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CULTIVAR DESCRIPTION

AAC NRG097 Canada Western Special Purpose spring wheat

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Abstract: AAC NRG097, a hard red spring wheat (*Triticum aestivum* L.), was developed at the Swift Current Research and Development Centre of Agriculture and Agri-Food Canada, in Swift Current, SK. AAC NRG097 has grain yield and time to maturity within the range of the checks, a semidwarf stature, and heavier seed mass than the checks. It expressed resistance to prevalent races of both leaf rust and common bunt, while expressing an intermediate level of resistance to *Fusarium* head blight. It received registration no. 7567 from the Variety Registration Office, Plant Production Division, Canadian Food Inspection Agency (CFIA) on 24 July 2014. AAC NRG097 was granted Plant Breeders' Rights Certificate no. 5089 by the Plant Breeders' Rights Office, CFIA on 7 Aug. 2015. It is eligible for grades of Canada Western Special Purpose.

Key words: Triticum aestivum L., cultivar description, grain yield, disease resistance.

Résumé : AAC NRG097 est une variété de blé roux vitreux de printemps (*Triticum aestivum* L.) créée à la station de recherche et de développement d'Agriculture et Agroalimentaire Canada de Swift Current, en Saskatchewan. Le cultivar se caractérise par un rendement grainier et une précocité situés dans la plage des variétés témoins, mais sa paille est semi-courte et ses grains, plus massifs. La variété résiste aux races courantes de la rouille des feuilles et de la carie, et résiste de façon moyenne à la brûlure fusarienne de l'épi. Le 24 juillet 2014, AAC NRG097 a été enregistré sous le numéro 7567 par le Bureau d'enregistrement des variétés de la Division de la production des végétaux de l'Agence canadienne d'inspection des aliments (ACIA). Le Bureau de la protection des obtentions végétales de l'ACIA lui a attribué le numéro de certificat 5089, le 7 août 2015. La variété est admissible au classement dans la catégorie « blé à des fins spéciales de l'Ouest canadien » (CWSP). [Traduit par la Rédaction]

Mots-clés : Triticum aestivum L., description de cultivar, rendement grainier, résistance à la maladie.

Introduction

AAC NRG097, a hard red spring wheat (*Triticum aestivum* L.) cultivar, was developed at the Swift Current Research and Development Centre (SCRDC), Agriculture and Agri-Food Canada (AAFC) in Swift Current, SK. It received registration no. 7567 from the Variety Registration Office, Plant Production Division, Canadian Food Inspection Agency (CFIA) on 24 July 2014. AAC NRG097 was granted Plant Breeders' Rights certificate no. 5089 by the Plant Breeders' Rights Office, CFIA on 7 Aug. 2015.

Pedigree and Breeding Methods

AAC NRG097 derives from the cross HY485/HY669//5700PR made in 2005 at SCRDC, AAFC in Swift Current, SK. The experimental line HY485, which derives from the cross CD87/AC Vista//9127:CS7C, was hybridized with the experimental line HY669, which derives from the cross HY627/95EPWB#9. The F_1 plants were top-crossed to the cultivar 5700PR, which derives from the cross N91-3051/AC Foremost. The 932 topcross F_1 seeds were multiplied at Plant and Food Research, Lincoln, New Zealand. In 2006, about 15 000 F_2 seeds were inoculated

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with common bunt [*Tilletia laevis* Kühn in Rabenh. and *T. tritici* (Bjerk.) G. Wint. in Rabenh.] races L16 and T19 (Hoffmann and Metzger 1976) and planted 10 cm apart in 90 m long rows. The rows were 23 cm apart, with every second row planted with CDC Kestrel winter wheat (Fowler 1997), which is susceptible to leaf rust (*Puccinia triticina* Eriks.) and stem rust (*P. graminis* Pers.:Pers. f. sp. *tritici* Eriks. & E. Henn.).

A leaf rust and stem rust epiphytotic nursery was established by planting genotypes susceptible to prevalent races of leaf and stem rust in every fifth spring wheat row. A sample of these plants were needle inoculated, followed by regular sprinkler irrigation. Representative leaf rust races found the previous year were applied (McCallum and Seto-Goh 2006). The stem rust races used were QTHJF (C25), RHTSC (C20), RKQSC (C63), RTHJF (C57), TMRTF (C10) and TPMKC (C53) (Jin et al. 2008). From the disease nursery, 333 disease-free, semidwarf stature, strong straw, and early maturing F_2 plants were selected, threshed individually, and further selected for healthy disease-free kernel characteristics.

The F_3 seed of 249 F_2-derived individuals was planted in 2 m long rows in a contra-season nursery near Lincoln, New Zealand. From these, 130 lines were selected on the basis of time to maturity comparable with the check commercial cultivars, plant height, straw strength, and shattering, and were harvested as individual rows. In the F_4 generation, seed of the selected 130 F_3 lines was inoculated with common bunt and grown in 1.5 m long rows near Swift Current. A rust epiphytotic nursery was established by planting genotypes lacking genes for resistance to prevalent races of leaf and stem rust in every 12th plot, inoculating a sample of plants within the row with representative rust races, and following with regular sprinkler irrigation.

Five heads were selected from each of 83 rows that expressed resistance to common bunt, leaf rust, and stem rust. Heads were threshed individually and grain examined for seed attributes. The selected grain samples from heads were composited on a row basis. The 83 $F_{4:5}$ bulks were grown out in a contra season nursery in 2 m long rows near Irwell, New Zealand. Selection among bulks was based on the same criteria as in the F_3. In the $F_{4:6}$ generation, 53 bulks were evaluated in agronomic trials near Swift Current and Indian Head, SK, and Lethbridge, AB, Canada. Agronomic plots were harvested at maturity and grain weight of each plot was measured. Seed weight and kernel attributes were measured on the same whole grain sample. A subsample was submitted to the Central Quality Laboratory, Cereal Research Centre (CRC), AAFC, Winnipeg, MB, to determine end-use suitability for the Canada Prairie Spring Red (CPSR) market class. Prior to harvest, five spikes had been collected from yield trial plots of each F_6 bulk at Swift Current. In the F_7 generation, 14 families at 5 lines per family were grown as 2 m long rows near Irwell, New Zealand. Families were selected on the basis of grain quality and kernel attributes assayed on grain from the F_6 yield trial. In the $F_{6:8}$ generations, 38 lines were grown in agronomic trials near Swift Current, Indian Head, and Lethbridge. Grain was harvested, processed, and a subsample analyzed for milling and rheological properties, similarly to grain from F_6 plots. In the F_6 and F_8 generations, reaction to leaf and stem rust was used as a selection criterion based on results of an epiphytotic nursery near Glenlea, MB. In the F_6 and F_8 generations, response to *Fusarium* head blight (FHB) was assessed in a nursery near Portage la Prairie, MB. Selected F_8 lines also were screened for reaction to a T2, T9, T10, and T39 mixture of races of loose smut [*Ustilago tritici* (Pers.) Rostr.] (Nielsen 1987) and races L16 and T19 of common bunt. Throughout this breeding process, the experimental line C0503-HY*02 met all selection criteria at each generation.

C0503-HY*02 was evaluated in the High Yield Wheat B Test in 2010 and entered into the General Purpose Cooperative (GPC) test for 2011 and 2012 as GP097. Annually, the GPC consisted of 33 experimental lines and two check commercial cultivars grown in a 6×6 lattice design with three replications at up to 11 locations per year. The check cultivars were 5702PR, AC Andrew, and Pasteur. The variables measured and protocols followed in the GPC test were described in the operating procedures of the Prairie Recommending Committee for Wheat, Rye and Triticale (Anonymous 2013; http://www.pgdc.ca/committees_wrt.html). The MIXED procedure of SAS® (Littell et al. 2006) was used to perform yearly analyses for agronomic data, with environments and their interactions considered random effects and cultivar treated as a fixed effect. Mean separation tests were performed using Fisher's protected least significant difference procedure.

Response to several diseases was assessed in specialized disease nurseries in 2011 and 2012. Stem rust seedling infection types (ITs) were assessed using races QTHJF (C25), RHTSC (C20), RKQSC (C63), RTHJF (C57), TMRTF (C10), and TPMKC (C53) (Jin et al. 2008) and leaf rust seedling ITs were assessed using races MBDS (12-3), MBRJ (128-1), MGBJ (74-2), TDBG (06-1-1), TDBJ (70-1), and TJBJ (77-2) (McCallum and Seto-Goh 2006). Field evaluations of leaf and stem rust reactions, using leaf rust races representative of those found the previous year and the same stem rust races as for the seedling tests, were measured annually in epiphytotic nurseries near Glenlea, MB. Reaction to FHB was assessed in artificially inoculated field tests conducted annually near Glenlea and Carman, MB; Ottawa, ON; Lévis, QC; and Charlottetown, PE (Gilbert and Woods 2006). To determine the response to loose smut, a mixture of the prevalent races T2, T9, T10, and T39 was injected into florets at anthesis of plants grown in the field, and the inoculated seed was subsequently grown out and rated in a

Table 1. Grain yield (kg ha^{-1}) of AAC NRG097 compared with check cultivars in the 2010 High Yield Wheat B Test.

	Swift Current	Regina	Indian Head	Brandon	Kernen	Edmonton	Mean[a]
5701PR	3213	3127	3446	4974	3244	6792	4186
5702PR	3783	3437	3712	6586	2641	8232	4702
NRG010	4110	3473	4513	7218	3790	7784	5136
Andrew	4515	3744	3856	4747	3996	8389	4848
AAC NRG097	4150	4110	4091	7412	3662	7016	5088
$LSD_{0.05}$[b]	581	563	559	1123	377	895	655

[a]Means based on LSMEANS procedure of SAS.
[b]LSD, least significant difference ($P \le 0.05$) includes the appropriate genotype × environment interaction variation.

Table 2. Grain yield (kg ha^{-1}) of AAC NRG097 compared with check cultivars in the 2011 and 2012 General Purpose Cooperative Tests.

	2011 GPC[a]					2012 GPC[a]					
	Zone 1[b]	Zone 2	Zone 3[c]	Zone 4	Mean[d]	Zone 1	Zone 2	Zone 3	Zone 4[e]	Mean[d]	2011–2012[d]
Andrew (check)	5293	5665	8656	7894	6588	4209	5072	3974	3995	4375	5490
5702PR (check)	5164	5171	7061	6155	5737	4316	4202	3654	2581	4013	4960
Pasteur (check)	5034	5219	8778	9397	6621	4165	4980	4031	3924	4348	5459
AAC NRG097	5054	5167	7980	6502	5994	4356	4817	3955	3036	4298	5240
Mean of checks	5164	5352	8165	7815	6315	4230	4751	3886	3500	4245	5303
$LSD_{0.05}$[f]	1009	462	1143	1124	543	530	569	942	675	395	339
No. of trials	2	3	2	1	8	5	3	2	—	10	18

[a]Zone 1: Brandon, Glenlea, and Rosebank, MB, and Indian Head, SK; Zone 2: Regina, Swift Current, and Kernen, SK; Zone 3: Ellerslie and Lacombe, AB, and Melfort, SK; Zone 4: Lethbridge, AB (irrigated). GPC, General Purpose Cooperative.
[b]Glenlea 2011 yield data not included in Zone 1 means, due to high coefficient of variation.
[c]Ellerslie 2011 yield data was not included in Zone 3 means, due to high coefficient of variation.
[d]Means based on LSMEANS procedure of SAS.
[e]Lethbridge 2012 yield data not included in Zone 4 means due to high coefficient of variation.
[f]LSD, least significant difference ($P \le 0.05$) includes the appropriate genotype × environment interaction variation.

greenhouse (Menzies et al. 2003). To determine the response to common bunt, a mixture of prevalent races L1, L16, T1, T6, T13, and T19 was used to inoculate the seed, planted in mid-April of each year near Lethbridge, AB (Gaudet and Puchalski 1989). Race designations are those described by Nielsen (1987) for loose smut and Hoffmann and Metzger (1976) for common bunt.

The Operating Procedures of the Prairie Recommending Committee on Wheat, Rye and Triticale require a minimum of 15 station–years of data collected in Western Canada over a period of three or more years, with at least two locations per province per year in at least two provinces. Preregistration trial data may be used to meet the minimum 15 station–years of agronomic data. Likewise, preregistration trial disease response data may be used to contribute to the 3 yr of disease response data. Consequently, the data package to support the registration of AAC NRG097 consisted of the 2010 High Yield Wheat B (HYWB) Trial and 2011 and 2012 GPC Tests.

Performance

In the 2010 HYWB test, AAC NRG097 yielded significantly more grain than 5701PR (Table 1). Averaged over 18 locations in 2 yr in the GPC, the grain yield of AAC NRG097 was not significantly different than the mean of the checks (Table 2). In the 2010 HYWB test, AAC NRG097 matured 4 d later than 5702PR and within the range of the other checks (Table 3). Averaged over 2 yr in the GPC, AAC NRG097 matured 2.6 d earlier than Pasteur and 2.4 d later than 5702PR (Table 4). AAC NRG097 was similar in height and straw strength to the checks, with the exception of the very strong strawed Pasteur (Table 4). AAC NRG097 had significantly heavier volume weight than 5702PR and AC Andrew in both the HYWB and GPC, and three of four checks in the HYWB (Tables 3 and 4). AAC NRG097 had significantly heavier seed weight than AC Andrew and NRG010 in the HYWB (Table 3), and significantly heavier seed weight than 5702PR, Andrew, and Pasteur in the GPC (Table 4).

Table 3. Agronomic characteristics of AAC NRG097 compared with check cultivars in the 2010 High Yield Wheat B Test.

	Maturity (d)	Height (cm)	Lodging score[a] (1–9)	Volume weight (kg h L^{-1})	Seed mass (mg)
5701PR	108	77	1.4	76.0	38.2
5702PR	107	82	2.1	74.7	37.2
NRG010	111	85	1.0	74.0	35.4
Andrew	110	83	2.0	72.6	33.2
AAC NRG097	111	83	2.4	77.4	39.3
$LSD_{0.05}$[b]	3	3	1.1	1.5	2.9
No. of trials	6	6	3	6	6

[a]Straw strength rated on a scale of 1 to 9, where 1 = all plants in plot are erect and 9 = all plants in a plot are lying horizontal.
[b]LSD, least significant difference ($P \leq 0.05$), includes the appropriate genotype × environment interaction variation.

Table 4. Two-year means[a] for agronomic characteristics of AAC NRG097 compared with check cultivars in the 2011 and 2012 General Purpose Cooperative Tests.

	Maturity (d)	Height (cm)	Lodging score[b] (1–9)	Volume weight (kg h L^{-1})	Seed mass (mg)
Andrew (check)	100.1	84	1.4	77.2	35.0
5702PR (check)	97.1	84	1.7	76.2	37.0
Pasteur (check)	102.1	85	1.2	78.9	36.1
AAC NRG097	99.5	84	1.7	79.3	40.7
Mean of checks	99.7	85	1.5	77.4	36.0
$LSD_{0.05}$[c]	1.1	2	0.3	0.7	1.2
No. of trials	20	21	13	20	20

[a]Means based on LSMEANS procedure of SAS.
[b]Straw strength rated on a scale of 1 to 9, where 1 = all plants in plot are erect and 9 = all plants in a plot are lying horizontal.
[c]LSD, least significant difference ($P \leq 0.05$) includes the appropriate genotype × environment interaction variation.

Other Characteristics

Seedling: medium intensity of anthocyanin colouration of coleoptile, glabrous lower leaf sheaths and blades.

Spike: Parallel-sided shape in profile, mid-dense, mid-long to long, inclined attitude at maturity, awned, glabrous, white, lower glume shoulder narrow to medium width, straight to elevated shape, lower glume beak primarily short to mid-long, straight.

Kernel: Color red, large, long to mid-long, mid-wide, ovate, cheeks rounded to angular, brush hairs mid-long to long, crease mid-wide, mid-deep, germ mid-size to large, oval.

Shattering: Resistant to seed shelling due to wind.

Disease reaction: AAC NRG097 expressed resistance to prevalent races of leaf rust and common bunt in 2 yr of testing (Table 5). It expressed moderate resistance to prevalent races of stem rust, intermediate resistance to prevalent races of loose smut, and susceptibility to stripe rust. AAC NRG097 appears to have more resistance to FHB than some of the checks and has been rated intermediate (Table 6).

End-use suitability: AAC NRG097 is eligible for grades of Canada Western Special Purpose wheat class. https://www.grainscanada.gc.ca/oggg-gocg/04/oggg-gocg-4e-eng.htm.

Maintenance and Distribution of Pedigreed Seed

The 110 Breeder Lines originated from F_6-derived F_{10} random single plants grown near Swift Current in 2011 followed by growth as 130 hill plots near Irwell, New Zealand, and again as 15 m rows near Indian Head in 2012, which generated approximately 277 kg of Breeder Seed. Breeder Seed will be maintained by the Seed Increase Unit of the Research Farm, Indian Head, SK S0G 2K0, Canada. The cultivar will be added to the Organisation for Economic Co-operation and Development's List of Cultivars. AAC NRG097 has been released for distribution and multiplication by Canterra Seeds, 201-1475 Chevrier Boulevard, Winnipeg, MB R3T 1Y7, Canada.

Table 5. Reactions of AAC NRG097 and check cultivars to leaf, stem, and yellow rust, common bunt, and loose smut in 2011 and 2012 General Purpose Cooperative Tests grown at various locations.

	Field leaf rust				Field stem rust				Yellow rust				Common bunt Lethbridge				Loose smut Glenlea			
	2011		2012		2011		2012		2011		2012		2011		2012		2011		2012	
	Severity[a] (%)	Rating[a]	Severity (%)	Rating	Severity[b] (%)	Disease response[c]	Severity	Disease response	Severity[d] (%)	Reaction[e]	Severity	Reaction	Infection[g] (%)	Reaction[e]	Infection (%)	Reaction	Infection[h] (%)	Reaction[e]	Infection (%)	Reaction
Andrew	10	R	50	MS	7	MR	50	I	25	I	40	S	51	S	21	I	44	I	38	I
5702PR	0	R	7	R	30	MS	40	MS	37	I	30	MS	6	MR	21	I	9	R	27	MR
Pasteur	0	R	2	R	5	MR	90	S	18	I	40	S	24	I	30	MS	28	MR	74	MS
AAC NRG097	0	R	2	R	10	MR	10MR/30MS[f]		42	S	80	S	0	R	3	R	51	I	42	I

[a]Severity is the percentage of leaf area affected by leaf rust; rating is the descriptive classification of disease resistance (or) susceptibility based on percent severity, where R (resistant) = 0%–10%, MR (moderately resistant) = 11%–30%, I (intermediate resistance) = 31%–39%, MS (moderately susceptible) = 40%–60%, and S (susceptible) >60%.

[b]Severity is the percentage of the stem infected with stem rust using the Modified Cobb Scale.

[c]Disease response categories: R, resistant; MR, moderately resistant; I, intermediate; MS, moderately susceptible; and S, susceptible.

[d]Severity is the percentage of leaf area affected by stripe rust.

[e]Disease reaction categories: R, resistant. MR, moderately resistant; I, intermediate; MS, moderately susceptible; and S, susceptible.

[f]The two disease responses indicate there was plant heterogeneity, with some expressing moderate resistance and others moderate susceptibility.

[g]Percentage of spikes with common bunt symptoms.

[h]Percentage of plants with loose smut symptoms.

Table 6. Response to *Fusarium* head blight and the mycotoxin deoxynivalenol of AAC NRG097 and check cultivars based on 2011 and 2012 General Purpose Cooperative Tests grown at Glenlea and Carman, MB, and Prince Edward Island (PEI).

	Carman			Glenlea								PEI				
	2012			2011				2012				2011		2012		
	Index[a]	Rating[b]	FDK[c]	Index	Rating	DON[d]	ISD[e]	Index	Rating	DON	ISD[f]	FDK	DON	Index	FDK	DON
Andrew	67	S	31	24	MS	4.5	4.6	15	I	6.7	17	7	15	37	8	7.6
5702PR	43	MS	22	11	I	2.9	3.7	15	I	6.1	19	9	14	38	8	2
Pasteur	35	I	12	12	I	2	3.1	5	MR	4	11	9	12	25	5	0.8
AAC NRG097	32	I	19	2	MR	2.8	2.8	6	MR	7	14	8	17	34	6	2.1

[a]*Fusarium* head blight disease index = (percentage of infected heads × percentage of diseased florets on infected heads)/100.
[b]Disease response category: R, resistant; MR, moderately resistant; I, intermediate reaction; MS, moderately susceptible; and S, susceptible.
[c]FDK, *Fusarium*-damaged kernels on a weight of kernels with *Fusarium* symptoms as a percent of the total sample weight.
[d]DON, deoxynivalenol (ppm).
[e]ISD, incidence severity DON index (2011) = [(0.3 × incidence) + (0.3 × severity) + (0.4 × DON)].
[f]ISD, incidence severity DON index (2012) = [(0.2 × incidence) + (0.2 × severity) + (0.6 × DON)]. The ISD was changed to place greater weight on DON.

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References

Anonymous. 2013. Operating procedures, prairie recommending committee for wheat, rye and triticale [Online]. Available: http://www.pgdc.ca/pdfs/wrt/2013-14%20PRCWRT%20Operating%20Procedures_May_2013.pdf.

Fowler, D.B. 1997. CDC Kestrel winter wheat. Can. J. Plant Sci. **77**: 673–675. doi:10.4141/P96-193.

Gaudet, D.A., and Puchalski, B.L. 1989. Races of common bunt (*Tilletia caries* and *T. foetida*) of wheat in western Canada. Can. J. Plant Pathol. **11**: 415–418. doi:10.1080/07060668909501089.

Gilbert, J., and Woods, S. 2006. Strategies and considerations for multi-location FHB screening nurseries. Pages 93–102 in T. Ban, J.M. Lewis, and E.E. Phipps, eds. The global *Fusarium* initiative for international collaboration: a strategic planning workshop. CIMMYT, El Batàn, Mexico.

Hoffmann, J.A., and Metzger, R.J. 1976. Current status of virulence genes and pathogenic races of the wheat bunt fungi in the northwestern USA. Phytopathology, **66**: 657–660. doi:10.1094/Phyto-66-657.

Jin, Y., Szabo, L.J., Pretorius, Z.A., Singh, R.P., Ward, R., and Fetch, T., Jr., 2008. Detection of virulence to resistance gene Sr24 within race TTKS of *Puccinia graminis* f. sp. *tritici*. Plant Dis. **92**: 923–926. doi:10.1094/PDIS-92-6-0923.

Littell, R.C., Milliken, G.A., Stroup, W.W., and Wolfinger, R.D. 2006. SAS® system for mixed models. 2nd ed. SAS Institute Inc., Cary, NC.

McCallum, B.D., and Seto-Goh, P. 2006. Physiologic specialization of *Puccinia triticina*, the causal agent of wheat leaf rust, in Canada in 2004. Can. J. Plant Pathol. **28**: 566–576. doi:10.1080/07060660609507335.

Menzies, J.G., Knox, R.E., Nielsen, J., and Thomas, P.L. 2003. Virulence of Canadian isolates of *Ustilago tritici*: 1964–1998, and the use of the geometric rule in understanding host differential complexity. Can. J. Plant Pathol. **25**: 62–72. doi:10.1080/07060660309507050.

Nielsen, J. 1987. Races of *Ustilago tritici* and techniques for their study. Can. J. Plant Pathol. **9**: 91–105. doi:10.1080/07060668709501888.

SAS Institute Inc. 2003. SAS software. Version 9. SAS Institute Inc., Cary, NC.