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Cultivar description

Redcliff hard red spring wheat

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Abstract

Redcliff hard red spring wheat was developed at the University of Alberta using a modified bulk breeding method. In 3 years of evaluation in the Parkland Cooperative test from 2018 to 2020, Redcliff produced 7.3% more grain and matured 1.9 days earlier than the highest yielding check Carberry. Redcliff had 3.9 cm taller plants than Carberry but shorter than the other checks and displayed good lodging tolerance. The test weight of Redcliff was slightly higher than Carberry and Parata but lower than Glenn. The grain weight of Redcliff was higher than Parata and similar to the other checks. Grain protein content was within the range of the checks. Redcliff was rated “resistant” to the prevalent races of stem rust, “resistant” to “moderately resistant” to *Fusarium* head blight, “intermediate” to leaf and stripe rusts, whereas “moderately susceptible” to common bunt. Three years of end-use quality evaluation have indicated that Redcliff is acceptable for the Canada Western Red Spring wheat market class, with improvements in flour yield.

Key words: spring wheat, Canada western red spring, grain quality, flour ash, grain yield, *Fusarium* head blight

Introduction

Redcliff hard red spring wheat (*Triticum aestivum* L.) was developed at the University of Alberta, Edmonton, AB, Canada. Redcliff is a high-yielding cultivar (7% higher than Carberry) with good lodging resistance. It has all the quality characters necessary for the Canada Western Red Spring (CWRS) wheat market class with excellent flour yield and was accepted to the Canadian Grain Commission CWRS variety designation list (https://www.grainscanada.gc.ca/en/grain-quality/variety-lists/2021/2021-18.html). CWRS is the largest wheat class grown in the three prairie provinces of Alberta, Saskatchewan, and Manitoba and is known globally for its excellent milling and baking qualities. Redcliff is moderately resistant to resistant to stem rust (*Puccinia graminis* Pers. f. sp. *tritici* Eriks. & E. Henn.) and *Fusarium* head blight (FHB) (*Fusarium graminearum* Schwabe). Redcliff was assigned registration no. 9498 by the Variety Registration Office, Plant Production Division, Canadian Food Inspection Agency (CFIA) on 18 February 2022.

Pedigree and breeding method

Redcliff derives from the cross Cardale/Carberry made at the University of Alberta in 2012. Cardale having the parentage McKenzie/Alsen (Fox et al. 2013) and Carberry having the parentage Alsen/Superb (DePauw et al. 2011) are registered CWRS wheat cultivars.

Filial generations were advanced using a modified bulk breeding method (Fischer and Rebetzke 2018; Haley et al. 2007). The F_1 seed from the final cross was planted in the F_1 nursery as a 1 m row in 2012 at Edmonton, AB, and the row was bulk harvested. Twenty-five grams of bulked F_2 seed was planted in New Zealand in four rows of 25 m each in 2012–2013 and 200 heads were selected based on leaf rust resistance, plant height, and maturity. The 200 F_3 heads were bulked and 40 grams of seed were grown in two rows (50 m long) in Edmonton in 2013 and plants were selected based on leaf rust resistance, plant height, and maturity. The selected F_4 heads were planted in two 25 m long rows in New Zealand in 2013–2014 and 150 plants were selected. The 150 F_5 heads were planted in head rows in a leaf rust nursery in Edmonton, AB in 2014, and 40 rows were selected based on leaf rust resistance, plant height, and maturity. Heads from the selected rows were grown in New Zealand in the 2014–2015 season as F_6 head rows and harvested as individual rows. The F_7 seed of these rows was tested in un-replicated preliminary yield trials in 3 m × 1.14 m plots in Edmonton, AB, and in leaf rust (*Puccinia triticina* Eriks.), common bunt (*Ustilago tritici* (Pers.) Rostr), and leaf spot nurseries in Edmonton, AB, and stripe rust (*Puccinia striiformis* Westend.) nurseries in Lethbridge, AB, and Creston, BC, in 2015. Details of disease screening protocols are given in Semagn et al. (2022). Based on agronomic, disease, and end-use quality data, a line UAW1267 × F7MBK78 was selected and subsequently evaluated in replicated multi-location Advanced Yield Trials in 2016. This line was further evaluated in the Parkland Wheat B test as entry number 18 in 2017 and then as PT793 in the Parkland Wheat Cooperative test from 2018 to 2020.

Table 1. Least squares means for agronomic traits of Redcliff and check cultivars in the Parkland Wheat Cooperative test, 2018–2020.

	Grain yield		Maturity	Height	Lodging	Test wt.	Grain wt.	NIR protein
Cultivar	(kg ha^{-1})	(% Carberry)	(days)[a]	(cm)	(1–9)[b]	(kg hL^{-1})	(g 1000^{-1})	(%)
Carberry	5082	100.0	106.2	84.4	1.5	80.8	40.0	13.9
Glenn	5042	99.2	105.0	92.3	1.6	82.7	38.6	14.2
Parata	5020	98.8	102.0	91.6	2.1	80.7	37.8	14.5
Redcliff	5452	107.3	104.3	88.3	2.0	81.9	39.4	14.1
LSD[c] (0.05)	188		1.1	1.5	0.5	1.3	1.1	0.8
No. of Env	33		33	35	15	35	36	34

[a]Number of calendar days from the day of seeding to physiological maturity.
[b]1 = no lodging (erect); 9 = completely lodged (flat).
[c]Least significant difference.

Redcliff was evaluated for agronomic, disease resistance, and end-use quality traits in the Parkland Wheat Cooperative test following protocols described in the operating procedures of the Prairie Recommending Committee for Wheat, Rye, and Triticale (PRCWRT, Anonymous 2020). The agronomic data for the test were analyzed for individual years and combined following a mixed model design in SAS (SAS Institute Inc. 2013), with the environment, genotype × environment, and replication as random effects and genotype as a fixed effect.

Response of test entries and checks to the Priority 1 diseases was determined in specialized disease nurseries for 3 years (2018–2020). Seedling infection types for leaf and stem rusts were assessed using prevalent races (McCallum et al. 2020; Fetch et al. 2021). Reactions to leaf and stem rusts in the field were measured for each test year in epiphytotic nurseries in Morden, MB, based on the modified Cobb scale (Peterson et al. 1948). Reaction to stripe rust (*P. striiformis* Westend.) was assessed in natural stripe rust nurseries in Lethbridge, AB (Randhawa et al. 2012). FHB (*F. graminearum* Schwabe; teleomorph *Gibberella zeae* (Schwein.) Petch) reaction of test entries was assessed in field tests in Morden and Carman, MB following artificial inoculation with FHB races (Gilbert and Woods 2006). Deoxynivalenol (DON) content of the grain was measured using Enzyme Linked Immunosorbent Assay tests as described in the Appendix E of the operating procedures of PRCWRT (Anonymous 2020). A mixture of prevalent races L1, L16, T1, T6, T13, and T19, collected at the Lethbridge Research and Development Centre, was used to determine the response of Redcliff to common bunt at Lethbridge, AB, following protocols of Gaudet and Puchalski (1989).

Eligibility for the CWRS market class was determined at the Grain Research Laboratory, Canadian Grain Commission, Winnipeg, MB, following the protocols of the American Association of Cereal Chemists (AACC 2000). Canadian grain commission first determined the grain grade and protein content for the check cultivars for all test locations and then devised a common site-blending formula for the checks and candidate cultivars to develop composite samples. Grain samples from test locations with serious down-grading factors were excluded from the composite samples. Quality data from the composite samples of Redcliff and check cultivars for individual years were used as a replication to estimate least squares means for all quality traits over the 3 test years.

We assessed Redcliff's seedling and plant growth characteristics in a description trial grown at the University of Alberta Research Farm at Edmonton during 2019 and 2020. We planted the trial each year, in a randomized complete block design with three replications. The trial included the reference cultivars AAC Viewfield (Cuthbert et al. 2019), Cardale (Fox et al. 2013), and Carberry (DePauw et al. 2011). All characteristics were recorded following the guidelines given in the Objective Description Form of the Variety Registration Office, CFIA (https://inspection.canada.ca/DAM/DAM-form-forme/STAGING/text-texte/c5865_re_1574266889394_eng.pdf).

Performance

In 3 years of evaluation in the Parkland Cooperative test, Redcliff significantly ($P < 0.05$) yielded higher than the check cultivars, Carberry, Glenn, and Parata (Table 1). It produced 7.3% more grain and matured 1.9 days earlier than Carberry. The plants of Redcliff were 3.9 cm taller than Carberry and paralleled with Parata in lodging score. The test weight of Redcliff was within the range of the checks while grain weight was higher than Parata but similar to the other checks (Table 1). Grain protein content measured using a Near Infra-Red spectrophotometer was also within the range of the checks.

Other characteristics

Seedling characteristics

Anthocyanin colouration of coleoptile: weak.
Pubescence of lower leaf sheath: glabrous.
Pubescence of lower leaf blade: glabrous.

Plant characteristics at booting

Plant growth habit (5–9 tiller stage): erect to semi-erect.
Flag leaf sheath pubescence/glaucosity: glabrous/medium.
Flag leaf blade pubescence/glaucosity: glabrous/weak.
Frequency of plants with recurved flag leaves: medium.
Anthocyanin coloration of flag leaf auricles: absent or very weak.
Pubescence of flag leaf auricle margins: absent or very sparse.

Table 2. Reaction of Redcliff to stripe, stem, and leaf rusts, and common bunt in Parkland B test (2017) and Parkland Wheat Cooperative test, 2018–2020.

		Stripe rust		Stem rust		Leaf rust		Common bunt	
Year	Entry	Severity	Rate[a]	Severity	Rate	Severity	Rate	Mean	Rate
2017[b]	Carberry	0	R	1	R	2	R	0.5	MR
2018	Carberry	6	R	5	MR	2.7	R	0	R
2019	Carberry	10	R	1	R	8.3	R	0	R
2020	Carberry	25	MR	1	R	5.0	R	—	—
2017[b]	Glenn	5	R	1	R	15	MR	4.5	MR
2018	Glenn	13.5	MR	5	MR	22.0	MR	4.0	R
2019	Glenn	42.5	MS	5	I	33.3	I	2.5	R
2020	Glenn	40	I	1	I	36.7	I	—	—
2017[b]	Parata	5	R	1	R	2	R	3.0	MR
2018	Parata	42.5	MS	5	MR	7.7	R	0	R
2019	Parata	60	S	2	R	25.0	MR	5	R
2020	Parata	40	I	1	R	35.0	I	—	—
2017[b]	Redcliff	2	R	1	R	6.5	R	13.8	I
2018	Redcliff	12.5	MR	10	MR	18.3	MR	22.5	I
2019	Redcliff	60	S	10	R	36.7	I	40	MS
2020	Redcliff	40	I	1	R	36.7	I	—	—

[a]I = Intermediate; MR = Moderately resistant; MS = Moderately susceptible; R = Resistant; S = Susceptible.
[b]Data from 2017 Parkland B Test.

Plant characteristics after heading

Culm neck shape: weakly to moderately curved.

Culm uppermost node pubescence/glaucosity: absent or very sparse/medium.

Stem color at maturity: white.

Anthocyanin intensity of straw at maturity: absent or very weak.

Straw pith in cross-section (middle of internode below the neck): thin.

Spike characteristics

Shape/density/length/glaucosity: parallel-sided/medium to dense/medium/medium.

Attitude/color at maturity: erect/white.

Awnedness/location of awns: awns present/full length of the spike.

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

Awn color/attitude: white/medium spreading.

Glume characteristics

Lower glume length/width: medium/mid-wide.

Lower glume pubescence of external surface: absent.

Lower glume shoulder shape: 50% straight, 40% slightly elevated, and 10% slightly sloping.

Lower glume shoulder width: medium.

Lower glume beak shape: 75% slightly curved; 20% moderately curved; and 5% straight.

Lower glume beak length: long.

Glume color at maturity: white.

Kernel characteristics

Kernel texture/color/shape: hard/medium red/oval.

Kernel size/length/width: small to medium/short to medium/medium.

Kernel cheek shape: round.

Kernel brush size/hair length: small to medium/medium.

Germ shape/size: broad elliptical/mid-size.

Kernel crease width/depth: narrow/shallow to medium.

Disease reactions

Redcliff was rated moderately resistant (MR) to resistant (R) to the prevalent races of stem rust; intermediate (I) to MR to leaf rust and susceptible (S) to MR to stripe rust during 3 years of testing (Table 2). Its reaction to common bunt was I in 2017 in the Parkland B test, whereas I in 2018 and MS in 2019 in the Parkland Cooperative test (Table 2). Based on the visual rating index of FHB, Redcliff was rated MR to R in both Morden and Carman during the 3 years of testing (Table 3). Based on the Incidence/Severity/DON Index (ISD) of FHB, Redcliff was rated MR to R in Morden and Carman (Table 3). Redcliff was also rated MR to R based on DON values in the two locations during 3 years of testing (Table 3). The disease evaluation team (DET) of PRCWRT gave Redcliff final ratings of R for stem rust, MR for FHB, I for leaf and stripe rusts, and MS for the common bunt.

End-use suitability

Three years of end-use quality data (Table 4) generated by the Grain Research Laboratory of Canadian Grain Commission indicated that Redcliff was acceptable for all grades of the CWRS wheat class. The grain protein content of Redcliff was similar to Glenn but lower than Carberry and Parata, whereas flour protein was similar to Carberry and Glenn but lower than Parata (Table 4). Protein loss was lower than Carberry but similar to other checks. The falling number and Amylograph peak viscosity of Redcliff were within the range of the checks. Starch damage of Redcliff was lower

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Table 3. Reaction of Redcliff to FHB in Parkland Wheat Cooperative test, 2018–2020.

		Morden								Carman								
Cultivar	Entry	Mean INC[a]	Mean SEV[b]	VRI[c]	VRI Rate[d]	DON[e] ppm	DON Rate	ISD[f]	ISD Rate	Mean INC	Mean SEV	VRI	VRI Rate	FDK[g] %	DON ppm	DON Rate	ISD	ISD Rate
2018	Carberry	3.7	4.8	12.8	MR	3.1	MR	3.6	MR	63.3	18.3	12.1	MR	1.2	3.0	—	3.4	MR
2019	Carberry	7.7	2.3	17.7	MR	9.5	MR	7.7		6.3	2.3	14.8	MR	3.1	8.4	I	5.2	
2020	Carberry	58.3	28.3	16.8	I	13.4	MR	25.3		71.7	28.3	20.1	MR	2.6	6.4	MR	5.8	
2018	Glenn	5.3	3.5	19.8	MR	3.1	MR	3.6	MR	68.3	25.0	17.3	I	2.3	4.8	—	4.7	I
2019	Glenn	8.2	3.7	29.9	I	8.3	MR	7.3		7.8	3.0	23.6	I	6.8	10.3	I	6.4	
2020	Glenn	61.7	40.0	23.8	I	10.7	MR	26.8		71.7	31.7	22.8	MR	3.0	5.1	MR	5.1	
2018	Parata	2.7	2.3	9.7	MR	2.2	MR	2.3	MR	75.0	26.7	20.3	I	1.0	3.7	—	4.2	I
2019	Parata	8.0	3.7	30.6	I	9.6	MR	8.1		7.8	2.3	18.3	MR	4.9	4.8	MR	3.1	
2020	Parata	60.0	41.7	26.2	MS	14.1	MR	28.8		90.0	41.7	37.7	I	7.1	9.6	I	8.4	
2018	Redcliff	1.8	1	2.3	R	2.5	MR	2.1	MR	40.0	5.0	2.0	R	0.3	1.3	R	1.7	R
2019	Redcliff	7.2	2.2	16.1	MR	5.0	MR	4.9		6.3	1.3	8.4	MR	2.9	6.5	MR	4.1	
2020	Redcliff	31.7	21.7	7.0	MR	5.5	R	14.0		56.7	25.0	14.6	MR	2.7	5.0	MR	4.6	

[a]Incidence (0–10 scale in 2018 and 2019, and % scale in 2020 for Morden; 0–10 scale in 2019 and %scale in 2018 and 2020 for Carman).
[b]Severity (0–10 scale in 2018 and 2019, and % scale in 2020 for Morden; 0–10 scale in 2019 and %scale in 2018 and 2020 for Carman).
[c]Visual Rating Index = ((R1inc∗R1sev) + (R2inc∗R2sev) + (R3inc∗R3sev))/3.
[d]I = intermediate; MR = moderately resistant; MS = moderately susceptible; R = resistant; S = susceptible.
[e]Deoxynivalenol.
[f]Incidence + Severity + DON = (0.2∗mean incidence + 0.2∗mean severity + 0.6∗mean DON).
[g]Fusarium damaged kernels. FHB = *Fusarium* Head Bligh.

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Table 4. Least squares means of end-use quality traits[a] for Redcliff and checks in Parkland Wheat Cooperative test, 2018–2020.

	Wheat and flour characteristics					Milling performance			
Cultivar	Grain protein (%)	Flour protein (%)	Protein loss (%)	Falling number (s)	Amylograph peak viscosity (BU)	Clean flour yield	Flour yield PB 0.50 ash	Flour ash (%)	Starch damage (mega-zeme)
Carberry	14.7	13.7	1.0	362	447	75.9	76.7	0.45	7.8
Glenn	14.5	13.8	0.7	357	625	75.7	77.7	0.43	8.6
Parata	15.0	14.1	0.8	433	648	76.6	77.2	0.44	7.5
Redcliff	14.3	13.5	0.8	398	520	77.6	77.7	0.43	7.5
CV (%)[b]	1.8	1.6	9.5	6	11	0.5	0.4	1.5	2.5
LSD ($p \leq 0.05$)[c]	0.39	0.35	0.13	40.0	97.8	0.63	0.53	0.01	0.31

	Dough properties						Baking quality (lean no time)				
	Farinogram			Extensogram							
Cultivar	Absorption (%)	Dough development time (min)	Stability (min)	Area (cm^2)	Rmax (BU)	Length (cm)	Absorption (%)	Mixing time (min)	Mixing energy (W-h kg^{-1})	Loaf volume (cm^3 100 g^{-1})	Loaf top ratio
Carberry	66.0	5.8	5.3	85	312	21.2	73.0	3.0	8.2	717	0.44
Glenn	67.6	7.7	8.7	133	548	19.9	74.7	3.7	9.9	818	0.56
Parata	66.4	7.1	9.3	111	448	19.8	73.3	3.3	8.6	737	0.46
Redcliff	64.6	6.4	6.7	96	371	20.3	71.3	3.3	8.9	744	0.50
CV (%)	0.5	9.9	6.7	7	9	3.1	0.5	4.6	7.6	1	4.0
LSD ($p \leq 0.05$)	0.51	1.1	0.88	13.1	65.7	0.98	0.58	0.25	1.1	13.9	0.03

[a]Quality data were obtained by Grain Research Laboratory of the Canadian Grain Commission using approved methods of American Association of Cereal Chemists (AACC 2000).
[b]Coefficient of variation was obtained by running a separate GLM procedure in SAS.
[c]Least Significant Difference = Standard error of the difference between means × 1.96.

than Glenn but similar to the other checks. Farinogram water absorption of Redcliff was lower than all checks, whereas dough development time was similar to Carberry and Parata but lower than Glenn. Farinogram stability was higher than Carberry but lower than Glenn and Parata. Extensogram area and R Max values of Redcliff were similar to Carberry but lower than the other checks, whereas length was similar to the checks. The Lean No time absorption of Redcliff was lower than the checks while the mixing time and mixing energy were similar to the checks. The loaf volume of Redcliff was higher than Carberry, similar to Parata but lower than Glenn. The loaf top ratio was higher than Carberry and Parata but lower than Glenn.

Maintenance and distribution of pedigreed seed

The breeder seed of Redcliff was derived from 150 F_{10} heads taken from the Parkland Wheat Coop test at Edmonton, AB, in 2018. The 150 heads were grown in pre-breeder 1 m rows in 2019 in Edmonton of which 119 uniform rows were individually harvested. Seeds of 119 rows were planted in 15 m breeder rows in 2020 at Edmonton and 107 uniform rows were harvested in bulk to produce approximately 250 kg of breeder seed. The breeder seed of Redcliff will be maintained by the University of Alberta's Cereal Breeding Program, Edmonton, AB.

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Data Availability statement

Data used in this manuscript are available on Prairie Recommending Committee for Wheat, Rye, and Triticale (PRCWRT) website to committee members at PRCWRT Committee Page (pgdc.ca).

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B. Beres served as Editor-in-Chief at the time of manuscript review and acceptance; peer review and editorial decisions regarding this manuscript were handled by another Editorial Board Member.

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Competing interests

The authors have no competing interests.

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