CULTIVAR DESCRIPTION

Emerson hard red winter wheat

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Received 10 October 2012, accepted 5 February 2013.

Graf, R. J., Beres, B. L., Laroche, A., Gaudet, D. A., Eudes, F., Pandeya, R. S., Badea, A. and Randhawa, H. S. 2013. **Emerson hard red winter wheat**. Can. J. Plant Sci. **93**: 741–748. Emerson hard red winter wheat (*Triticum aestivum* L.), a cultivar developed using doubled haploid technology, was registered for western Canadian production in 2012. It is eligible for grades of the Canada Western Red Winter (CWRW) wheat market class. Evaluation across western Canada from 2008 to 2010 was relative to CDC Osprey, AC Bellatrix, Radiant, and CDC Buteo, the CWRW wheat checks in the Western Winter Wheat Cooperative Registration trials. Overall, Emerson had significantly lower grain yield than the mean of these checks; however, in the stem rust, leaf rust and fusarium head blight prone eastern prairies the grain yield of Emerson was not significantly different from CDC Buteo and CDC Falcon, which have been the predominant cultivars in this region. Emerson had good winter survival, intermediate maturity, medium height, strong straw, high test weight, and high grain protein concentration. It expressed improved resistance to fusarium head blight, stem rust, leaf rust, and stripe rust relative to the checks. End-use suitability analysis indicated that Emerson had strong dough rheology, and excellent milling and baking properties.

Key words: *Triticum aestivum* L., wheat (winter), cultivar description, disease resistance, fusarium head blight, protein concentration, molecular marker, doubled haploid

Graf, R. J., Beres, B. L., Laroche, A., Gaudet, D. A., Eudes, F., Pandeya, R. S., Badea, A. et Randhawa, H. S. 2013. **Le blé roux vitreux d'hiver Emerson**. Can. J. Plant Sci. **93**: 741–748. Emerson est un cultivar de blé roux vitreux d'hiver (*Triticum aestivum* L.) créé par haploïdie double. La variété a été homologuée pour la culture dans l'Ouest canadien en 2012 et est admissible aux classes marchandes « blé rouge d'hiver de l'Ouest canadien » (CWRW). Le cultivar a été évalué dans l'Ouest de 2008 à 2010 et comparé aux variétés témoins CDC Osprey, AC Bellatrix, Radiant et CDC Buteo dans le cadre des essais d'homologation coopératifs de l'Ouest pour le blé d'hiver. En général, Emerson se caractérise par un rendement grainier sensiblement inférieur à la moyenne des témoins. Cependant, dans l'est des Prairies où sévissent la rouille de la tige, la rouille des feuilles et la brûlure de l'épi attribuable à *Fusarium*, le rendement grainier d'Emerson était semblable à celui de CDC Buteo et de CDC Falcon, les cultivars prédominants dans cette région. Emerson survit bien à l'hiver et parvient à maturité au bout d'un temps moyen. La variété a une taille moyenne, une paille robuste, un poids spécifique élevé et une forte concentration en protéines. Elle résiste mieux que les cultivars témoins à la brûlure de l'épi causée par *Fusarium*, à la rouille de la tige, à la rouille des feuilles et à la rouille jaune. Selon l'analyse de la capacité à se prêter à l'utilisation finale, Emerson donne une pâte de bonne rhéologie et possède d'excellentes propriétés meunières et boulangères.

Mots clés: *Triticum aestivum* L., blé (d'hiver), description de cultivar, résistance à la maladie, brûlure de l'épi causée par *Fusarium*, concentration de protéines, marqueur moléculaire, haploïde double

Emerson hard red winter wheat (*Triticum aestivum* L.) was developed by the cereal research team at the Lethbridge Research Centre (LRC) of Agriculture and Agri-Food Canada (AAFC) in Lethbridge, AB. Evaluated as LF1313 and W454, Emerson was recommended for registration by the Prairie Recommending Committee for Wheat, Rye and Triticale in February 2011 and received registration No. 7253 from the Variety Registration Office, Plant Production Division, Canadian Food Inspection Agency on 2012 Nov. 01. An application for Plant Breeders' Rights has been filed.

Acceptable grain yield, excellent agronomic and end-use quality traits, and superior resistance to stem rust,

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Abbreviations: **AAFC**, Agriculture and Agri-Food Canada; **CGC**, Canadian Grain Commission; **CWRW**, Canada Western Red Winter; **DH**, doubled haploid; **DON**, deoxynivalenol; **FHB**, fusarium head blight; **GRL**, Grain Research Laboratory; **LRC**, Lethbridge Research Centre

leaf rust, stripe rust and fusarium head blight (FHB) make Emerson particularly well suited to the eastern prairie production environment. The name ''Emerson'' was considered appropriate for this cultivar as it is a town in the heart of the Red River Valley in south-central Manitoba, an area where its disease resistance characteristics will be of greatest benefit to producers.

Pedigree and Breeding Method

Emerson is an F_1-derived doubled haploid (DH) cultivar produced from the cross McClintock/CDC Osprey made in 2000 at the AAFC, LRC in Lethbridge. McClintock and CDC Osprey are both registered CWRW wheat cultivars, developed by the University of Manitoba and the University of Saskatchewan Crop Development Centre, respectively. The parentage of McClintock is VT2222/Norstar (A. L. Brûlé-Babel, personal communication, University of Manitoba, Winnipeg, MB), whereas the parentage of CDC Osprey is Plainsman V/CIMMYT Selection//Agritriticum 100 (Fowler 1997).

Utilizing minor modifications to standard wheat: maize hybridization techniques (Fedak et al. 1997; Knox et al. 2000), 171 DH lines were produced from 32 F_1 ovule donor plants in 2001. Sixteen DH lines were produced from the specific F_1 plant from which Emerson was derived. Initial evaluation of the majority of the DH genotypes originating from this cross occurred in 2-m observation rows with 46-cm spacing under irrigation near Lethbridge in 2003, resulting in the harvest of 80 lines based on winter survival, vigour, plant type, height and straw strength. These selections were rated in an artificially inoculated stem rust (*Puccinia graminis* Pers.: Pers. f.sp. *tritici* Eriks. & E. Henn.) and leaf rust (*P. triticina* Eriks.) nursery in 2004, grown in collaboration with the University of Manitoba in Winnipeg, MB. Grain from the rows harvested in 2003 was also screened for test weight, protein concentration and sodium dodecyl sulphate sedimentation volume during the winter of 2003/2004. Based on these criteria, LF1313 was among 33 lines identified and subsequently tested in a single replicate agronomic trial near Lethbridge, and the inoculated stem and leaf rust nursery in Winnipeg, in 2005. Favourable agronomic performance, disease resistance, and end-use quality prompted the advancement of three lines into replicated trials across western Canada in 2006 and 2007.

The similarity in stem, leaf and stripe rust expression to McClintock, and further pedigree expansion of the parental line VT2222 (VT1215//VPM1/Moisson) suggested that the resistance carried by Emerson was at least partially due to the presence of the *Sr38*/*Lr37*/*Yr17* gene cluster from VPM1 (Maia 1967; Bariana and McIntosh 1993; McIntosh et al. 1995). To verify the presence of these resistance genes in McClintock and Emerson, two PCR primers identified as tvnest for4295 (5′-GGT TGT GAT TTG ATG TTG CG-3′) and tvnest rev4634 (5′-GCG GCA CTT GTT TAC CAT TT-3′), which amplified a DNA fragment of 320 base pairs (bp), were designed based on an available VPM1 sequence (GenBank accession AF158634) (Seah et al. 2001). The original VPM1 primers amplified the diagnostic 886 bp fragment and additional fragments within a conspicuous background under our conditions. The selected primers amplified a single dominant and easily detected 320 bp fragment. The ''tvnest'' DNA fragment was selected to partially overlap the original marker sequence in the 3′ UTR region of AF158634. The reliability of the tvnest primers was verified with a subset of 192 lines originating from a VPM1 introgression into a susceptible winter wheat background. Perfect concordance between the presence of the 320 bp DNA marker and the resistant phenotype was observed, and confirmed its occurrence in McClintock and Emerson.

Based on 11 site-years of replicated pre-registration agronomic trials, 4 yr of disease resistance screening, and three years of detailed end-use quality testing, LF1313 was entered into the Western Winter Wheat Cooperative registration trial as W454 and evaluated for 3 yr (2008–2010). Assessment of grain yield, agronomic performance, and end-use suitability for the CWRW wheat class was relative to CDC Osprey, AC Bellatrix (Thomas et al. 2012b), Radiant (Thomas et al. 2012a) and CDC Buteo (Fowler 2010). The agronomic trials were grown in Alberta (Beaverlodge, Lacombe, Lethbridge ''dry land'', Lethbridge ''irrigated'', Olds, Vauxhall, Warner), Saskatchewan (Indian Head, Melfort, Saskatoon, Swift Current), and Manitoba (Brandon, Carman, Winnipeg) through the collaborative efforts of AAFC, Alberta Agriculture and Rural Development, the University of Saskatchewan, and the University of Manitoba. 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 in the means compared with the check cultivars.

During registration testing, reactions to the major diseases of economic importance to winter wheat in both the eastern and western prairies were determined by personnel at the University of Manitoba and AAFC. Supplementary checks were added as required to aid in these assessments. The adult plant reactions to stem and leaf rust were determined in artificially inoculated field nurseries conducted by the University of Manitoba in Winnipeg using race composites supplied by the AAFC Cereal Research Centre, and reported using the modified Cobb scale (Peterson et al. 1948). The stem rust races used for 1 or more years included: MCCFC (C17), QTHJC (C25), RHTSC (C20), RKQSC (C63), RTHJC (C57), TMRTC (C95) and TPMKC (C53) (Fetch 2005; Jin et al. 2008). Each year, the leaf rust races used for inoculation were a representative mixture collected in western Canada during the previous field season (McCallum et al. 2010, 2011). University of Manitoba staff also assessed the response to FHB {caused by *Fusarium graminearum* Schwabe [teleomorph *Gibberella*

zeae (Schwein.) Petch]} in a three replicate, mist-irrigated field nursery in Carman. Each line was spray-inoculated with a suspension of *F. graminearum* macroconidia at 50% anthesis and again three to four days later. The spore suspension had a concentration of 50 000 macroconidia mL^{-1} and was prepared using equal quantities of two 3-acetyldeoxynivalenol (3-ADON) and two 15-acetyldeoxynivalenol (15-ADON) producing chemotypes. A visual index (% incidence × % severity/100) was used to rate the plants, typically 18 to 21 d after anthesis or when symptoms were well developed (Gilbert and Woods 2006; Cuthbert et al. 2007). The reaction to common bunt was estimated in nurseries conducted at AAFC, LRC by inoculating seed with a composite of races that included L1, L16, T1, T6, T13, and T19 (Hoffman and Metzger 1976; Gaudet and Puchalski 1989) prior to planting into cold soil at two locations in October. Stripe rust (*Puccinia striiformis* Westend.) ratings were determined under conditions of natural infection and artificially inoculated nurseries near Lethbridge in 2010 (Puchalski and Gaudet 2011). 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 analyses were conducted by the Canadian Grain Commission (CGC), Grain Research Laboratory (GRL), following protocols of the American Association of Cereal Chemists (2000). The grain used for these analyses was a composite sample consisting 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.

Performance

Data from across the Canadian prairies, collected at 25 sites over 3 yr, were used to establish the agronomic performance of Emerson relative to the check cultivars. There were fewer data available for comparisons with CDC Buteo because it was added as a check cultivar in 2009, 1 yr after the entry of Emerson into the registration trial. Although it is not a registration check for the CWRW wheat class, relevant data for CDC Falcon (Fowler 1999) have also been reported because it has been the predominant winter wheat cultivar in the eastern prairies since 2002 (M. Grenier, personal communication, Canadian Wheat Board, Winnipeg, MB). CDC Falcon had been included in the Western Winter Wheat Cooperative registration trials as a well-adapted, high-yielding agronomic check for the Canada Western General Purpose class in the eastern prairies.

On average, across all sites over 3 yr, the grain yield of Emerson was 95% of the CWRW check mean ($P \leq 0.05$) and significantly lower than CDC Osprey and CDC Falcon (Table 1). Examination of these yield data in the various agri-climatic zones across the Canadian prairies shows that Emerson had better performance in some regions than in others. In the eastern prairie rust-hazard region (Zone 4), characterized by higher rainfall and soil fertility, and prone to epidemics of stem rust, leaf rust and FHB, the grain yield of Emerson was similar (NS) to CDC Buteo (96%) and CDC Falcon (99%), the adapted stem and leaf rust resistant cultivars that are most popular in this region. Emerson also produced yields comparable to all of the CWRW wheat checks in the parkland (Zone 2) and semi-arid prairie regions (Zone 3).

Emerson exhibited winter survival equal to the check cultivars ($P \leq 0.05$) (Table 2). It was within the range of the CWRW checks for heading date and maturity, showing similarity to CDC Buteo for both

Table 1. Grain yield (t ha^{-1})[z] of Emerson and the check cultivars, Western Winter Wheat Cooperative registration trials (2008–2010)

	2009–2010					2008–2010				
	Zone[y]					Zone[y]				
Cultivar	1	2	3	4	Mean	1	2	3	4	Mean
CDC Osprey	5.83	5.31	4.28	6.02	5.61	5.95	5.08	4.28	5.90	5.63
AC Bellatrix	5.39	5.39	4.17	5.87	5.42	5.65	5.21	4.17	5.87	5.51
Radiant	5.75	4.89	3.85	5.42	5.24	6.14	4.87	3.85	5.50	5.50
CDC Buteo	5.58	5.04	4.18	5.90	5.41	–	–	–	–	–
CDC Falcon	5.81	4.98	3.62	5.70	5.34	6.09	4.97	3.62	5.75	5.56
Emerson	5.06	5.05	4.30	5.67	5.18	5.30	4.89	4.30	5.67	5.26
LSD ($P \leq 0.05$)[x]	0.75	0.83	0.53	0.56	0.37	0.51	0.60	0.51	0.49	0.29
No. of tests	6	4	2	6	18	10	5	2	8	25

[z]Means are weighted by the number of tests.
[y]Zone 1: Southern Alberta sites (Lethbridge "dry land", Lethbridge "irrigated", Vauxhall, Warner); Zone 2: Parkland sites (Beaverlodge, Lacombe, Olds, Melfort); Zone 3: Semi-arid prairie site (Swift Current); Zone 4: Eastern prairie rust hazard sites (Brandon, Carman, Indian Head, Saskatoon, Winnipeg).
[x]Least significant difference includes variation from the genotype by environment interaction.

Table 2. Agronomic performance of Emerson and the check cultivars, Western Winter Wheat Cooperative registration trials (2008–2010)

	Winter survival (%)		Heading[z] (d)		Maturity[z] (d)		Height (cm)		Lodging[y] (1–9)	
Cultivar	2009–2010	2008–2010	2009–2010	2008–2010	2009–2010	2008–2010	2009–2010	2008–2010	2009–2010	2008–2010
CDC Osprey	82	85	174.5	174.5	218.2	217.5	97	96	3.2	3.6
AC Bellatrix	79	84	176.4	176.4	220.4	219.8	96	95	4.0	4.2
Radiant	80	83	175.2	175.3	221.8	221.1	94	92	2.2	2.4
CDC Buteo	82	–	174.4	–	219.5	–	95	–	3.3	–
CDC Falcon	80	84	173.1	173.2	216.7	216.1	77	77	2.2	2.6
Emerson	79	83	174.2	174.4	219.5	218.9	88	87	2.3	2.6
LSD ($P \leq 0.05$)[x]	6	5	0.7	0.6	1.2	1.1	2	2	0.6	0.6
No. of tests	15	20	13	18	14	18	17	23	10	13

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

characteristics. Emerson had significantly shorter straw than the CWRW checks, but was significantly taller than CDC Falcon ($P \leq 0.05$). Lodging was significantly lower than the checks except for Radiant and CDC Falcon ($P \leq 0.05$), which were similar to Emerson.

The test weight of Emerson was equal to AC Bellatrix, significantly higher than CDC Osprey, Radiant and CDC Falcon, but significantly less than CDC Buteo ($P \leq 0.05$) (Table 3). Kernel mass was lower than all of the checks ($P \leq 0.05$), being most similar to CDC Falcon. Emerson accumulated significantly higher grain protein than all of the checks except AC Bellatrix ($P \leq 0.05$); the grain protein yield per hectare was also lower than AC Bellatrix ($P \leq 0.05$), but similar to the other check cultivars.

Emerson demonstrated resistant reactions to stem rust and stripe rust, and moderate resistance to leaf rust (Table 4). The reactions to leaf spotting diseases and powdery mildew were within the range of the check cultivars, but tended towards the more susceptible checks. Emerson was highly susceptible to common bunt, hence seed treatment with an effective fungicide is recommended. The FHB visual rating index, relative to several supplemental checks with established reactions, indicated a consistently high level of resistance over the 3 yr of evaluation (Table 5). The absence of any known quantitative trait loci conferring FHB resistance in McClintock (Badea et al. 2008) and the transgressive segregation over both parents suggest that the low FHB reaction exhibited by Emerson is the result of a unique grouping of genes and may involve an uncharacterized source of resistance. Research to characterize this resistance warrants attention, since the breeding and use of resistant cultivars is essential for effective management of this disease (Shen et al. 2003; Gilbert et al. 2010; von der Ohe et al. 2010).

Three years of extensive end-use quality testing by the CGC, GRL and evaluation by the Prairie Recommending Committee for Wheat, Rye and Triticale Quality Evaluation Team established that Emerson was equal in quality to the CWRW check cultivars and eligible for grades of CWRW wheat (Table 6). Emerson was within the range of the check cultivars for many parameters, but demonstrated notably higher grain and flour protein concentration, slightly softer kernels, lower starch damage, brighter flour colour, stronger farinograph dough rheology, and larger Remix loaf volume.

Although Emerson had somewhat lower grain yield than the check cultivars, the improvements in disease

Table 3. Seed characteristics of Emerson and the check cultivars, Western Winter Wheat Co-operative registration trials (2008–2010)

	Test weight (kg hL^{-1})		Seed mass (mg)		Grain protein[z] (%)		Grain protein yield (kg ha^{-1})	
Cultivar	2009–2010	2008–2010	2009–2010	2008–2010	2009–2010	2008–2010	2009–2010	2008–2010
CDC Osprey	77.3	77.9	31.6	31.2	11.6	11.7	649	658
AC Bellatrix	78.6	79.0	35.6	35.4	12.2	12.4	665	683
Radiant	78.2	78.6	35.2	35.2	11.7	11.8	616	654
CDC Buteo	79.2	–	33.6	–	11.8	–	633	–
CDC Falcon	77.5	78.1	31.0	30.7	11.5	11.4	609	632
Emerson	78.6	79.1	29.5	29.4	12.3	12.3	628	638
LSD ($P \leq 0.05$)[y]	0.5	0.5	1.0	0.9	0.3	0.4	41	36
No. of tests	19	26	19	26	17	24	17	24

[z]Grain protein concentration determined using whole grain near infrared spectroscopy (NIRS) analysis (Williams 1979).
[y]Least significant difference includes variation from the genotype by environment interaction.

Table 4. Disease reactions of Emerson and the check cultivars, Western Winter Wheat Cooperative registration trials (2008–2010)

	Year	CDC Osprey	AC Bellatrix	Radiant	CDC Buteo	CDC Falcon	Emerson
Stem rust[z]	2008	50 S	50 S	50 S	–	5 R-MR	tr R
	2009	60 S	60 S	50 S	30 MS-S	20 MR	2 R
	2010	40 S	70 S	40 S	5 R/40 S	20 MR	tr R
Leaf rust[z]	2008	50 S	20 MS-S	40 S	–	10 MR	20 I
	2009	30 S	20 S	20 S	30 I	20 I	10 R
	2010	35 S	35 S	25 MS-S	15 R-MR	30 MR	5 R-MR
Stripe rust[z]	2010	40 S	55 S	23 I	23 I	23 I	5 R
Common bunt[z]	2008	67 VS	7 R	62 VS	–	58 VS	76 VS
	2009	36 S	9 R	39 S	77 VS	46 VS	76 VS
	2010	48 VS	20 MR	29 MS	50 VS	33 VS	50 VS
Leaf spots[yx]	2009	2.0	1.5	3.2	2.0	2.7	2.3
	2010	4.0	3.0	3.3	2.3	3.0	4.0
Powdery mildew[x]	2008	3.7	3.0	4.0	–	3.0	3.7
	2009	4.3	3.0	2.7	3.0	2.7	4.3
	2010	4.7	4.0	4.4	4.5	1.5	4.7

[z]Percent infection and type of reaction: tr = trace, R = resistant, MR = moderately resistant, I = intermediate, MS = moderately susceptible, S = susceptible, VS = very susceptible.
[y]Specific leaf spotting pathogens were not determined.
[x]Rated using a 1–9 scale: 1 = disease free, 9 = very severe symptoms.

resistance (FHB, stem rust, leaf rust, stripe rust) and grain protein concentration should result in higher probabilities of receiving the top CWRW grades and protein premiums, offsetting the perceived yield penalty. Combined with agronomic characteristics similar or intermediate to those of the currently popular winter wheat cultivars in Manitoba and eastern Saskatchewan, Emerson hard red winter wheat offers the potential for improved food and feed safety, reduced use of foliar fungicides, lower production costs, favourable net returns to the grower, and enhanced agricultural sustainability.

Table 5. Fusarium head blight (FHB) reaction of Emerson, the check cultivars and supplementary checks, Western Winter Wheat Cooperative Registration trials (2008–2010)

	Visual rating[z] (index and response[y])			
Cultivar	2008	2009	2010	Mean
CDC Osprey	11 MR	7 R	33 MS	17
AC Bellatrix	27 I	13 MR	21 I	20
Radiant	45 MS	46 S	22 I	37
CDC Buteo	–	12 MR	12 MR	12
CDC Falcon	53 S	51 S	36 MS	46
Emerson	7 R	3 R	4 R	5
Supplementary checks[x]				
FHB148	5 R	6 R	5 R	5
Freedom	24 I	13 MR	14 MR	17
DH01W43I*18	17 MR	15 I	26 I	20
Caledonia	68 S	41 S	37 MS	49
Hanover	75 S	42 S	59 S	59

[z]Visual rating index = % incidence × % severity/100.
[y]Disease response category: R = resistant, MR = moderately resistant, I = intermediate, MS = moderately susceptible, S = susceptible.
[x]Supplementary checks were chosen to assist in the differentiation of resistance levels based on long term data collection.

Other Characteristics

Seedling characteristics

Anthocyanin colouration of coleoptile: absent.
Juvenile growth habit: intermediate to semi-erect (unvernalized).
Pubescence of lower leaf sheath: glabrous.
Colour of lower leaf blade: medium to dark green.
Pubescence of lower leaf blade: glabrous.
Tillering capacity at low densities: high.

Plant characteristics at booting

Growth habit: semi-erect to intermediate.
Pubescence of flag leaf sheath: glabrous.
Waxiness of flag leaf sheath: moderate.
Colour of flag leaf blade colour: dark green.
Pubescence of flag leaf blade: glabrous.
Waxiness of flag leaf blade: moderate.
Flag leaf length: medium.
Flag leaf width: medium.
Frequency of recurved flag leaves: high to very high.
Flag leaf attitude: intermediate to drooping.
Anthocyanin colouration of flag leaf auricles: weak.
Pubescence of flag leaf auricle margins: slight.

Plant characteristics after heading

Culm neck shape: barely perceptible curve.
Upper internode pubescence: glabrous.
Upper internode waxiness: moderate.
Rachis margin pubescence: long and very abundant.
Stem colour at maturity: yellow.
Anthocyanin intensity of straw at maturity: absent.
Pith in cross section (middle of internode below the neck): hollow.

Table 6. End-use quality characteristics[z] of Emerson and the check cultivars, Western Winter Wheat Cooperative Registration trials (2008–2010)

Cultivar	Test years	Wheat protein (%)	Flour protein (%)	Protein loss (%)	Hagberg falling no. (s)	Amylograph peak viscosity (BU)	Flour yield (%)	Flour ash (%)	Flour colour (Agtron)	Starch damage (%)	Particle size index
CDC Osprey	2008–2010	12.1	11.4	0.7	390	637	77.0	0.35	89	5.6	59
AC Bellatrix	2008–2010	12.6	11.8	0.8	402	443	76.0	0.38	83	6.5	57
Radiant	2008–2010	12.4	11.5	0.9	405	610	77.3	0.36	88	6.3	57
CDC Buteo	2009–2010	12.5	11.5	0.9	388	420	76.7	0.34	84	6.0	58
Check mean[y]	2008–2010	12.4	11.6	0.8	397	534	76.7	0.36	86	6.2	58
Emerson	2008–2010	13.1	12.4	0.8	408	645	76.0	0.34	90	5.3	60
SD[w]		0.1	0.1	0.1	15	5	0.3	0.01	0.9	0.1	0.9

	Farinograph			Remix-to-peak bake						
	Water absorption (%)	DDT[x] (min)	Stability (min)	Baking absorption (%)	Peak time (min)	Mixing energy (W h kg^{-1})	Loaf volume (cm^3)	Loaf appearance (1–10)	Crumb structure (1–10)	Crumb colour (1–10)
CDC Osprey	57.2	7.75	16.7	57.7	2.3	5.0	837	8.8	5.0	5.7
AC Bellatrix	63.0	6.33	10.8	61.3	2.3	4.8	853	8.6	5.5	5.7
Radiant	58.8	7.58	15.7	60.0	3.4	6.4	872	8.7	5.4	5.7
CDC Buteo	59.8	7.50	11.3	60.0	3.0	5.9	833	8.8	5.3	6.0
Check mean[y]	59.8	7.33	14.1	59.8	2.7	5.4	853	8.7	5.3	5.7
Emerson	57.5	22.00	29.0	60.3	4.2	7.8	935	8.8	5.2	6.0
SD[w]	0.2	0.4	1.4	0.0	0.1	0.3	14	NA[v]	NA	NA

[z]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.
[y]Grand mean of the annual check means.
[x]Farinograph dough development time.
[w]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.
[v]Not available.

Spike characteristics
Shape: tapering.
Attitude at maturity: inclined to nodding.
Density: medium.
Length: medium.
Colour at maturity: yellow.
Awnedness: awned.
Length of awns at tip of spike: shorter than spike.
Awn colour: light yellow.
Awn attitude: intermediate to strongly spreading.
Supernumary spikelets: absent.
Hairiness of convex surface of apical rachis segment: absent.

Lower glume characteristics
Width: medium.
Length: medium to long.
Pubescence: glabrous to very slight.
Shoulder shape: oblique.
Shoulder width: narrow to medium.
Beak shape: acuminate.
Beak length: medium-short to medium.
Internal imprint: medium size.
Colour at maturity: white to yellow.

Kernel characteristics
Texture: hard.
Colour: medium red.
Phenol reaction: very dark brown.

Maintenance and Distribution of Breeder Seed

A traditional approach to Breeder Seed production was taken to preserve the high level of genetic purity inherent in DH genotypes. The breeder lines of Emerson were derived from 126 random head selections taken from a rogued increase plot near Lethbridge in 2009. In 2009/2010, these selections were grown under isolation as head rows, 2 m in length with 46 cm spacing between rows. Following the elimination of rows showing variability or contamination, 99 lines were harvested separately and subsequently grown as individual four-row plots near Indian Head. Seven breeder lines were eliminated in summer 2011 on account of tall plants and a ragged appearance. The remaining 92 breeder lines were then inspected by the Canadian Food Inspection Agency in cooperation with the Canadian Seed Growers' Association. Bulk harvest of these plots produced 742 kg of cleaned Breeder Seed and occurred eight generations after the production of the original DH plant. The AAFC Seed Increase Unit at Indian Head will maintain the Breeder Seed of Emerson. All other classes of pedigreed seed will be multiplied and distributed by Canterra Seeds Ltd., 201–1475 Chevrier Blvd., Winnipeg, Manitoba, Canada R3T 1Y7.

Sincere appreciation is expressed to the dedicated technical staff at the AAFC LRC who contributed to the development of Emerson winter wheat, in particular: D. Quinn, J. Prus, M. Fast, L. Kneeshaw, B. Puchalski, T. Despins and M. Frick. The authors also acknowledge the scientific and technical support provided by AAFC personnel, particularly those reporting to the research centres in Lethbridge, Swift Current, Brandon, Winnipeg, and Ottawa; the provision of an inoculated stem and leaf rust selection nursery by Dr. A. Brûlé-Babel and M. Meleshko at the University of Manitoba; and all contributors to the Western Winter Wheat Cooperative registration trials. We also thank D. Gehl and the staff of the AAFC Seed Increase Unit at Indian Head for their meticulous care and attention in producing and maintaining Breeder Seed. Financial assistance from the Western Grains Research Foundation producer check-off on wheat, Ducks Unlimited Canada, and the Alberta Winter Wheat Producers' Commission is gratefully recognized.

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