CDC Fortitude durum wheat

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Pozniak, C. J., Nilsen, K., Clarke, J. M. and Beres, B. L. 2015. **CDC Fortitude durum wheat**. Can. J. Plant Sci. **95**: 1013–1019. CDC Fortitude durum wheat is adapted to the durum production area of the Canadian prairies. This conventional-height durum wheat cultivar combines high grain yield potential with high grain pigment and protein concentrations and low grain cadmium. CDC Fortitude has strong straw with a solid stem (high degree of pith expression) conferring wheat stem sawfly resistance. CDC Fortitude expresses leaf, stem, and stripe rust, common bunt, loose smut and *Fusarium* head blight resistance similar to the current check cultivars.

Key words: *Triticum turgidum* L. var *durum*, durum wheat, yield, yellow pigment, cadmium, wheat stem sawfly, solid stem, cultivar description

Pozniak, C. J., Nilsen, K., Clarke, J. M. et Beres, B. L. 2015. **Le blé dur CDC Fortitude**. Can. J. Plant Sci. **95**: 1013–1019. Le blé dur CDC Fortitude est une variété adaptée aux zones de culture du blé dur des Prairies canadiennes. Ce cultivar de taille ordinaire combine un rendement grainier élevé à une intense pigmentation du grain ainsi qu'à une concentration élevée de protéines et à une faible teneur en cadmium. CDC Fortitude se caractérise par une paille robuste à tige pleine (forte expression de l'endocarpe), ce qui lui permet de résister au cèphe. CDC Fortitude exprime une résistance à la rouille des feuilles, à la rouille de la tige, à la rouille jaune, à la carie, au charbon nu et à la brûlure de l'épi par Fusarium semblable à celle des cultivars témoins actuels.

Mots clés: *Triticum turgidum* L. var *durum*, blé dur, rendement, pigmentation jaune, cadmium, cèphe, tige pleine, description de cultivar

CDC Fortitude, a spring durum wheat (*Triticum turgidum* L. var *durum*), was developed at the Crop Development Centre, University of Saskatchewan, and was tested in cultivar registration trials with the experimental designation of DT570. CDC Fortitude received registration No. 7563 from the Canadian Food Inspection Agency on 2014 Jul. 03. A Plant Breeders' rights application was granted (No. 14-8241) by the Canadian Food Inspection Agency on 2014 Mar. 19.

Pedigree and Breeding Method

CDC Fortitude is derived from the cross CDC Verona/DT732 made at the Crop Development Centre (CDC), University of Saskatchewan, in the summer of 2003. CDC Verona (Pozniak et al. 2009) is a registered Canadian cultivar. DT732 is a durum wheat breeding line from the cross DT663/DT677//DT665/AC Navigator made at Agriculture and AgriFood Canada, Swift Current, SK, that expresses solid stem. DT677 (Kyle*2/Biodur) is the source of stem solidness, which was introduced from Biodur, a solid-stemmed durum genotype from Germany. DT663, DT665 and DT677 are all from Agriculture and Agri-Food Canada, Swift Current, and AC Navigator is a registered Canadian cultivar (Clarke et al. 2000). The F_1 generation was increased in a contra-season nursery near Irwell, New Zealand, and the F_2 offspring were grown in a space-planted nursery at Saskatoon, SK, in 2004. Desirable F_2 plants that expressed solid stem were selected, and increased as single plants in the greenhouse. The F_4 generation was planted at Saskatoon in 2005 as single $F_{3:4}$ head rows. Rows with acceptable maturity and plant height, and that expressed a solid stem were identified, and five single spikes were selected from each row. $F_{4:5}$ rows were planted at Saskatoon in 2006, and D03X.48.013 was selected based on acceptable plant height, maturity and straw strength, and expressed a solid stem. D03X.48.013 was grown in unreplicated F_6 yield trials conducted at Saskatoon in 2007. In the same year, resistance to leaf rust (caused by *Puccinia triticina* Eriks.) and *Fusarium* head blight (FHB) (caused by *Fusarium graninearum* Schwabe) were evaluated in endemic nurseries at Saskatoon, and Carman, MB, respectively. The rust races used in the nursery were representative of those found in disease surveys the previous year (McCallum and Seto-Goh 2008, 2009; Fetch 2011). Quality evaluations on F_6 harvested seed indicated high yellow pigment

Abbreviation: **FHB**, *Fusarium* head blight

and acceptable grain protein concentration and gluten strength as determined by gluten index. DNA marker tests in the F_6 confirmed that D03X.48.013 carries the *SSt1* locus, which confers expression of the solid-stem phenotype (Houshmand et al. 2007). In 2008, D03X.48.013 was evaluated for agronomic traits in replicated yield trials at Saskatoon, Floral, Swift Current, and Avonlea, SK. In the same year, resistance to leaf, stem and stripe rusts and FHB were evaluated in artificially inoculated nurseries at Saskatoon and Carman, respectively.

D03X.48.013 was evaluated in agronomic yield trials at Saskatoon, SK, Lethbridge, AB, Regina, SK, and Swift Current, SK, in the Durum Western Wheat A-test in 2009. Reaction to FHB was assessed in the Durum Western Wheat A-Test in a nursery near Portage la Prairie, MB, and for leaf and stem rust at nurseries established near Glenlea, MB. D03X.48.013 was evaluated as DT570 in the Durum Wheat Cooperative registration tests over 4 yr (2010–2013). The variables measured and the operating protocols followed in the Durum Wheat Cooperative Registration test were those approved each year by the Prairie Recommending Committee for Wheat Rye and Triticale (current operating procedures can be found at http://www.pgdc.ca/committees_wrt.html). In agronomic performance trials, the check cultivars over all 4 yr of trialing were: AC Avonlea (Clarke et al. 1998), Strongfield (Clarke et al. 2005a), and AC Navigator (Clarke et al. 2000). AC Morse and Commander (Clarke et al. 2005b) were checks in 2010–2012, and Brigade (Clarke et al. 2009) was added as check in 2013. In cooperative trials, the stem rust races were TPMK, TMRT, RHTS, QTHS, RTHJ, RKQS, and MCCF (Roelfs and Martens 1988; Fetch 2009; Fetch et al. 2011). The leaf rust inoculum comprised a mixture of prevalent races isolated from the western Canadian prairies as determined from yearly survey studies (McCallum et al. 2010, 2011, 2013). Resistance to races T26, T32, and T33 of loose smut [*Ustilago tritici* (Pers.) Rostr] (Nielsen 1987) and L1, L16, T1, T6, T13, and T19 of common bunt [*Tilletia laevis* Kuhn in Rabenh. and *T. tritici* (Bjerk.) G. Wint. in Rabenh.] (Hoffman and Metzger 1976) were evaluated in the Durum Cooperative tests. Stripe rust (caused by *Puccinia striiformis* Westend. f. sp. *tritici*. Eriks) was evaluated in 2012, 2013, and 2014 at Creston, BC, and Lethbridge, AB, under natural infection. Reaction to FHB was evaluated near Glenlea and Carman. End-use quality was assessed at the Grain Research Laboratory, Canadian Grain Commission in 2011, 2012 and 2013 using approved methods (American Association of Cereal Chemists 2000) on a composite grain sample made up from all locations with acceptable physical condition (grade Canada Western Amber Durum no. 3 or better) to give a target grain protein concentration of 13%. End-use quality data from 2010 were not used because the check samples did not grade no. 3 or better.

Independent trials to assess stem solidness of CDC Fortitude were established, as this trait was not evaluated as part of the official variety registration trials conducted by the Prairie Recommending Committee for Wheat Rye and Triticale. CDC Fortitude was evaluated against check cultivars Strongfield (hollow-stemmed), Lillian (solid-stemmed hexaploid wheat; DePauw et al. 2005), and AAC Raymore (solid-stemmed; Sing et al. 2014) and Goldenball (solid-stemmed; Beres et al. 2013) in replicated yield trials established in 2012 and 2013 at Coalhurst and Lethbridge, AB, and at Saskatoon, SK. To ensure an adequate estimate of stem solidness, a 0.50-m section of row was collected 2 to 10 d prior to harvest in two random locations in each plot to determine stem diameter and pith expression or degree of stem solidness in the lumen of the main stem (Cárcamo et al. 2007). To determine mean pith expression, each stem was split lengthwise from crown to neck and, starting from the crown, each internode was assessed visually for pith development. Ratings were as follows: 1, hollow stem, no pith development; 2, some degree of pith development, may appear "cotton like"; 3, large hollow tunnel in the stem, or a huge cavity at a particular point in the internode; 4, -size of hollow equivalent to a pencil lead, or some cavitation has occurred at a particular point in the internode; and 5, solid stem (DePauw and Read 1982).

The data were analyzed using SAS PROC MIXED (Littell et al. 2006), with replications, sub-blocks, zones, locations, and years considered as random effects. Entries were considered as fixed effects. The *diff* command was used to estimate the standard error of the difference between entries, which in turn was used to estimate an *F*-protected least significant difference at a significance level of 5% ($LSD_{0.05}$). For end-use quality data, years were considered as replications.

To generate Breeder Seed, approximately 200 random single spikes of CDC Fortitude were selected from a rogued F_9 increase grown at Saskatoon, SK, in 2010. Heads were grown as single 1-m row plots in 2011 and off-type rows were discarded. The remaining head rows were harvested individually and used to establish 185, 30-m rows in 2012. Off-type rows were discarded and molecular tests (Beres et al. 2013) were used to confirm that each of the individual rows carried *SSt1*. In total, 151 breeder lines were composited to form the Breeder Seed.

Performance

AGRONOMY: Averaged over 3 station-years in the main durum production area (Brown soil agroecological zone), CDC Fortitude yielded approximately 3% more than Strongfield, 9% more than AC Navigator and 11% more than AC Avonlea (Table 1). CDC Fortitude expresses conventional height, similar to AC Avonlea and Strongfield, but has superior lodging resistance (Table 2). Maturity and test weight of CDC Fortitude were similar to Strongfield, while kernel weight was slightly lower than the checks. Test weight of CDC Fortitude was better than AC Avonlea, AC Morse, Commander, and AC Navigator (Table 2). In all years of testing, grain

Table 1. Grain yield (kg ha^{-1}) of CDC Fortitude and check cultivars in the Durum Cooperative Test 2010–2013[z]

	2010			2011			2012			2013			2010–2013 Mean		
	Black	Brown	Mean	Black	Brown	Mean	Black	Brown	Mean	Black	Brown	Mean	Black	Brown	Mean
AC Avonlea	4466	3607	3895	4312	3700	3823	2947	3008	2991	4312	4363	4348	3963	3684	3768
AC Morse	4907	3746	4145	4245	3876	3948	2723	3352	3163	–	–		–	–	–
AC Navigator	3635	3631	3633	3793	3667	3692	2138	3055	2780	3556	4540	4267	3190	3740	3599
Brigade	–	–	–	–	–	–	–	–	–	4891	5156	5108	–	–	–
Strongfield	4658	3749	4053	4487	3886	4008	2934	3359	3232	4174	4816	4701	4046	3978	4007
Commander	4307	3767	3935	4164	3940	3982	2794	3302	3153	–	–		–	–	–
CDC Fortitude	4719	4012	4247	4686	4026	4159	3018	3597	3420	4355	4658	4602	4156	4088	4113
$LSD_{0.05}$	446	330	280	878	208	231	473	383	309	645	246	241	332	204	188
No. stations	3	6	9	2	8	10	3	7	10	2	9	11	10	30	40

[z]Black soils: Indian Head, SK (not included 2010); Brandon (not harvested 2011) and Souris, MB (2010–2012); Langdon, ND (2010 only); Brown and Dark Brown soils: Moose Jaw, Pense (2013), Regina (2010–2012), Scott (not harvested 2010), Saskatoon, Stewart Valley, Swift Current, Vanguard (2013) SK; Lethbridge, Vulcan, AB.

protein concentration of CDC Fortitude was similar to Strongfield, and generally higher than AC Morse, AC Navigator, Brigade and Commander (Table 3). In the four environments where pith expression was assessed, CDC Fortitude expressed a solid stem phenotype (Table 4), which is known to confer resistance to the wheat stem sawfly (Beres et al. 2011, 2013).

DISEASE: CDC Fortitude is resistant to prevalent races of leaf and stem rust, and has excellent common bunt resistance, like the checks (Table 5). Leaf spot reaction was similar to the most susceptible checks. CDC Fortitude is susceptible to FHB like the check cultivars other than Brigade. The dexoynivalenol (DON) levels of CDC Fortitude were slightly lower than those of the check cultivars. Reaction to loose smut was variable, but CDC Fortitude appears to be similar to AC Avonlea. CDC Fortitude showed a resistant reaction to stripe rust over 3 yr of testing (Table 5).

END-USE SUITABILITY: Grain protein concentration of CDC Fortitude was similar to Strongfield in field (Table 3) and composite samples (Table 6). CDC Fortitude has low cadmium concentration like Strongfield, but expresses yellow pigment higher than all of the check cultivars (Table 6). The high yellow pigment was reflected in greater pasta b^* values when compared with all of the checks. The average falling number of CDC Fortitude was within the range of the check cultivars, similar to Strongfield and AC Avonlea. CDC Fortitude is a conventional gluten strength type, with gluten index and alveograph parameters similar to Strongfield. Semolina milling yield and semolina ash content were within the range of the check cultivars.

Other Characteristics

SPIKES: Spikes of CDC Fortitude are parallel sided, dense, mid-long and erect, with waxy bloom similar to Strongfield. Spikes express white awns that are longer than the spike; the width of the lower glumes is narrow-medium, while glumes are medium length and glabrous; glume shoulders are slightly sloping, elevated, and narrow; the glume beak is slightly curved; the lemma beak is straight to slightly curved.

KERNELS: Kernels are amber in color, midsize, and elliptical; cheeks are slightly angular; crease is mid-deep, and mid-wide; brush is med-long; the embryo is mid-sized.

END-USE SUITABILITY: CDC Fortitude is eligible for grades of the Canada Western Amber Durum wheat class.

Maintenance and Distribution of Pedigreed Seed

CDC Fortitude consists of a composite of 151 $F_{8:10}$ breeder lines. Breeder seed will be maintained by the Crop Development Centre, University of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 5A8. A Plant Breeders' Rights application has been filed. CDC Fortitude will be added to the OECD list of cultivars. Distribution and multiplication of pedigreed seed stocks

Table 2. Agronomic performance of CDC Fortitude and check cultivars in the Durum Cooperative test 2010–2013

	Maturity (d)		Test wt. (kg hL^{-1})		1000-kernel wt (g)		Height (cm)	Lodging (1 – 9)
	Black[z]	Brown	Black	Brown	Black	Brown	Mean	Mean
AC Avonlea	97	108	74.3	77.9	37.9	41.4	92	2.2
AC Morse	97	107	73.2	77.7	37.5	41.8	89	1.6
AC Navigator	98	109	72.9	79.0	37.8	46.0	80	2.2
Brigade	99	109	75.8	80.0	39.9	43.6	100	2.0
Strongfield	97	107	75.3	79.2	38.1	42.8	91	2.7
Commander	98	108	73.0	78.1	38.7	45.9	78	1.9
CDC Fortitude	98	108	74.9	79.3	36.8	40.3	90	1.9
$LSD^{y}_{0.05}$	1.0	1.0	1.0	0.5	1.7	1.0	2	0.7
$LSD^{x}_{0.05}$	1.0	1.0	1.0	0.5	1.8	1.1	2	0.7
$LSD^{w}_{0.05}$	1.0	1.0	1.7	0.7	3.1	1.0	2	1.0
No. stations	7	27	10	30	10	30	40	15

[z]Black soils: Indian Head, SK; Brandon (not harvested 2011) and Souris, MB (2010–2012); Langdon, ND (2010 only); Brown and Dark Brown soils: Moose Jaw, Pense (2013), Regina (2010–2012), Scott (not harvested 2010), Saskatoon, Stewart Valley Swift Current, Vanguard (2013) SK; Lethbridge, Vulcan, AB.
[y]For comparisons of CDC Fortitude with AC Avonlea, AC Navigator and Strongfield.
[x]For comparisons of CDC Fortitude with AC Morse and Commander.
[w]For comparisons with Brigade.

Table 3. Grain protein concentration (%) of CDC Fortitude compared with check cultivars in the Durum Cooperative test 2010–2013

	2010			2011			2012			2013			
	Black[z]	Brown	Mean	Black	Brown	Mean	Black	Brown	Mean	Black	Brown	Mean	4-yr Mean
AC Avonlea	15.4	13.3	13.8	15.8	12.5	13.2	16.1	15.2	15.5	13.3	13.9	13.8	14.3
AC Morse	14.2	12.7	13.1	15.3	12.4	13.0	15.4	14.1	14.5	–	–	–	–
AC Navigator	14.7	12.5	13.1	14.5	12.0	12.5	15.3	14.3	14.6	13.5	12.9	13.0	13.5
Brigade	–	–	–	–	–	–	–	–	–	12.7	12.7	12.7	–
Commander	14.8	12.8	13.3	14.9	11.8	12.4	14.9	14.3	14.5	–	–	–	–
Strongfield	15.8	13.4	14.0	15.4	12.4	13.0	16.2	14.9	15.3	14.7	13.6	13.8	14.2
CDC Fortitude	15.4	13.2	13.7	15.1	12.4	12.9	15.9	14.8	15.1	13.5	13.5	13.5	14.0
$LSD_{0.05}$	0.9	0.5	0.4	0.9	0.4	0.4	0.9	0.6	0.5	1.2	0.4	0.4	0.3
No. stations	2	6	8	2	8	10	3	7	10	2	9	11	39

[z]Black soils: Indian Head, SK; Brandon (not harvested 2011) and Souris, MB (2010–2012); Langdon, ND (2010 only); Brown and Dark Brown soils: Moose Jaw, Pense (2013), Regina (2010–2012), Scott (not harvested 2010), Saskatoon, Stewart Valley Swift Current, Vanguard (2013) SK; Lethbridge, Vulcan, AB.

Table 4. Stem solidness (1–5; 1 hollow, 5 solid) of CDC Fortitude and relevant check cultivars measured at four internodes; means of four replications and four seeding rates

	Coalhurst, AB				Lethbridge, AB				Saskatoon (Goodale), SK			
	IN1[z]	IN2	IN3	IN4	IN1	IN2	IN3	IN4	IN1	IN2	IN3	IN4
Lillian	2.7	2.7	2.2	1.5	2.3	1.8	1.3	1.1	1.8	1.6	1.2	1.4
Strongfield	2.3	2.5	2.3	2.1	2.9	2.2	1.6	1.3	1.9	1.1	1.1	1.0
GoldenBall	3.9	4.0	4.1	4.2	3.6	3.6	4.0	4.1	3.1	3.1	2.8	3.3
AAC Raymore	3.6	3.8	4.0	4.4	3.1	3.3	3.5	3.9	3.3	3.2	3.1	3.9
CDC Fortitude	3.8	4.5	4.7	4.9	3.1	4.5	4.4	4.5	3.6	3.9	3.9	4.5
$LSD_{0.05}$	0.5	0.5	0.6	0.7	0.6	0.7	0.6	0.5	0.3	0.3	0.3	0.4

[z]Stem internodes 1 (base) to 4 (top).

Table 5. Disease reactions of CDC Fortitude and check cultivars grown in the Durum Cooperative test (2010–2013)

Year	Entry	Stem rust[z]	Leaf rust[z]	Stripe rust[z]	Common bunt[z]	Loose smut	Leaf spots[y]	FHB index[x]		DON[w] (mg kg^{-1})
								Carman	Glenlea	
2010	AC Avonlea	R	R	–	MS	I	7.2	64	38	41.0
	AC Morse	R	R	–	R/RMR	MS	9.7	68	21	38.1
	AC Navigator	R	R	–	R/RMR	MR	8.5	59	43	40.2
	Strongfield	R	R	–	R/RMR	I	7.7	61	44	49.0
	Commander	R	R	–	R/RMR	I	7.7	61	59	52.4
	CDC Fortitude	R	R	–	R/RMR	I	9.3	53	23	35.0
2011	AC Avonlea	MR	R	S	MR	MR	7.5	–	17	7.8
	AC Morse	MR	R	R	MR	MS	7.9	–	25	11.3
	AC Navigator	R	R	R	R	R	8.0	–	21	16.2
	Strongfield	R	R	R	MR	MR	7.3	–	15	7.8
	Commander	R	R	R	R	R	7.8	–	15	16.7
	CDC Fortitude	R	R	R	R	I	8.3	–	14	6.4
2012	AC Avonlea	MR	R	R	R	I	8.5	34	23	11.1
	AC Morse	MR	R	R	R	MS	9.8	55	24	29.4
	AC Navigator	I	R	VR	R	I	10	66	10	33.7
	Strongfield	MR	R	R	R	MR	7.8	54	12	12.5
	Commander	R	R	R	R	MS	9.5	79	26	42.6
	CDC Fortitude	MR	R	VR	R	MS	9	34	14	12.7
2013	AC Avonlea	MR	R	R	R	MR	8	49	–	–
	AC Navigator	MR	R	S	R	MR	9.3	50	–	–
	Brigade	R	R	R	R	R	8.3	23	–	–
	Strongfield	R	R	R	R	R	8.3	30	–	–
	CDC Fortitude	R	R	R	R	I	9.5	36	–	–

[z]VR, very resistant; R, resistant; MR, moderately resistant; I, intermediate resistance; MS, moderately susceptible; S, susceptible.
[y]Adult plant rated at mid-grain fill at Swift Current, using the McFadden Scale where $<5 = 6$, 6 = MR, 7 = I, 8–9 = MS, and S = 10–11.
[x]*Fusarium* head blight index: (% infected spikelets × % infected heads)/100. Indices are averages from replicated trials at Carman and Glenlea, MB.
[w]Deoxynivalenol measured on composites of replications at Glenlea, MB.

Table 6. Average values for quality traits measured on yearly composite samples of CDC Fortitude and check cultivars evaluated in the 2011–2013 Durum Cooperative tests (quality was not evaluated in 2010 due to poor physical condition of the composites)

			Semolina						Alveograph			
	Grain protein (%)	FN[z] (s)	Yellow pigment	Protein (%)	*b**	Yield (%)	Ash (%)	Pasta *b**	GI[y] (%)	P	W	L	P/L	Grain Cd (ppm)
AC Avonlea	13.9	437	9.1	13.0	32.1	67.7	0.68	65.6	17	40	94	109	0.37	0.207
AC Morse[x]	13.2	472	8.8	12.3	31.3	67.1	0.69	64.0	56	64	162	93	0.70	0.166
AC Navigator	12.9	457	10.0	12.0	32.9	68.2	0.69	66.1	64	75	192	90	0.84	0.237
Brigade[w]	12.9	441	10.4	11.7	33.3	66.8	0.68	65.8	81	82	238	89	0.93	0.076
Strongfield	13.7	432	9.1	12.6	31.7	67.1	0.63	64.7	58	60	169	98	0.62	0.078
Commander[x]	12.9	465	10.0	12.0	33.0	68.2	0.66	66.8	96	110	297	80	1.38	0.247
CDC Fortitude	13.6	422	10.3	12.7	33.7	66.9	0.69	67.7	65	64	188	104	0.62	0.071
$LSD^{y}_{0.05}$	0.4	31	0.3	0.4	0.6	0.5	0.02	1.0	10	7	22	11	0.14	0.018
$LSD^{u}_{0.05}$	0.5	34	0.3	0.4	0.6	0.6	0.02	1.1	12	8	25	13	0.16	0.020
$LSD^{t}_{0.05}$	0.6	44	0.4	0.6	0.8	0.7	0.03	1.4	15	11	32	16	0.20	0.026

[z]Falling number.
[y]Gluten index.
[x]2011 and 2012.
[w]2013 only.
[v]For comparisons of CDC Fortitude with AC Avonlea, AC Navigator and Strongfield.
[u]For comparisons of CDC Fortitude with AC Morse and Commander.
[t]For comparisons with Brigade.

will be handled by CPS Canada Inc., PO Box 770 Station Main, Regina, Saskatchewan, Canada S4P 3A8. Commercial launch of CDC Fortitude is anticipated in the spring of 2015.

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