CULTIVAR DESCRIPTION

CDC Carbide durum wheat

C. J. Pozniak[1] and J. M. Clarke[2]

[1]Crop Development Centre; and [2]Department of Plant Sciences, University of Saskatchewan, 51 Campus Drive, Saskatoon, Saskatchewan, Canada S7N 5A8 (e-mail: curtis.pozniak@usask.ca).
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Pozniak, C. J. and Clarke, J. M. 2015. **CDC Carbide durum wheat**. Can. J. Plant Sci. **95**: 1007–1012. CDC Carbide 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 Carbide carries the *Sm1* gene conferring resistance to the Orange Wheat Blossom Midge [*Sitodiplosis modellana* (Gehin)]. CDC Carbide is resistant to prevalent races of leaf, stem and stripe rust, and common bunt, and expresses end-use quality suitable for the Canada Western Amber Durum class.

Key words: *Triticum turgidum* L. *var durum*, durum wheat, yield, yellow pigment, orange wheat blossom midge resistance, cultivar description

Pozniak, C. J. et Clarke, J. M. 2015. **Le blé dur CDC Carbide**. Can. J. Plant Sci. **95**: 1007–1012. Le blé dur CDC Carbide 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 Carbide porte le gène *Sm1* qui confère la résistance à la cécidomyie du blé [*Sitodiplosis modellana* (Gehin)]. CDC Carbide résiste aux races courantes de rouille des feuilles, de rouille de la tige et de rouille jaune, ainsi qu'à la carie, et sa qualité correspond à celle de la catégorie Blé dur ambré de l'Ouest canadien.

Mots clés: *Triticum turgidum* L. *var durum*, blé dur, rendement, pigmentation jaune, résistance à la cécidomyie du blé, description de cultivar

CDC Carbide, a spring durum wheat (*Triticum turgidum* L. var. *durum*), was developed at the Crop Development Centre, University of Saskatchewan, and received registration No. 7580 from the Canadian Food Inspection Agency (CFIA) on 2014 Aug. 01. A Plant Breeders' Rights protection has been filed with the CFIA (No. 14-8319).

Pedigree and Breeding Method

CDC Carbide is derived from the cross Strongfield/DT780 made at the Crop Development Centre (CDC), University of Saskatchewan in the summer of 2005. DT780 derives from the cross Kyle//27IDSN-138/94B27-BR1C/3/Napoleon/4/ACNavigator/5/Strongfield made by Dr. J. B. Thomas, Agriculture and Agri-Food Canada, Winnipeg, MB, wherein the hexaploid wheat 94B27-BR1C (Caldwell/ 88B27-D3A1C) was the donor of the *Sm1* locus that confers resistance to the orange wheat blossom midge. Kyle (Townley-Smith et al. 1987), Strongfield (Clarke et al. 2005a), Napoleon (Humphreys et al. 2010) and AC Navigator (Clarke et al. 2000) are registered Canadian cultivars, and 27IDSN-138 (CD92655-1PAP-2Y-040M-2Y-0PAP) is an introduction from CIMMYT. The F_1 generation was increased at a contra-season nursery in New Zealand and approximately 5000 F_2 plants were grown in a space-planted nursery at Saskatoon, SK. More than 400 single spikes were selected at random from F_2 plants and the population was advanced in the greenhouse for two generations using single seed descent. In 2007, 245 $F_{4:5}$ lines were planted as 0.8-m rows at Saskatoon, SK, and D05X.81.025 was identified as having acceptable plant height, maturity and straw strength. The selected $F_{4:5}$ lines were harvested individually and D05X.81.025 was evaluated in un-replicated F_6 yield trials conducted at Saskatoon and Elrose, SK, in 2008. Check cultivars included Strongfield, AC Navigator, AC Morse and Commander (Clarke et al. 2005b) and were randomized and replicated among un-replicated experimental lines at each environment. End-use Quality evaluations on F_6 harvested seed were performed on samples from individual sites, and D05X.81.025 expressed appropriate yellow pigment and acceptable grain protein concentration, as assessed using calibrated near-infrared reflectance spectrophotometry, and gluten strength [as assessed using the gluten index (American Association of Cereal Chemists 2000)] for the Canada Western Amber Durum class. DNA marker tests using *Barc35*, a DNA marker linked to *Sm1* (Thomas et al. 2005), were performed in the F_6 and confirmed that D05X.81.025 likely carried the *Sm1* locus. In 2009, D05X.81.025 was evaluated for

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

agronomic traits in replicated yield trials in the Saskatoon area at the University of Saskatchewan Kernen and Goodale farms, Swift Current, and Moose Jaw, SK. In the same year, resistance to leaf rusts (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. Leaf spot reaction, primarily caused by tan spot (*Pyrenophora tritici-repentis* Died.) and septoria (*Septoria tritici* Roberge in Desmaz.), was noted in trials from Kernen, Goodale, and Swift Current. Antibiosis resistance to feeding larvae of the orange wheat blossom midge was assessed at Kernen and Indian Head, SK, and at Glenlea, MB, by visual inspection of seed samples from approximately 15–20 wheat spikes collected at random from yield plots (Kernen) or 1-m rows (Indian Head and Glenlea). 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 2009).

In 2010, D05X.81.025 was further evaluated at Swift Current, Regina, SK, Lethbridge, AB, Kernen, and Goodale in the Durum Wheat B Test (and associated disease nurseries) and advanced after evaluation of end-use functionality on composite samples. D05X.81.025 was evaluated as DT574 in the Durum wheat co-operative tests over 3 yr (2011–2013). The variables measured and the operating protocols followed in the Durum Wheat Cooperative 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, and AC Navigator. AC Morse and Commander were checks in 2010–2012, and Brigade (Clarke et al. 2009) was added as a check in 2013. In cooperative trials, the stem rust races were TPMK, TMRT, RHTS, QTHS, RTHJ, RKQS, and MCCF (Roelfs et al. 1988; 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) was evaluated in the Durum Cooperative tests. To confirm antibiosis resistance to the orange wheat blossom midge, approximately 20 spikes were selected from yield plots at Kernen and Indian Head in 2013 and were harvested individually. Samples were then inspected for midge damage as described previously (Lamb et al. 2000). Stripe rust (caused by *Puccinia striiformis* Westend. f. sp. *tritici*. Eriks) was evaluated in 2011 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, using approved methods (American Association of Cereal Chemists 2000) each year on composite grain samples 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%.

Data presented here were analyzed using SAS PROC MIXED (Littell et al. 2006), with replications, sub-blocks, zones, locations, and years considered as random effects, and entries considered fixed. 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.

Approximately 190 Single spikes of CDC Carbide were selected from an F_9 increase grown at Saskatoon in 2011 to generate Breeder Seed. Heads were grown as single 1-m row plots in 2012 and off-type rows were discarded. The remaining head rows were harvested individually and used to establish 151, 27-m rows in 2013. Again, off-type rows were discarded and molecular tests using DNA marker *usw*184 (Pozniak, unpublished

Table 1. Grain yield (kg ha^{-1}) of CDC Carbide and check cultivars in the Durum Cooperative Test 2011–2013[z]

	2011			2012			2013			3-yr mean		
	Black[z]	Brown	Mean	Black	Brown	Mean	Black	Brown	Mean	Black	Brown	Mean
AC Avonlea	4312	3700	3821	2947	3008	2992	4312	4363	4341	3831	3707	3723
AC Morse	4245	3876	3948	2723	3352	3163	—	—		—	—	
AC Navigator	3793	3667	3691	2138	3055	2781	3556	4540	4358	3124	3775	3614
Brigade	—	—	—	—	—		4891	5156	5092	—	—	
Strongfield	4487	3886	4007	2934	3359	3233	4174	4816	4697	3861	4038	3984
Commander	4164	3940	3982	2794	3302	3153	—	—		—	—	
CDC Carbide	4260	4126	4152	3247	3998	3777	4946	4989	4968	4110	4381	4303
LSD (0.05)	878	208	231	473	383	309	645	246	241	332	204	225
No. stations	2	8	10	3	7	10	2	9	11	7	24	31

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

Table 2. Agronomic performance of CDC Carbide and check cultivars in the Durum Cooperative test 2011–2013

	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	104	75.2	78.4	37.7	41.1	92	1.8
AC Morse	97	104	73.4	78.1	36.8	41.6	89	1.3
AC Navigator	98	105	73.7	79.7	37.5	46.0	80	1.8
Brigade	99	106	76.7	80.6	39.9	43.3	100	1.7
Strongfield	97	104	76.2	79.8	37.8	42.6	90	2.5
Commander	98	105	74.0	78.8	39.6	45.6	79	1.9
CDC Carbide	97	104	76.0	80.1	36.7	41.3	92	2.5
$LSD^{y}_{0.05}$	1	1	1.0	0.5	2.1	1.1	2	1.0
$LSD^{x}_{0.05}$	1	1	1.1	0.6	2.3	1.2	2	1.1
$LSD^{w}_{0.05}$	2	1	1.6	0.7	3.2	1.5	3	1.3
No. stations	6	21	7	24	7	24	31	12

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

Table 3. Grain protein concentration (%) of Carbide compared with check cultivars in the Durum Cooperative test 2011–2013

	2011			2012			2013			
	Black[z]	Brown	Mean	Black	Brown	Mean	Black	Brown	Mean	3-year mean
AC Avonlea	15.8	12.5	13.2	16.1	15.2	15.5	13.3	13.9	13.8	14.3
AC Morse	15.3	12.4	13.0	15.4	14.1	14.5	–	–	–	–
AC Navigator	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	14.9	11.8	12.4	14.9	14.3	14.5	–	–	–	–
Strongfield	15.4	12.4	13.0	16.2	14.9	15.3	14.7	13.6	13.8	14.2
CDC Carbide	15.1	12.2	12.8	15.8	14.2	14.7	13.9	13.3	13.4	13.8
$LSD_{0.05}$	0.9	0.4	0.4	0.9	0.6	0.5	1.2	0.4	0.4	0.3
No. tests	2	8	10	3	7	10	2	9	11	31

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

data) were used to confirm that each of the selected rows carried *Sm1* prior to bulk harvesting to produce Breeder Seed. In total, 106 breeder lines were composited to form the Breeder Seed.

Performance

AGRONOMY: Averaged over 24 station-years in the main durum growing area (Brown and Dark Brown soils), CDC Carbide yielded 8% more than Strongfield, 16% more than AC Navigator and 18% more than AC Avonlea (Table 1). CDC Carbide yielded approximately 3% less than Brigade in 1 yr of comparison (2013). CDC Carbide expresses conventional height similar to AC Avonlea and Strongfield, with lodging resistance similar to Strongfield (Table 2). Maturity and test weight of CDC Carbide were similar to Strongfield, while kernel

Table 4. Midge assessment of CDC Carbide at Glenlea, MB, Kernen Research Farm, Saskatoon, SK, and Indian Head, SK, in 2009 and 2013

	Glenlea '09			Kernen '09			Indian Head '09			Kernen '13			Indian Head '13			Total[z]		
ID	R	S	U	R	S	U	R	S	U	R	S	U	R	S	U	R	S	U
AC Avonlea	0	7	9	0	16	1	0	12	1	0	20	3	0	18	0	0	73	14
Strongfield	0	10	3	0	19	1	0	12	1	0	14	8	0	18	0	0	73	13
AC Morse	0	12	1	0	16	0	0	12	1	–	–	–	–	–	–	–	–	–
AC Navigator	0	9	9	0	17	0	0	12	1	–	–	–	–	–	–	–	–	–
Commander	0	8	9	0	15	1	0	12	9	–	–	–	–	–	–	–	–	–
CDC Carbide	9	0	7	9	0	7	9	1	6	10	5	7	13	10	0	50	16	27

[z]R, resistant; S, susceptible; U, unable to classify.

Table 5. Disease reactions of CDC Carbide and check cultivars grown in the Durum Cooperative test (2011–2013)

Year	Entry	Stem rust[z]	Leaf rust[z]	Stripe rust[z]	Common bunt[z]	Loose smut	Leaf spots[y]	*Fusarium* head blight index[x]		DON[w] (mg kg^{-1})
								Carman	Glenlea	
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 Carbide	R	R	R	MR	I	7.5	–	21	6.0
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 Carbide	MR	R	VR	R	MS	8	57	16	12.4
2013	AC Avonlea	MR	R	R	R	MR	8	49	–	–
	AC Navigator	MR	R	S	R	MR	9.3	51	–	–
	Brigade	R	R	R	R	R	8.3	23	–	–
	Strongfield	R	R	R	R	R	8.3	30	–	–
	CDC Carbide	**R**	**R**	**R**	**R**	**R**	**8.5**	**51**	**–**	**–**

[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 $\times$ % 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 Carbide and check cultivars evaluated in the 2011–2013 Durum Cooperative tests

				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 Carbide	13.4	422	10.0	12.4	33.0	67.3	0.65	65.7	49	53	140	95	0.56	0.086
$LSD^v_{.05}$	0.4	31	0.3	0.4	0.6	0.5	0.02	1.0	10	7	22	11	0.14	0.018
$LSD^u_{.05}$	0.5	34	0.3	0.4	0.6	0.6	0.02	1.1	12	8	25	13	0.16	0.020
$LSD^t_{.05}$	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 Carbide with AC Avonlea, AC Navigator and Strongfield.
[u]For comparisons of CDC Carbide with AC Morse and Commander.
[t]For comparisons with Brigade.

weight was similar to AC Avonlea and slightly lower than the other checks. Test weight of CDC Carbide was higher than AC Avonlea and AC Navigator (Table 2). Grain protein concentration of CDC Carbide was higher than AC Navigator over the 3 yr, higher than Brigade in 2013, and lower than AC Avonlea and Strongfield (Table 3). Evaluation of single spikes for midge damage was performed in five environments, and revealed that CDC Carbide is resistant to the orange wheat blossom midge (Table 4).

DISEASE: CDC Carbide is resistant to prevalent races of leaf and stem rust, and has excellent common bunt resistance, like the checks. Leaf spot reaction was intermediate to the most resistant and most susceptible checks (Table 4). CDC Carbide is susceptible to FHB like the check cultivars, with DON concentrations similar to AC Avonlea and Strongfield, but lower than AC Navigator (Table 5). Reaction to loose smut was variable, but within the range of the checks.

END-USE SUITABILITY: Grain protein concentration of CDC Carbide was lower than Strongfield but higher than AC Navigator and Brigade in field (Table 3) and composite samples (Table 6). CDC Carbide has low cadmium concentration like Strongfield and Brigade, and expresses yellow pigment similar to AC Navigator (Table 5). The high yellow pigment was reflected in greater pasta b^* values than Strongfield. The average falling number of CDC Carbide was similar to the check cultivars. CDC Carbide is a conventional gluten strength type, with gluten index and alveograph parameters similar to Strongfield. Semolina milling yield and semolina ash content of CDC Carbide were within the range of the check cultivars.

Other Characteristics

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

KERNELS: Kernels are amber in color, medium sized, and elliptical; cheeks are slightly angular; crease is mid-deep, and mid-wide to wide; brush is short; embryo is medium sized.

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

Maintenance and Distribution of Pedigreed Seed

CDC Carbide consists of a composite of 106 $F_{8:10}$ breeder lines. Breeder seed will be maintained by the Crop Development Centre, University of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 5A8. CDC Carbide will be added to the OECD list of cultivars. Distribution

and multiplication of pedigreed seed stocks will be handled by Crop Protection Services, PO Box 770 Station Main, Regina, Saskatchewan, Canada S4P 3A8. Commercial launch of CDC Carbide is anticipated in 2016/2017.

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