*P. triticina* Eriks.). AC Readymade and AC Tempest were named after small communities near Lethbridge, well within the area of adaptation for these cultivars.

Pedigree and Breeding Method

AC Readymade and AC Tempest were selected from Redwin to conform to the KVD requirements of the CWRW wheat class. Redwin was developed from the cross MT6324/MT7301. MT6324 is a tall selection from the cross Yogo/Cheyenne; MT7301 is a shattering resistant, stiff-strawed, semi-dwarf line from the cross Norin 10/Brevor//3*Yogo. It is of note that Tiber, another cultivar developed in Montana, is also a selection from Redwin (Kisha et al. 1992).

AC Readymade and AC Tempest were derived from separate single head selections taken from rogued, advanced generation (greater than F₁₀) increase plots of Redwin grown in Lethbridge. As an F₅-derived line, Redwin exhibited sufficient variation among individual plants to suggest that selection for uniform kernel attributes might be successful. In both cases, several hundred head selections were examined for uniform kernel characteristics that met the CWRW wheat definition (plump kernels, medium red, elongate to ovate or elliptical, narrow germ, elliptical scutellum). Following the registration of AC Readymade in 1991, another selection effort was undertaken in an attempt to identify lines with improved flour yield.

Following examination and increase of the seed from each head, numerous Redwin sister selections were screened in replicated trials over several years and locations on the basis of kernel type, grain yield, protein content, and in the case of AC Tempest, flour yield. In fall 1987, a line designated RedwinR-0500 was entered into the Western Winter Wheat Cooperative (WWWC) registration trials as W188 and evaluated for

3 yr (1988–1990). W188 was recommended for registration by the Prairie Registration Recommending Committee for Grain, Subcommittee on Wheat, Rye and Triticale in 1991 and subsequently registered as AC Readymade. For AC Tempest, the line R6645 was evaluated in the WWWC registration trials as W288 from 1994–1996 and recommended for registration in 1997.

The suitability of AC Readymade for registration was evaluated relative to Winalta (Andrews and Grant 1962), Sundance (Grant 1972), Norstar and Norwin (Taylor et al. 1986). AC Tempest was assessed against Winalta, Norstar, CDC Clair (Fowler 1997a), CDC Osprey (Fowler 1997b) and AC Readymade. Collaboration among AAFC, Alberta Agriculture and Rural Development, the University of Saskatchewan, and the University of Manitoba facilitated a distribution of trials across western Canada. In Alberta, agronomic trial sites were at Beaverlodge, Bowden, Lacombe, Lethbridge (dry land and irrigated), Olds, Spring Coulee, Vauxhall, Warner, and Wilson Siding. In Saskatchewan, the locations included Canora, Indian Head, Melfort, Saskatoon, and Swift Current; in Manitoba, evaluation was conducted at Brandon, Carman, and Neepawa. The PROC MIXED procedure of SAS (Littell et al. 2006) was used to perform the combined mixed model statistical analysis, in which the effects of environment were considered random and genotypes were fixed.

During registration testing, resistance to several diseases common in western Canada was assessed annually by the agronomic trial collaborators and AAFC pathologists. Adult plant reactions to stem and leaf rust were recorded from inoculated and naturally infected nurseries. The reaction to common bunt [*Tilletia tritici* (Bjerk.) G. Wint. in Rabenh. and *T. laevis* Kühn in Rabenh.] was estimated visually by AAFC LRC staff in replicated nurseries under rainfed and irrigated conditions, using seed that was inoculated 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 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 analysis was performed by the AAFC Central Quality Laboratory for AC Readymade, and the Canadian Grain Commission (CGC), Grain Research Laboratory (GRL) for AC Tempest, using 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. Kernel visual distinguishability attributes from each test site were examined by the

Table 1. Mean^z grain yield (t ha⁻¹) of AC Readymade and AC Tempest compared with the check cultivars, Western Winter Wheat Cooperative registration trials (1988–1996)

Cultivar	Southern Alberta			Outside S. Alberta			Western Canada		
	1988–1990	1988–1996	1994–1996	1988–1990	1988–1996	1994–1996	1988–1990	1988–1996	1994–1996
Winalta	2.91	3.11	3.10	2.39	3.69	4.36	2.60	3.44	3.81
Sundance	2.60	–	–	2.58	–	–	2.59	–	–
Norstar	2.82	3.34	3.45	2.60	4.14	4.92	2.69	3.80	4.28
Norwin	3.43	–	–	2.24	–	–	2.71	–	–
CDC Clair	–	–	3.70	–	–	5.25	–	–	4.58
CDC Osprey	–	–	3.75	–	–	5.20	–	–	4.57
AC Readymade	3.27	3.49	3.38	2.55	3.91	4.66	2.86	3.73	4.10
AC Tempest	–	–	3.50	–	–	4.90	–	–	4.29
LSD ($P \leq 0.05$) ^y	0.35	0.18	0.27	0.30	0.23	0.33	0.25	0.15	0.22
No. of tests	8	30	13	12	40	17	20	70	30

^zAll means are weighted by the number of tests.

^yFisher's protected least significant difference.

CGC, Grain Inspection Division to determine eligibility into the CWRW wheat class.

Performance

Evaluation to determine the eligibility of AC Readymade for registration (1988–1990) revealed significantly higher grain yield than Winalta and Sundance (Table 1), but significantly lower spring stands than all of the checks across the western Canadian testing sites (Table 2). At the southern Alberta sites, a region of relatively low risk for winterkill (Savdie et al. 1991), AC Readymade had significantly higher grain yield than Winalta (112%), Sundance (125%) and Norstar (116%), and exhibited spring stands similar to Winalta and Norstar, suggesting sufficient cold tolerance for this region.

Following the support for registration by the Prairie Registration Recommending Committee for Grain, AC Readymade became a check cultivar in the WWWC registration trials, resulting in an accumulation of 9 yr (1988 to 1996) of grain yield and spring stand data relative to Winalta and Norstar. Overall, AC Readymade was 8% higher yielding than Winalta and 2% lower yielding than Norstar. In southern Alberta, these long-term data showed that AC Readymade was 12% and 4% higher yielding than Winalta and Norstar, respectively. The long-term survival data, sub-grouped

as locations within and outside of southern Alberta, were examined using a biplot graphing technique (Francis and Kannenberg 1978). Presented in this manner, the data clearly reveal that compared with the checks, AC Readymade had a similar spring stand percentage and lower stand variability at the southern Alberta locations (Fig. 1). This was not the case outside of southern Alberta, where AC Readymade exhibited reduced stands with greater variability among sites than both Winalta and Norstar. It was therefore appropriate that AC Readymade (and later AC Tempest) was considered sufficiently winter hardy for production in southern Alberta, but was not recommended for production in other areas of western Canada (Saskatchewan Agriculture and Food 1993).

The 9-yr period from 1988 to 1996 included the 3 yr in which AC Tempest was evaluated for registration (1994–1996). As expected, spring stands for AC Tempest were similar to those for AC Readymade, indicating a similar zone of adaptation (Table 3). In southern Alberta, AC Tempest was 13% higher yielding than Winalta, 4% higher yielding than AC Readymade, 2% higher yielding than Norstar, 5% lower yielding than CDC Clair, and 7% lower yielding than CDC Osprey (Table 1).

The remaining characteristics describing AC Readymade and AC Tempest are based on the 1994–1996

Table 2. Mean^z spring stand (%) and coefficient of variation for AC Readymade compared with the long term checks Winalta and Norstar, Western Winter Wheat Cooperative registration trials (1988–1996)

Cultivar	Southern Alberta		Outside S. Alberta		Western Canada	
	Mean	CV	Mean	CV	Mean	CV
Winalta	51	57	69	45	64	48
Norstar	48	59	79	30	71	39
AC Readymade	52	48	55	61	54	58
LSD ($P \leq 0.05$) ^y	NS	–	10	–	8	–
No. of tests	6	–	19	–	25	–

^zAll means are weighted by the number of tests.

^yFisher's protected least significant difference.

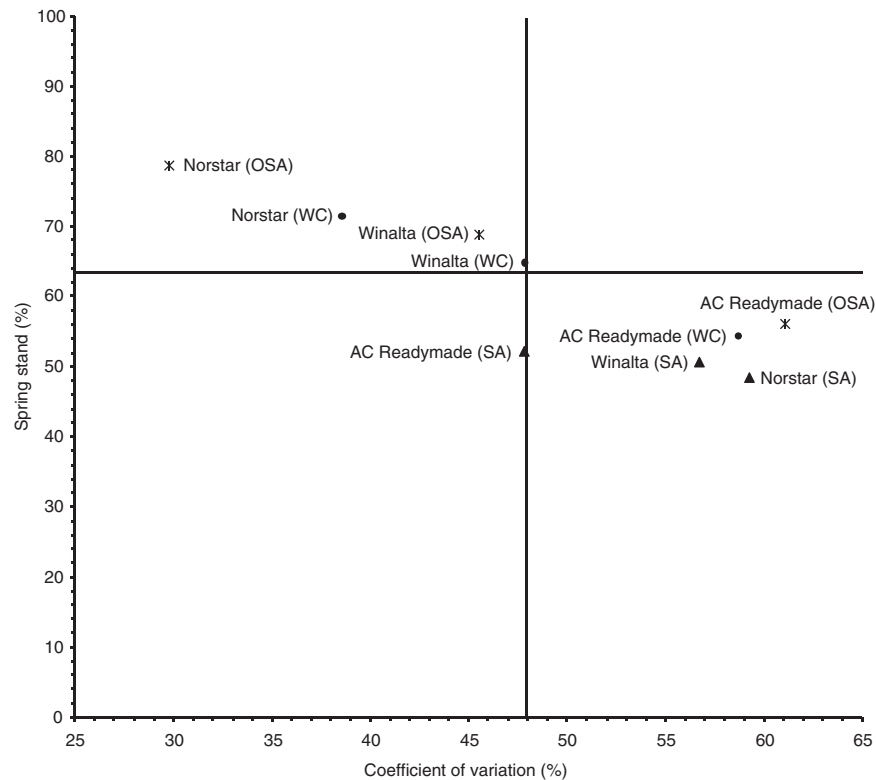


Fig. 1. Biplot of spring stand (mean vs. coefficient of variation) collected from 1988 to 1996 for AC Readymade and the long-term checks Winalta and Norstar at locations in southern Alberta (SA), locations outside of southern Alberta (OSA), and all western Canadian locations combined (WC).

WWWC registration trials in which both cultivars were present, permitting direct comparisons between the two cultivars and various pertinent checks (Table 3–6). The days to heading and maturity, height, and lodging resistance were very similar for AC Readymade and AC Tempest (Table 3). Both cultivars were similar to CDC Clair and CDC Osprey for days to heading, whereas Norstar was later and Winalta earlier. AC Readymade and AC Tempest were later maturing than all of the comparative cultivars. Height was similar to CDC

Clair and CDC Osprey; lodging resistance was significantly improved over these cultivars, Winalta and Norstar.

AC Readymade and AC Tempest showed significantly higher test weights than CDC Clair and CDC Osprey; kernel masses were significantly higher than all of the checks (Table 4). The grain protein concentrations for AC Readymade and AC Tempest was also significantly higher than all of the checks, which was reflected in higher values for protein yield per hectare and much

Table 3. Agronomic performance of AC Readymade and AC Tempest compared with the check cultivars, Western Winter Wheat Cooperative registration trials (1994-1996)

Cultivar	Spring stand (%)	Heading ^z (d)	Maturity ^z (d)	Height (cm)	Lodging ^y (1–9)
Winalta	61	170.2	217.1	100.5	4.3
Norstar	74	173.2	219.3	110.1	3.9
CDC Clair	60	171.4	218.1	90.3	3.8
CDC Osprey	69	171.0	216.9	92.4	3.1
AC Readymade	41	171.3	220.7	92.8	1.4
AC Tempest	44	171.4	221.1	91.5	1.4
LSD ($P \leq 0.05$) ^w	13	0.6	1.1	1.9	0.7
No. of tests	6	16	16	23	14

^zDays to heading and maturity expressed as day of year.

^yLodging scale: 1 = all plants vertical, 9 = all plants horizontal.

^wFisher's protected least significant difference.

Table 4. Seed characteristics of AC Readymade and AC Tempest compared with the check cultivars, Western Winter Wheat Cooperative registration trials (1994–1996)

Cultivar ^z	Test weight (kg hL ⁻¹)	Kernel mass (mg)	Grain protein ^z (%)	Protein yield (kg ha ⁻¹)	Black point (%)	Piebald (%)
Winalta	—	—	—	—	—	—
Norstar	80.2	34.3	12.3	478	7.7	17.2
CDC Clair	79.2	34.1	12.5	505	7.8	18.8
CDC Osprey	79.1	32.3	12.5	513	6.2	24.1
AC Readymade	79.8	36.4	14.1	523	8.5	7.2
AC Tempest	79.9	37.2	14.2	554	7.5	7.7
LSD (<i>P</i> ≤ 0.05) ^y	0.4	0.9	0.4	31	NS	5.1
No. of tests	31	29	20	19	27	25

^zWinalta seed characteristics were not determined in all years.

^yFisher’s protected least significant difference.

lower frequencies of piebald (starchy) kernels. The incidence of kernel black point was similar for all of the cultivars.

AC Readymade and AC Tempest showed moderately resistant reactions to common bunt, whereas all of the checks were susceptible (Table 5). There was little difference among the cultivars in their susceptible reactions to powdery mildew, leaf spotting diseases, stem rust and leaf rust.

End-use quality testing by the CGC, GRL established that AC Readymade and AC Tempest were eligible for all grades of CWRW wheat, with major improvements shown in grain and flour protein content, farinograph and bake absorption, and loaf volume (Table 6). AC Tempest showed significantly better flour yield and

slightly lower flour ash than AC Readymade, demonstrating that the repeated selection process was successful.

AC Readymade became popular with southern Alberta producers in the 1990s, occupying over 50% of the winter wheat acreage in the province, while AC Tempest achieved about 20% adoption in the early 2000s (Canadian Wheat Board 1998, 2002). Both cultivars 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.

Other Characteristics

Because AC Readymade and AC Tempest are advanced generation selections from the same parent

Table 5. Disease reactions of AC Readymade and AC Tempest compared with the check cultivars, Western Winter Wheat Cooperative registration trials (1994–1996)

	Year	Winalta	Norstar	CDC Clair	CDC Osprey	AC Readymade	AC Tempest
Common bunt ^z	1994	4	8	9	13	3	0
	1995	50	46	53	58	20	23
	1996	28	21	24	32	6	7
	Mean	27	25	29	34	10	10
	Classification	S	S	S	S	MR	MR
Powdery mildew	1994 ^y	2.2	2.5	2.8	3.3	2.2	2.6
	1995 ^x	4.3	4.4	4.2	4.0	3.8	3.6
	1996 ^x	4.9	4.1	4.8	5.0	4.6	4.7
Leaf spots ^{w,x}	1994	—	—	—	—	—	—
	1995	4.9	4.1	4.3	3.8	4.2	4.1
	1996	2.9	2.9	2.6	3.1	2.6	2.5
Stem rust ^v	1994	4.0	4.0	2.5	3.5	3.8	4.0
	1995	4.0	4.0	4.0	4.0	4.0	4.0
	1996	—	—	—	—	—	—
Leaf rust ^u	1994	7.0	4.3	7.4	7.5	8.6	8.5
	1995	—	—	—	—	—	—
	1996	2.6	4.1	3.4	2.7	3.5	3.6

^zPercent infection and resistance classification: MR = moderately resistant, S = susceptible.

^y1–4 rating scale: 1 = disease free, 4 = severe symptoms.

^x1–6 rating scale: 1 = disease free, 6 = severe symptoms.

^wSpecific leaf spotting pathogens were not determined.

^v1–4 rating scale: 1 = resistant, 4 = susceptible.

^u1–9 rating scale: 1 = resistant, 9 = susceptible.

Table 6. Mean end-use quality characteristics² of AC Readymade, AC Tempest and check cultivars, Western Winter Wheat Cooperative registration trials (1994–1996)

Cultivar	Farinograph										Remix-to-peak bake						
	Wheat protein (%)	Flour protein (%)	Protein loss (%)	Hagberg falling no. (s)	Amylograph viscosity (BU)	Flour yield (%)	Flour ash (%)	Flour Colour (K-J)	Starch damage (%)	Particle size index	Absorption (%)	DDT ³ (min)	MTI ⁴ (BU)	Stability (min)	Absorption (%)	Peak time (min)	Loaf volume (cm ³)
Norstar	12.6	11.9	0.7	367	443	77.3	0.39	-2.1	19.7	59.9	58.6	5.8	47	9.0	59.7	2.1	803
CDC Clair	12.5	11.5	1.0	383	452	75.7	0.40	-1.6	20.0	61.3	60.2	5.4	50	8.4	61.0	2.1	818
CDC Osprey	12.7	12.0	0.7	410	780	77.7	0.39	-2.4	18.7	60.8	58.1	6.4	37	10.6	59.3	2.1	837
AC Readymade	14.0	13.3	0.7	412	623	75.2	0.39	-1.6	22.3	58.8	65.2	6.7	27	11.4	66.7	2.4	898
AC Tempest	13.9	13.2	0.7	410	578	76.0	0.38	-1.7	24.3	58.7	65.4	6.3	30	10.7	65.3	2.1	852
SD ⁵	0.1	0.1	0.1	15	5	0.3	0.01	-	0.1	0.9	0.2	0.4	3	1.4	0.0	0.1	14

²American 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.

³Farinograph parameters: DDT = dough development time, MTI = mixing tolerance index.

⁴Standard 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.

cultivar, their botanical descriptions are very similar. A protocol for amplified fragment length polymorphism (AFLP) based molecular markers to distinguish between them is available upon request.

Seedling Characteristics

Coleoptile anthocyanin colouration: absent (green).

Juvenile growth habit: prostrate; rapidly becomes erect in spring.

Pubescence of lower leaf sheath: glabrous; minute hairs visible with magnification.

Pubescence on lower leaf blade: glabrous.

Colour of lower leaf blade: medium green.

Tillering capacity (at low densities): intermediate, lower than Norstar.

Plant Characteristics at Booting

Flag leaf colour: medium green.

Pubescence of flag leaf blade: glabrous.

Waxiness of lower side of flag leaf blade: slight.

Waxy bloom of flag leaf sheath: slight.

Pubescence of flag leaf sheath: glabrous.

Flag leaf width: medium.

Flag leaf length: medium.

Flag leaf curvature: recurved (drooping).

Flag leaf attitude: intermediate.

Anthocyanin colouration of flag leaf auricles: white to pink.

Pubescence of flag leaf auricle margins: slight.

Plant Characteristics After Heading

Shape of culm neck: very slight curve.

Waxiness of culm upper internode: slight.

Pubescence of culm upper internode: glabrous.

Pubescence of rachis margins: strong.

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: erect to slightly inclined.

Density: medium.

Length: medium.

Waxy bloom: slight.

Colour at maturity: red to brown.

Awedness: awned.

Length of awns at tip of spike: shorter than spike.

Awn colour: light brown.

Awn attitude: slightly spreading.

Lower Glume Characteristics

Width: narrow.

Length: medium.

Pubescence: glabrous, some hairs at glume base.

Shape of shoulder: oblique.

Shoulder width: narrow.
 Shape of beak: acuminate.
 Beak length: short.
 Internal imprint: absent.
 Colour at maturity: brown.

Kernel Characteristics

Class eligibility: CWRW wheat.
 Type: hard.
 Colour: dark red.
 Size: medium.
 Length: medium.
 Width: medium.
 Shape: ovate to elliptical.
 Cheek shape: rounded to slightly angular.
 Length of brush hairs: medium.
 Size of brush: medium.
 Germ shape: oval.
 Germ size: small.
 Crease width: narrow.
 Crease depth: shallow to mid-deep.
 Phenol reaction: light brown.

Maintenance and Distribution of Breeder Seed

AC Readymade and AC Tempest are exceptionally uniform in plant type. The Breeder Seed of AC Readymade was produced by bulking 97 breeder lines grown in isolation, derived from the 1988 registration trial seed increase plot. In the case of AC Tempest, 79 isolated breeder lines were bulked, also derived from a purified seed increase plot. The AAFC Seed Increase Unit at Indian Head, SK, will maintain the Breeder Seed of both cultivars. All other classes of pedigreed seed will be multiplied and distributed by SeCan Association, 400–300 Terry Fox Drive, Kanata, Ontario, Canada K2K 0E3.

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