Canadian Science Publishing | Canadian Journal of Plant Science

AAC Succeed Durum Wheat

Journal:	*Canadian Journal of Plant Science*
Manuscript ID	CJPS-2019-0342.R4
Manuscript Type:	Cultivar description
Date Submitted by the Author:	19-Oct-2020
Complete List of Authors:	Ruan, Yuefeng; Swift Current Research and Development Centre, AAFC Singh, Asheesh; Iowa State University, Agronomy DePauw, R.; Advancing Wheat Technologies, Knox, Ron; Swift-Current Research and Development Centre, AAFC Cuthbert, Richard; Swift-Current Research and Development Centre, Mccallum, Brent; Morden Research and Development Centre, AAFC Fetch, Thomas; Agriculture and Agri-food Canada, Brandon Research & Development Centre
Keywords:	Triticum turgidum, grain yield, orange wheat blossom midge resistance, cadmium uptake
Is the invited manuscript for consideration in a Special Issue?:	Not applicable (regular submission)

SCHOLARONE™
Manuscripts

© The Author(s) or their Institution(s)

Cultivar Description

AAC Succeed Durum Wheat

Short title: Ruan et al. – AAC Succeed durum wheat

Y. Ruan[1*], A.K. Singh[1,2], R.M. DePauw[3,4], R.E. Knox[1], R.D. Cuthbert[1], B. McCallum[5], T. Fetch[5]

[1]Agriculture and Agri-Food Canada, Swift Current Research and Development Centre, Box 1030, Swift Current, SK, S9H 3X2; [2] Present Address: Department of Agronomy, Iowa State University, Ames, IA, USA; [3]Advancing Wheat Technologies, 870 Field Drive, Swift Current, SK, S9H 4N5; [4] retired from Agriculture and Agri-Food Canada, Swift Current Research and Development Centre; [5]Agriculture and Agri-Food Canada, Morden Research and Development Centre, 101 Route 100, Morden, Manitoba, Canada.

* corresponding author (email: yuefeng.ruan@canada.ca)

For Review Only

© The Author(s) or their Institution(s)

Y. Ruan, A.K. Singh, R.M. DePauw, R.E. Knox, R.D. Cuthbert, B. McCallum, T. Fetch. 20xx. AAC Succeed durum wheat. Can. J. Plant Sci. xx:000-000. AAC Succeed durum wheat (*Triticum turgidum* L. subsp. *durum* (Desf.) Husn.) is adapted to the durum production area of the Canadian prairies. AAC Succeed carries the *Sm1* gene which confers antibiosis-based resistance to orange wheat blossom midge [*Sitodiplosis modellana* (Gehin)]. Averaged over three years, AAC Succeed yielded significantly more grain than Strongfield (7%) and AC Navigator (21%). AAC Succeed had a protein concentration significantly higher than Brigade and AC Navigator and similar to Strongfield. AAC Succeed had significantly stronger straw as measured by lodging score than Strongfield and similar to Brigade. AAC Succeed is eligible for grades of Canada Western Amber Durum, has low grain cadmium concentration, and it has higher yellow pigment concentration than the check cultivars.

Key words: *Triticum turgidum*, cultivar description, grain yield, orange wheat blossom midge resistance, *Sm1*, yellow pigment, cadmium.

For Review Only

AAC Succeed durum wheat (*Triticum turgidum* L. subsp. *durum* (Desf.) Husn.) was developed at the Swift Current Research and Development Centre (SCRDC), Agriculture and Agri-Food Canada (AAFC), Swift Current, SK. Plant Breeders' Rights, grant of rights certificate #5980 was granted by the Plant Breeders' Rights Office, Canadian Food Inspection Agency, Ottawa, ON, on 31 May 2019, and AAC Succeed received registration No. #8346 from the Variety Registration Office, Canadian Food Inspection Agency, on 18 August 2017.

Pedigree and Breeding Method

AAC Succeed (experimental names: DT871, A0827-FK04) was selected from the cross

© The Author(s) or their Institution(s)

DT814/DT794//DT809 made in 2008 at the Swift-Current Research and Development Centre, Swift Current, SK. DT814 (A0204-AZZ01C) is a breeding line derived from a cross of DT721/Commander//DT720. DT794 (A0039-758BC05) is a midge tolerant breeding line derived from a cross of Kyle//9560A-138/94B27-BR1C/3/Napoleon /4/AC Navigator/5/9687-CA4. 94B27-BR1C is a midge tolerant hexaploid line derived from the cross of Caldwell/ 88B27-D3A1C where Caldwell (Patterson et al. 1982) is a midge resistant genotype. DT809 (A0144-QX02) is a breeding line derived from a cross of A9900H-069/2*Strongfield. 9560A-138 and A9900H-069 are the CIMMYT lines CD92655-1PAP-2Y-040M-2Y-0PAP and CD98578-F-1Y-040M-040YRC-8M-1Y-0B, respectively. DT721, DT720 and 9687-CA4 are the breeding lines developed by AAFC - SCRDC. Commander (Clarke et al. 2005a), Kyle (Townley-Smith et al. 1987), Napoleon (Humphreys et al. 2010), AC Navigator (Clarke et al. 2000), and Strongfield (Clarke et al. 2005b) are registered durum cultivars. The parents were haplotyped with the DNA markers namely *ScOPC20* SCAR marker linked to *Cdu1* controlling cadmium uptake (Knox et al. 2009), and *Barc35* SSR marker linked to *Sm1* controlling orange wheat blossom midge [*Sitodiplosis modellana* (Gehin)] insect resistance (Thomas et al. 2005).

In 2009, F_1 seeds were planted in the greenhouse to produce F_2 seeds. In the spring of 2009, approximately 8000 seeds of the F_2 generation were space-planted at 14 cm intervals within a row in an irrigated epiphytotic field nursery near Swift Current. Genotypes susceptible to prevalent races of leaf rust (*Puccinia triticina* Eriks.) and stem rust (*P. graminis* Pers.:Pers. f. sp. *tritici* Eriks. and E. Henn.) were planted as disease spreaders every tenth row. Between the spreader rows, five rows of spring planted winter wheat were alternated with four rows of F_2 seed at a row spacing of 23 cm. The winter wheat cultivar CDC Kestrel (Fowler 1997), which is susceptible to leaf and stem rust, was used to contribute to the multiplication of rust inoculum. Spreader rows were inoculated by injecting, with a syringe and needle, a water suspension of leaf

© The Author(s) or their Institution(s)

For Review Only

rust and stem rust spores into a sample of plants every 3 m. Representative leaf rust races found the previous year were applied (McCallum and Seto-Goh 2006). Stem rust races used were: QTHJF (C25), RHTSC (C20), RKQSC (C63), RTHJF (C57), TMRTF (C10), and TPMKC (C53) (Roelfs and Martens 1988; Fetch et al. 2015). Leaf spotting diseases developed through natural infection. Individual plants were selected for plant height, straw strength, maturity, and resistance to leaf spotting diseases, leaf rust, and stem rust.

The F_3 seeds from individual spikes from 343 selected F_2 plants were grown in 2 m long rows in a contra-season nursery near Lincoln, New Zealand, in 2009-2010. Based on plant height, days to maturity, and straw strength, 212 rows were selected, and the rows were harvested individually to produce the seed used for agronomic and disease trials in Canada. In 2010, 212 F_4 lines, their parents, and other check cultivars AC Avonlea (Clarke et al.1998), Brigade (Clarke et al. 2009a), Eurostar (Clarke et al. 2009b), Enterprise (Singh et al. 2010), Commander, AC Navigator, AC Morse, and Strongfield were grown in unreplicated four-row plot experiments near Swift Current and Regina, SK. The experiments had a harvest area of 2.74 m^2 per plot. The agronomic traits grain yield, plant height, time to maturity and straw strength as measured by plant stems deviating from upright on a scale of 1 indicating that all plants in a plot are erect to 9 indicating that all plants in a plot are lying horizontal with the trait designated lodging, and leaf spotting disease based on natural infection were assessed and used for selection of F_4 lines. Prior to plot harvest, five spikes per F_4 line from within plots grown near Swift Current were selected for plant height, straw strength, and leaf spotting disease symptoms caused primarily by tan spot [*Pyrenophora tritici-repentis* (Died.) Drechs., anamorph *Drechslera tritici-repentis* (Died.) Shoemaker] and stagonospora nodorum blotch [*Phaeosphaeria nodorum* (E. Müll.) Hedjaroude, anamorph *Stagonospora nodorum* (Berk.) Castell. & E.G. Germano]. The grain quality traits protein concentration, yellow pigment concentration, and volume weight

© The Author(s) or their Institution(s)

For Review Only

were assessed on grain harvested from field trials following AACC protocols (American Association of Cereal Chemists, 2000). Based on this suite of agronomic, disease, and quality traits, 78 F_4 lines were selected.

In 2010-11, 390 F_5 lines (from the 78 $F_{4:5}$ families at 5 spikes per F_4 line) were grown in 2 m long rows near Leeston, New Zealand and selected first on a family basis for the quality trait gluten strength using the F_4 yield trial seed and secondly on an F_5 row basis for plant height, straw strength, and days to maturity. After selection, 232 $F_{4:6}$ lines were grown in 2011 under dryland conditions near Swift Current, Regina and Saskatoon, SK. Twenty-five $F_{4:6}$ lines were selected based on agronomic performance, disease resistance, and quality traits assessed as described for the F_4 generation.

Eighteen $F_{4:7}$ lines were grown in the 2012 Durum A-level tests as a two replicate lattice design with four-row plots planted under dryland conditions near Swift Current, Stewart Valley, Regina, and Indian Head, SK, and under both dryland and irrigated conditions near Lethbridge, AB, to assess agronomic performance as described for the F_4 generation. Check cultivars in the Durum A test were AAC Marchwell (Singh et al. 2015), AC Avonlea, AC Navigator, Brigade, and Strongfield. Remnant seeds from the yield trials were bulked over replications within a location and a subsample from each location that graded better than No.3 Canada Western Amber Durum was used to assess end-use suitability by the Central Quality Lab, Cereal Research Centre, Winnipeg, MB. Assessment included grain protein concentration, yellow pigment concentration, milling properties, gluten strength, and Hagberg Falling Number following AACC protocols (American Association of Cereal Chemists, 2000). Response to loose smut [*Ustilago tritici* (Pers.) Rostr.] was tested with a mixture of races T26, T32, and T33 (Nielsen 1987) under field conditions near Swift Current. Response to leaf rust and stem rust were evaluated in hill plots in a rust nursery near Glenlea, MB, using a mixture of races similar

For Review Only

© The Author(s) or their Institution(s)

to that in the F_2 rust nursery. Response to leaf spotting pathogens was assessed from within the yield plots under conditions of natural inoculum. Response to *Fusarium* was assessed in FHB nurseries near Carman, MB for incidence (%) and severity (%), and near Portage la Prairie, MB on a 1 to 9 scale. Scoring for FHB was performed when a significant differential reaction was observed among checks. The protocols for assessing these diseases are described in the Prairie Recommending Committee for Wheat, Rye and Triticale operating procedures (Anonymous 2015). Response to midge reaction was assessed in a midge screening nursery near Glenlea, MB (Thomas et al. 2005). Midge reaction was noted as resistant or susceptible. DNA marker analysis was performed to confirm the presence of *Sm1* gene. These procedures identified the line A0827-FK04, which met all of the selection criteria at each stage of selection.

The five lines from the population designated A0827, including A0827-FK04 were tested in the 2013 Durum-B test in an alpha-lattice design with two replications and grown near Swift Current, Stewart Valley, Saskatoon, and Indian Head, SK, and Lethbridge, AB, using the same check cultivars as in the 2012 Durum A tests. Response to diseases was measured using protocols similar to that for the A-level tests described above. Remnant seed from the yield trials was used to prepare a composite using the same protocols and to assess the same end-use suitability parameters as in the Durum A-level tests, by the Central Quality Lab, Cereal Research Centre, MB. This procedure identified the line A0827-FK04, which met all of the selection criteria at each stage of selection.

A0827-FK04 was advanced to the Durum Wheat Cooperative Test and evaluated as DT871 from 2014 to 2016. The Durum Wheat Cooperative Test was grown in four-row plots at 11 locations annually in a two replicate 5 x 6 lattice design including four check cultivars in two repetitions and two replications. The check cultivars were AAC Cabri (Singh et al. 2017), AC Navigator, Brigade, and Strongfield. The Durum Wheat Cooperative Test operating protocols are

© The Author(s) or their Institution(s)

For Review Only

described in the Prairie Recommending Committee for Wheat Rye and Triticale operating procedures (Anonymous 2015). The PROC MIXED procedure in SAS version 9 (SAS Institute Inc. 2003) was used to analyze the data annually and to perform a combined analysis over years, using a mixed model with environments and replications considered random effects and genotypes considered fixed effects (Littell et al. 2006). Least squares means (LS means) were estimated by the mixed model. Least significant differences were calculated using appropriate mean squares and degrees of freedom, and differences were declared significant at the 5% probability level.

The Durum Wheat Cooperative Test entries were evaluated in inoculated disease nurseries near Brandon, Portage la Prairie and Morden, MB to determine the response to leaf rust, stem rust, and loose smut. *Fusarium* head blight was assessed in inoculated nurseries near Carman and Morden MB, Ottawa, ON, and Charlottetown, PEI. Inoculum composition for leaf rust, stem rust, and loose smut was as described above. Response to common bunt caused by *Tilletia laevis* Kuhn in Rabenh., and *T. tritici* (Bjerk.) G. Wint. in Rabenh., was assessed in a nursery grown near Lethbridge, using a mixture of prevalent races: T-1, T-6, T-13, T-19, L-1, and L-16 (Hoffmann and Metzger 1976; Gaudet and Puchalski 1989). Leaf spotting reaction was determined based on natural infection at Swift Current. Reaction to stripe rust (*Puccinia striiformis* f. *tritici* Eriks) was determined in nurseries near Lethbridge, AB and Creston, BC. Midge reaction was determined on spikes from yield plots of two locations with the highest midge pressure from the Durum Wheat Cooperative Test in 2015 and 2016.

A sample of grain of DT871 and the check cultivars from each location was submitted to the Canadian Grain Commission to determine grain grade and protein concentration. End-use suitability was determined on a composite sample made up from sites with grain samples representative only of the top durum wheat grades available. The quantity of grain from a

For Review Only

© The Author(s) or their Institution(s)

location was adjusted to achieve a final composite protein concentration approximating that of the average for the crop that year. An 800 g grain per replication within a location for all experimental lines was used to make up the composite each year. All end-use suitability analyses were performed by personnel at the Grain Research Laboratory, Canadian Grain Commission, Winnipeg, MB following AACC protocols (American Association of Cereal Chemists, 2000).

Performance

In three years of cooperative testing, the grain yield of AAC Succeed was significantly higher than Strongfield and AC Navigator (Table 1). AAC Succeed had significantly higher grain yield than AC Navigator in both Zone 1 and Zone 2. Averaged over zones, AAC Succeed was significantly earlier maturing than Brigade and AC Cabri (Table 2). Test weight (kg hL^{-1}) of AAC Succeed was significantly lower than Brigade and AAC Cabri, while the 1000-kernel weight (g) was significantly heavier than Strongfield and AAC Cabri. AAC Succeed had plant height significantly shorter than Brigade and significantly taller than AC Navigator. Straw strength, as measured by lodging score of AAC Succeed was significantly stronger than Strongfield and AAC Cabri. Grain protein concentration of AAC Succeed was significantly higher than Brigade (Table 3).

AAC Succeed was resistant to leaf rust, loose smut and common bunt, moderately resistant to stem rust, intermediate reaction to stripe rust, and moderately susceptible to leaf spot (Table 4). The FHB reaction and deoxynivalenol (DON) accumulation of AAC Succeed was rated as susceptible to intermediate (Table 5). AAC Succeed has the *Sm1* gene and is resistant to orange wheat blossom midge insect (Table 6) (McKenzie et al. 2002).

AAC Succeed has slightly higher grain Cadmium concentration than Strongfield (Table 7). The semolina yellow pigment concentration of AAC Succeed was higher relative to the

For Review Only

© The Author(s) or their Institution(s)

checks. AAC Succeed had gluten index and alveograph W values higher than Strongfield as well as pasta b* colour desirably higher. The semolina ash of AAC Succeed was higher than Strongfield.

Other Characteristics

Spikes: parallel-sided shape, dense, erect attitude; off-white at maturity; awns longer than spike, white at maturity.

Kernel: amber colour; large kernel size, elliptical, short brush hairs.

Lower glume: long length, medium width; glabrous.

Lower glume shoulder: very narrow to narrow width; sloping to strongly elevated shape.

Lower glume beak: short length, straight to slightly curved shape.

End-use suitability: eligible for the grades of Canada Western Amber Durum wheat market class.

Maintenance and Distribution of Pedigreed Seed

The 93 breeder lines originated from random $F_{4:9}$ single plants of A0827-FK04 grown as 108 pre-breeder lines in 3 m long rows in isolation near Swift Current in 2015, and again as 15 m rows near Indian Head in 2016. Breeder Seed will be maintained by the Seed Increase Unit of the Research Farm, Indian Head, SK, S0G 2K0. Distribution and multiplication of pedigreed seed stocks will be handled by FP Genetics, 426 McDonald Street, Regina, SK., S4N 6E1, Canada (https://www.fpgenetics.ca).

Acknowledgements

We gratefully acknowledge the financial support of the producer-funded wheat research check-off (administered by the Western Grains Research Foundation); D. Niziol and J. Fehr of AAFC,

© The Author(s) or their Institution(s)

For Review Only

Cereal Research Centre (CRC) (Winnipeg, MB) for providing end-use quality analyses; J. Gilbert of AAFC, CRC and M. Henriquez of AAFC, Morden Research and Development Centre for providing FHB evaluations; J. Menzies of AAFC, Morden Research and Development Centre for loose smut evaluation; C. McCartney of AAFC, Morden Research and Development Centre for midge evaluation; D. Gaudet and T. Despins of AAFC, Lethbridge Research and Development Centre for providing reaction to stripe rust and common bunt; E. Johnson, Scott Research Farm, AAFC, for agronomic assessment at Scott; C.J. Pozniak, University of Saskatchewan, for agronomic assessment near Saskatoon, SK; F. Kirigwi, Syngenta AgriPro, for agronomic assessment at Souris, MB and Pense, SK; T. Ferguson, Viterra, for agronomic assessment at Moose Jaw, SK, and Vulcan, AB; S. Fox, G. Humphreys and D. Brown of AAFC, CRC for agronomic assessment at Brandon, MB and FHB nursery at Portage la Prairie, MB; S. Kumar and A. Burt of AAFC, Brandon Research and Development Centre for agronomic assessment and FHB nursery at Brandon, MB; B. Beres of AAFC, Lethbridge Research and Development Centre for agronomic assessment at Lethbridge, AB; A. Brûlé-Babel of University of Manitoba for FHB evaluations at Carman, MB; B.X. Fu and L. Schlichting of the Grain Research Laboratory, Canadian Grain Commission, Winnipeg, MB, for end-use quality assessment; H. Naeem of AAFC Seed Increase Unit, Indian Head, SK for multiplication of Breeder seed; M. Olfert, J. Ross, L. Oakman, J. Powell, H. Campbell, S. Friesen, T. Greenwood, and all members of the wheat genetic enhancement group at AAFC, Swift Current Research and Development Centre (SCRDC); B. Meyer, A. Banman, T. Colenutt, and C. Barlow of the wheat molecular genetics lab at AAFC-SCRDC for molecular marker work; M. Knelsen, AAFC, Regina, SK; O. Thompson and E. Schuurmans, AAFC, Indian Head, SK; and R. Dyck, AAFC, Lethbridge, AB, for their assistance in conducting field trials.

For Review Only

© The Author(s) or their Institution(s)

References

American Association of Cereal Chemists. 2000. Approved Methods of the AACC, 10th Ed. St. Paul, MN.

Anonymous. 2015. Prairie Recommending Committee for Wheat, Rye and Triticale. Operating Procedures. [Online]. Available: http://www.pgdc.ca/pdfs/wrt/Proposed%20PRCWRT%20OPS%20-%20FINAL%20DRAFT%20-%2027%20Nov%202013%20Updated%205%20December%202015.pdf [06 Jun. 2020].

Clarke, J.M., McLeod, J.G., McCaig, T.N., DePauw, R.M., Knox, R.E., and Fernandez, M.R. 1998. AC Avonlea durum wheat. Can. J. Plant Sci. **78**: 621-623. doi:10.4141/P98-002.

Clarke, J.M., McLeod, J.G., DePauw, R.M., Marchylo, B.A., McCaig, T.N., Knox, R.E., Fernandez, M.R., and Ames, N. 2000. AC Navigator durum wheat. Can. J. Plant Sci. **80**: 343-345. doi:10.4141/P99-108.

Clarke, J.M., McCaig, T.N., DePauw, R.M., Knox, R.E., Ames, N.P., Clarke, F.R., Fernandez, M.R., Marchylo, B.A., and Dexter, J.A. 2005a. Commander durum wheat. Can. J. Plant Sci. 85: 901 – 904. doi:10.4141/P04-189.

Clarke, J.M., McCaig, T.N., DePauw, R.M., Knox, R.E., Clarke, F.R., Fernandez, M.R. and Ames, N.P. 2005b. Strongfield durum wheat. Can. J. Plant Sci. **85**: 651 – 654. doi:10.4141/P04-119.

Clarke, J.M., Knox, R.E., DePauw, R.M., Clarke, F.R., Fernandez, M.R., McCaig, T.N. and Singh, A.K. 2009a. Brigade durum wheat. Can. J. Plant Sci. **89**: 505 – 509. doi:10.4141/CJPS08168.

Clarke, J.M., Knox, R.E., DePauw, R.M., Clarke, F.R., McCaig, T.N. Fernandez, M.R. and Singh, A.K. 2009b. Eurostar durum wheat. Can. J. Plant Sci. **89**: 317 – 320. doi:10.4141/CJPS08129.

Fetch, T., Mitchell Fetch, J. Zegeye, T. and Xue, A. 2015. Races of *Puccinia graminis* on wheat, oat, and barley in Canada in 2009 and 2010. Can. J. Plant Pathol. **37**: 476-484. doi:10.1080/07060661.2015.1119735.

© The Author(s) or their Institution(s)

For Review Only

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.

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.

Humphreys, D.G., Townley-Smith, T.F., Leisle, D., McCallum, B., Gaudet, D., Gilbert, J. and Menzies, J. 2010. Napoleon Amber durum wheat. Can. J. Plant Sci. **90**: 863-867.

Knox, R.E., Pozniak, C.J., Clarke, F.R., Clarke, J.M., Houshmand, S. and Singh, A.K. 2009. Chromosomal location of the cadmium uptake gene (*Cdu1*) in durum wheat. Genome **52**: 741-747. doi:10.1139/G09-042. PMID:19935921.

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.

McFadden, W. 1991. Etiology and epidemiology of leaf-spotting diseases in winter wheat in Saskatchewan. Ph.D. Thesis, University of Saskatchewan, Saskatoon, SK. 151 pp.

McKenzie, R.I.H., Lamb, R.J., Aung, T., Wise, I.L, Barker, P. and Olfert, O.O. 2002. Inheritance of resistance to wheat midge, *Sitodiplosis mosellana*, in spring wheat. Plant Breed. **121**: 3833-388. doi:10.1046/j.1439-0523.2002.745267.x.

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

Patterson, F.L., Ohm, H.W., Shaner, G.E., Finney, R.E., Gallun, R.L., Roberts, J.J., Foster, J.E.

For Review Only

© The Author(s) or their Institution(s)

1982. Registration of Caldwell wheat. Crop Sci. **22**: 691-692. doi:10.2135/cropsci1982.0011183X002200030081x.

Roelfs, A.P. and Martens, J.W. 1988. An international system of nomenclature for *Puccinia graminis f. sp. tritici*. Phytopathology **78**: 525-533. doi:10.1094/Phyto-78-526.

SAS Institute Inc. 2003. SAS Software. Version 9. SAS Institute Inc. Cary, NC, USA.

Singh, A.K., Clarke, J.M., DePauw, R.M., Knox, R.E., Clarke, F.R., Fernandez, M.R. and McCaig, T.N. 2010. Enterprise durum wheat. Can. J. Plant Sci. **90**: 353–357. doi:10.4141/ CJPS09147.

Singh, A.K., Clarke, J.M., Knox, R.E., DePauw, R.M., Wise, I., Thomas, J., McCaig, T.N., Cuthbert, R.D., Clarke, F.R. and Fernandez, M.R. 2015. AAC Marchwell durum wheat. Can. J. Plant Sci. **95**: 189–195. doi:10.4141/cjps-2014-223.

Singh, A.K., DePauw, R.M., Knox, R.E., Clarke, J.M., McCaig, T.N., Cuthbert, R.D., Ruan, Y. 2017. AAC Cabri durum wheat. Can. J. Plant Sci. **97**: 135-143. doi:10.1139/cjps-2016-0044.

Thomas, J., Fineberg, N., Penner, G., McCartney, C., Aung, T., Wise, I. and McCallum, B. 2005. Chromosome location and markers of *Sm1*: a gene of wheat that conditions antibiotic resistance to orange blossom wheat midge. Mol. Breed. **15**: 183-192. doi:10.1007/s11032-004-5041-2.

Townley-Smith,T.F., DePauw, R.M., Lendrum, C.W.B., McCrystal, G.E., and Patterson, L.A. 1987. Kyle durum wheat. Can. J. of Plant Sci. **67**: 225–227. doi:10.4141/cjps87-026.

For Review Only

© The Author(s) or their Institution(s)

Table 1. Grain yield (kg ha^{-1}) of AAC Succeed and check cultivars in the Durum Cooperative Test, 2014 to 2016 in Zones 1 and 2.

	2014			2015			2016			2014 – 2016		
	Zone[a] 1	Zone 2	Mean[b]	Zone 1	Zone 2	Mean	Zone 1	Zone 2	Mean	Zone 1	Zone 2	Mean
AC Navigator	4045	3349	3490	3640	3099	3197	2887	3190	3128	3509	3164	3232
Brigade	5170	4173	4375	4062	3415	3540	4123	4077	4086	4470	3827	3946
Strongfield	4896	3748	3978	4160	3231	3391	3455	3828	3755	4168	3538	3658
AAC Cabri	5078	3874	4113	3734	3549	3594	3824	3702	3727	4202	3657	3764
Mean of Checks	4797	3786	3989	3899	3324	3431	3572	3699	3674	4087	3547	3650
AAC Succeed	5420	4025	4304	4359	3445	3606	4176	3974	4014	4650	3750	3915
LSD[c]$_{0.05}$	755	356	334	826	182	204	776	469	401	604	274	234
No. of tests	2	8	10	2	9	11	2	8	10	6	25	31

[a]Zone 1 (Black Soils): Indian Head, Brandon; Zone 2 (Brown and Dark Brown Soils): Swift Current, Stewart Valley, Saskatoon, Lethbridge, Vulcan (2014-2015), Moose Jaw (2015), Pense, Scott, Vanguard, Brooks (2016).

[b]Means across Zones in AAC Succeed and individual check cultivars are LS means obtained from the PROC MIXED procedure of SAS; Means across check cultivars are arithmetic mean.

[c]Least significant difference, $P \leq 0.05$, includes the appropriate genotype by environment interaction variation.

For Review Only

© The Author(s) or their Institution(s)

Table 2. Agronomic characteristics of AAC Succeed and check cultivars in the Durum Cooperative Test, 2014-2016.

	Days to maturity[a]			Test Weight[b] (kg hL^{-1})			1000-kernel	Height[b]	Lodging[c]
	Zone 1	Zone 2	Mean[d]	Zone 1	Zone 2	Mean	wt[b] (g)	(cm)	(1-9)
AC Navigator	99.9	101.9	101.5	73.5	78.2	77.5	42.2	77.0	2.9
Brigade	102.6	105.5	104.8	74.4	79.1	78.4	41.9	97.8	2.6
Strongfield	98.7	101.6	101.1	74.9	77.9	77.5	39.8	89.1	3.7
AAC Cabri	100.7	103.8	103.2	75.6	79.0	78.6	39.3	92.4	3.8
AAC Succeed	98.8	101.9	101.4	74.0	77.2	76.8	42.5	90.9	2.7
LSD[e]$_{0.05}$	4.0	1.2	1.1	2.0	0.8	0.7	1.4	2.6	0.9
No. of tests	4	18	22	5	25	30	30	30	14

[a]All Zone 1 and Zone 2 locations, except Brandon (2015) in Zone 1, Vanguard (2014, 2016), Scott (2016), Brooks (2016) and Stewart Valley in Zone 2.
[b]Zone 1 (Black Soils): Indian Head, Brandon (2015-2016); Zone 2 (Brown and Dark Brown Soils): Swift Current, Stewart Valley, Saskatoon, Lethbridge, Vulcan (2014-2015), Moose Jaw (2015), Pense, Scott, Vanguard, Brooks (2016).
[c]Lodging rated on a scale of 1 indicating that all plants in plot are erect to 9 indicating that all plants in a plot are lying horizontal. Swift Current (2014, 2016), Moose Jaw (2015), Saskatoon (2014, 2016), Stewart Valley (2014-2015), Brandon (2016), Pense, Vanguard (2014-2015), Indian Head (2014).
[d]Means are LS means obtained from PROC MIXED procedure of SAS.
[e]Least significant difference, $P \leq 0.05$, includes the appropriate genotype by environment interaction variation.

For Review Only

© The Author(s) or their Institution(s)

Table 3. Grain protein concentration (13.5% moisture basis) of AAC Succeed and check cultivars measured on grain samples bulked across replications at each location of the Durum Cooperative Test, 2014-2016 in Zones 1 and 2.

	2014			2015			2016			2014-2016
	Zone[a] 1	Zone 2	Mean[b]	Zone 1	Zone 2	Mean	Zone 1	Zone 2	Mean	Mean
AC Navigator	12.8	13.3	13.2	14.8	13.5	13.7	13.8	13.8	13.8	13.7
Brigade	12.8	13.0	12.9	14.1	12.8	13.0	12.8	13.8	13.6	13.3
Strongfield	13.5	13.9	13.8	15.2	13.5	13.8	14.3	14.9	14.8	14.2
AAC Cabri	13.5	13.9	13.8	16.3	13.1	13.7	13.4	14.9	14.6	14.1
AAC Succeed	14.0	13.5	13.5	15.1	13.8	14.0	14.3	14.1	14.2	14.0
$LSD^{c}_{0.05}$	-	0.6	0.6	0.9	0.6	0.5	1.2	0.5	0.5	0.3
No. of tests	1	8	9	2	9	11	2	8	10	30

[a]Zone 1 (Black Soils): Indian Head, Brandon (2015-2016); Zone 2 (Brown and Dark Brown Soils): Swift Current, Stewart Valley, Saskatoon, Lethbridge, Vulcan (2014-2015), Moose Jaw (2015), Pense, Scott, Vanguard, Brooks (2016).

[b]Means are LS means obtained from PROC MIXED procedure of SAS.

[c]Least significant difference, $P \leq 0.05$, includes the appropriate genotype by environment interaction variation.

For Review Only

© The Author(s) or their Institution(s)

Table 4. Summary of disease reactions to stem rust, leaf rust, stripe rust, common bunt, loose smut, and leaf spots of AAC Succeed and check cultivars grown in the Durum Cooperative test, 2014-2016.

		Stem rust[a]		Leaf rust[a]		Common bunt[a]		Loose smut[a]		Leaf spot Swift Current			Stripe rust Lethbridge			Stripe rust Creston		
	Year	Severity[b] (%)	Rating[c]	Severity[d] (%)	Rating[c]	Incidence[e] (%)	Rating[c]	Incidence[f] (%)	Rating[c]	Infection response[g]		Rating[c]	Severity[h] (%)	Infection response[i]		Severity[h] (%)	Infection response[i]	
AC Navigator	2014	7	MR	0	R	1	R	7	R	9.8		S	5	R		15	-	
	2015	15	MR	0	R	0	R	0	R	-		-	15	I		-	-	
	2016	5	R	0	R	0	R	14	MR	11.0		S	30	I		35	I	
Brigade	2014	7	MR	0	R	1	R	3	R	8.5		MS	25	MR		25	-	
	2015	5	R	0	R	0	R	0	R	-		-	25	I		-	-	
	2016	10	MR	0	R	1	R	0	R	8.5		I	50	MS		15	MR	
Strongfield	2014	1	R	0	R	1	R	11	MR	8.8		MS	5	R		5	-	
	2015	2	R	0	R	1	R	0	R	-		-	10	MR		-	-	
	2016	15	MR	0	R	0	R	0	R	9.0		MS	15	MR		5	R	
AAC Cabri	2014	10	MR	0	R	0	R	8	R	8.5		MS	20	MR		15	-	
	2015	5	R	0	R	1	R	0	R	-		-	5	R		-	-	
	2016	5	MR	0	R	0	R	0	R	9.0		MS	10	MR		5	R	
AAC Succeed	2014	5	MR	13	MR	0	R	9	R	7.0		I	25	MR		5	-	
	2015	10	MR	0	R	1	R	0	R	-		-	50	S		-	-	
	2016	20	MR	2	R	0	R	5	R	10.5		S	7	R		5	R	

[a]Stem rust: Brandon; Leaf rust: Portage la Prairie (2014), Morden (2015-2016); Loose smut: Modern; Common bunt: Lethbridge.
[b]Severity is a percentage of the stem infected with stem rust using the Modified Cobb Scale.
[c]Rating: VR, very resistant; R, resistant; MR, moderately resistant; I, intermediate; MS, moderately susceptible; S, susceptible.
[d]Severity is a percentage of the leaf infected with leaf rust using the Modified Cobb Scale.
[e]Percentage of total spikes with common bunt symptoms.
[f]Percentage of total plants with loose smut symptoms.
[g]Adult plant, rated mid-grainfill at Swift Current using the McFadden scale (0=no symptoms, 11=severe symptoms) (McFadden 1991).
[h]Severity is a percentage of the leaf infected with stripe rust using the Modified Cobb Scale.
[i]Infection response: VR, very resistant; R, resistant; MR, moderately resistant; I, intermediate; MS, moderately susceptible; S, susceptible.

For Review Only

© The Author(s) or their Institution(s)

Table 5. Summary of *Fusarium* head blight disease reactions of AAC Succeed and check cultivars grown in the Durum Cooperative Test, 2014-2016.

		Fusarium Head Blight						DON (ppm)[e]				ISD[f]				FDK[g]	
		Carman		Morden		Ottawa	PEI[d]					Morden		Carman			
	Year	Index[a]	Rating[b]	Index[a]	Rating[b]	Score[c] (1-100)	Index[a]	Carman	Morden	Ottawa	PEI	Score	Rating[b]	Score	Rating[b]	CM[d] %[h]	PEI 1-9[i]
AC Navigator	2014	56	S	89	S	90	49	42	118	19	87	74	S	28	S	31	8.7
	2015	56	MS	68	S	-	-	70	91	23	26	58	S	45	-	48	8.3
	2016	40	MS	100	S	93	61	62	127	37	28	80	S	40	-	71	7.7
Brigade	2014	19	I	16	R	37	46	30	101	5	47	62	S	20	S	23	9.0
	2015	30	I	29	MR	-	-	45	20	8	19	14	MR	29	-	45	7.3
	2016	20	I	65	MS	43	45	65	63	14	20	41	MS	41	-	83	7.3
Strongfield	2014	40	MS	42	I	53	52	35	80	26	56	51	MS	24	S	24	9.0
	2015	39	MS	67	S	-	-	36	40	13	18	27	MS	24	-	39	8.0
	2016	24	MS	94	S	75	55	56	93	14	22	60	S	36	-	89	7.7
AAC Cabri	2014	32	MS	41	I	27	47	32	72	14	44	46	I	22	S	15	8.3
	2015	41	MS	57	MS	-	-	41	37	13	17	25	I	27	-	41	6.7
	2016	35	MS	69	MS	55	48	56	65	15	23	42	S	36	-	82	7.0
AAC Succeed	2014	51	S	46	I	57	50	32	85	12	37	54	MS	22	S	32	9.0
	2015	55	MS	71	S	-	-	48	38	15	18	26	I	32	-	41	7.7
	2016	43	S	97	S	60	56	56	94	26	22	61	S	36	-	85	7.7

[a]*Fusarium* head blight index: [(mean percent incidence X mean percent severity)/100].
[b]Disease response category: R, resistant; MR, moderately resistant; I, intermediate; MS, moderately susceptible; S, susceptible.
[c]Score is based on a 1–100 scale of spikes infected with *Fusarium* head blight.
[d]CM, Carman; PEI, Prince Edward Island.
[e]DON, deoxynivalenol in parts per million;
[f]ISD, incidence-severity-DON index calculated as (0.2 x mean incidence) + (0.2 x mean severity) + (0.6 x DON).
[g]FDK, *Fusarium*-damaged kernels.
[h]*Fusarium*-damaged kernels on a weight of kernels with *Fusarium* symptoms as a percent of the total sample weight.
[i]*Fusarium*-damaged kernels on a 1 (low) to 9 (high) scale.

For Review Only

© The Author(s) or their Institution(s)

Table 6. Midge response of AAC Succeed and check cultivars from the 2012 Durum A-test and 2015-16 the Durum Cooperative Test.

		Midge reaction[b]			Midge rating[c]
	Year[a]	Resistant	Susceptible	Undamaged	
AC Navigator	2012	0	9	1	S
	2015	0	14	6	S
	2016	0	20	0	S
Brigade	2012	-	-	-	-
	2015	0	17	3	S
	2016	0	20	0	S
Strongfield	2012	0	6	4	S
	2015	0	17	3	S
	2016	0	20	0	S
AAC Cabri	2012	-	-	-	-
	2015	0	18	2	S
	2016	0	20	0	S
AAC Succeed	2012	6	0	4	R
	2015	8	0	12	R
	2016	14	0	7	R

[a]Glenlea (2012), Brandon (2015), Scott (2015), Indian Head (2016), Swift Current (2016).
[b]Total number of spikes of each reaction type to the midge infestation; Resistant: tubby kernels and no third instar larvae; Susceptible: the presence of midge-damaged kernels, third instar larvae, or larval exoskeletons; Undamaged: no observable midge damage.
[c]Midge response category: R, Resistant; S, Susceptible.

For Review Only

© The Author(s) or their Institution(s)

Table 7. End-use suitability[a,b,c] measured on yearly composites of AAC Succeed and check cultivars from 2014 to 2016 in the Durum Cooperative Test.

	FN	HVK	Cd	Milling	Semo	Semo	Wht	Semo	GI		W	Semo YP	Pasta Colour	
	(sec)	(%)	(µg kg^{-1})	YLD (%)	YLD (%)	Ash (%)	Prot (%)	Prot (%)	(%)	P/L	(ergs)	(mg kg^{-1})	b*	a*
AC Navigator	355	76.3	216	75.6	66.9	0.70	13.0	12.1	85.6	1.1	226	9.8	62.9	6.2
Brigade	278	71.0	75	74.7	65.3	0.69	12.9	11.9	94.0	0.8	255	9.7	61.5	5.8
Strongfield	293	72.0	75	74.6	65.3	0.65	13.8	12.7	74.9	0.9	199	8.9	61.4	5.1
AAC Cabri	308	78.0	67	75.0	65.9	0.68	13.5	12.4	74.0	0.6	178	9.9	62.7	5.7
AAC Succeed	287	71.7	87	74.4	65.8	0.71	13.5	12.6	79.8	0.8	239	10.8	62.6	7.2
SD[d]	5	-	1	0.4	0.4	0.006	0.06	0.05	3	0.04	6	0.04	0.3	0.1

[a]American Association of Cereal Chemists methods were followed by the Grain Research Laboratory (GRL), Canadian Grain Commission (CGC) for determining the various end-use suitability traits on a composite of 5-8 locations each year.

[b]FN, Hagberg falling number; HVK, hard vitreous kernel; Cd, grain cadmium; Milling Yld, milling yield; Semo Yld, semolina yield; Wht Prot, wheat protein; GI, gluten index; P/L and W values determined through Alveograph; Semo YP, semolina yellow pigment; spectrophotometer colour b*, yellowness; a*, redness on the CIE scale.

[c]Means are from 2014, 2015 and 2016 durum composites.

[d]SD, standard deviation based on repeated testing of check samples with replicate tests carried out over an extended period of time each season, provided by GRL, CGC.

For Review Only

© The Author(s) or their Institution(s)