CULTIVAR DESCRIPTION

McKenzie hard red spring wheat

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Graf, R. J., Hucl, P., Orshinsky, B. R. and Kartha, K. K. 2003. **McKenzie hard red spring wheat.** Can. J. Plant Sci. **83**: 565–569. McKenzie hard red spring wheat is the first doubled haploid wheat (*Triticum aestivum* L.) cultivar registered in Canada. Evaluation in the Central Bread Wheat Cooperative registration tests from 1994 to 1996 was relative to Neepawa, Katepwa, Roblin and AC Majestic. McKenzie displayed high grain yield, early maturity, high test weight and high Hagberg falling number. It had resistance to the prevalent races of stem rust, leaf rust, and common bunt, and exhibited intermediate resistance to Fusarium head blight. McKenzie is well adapted to all areas of the Canadian prairies and eligible for all grades of Canada Western Red Spring (CWRS) wheat.

Key words: *Triticum aestivum* L., cultivar description, red spring wheat, doubled haploid, grain yield, early maturity

Graf, R. J., Hucl, P., Orshinsky, B. R. et Kartha, K. K. 2003. **Le blé roux vitreux de printemps McKenzie**. Can. J. Plant Sci. **83**: 565–569. McKenzie est le premier cultivar de blé roux vitreux de printemps (*Triticum aestivum* L.) à double haploïdie à être homologué au Canada. Les épreuves de la Central Bread Wheat Cooperative qui ont permis de l'évaluer entre 1994 et 1996 et ont conduit à son homologation le comparaient aux variétés Neepawa, Katepwa, Roblin et AC Majestic. McKenzie se caractérise par un rendement grainier élevé, une bonne précocité, un fort poids spécifique et un haut indice de Hagberg. La variété résiste aux races prévalentes de rouille de la tige, de rouille de la feuille et de carie, et présente une résistance moyenne à la brûlure de l'épi causée par *Fusarium*. McKenzie est bien adaptée aux zones de culture des Prairies canadiennes et est admissibles à toutes les classes de blé roux vitreux de l'Ouest canadien.

Mots clés: *Triticum aestivum* L., description de variété, blé roux vitreux de printemps, haploïde double, rendement grainier, précocité

McKenzie hard red spring wheat (*Triticum aestivum* L.) is the first doubled haploid wheat cultivar registered in Canada. It was developed by Saskatchewan Wheat Pool (SWP), Agricultural Research and Development, Saskatoon, SK. McKenzie received registration No. 4638 from the Variety Registration Office, Canadian Food Inspection Agency on 20 October 1997.

McKenzie wheat is named after Roy Edward McKenzie, P. Ag., FAIC, whose career was dedicated to the practice of agrology and service to farmers. Mr. McKenzie was one of nine individuals who drafted the legislation that established the Saskatchewan Institute of Agrology. During his career, he served as a research officer for Agriculture and Agri-Food Canada (1939–1951), was director of the Plant Industry Branch of Saskatchewan Agriculture and Food (1951–1964), and was the director of the Farm Service Division of Saskatchewan Wheat Pool until retiring in 1982. He was inducted into the Saskatchewan Agricultural Hall of Fame in 1994. During his tenure at SWP, Mr. McKenzie was instrumental in the establishment of internal crop research activities; thus, it was appropriate that the first cultivar developed and registered by SWP be named in his honour.

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Breeding Methods and Pedigree

McKenzie is a doubled haploid wheat cultivar produced from the F_1 hybrid of the cross Columbus/Amidon, made in 1989 at the SWP Agricultural Research and Development Farm in Watrous, SK. Columbus is a CWRS wheat cultivar developed at the Cereal Research Centre, Agriculture and Agri-Food Canada (AAFC), Winnipeg, MB (Campbell and Czarneki 1981); Amidon is a Dark Northern Spring wheat cultivar developed and released by North Dakota State University in 1988. Doubled haploids were produced in collaboration with the National Research Council, Plant Biotechnology Institute in Saskatoon, using the anther culture protocol described by Orshinsky et al. (1990).

Following one generation of greenhouse increase after chromosome doubling, two rows of each doubled haploid line were grown in an irrigated, artificially inoculated stem rust (*Puccinia graminis* Pers.: Pers. f. sp. *tritici* Eriks. & E. Henn.) and leaf rust (*P. triticina* Eriks. = *P. recondita* Roberge ex Desmaz.) screening nursery near Saskatoon in 1991. Selection was based on resistance to stem and leaf rust, maturity, plant height, straw strength, plant vigour, protein content and SDS sedimentation volume. In 1992, an experimental line designated SWP 924-017 was grown under irrigation in a single replicate trial with repeated checks, near Outlook, SK. Stem and leaf rust reaction was determined in an artificially inoculated nursery at Portage la Prairie, MB; the reaction to common bunt [*Tilletia laevis* Kuhn in Rabenh., and *T. tritici* (Bjerk.) G. Wint. in Rabenh.] was determined in a nursery at Watrous. Based on exceptional agronomic performance, good disease resistance and favourable end-use quality results, the line was advanced to multi-location agronomic testing across Alberta, Saskatchewan and Manitoba in 1993, through the cooperation of the Alberta Wheat Pool and Manitoba Pool Elevators. The reactions to stem and leaf rust were verified at Portage la Prairie and Glenlea, MB; common bunt, loose smut [*Ustilago tritici* (Pers.) Rostr.] and common root rot [caused primarily by *Bipolaris sorokiniana* (Sacc.) Shoemaker] resistance was assessed at Watrous, and the response to leaf spots caused by *Septoria tritici* Rob. ex Desm. and *Stagonospora nodorum* (Berk.) was assessed at Outlook.

Evaluation of suitability for registration was conducted as BW205 in the Central Bread Wheat Cooperative (CBWC) registration tests from 1994 to 1996. Agronomic performance was measured relative to Neepawa (Campbell 1970), Katepwa (Campbell and Czarnecki 1987a), Roblin (Campbell and Czarnecki 1987b) and AC Majestic, through the collaborative efforts of AAFC, the University of Saskatchewan and United Grain Growers; disease resistance was assessed by AAFC; end-use quality analysis was performed by the Canadian Grain Commission. The MINITAB GLM procedure was used for the combined statistical analysis of the data presented, in which the effects of environment were considered random and genotypes were fixed (MINITAB Inc. 2000).

During testing in the registration trials, stem and leaf rust seedling infection types were determined by pathologists at the Cereal Research Centre in Winnipeg. The stem rust races used for 1 or more years were: QTH (C25), RTH (C57), RRQ (C63), TMR (C10), TMR (C95) and TPM (C53) (Harder et al. 1994, 1996; Harder 1997). The leaf rust races used for 1 or more years were: Race 1, Race 15, KBG, MBR, MCR, MFM, MJB, TBD, TDG and TDT (Kolmer 1994, 1996; Kolmer and Lui 1997). Field reactions to stem and leaf rust were determined near Glenlea, using races similar to those used for the seedling tests. Reaction to common bunt was determined by inoculating the seed with races L1, L16, T1, T6, T13 and T19 and planting into cold soil at Lethbridge, AB. To determine loose smut reaction, the prevalent races T2, T9, T10 and T39 were mixed and artificially injected into florets at anthesis. Fusarium head blight (caused by *Fusarium* spp.) and leaf spot reactions were assessed in artificially inoculated nurseries near Winnipeg and Charlottetown, PE. The race designations used are those described by Green (1965) and Roelfs and Martens (1988) for stem rust, Long and Kolmer (1989) for leaf rust, Hoffman and Metzger (1976) for common bunt, and Nielsen (1987) for loose smut.

Performance

McKenzie yielded significantly higher than all of the check cultivars in the CBWC test from 1994 to 1996 (Table 1). The mean grain yield of McKenzie was 15.0% higher than Neepawa, 12.8% higher than Katepwa, 18.0% higher than Roblin, and 14.0% higher than AC Majestic. The yield advantage of McKenzie was greatest in Zone 1 (Manitoba), where it yielded 18.2% more than Neepawa, 15.5% more than Katepwa, 24.5% more than Roblin, and 16.5% more than AC Majestic. In Zone 2 (eastern Saskatchewan), McKenzie yielded 12.2% more than Neepawa, 10.1% more than Katepwa, 12.5% more than Roblin, and 11.6% more than AC Majestic. McKenzie had similar maturity to Katepwa, being 0.6 d earlier than Neepawa, 2 d later than Roblin, and 2.3 d earlier than AC Majestic (Table 2). McKenzie was 5 cm shorter than Neepawa and Katepwa, 5 cm taller than Roblin, and 1 cm shorter than AC Majestic, with straw strength equal to Neepawa and Katepwa, but weaker than Roblin and AC Majestic. McKenzie had a higher test weight than all of the check cultivars; seed weight was similar to that of Neepawa, but lighter than the other checks. McKenzie maintained a higher Hagberg falling number than all of the checks except AC Majestic following 48–49 h of artificial weathering in a rainfall simulator.

McKenzie expressed resistance to the prevalent races of stem rust, leaf rust and common bunt during registration testing (Table 3). It was susceptible to loose smut and similar to the check cultivars for root rot reaction. Based on registration test data and additional data collected since registration (not presented), McKenzie has been rated intermediate in reaction to Fusarium head blight.

McKenzie exhibited grain protein content, milling properties, dough functionality and baking performance similar to the check cultivars (Table 4). McKenzie had slightly harder kernel texture and higher starch damage than the checks. Flour yield and farinograph absorption were similar to AC Majestic. Loaf volume was slightly lower than Neepawa. Based on 3 yr of registration testing, McKenzie was deemed equal to Neepawa for grain quality and eligible for all grades of Canada Western Red Spring Wheat.

Upon recommendation for registration by the Prairie Registration Recommending Committee for Grain (PRRCG) in 1997, McKenzie replaced Katepwa as a check cultivar in the CBWC test. As a registration check, long-term data are collected, which provide a more reliable indication of overall performance. During the 7-yr period from 1994 to 2000, McKenzie yielded 19.4% more grain than Neepawa, 23.3% more than Roblin, and 14.8% more than AC Majestic (data not presented). The long-term yield advantage of McKenzie increased in Manitoba (Zone 1), where it yielded 25.4% higher than Neepawa; in eastern Saskatchewan (Zone 2) the

Table 1. Grain yield of McKenzie compared with check cultivars, Central Bread Wheat Cooperative registration test, 1994–1996

	Grain yield (kg ha^{-1})											
	Zone 1[z]					Zone 2					Grand	
Cultivar	1994	1995	1996	Mean	% Np[y]	1994	1995	1996	Mean	% Np	mean	% Np
Neepawa	3820	2800	3620	3350	100	3750	3440	3910	3700	100	3530	100
Katepwa	3960	2880	3660	3430	102	3980	3470	3860	3770	102	3600	102
Roblin	3870	2460	3290	3180	95	4100	3380	3590	3690	100	3440	98
AC Majestic	4150	2550	3700	3400	102	4240	3500	3400	3720	101	3560	101
McKenzie	4400	3310	4390	3960	118	4460	3770	4210	4150	112	4060	115
SE[x]	110	110	120	70		120	110	130	70		50	
LSD[w]	300	280	330	190		320	320	360	200		150	
Tests	4	5	5	14		4	5	5	14		28	

[z]Zone 1, locations in Manitoba; zone 2, locations in eastern Saskatchewan.
[y]Percent of Neepawa.
[x]Standard error of the mean using the genotype-by-environment interaction mean square.
[w]Least significant difference, $P \leq 0.05$, based on mean squares genotype-by-environment interaction.

Table 2. Mean agronomic performance of McKenzie and check cultivars, Central Bread Wheat Cooperative registration test, 1994–1996

	Maturity (d)			Height	Lodging[y]	Test weight	Kernel weight	Hagberg falling
Cultivar	Zone 1[z]	Zone 2	Mean	(cm)	(1–9)	(kg hL^{-1})	(mg)	number (s)[x]
Neepawa	92.9	98.8	96.0	103	2.8	78.1	32.2	193
Katepwa	92.6	98.0	95.4	103	2.7	78.6	33.1	161
Roblin	90.9	95.7	93.4	93	1.5	76.9	34.3	140
AC Majestic	94.6	100.7	97.7	99	1.6	78.9	34.5	234
McKenzie	93.4	97.3	95.4	98	2.6	79.6	32.3	224
SE[w]	0.3	0.5	0.3	0.6	0.1	0.1	0.2	19
LSD[v]	0.8	1.3	0.8	1.8	0.4	0.4	0.7	62
Tests	13	14	27	28	21	30	30	2

[z]Zone 1, locations in Manitoba; zone 2, locations in eastern Saskatchewan.
[y]Lodging rated as 1 = all plants vertical; 9 = all plants horizontal.
[x]Hagberg falling number determined following 48–49 h in a rainfall simulator.
[w]Standard error of the mean using the genotype-by-environment interaction mean square.
[v]Least significant difference, $P \leq 0.05$, based on mean squares genotype-by-environment interaction.

Table 3. Disease reactions of McKenzie and check cultivars, Central Bread Wheat Cooperative registration test, 1994–1996

		Stem	Leaf	Common	Loose	Common	FHB[w]	
Cultivar	Year	rust[z]	rust[z]	bunt[z]	smut[z,y]	root rot[x]	Wpg	Char
Neepawa	1994	5R	40MR	13I	6R	11.0	12	–
	1995	20RMR	50MR	10I	8R	1.3	41	19
	1996	10MRMS	50MRMS	12R	0R	9.0	27	20
Katepwa	1994	10R	30MR	3R	0R	9.0	17	–
	1995	15RMR	50MR	6I	15R	1.3	35	15
	1996	1RMR	50MRMS	15R	13R	7.0	33	22
Roblin	1994	10RMR	30MR	23I	0R	5.0	48	–
	1995	20R	5M	26S	25MR	0.0	74	28
	1996	1R	10M	16I	5MR	7.0	74	48
AC Majestic	1994	10R	10R	1R	40MS	24.0	17	–
	1995	20RMR	10R	0R	61S	0.0	35	17
	1996	1R	20R	3R	38S	4.0	39	26
McKenzie	1994	5R	5VR	0R	61S	19.0	16	–
	1995	50RMR-MS	tR	1R	81HS	0.0	38	21
	1996	3R	tR	2R	90HS	13.0	41	23

[z]Percent infection and type of reaction: t = trace; VR = very resistant; R = resistant; MR = moderately resistant; I = intermediate resistant; MS = moderately susceptible; S = susceptible; HS = highly susceptible.
[y]Ratings for the checks are based on reported data and previous screening results.
[x]Percentage of plants with moderate to large lesions on the subcrown internode.
[w]Fusarium head blight index = (% infected spikelets × % infected spikes)/100. Wpg = Winnipeg, MB; Char = Charlottetown, PE.

yield advantage remained relatively constant at 14.4% higher than Neepawa. The long-term values and relative rankings for McKenzie and the other check cultivars for maturity, height, lodging resistance, test weight, seed weight, and Hagberg falling number were similar to those collected during the 3 yr of registration testing.

Table 4. Mean end-use quality[z] of McKenzie and check cultivars, Central Bread Wheat Cooperative registration test, 1994–1996

Cultivar	Wheat: Protein (%)	Wheat: Ash (%)	Wheat: Amylase (EU)	Hagberg falling no. (s)	Kernel hardness (PSI)	Starch damage (Ferrand units)	Amylograph peak viscosity (B.U.)
Neepawa	14.2	1.58	5.7	387	57.6	31	547
Katepwa	14.3	1.58	6.5	378	56.2	32	607
Roblin	15.0	1.58	7.5	358	59.4	24	495
AC Majestic	14.8	1.57	3.3	417	55.4	32	1033
McKenzie	14.3	1.52	6.7	390	53.1	36	663
Tests	3	3	3	3	3	3	3

Cultivar	Flour: Yield (%)	Flour: Protein (%)	Flour: Ash (%)	Flour: Colour (KJ)	Flour: Amylase (EU)	Farinograph: Absorption (%)	Farinograph: Dough development time (min)	Farinograph: Mixing tolerance index (B.U.)	Farinograph: Stability (min)
Neepawa	75.4	13.7	0.45	–1.3	1.5	66.1	4.3	33	7.5
Katepwa	75.8	13.7	0.45	–1.5	1.3	66.1	4.5	32	8.3
Roblin	75.7	14.5	0.44	–1.2	2.3	66.4	7.3	20	14.7
AC Majestic	76.6	14.3	0.45	–1.3	0.8	67.6	4.7	33	7.5
McKenzie	76.7	13.6	0.45	–1.3	1.3	67.4	5.1	33	7.8
Tests	3	3	3	3	3	3	3	3	3

Cultivar	Extensigraph: Length	Extensigraph: Height	Extensigraph: Area	Extensigraph: L/T	Baking: Canadian short process: Loaf volume (cm^3)	Baking: Canadian short process: Absorption (%)	Baking: Canadian short process: Mixing energy (Whr kg^{-1})	Baking: Canadian short process: Mixing time (min)
Neepawa	23	370	115	6.13	1449	70	8.3	6.5
Katepwa	22	400	120	5.51	1448	70	8.8	7.1
Roblin	26	563	190	4.58	1468	70	12.8	10.5
AC Majestic	24	380	125	6.19	1483	72	10.2	8.2
McKenzie	24	388	125	6.08	1438	71	10.5	8.2
Tests	2	2	2	2	3	3	3	3

[z]American Association of Cereal Chemists (AACC) methods were followed by the Grain Research Laboratory, Canadian Grain Commission for determining the end-use quality characteristics on a composite of six to eight locations per year.

Other Characteristics

SEEDLING: Coleoptile exhibits purple anthocyanin colouration.

SPIKES: Fusiform, slightly inclined at maturity, mid-dense, mid-short to medium length; awns mid-spreading, white, partially deciduous at maturity; glumes mid-narrow, mid-short to medium in length, glabrous, white to yellow; glume shoulders elevated to apiculate, narrow width; glume beak short and acuminate.

CULM: Strong red-purple anthocyanin colouration at maturity in some environments, glabrous upper internode, large proportion of stems are thick-walled at the middle of the internode below the neck.

KERNEL: Medium red colour, mid-size, mid-long, mid-wide, ovate to elliptical; cheeks angular to slightly rounded; crease mid-wide, mid-long; brush size medium to small, hairs short to mid-long; embryo mid-size to small, oval to ovate.

SHATTERING: Resistant, similar to Neepawa.

PHOTOPERIOD RESPONSE: Sensitive.

END-USE QUALITY: Eligible for all grades of Canada Western Red Spring Wheat.

Availability of Propagating Material

Although McKenzie is a doubled haploid cultivar that shows morphological uniformity, a traditional approach was used to produce Breeder Seed. Breeder lines were derived from approximately 200 random head selections taken from an increase plot grown in Watrous in 1992. Following head row increase in 1993, the seed derived from each head row was grown in isolated small plots and inspected for contamination and out-cross progeny. Selected plots were bulked to form pre-breeder seed, which was grown under isolation and inspected as Breeder Seed in 1995. Bulking of the selected plots occurred six generations after the development of the original doubled haploid line.

Breeder Seed is maintained by Saskatchewan Wheat Pool, Agricultural Research and Development, Watrous, Saskatchewan, Canada S0K 4T0. Multiplication and distribution of pedigreed seed stock is handled by Saskatchewan Wheat Pool, Seed Marketing, 2625 Victoria Avenue, Regina, Saskatchewan, Canada S4T 7T9.

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Campbell, A. B. 1970. Neepawa hard red spring wheat. Can. J. Plant Sci. **50**: 752–753.

Campbell, A. B. and Czarnecki, E. M. 1981. Columbus hard red spring wheat. Can. J. Plant Sci. **61**: 147–148.

Campbell, A. B. and Czarnecki, E. 1987a. Katepwa hard red spring wheat. Can. J. Plant Sci. **67**: 229–230.

Campbell, A. B. and Czarnecki, E. 1987b. Roblin hard red spring wheat. Can. J. Plant Sci. **67**: 803–804.

Green, G. J. 1965. Stem rust of wheat, rye and barley in Canada in 1964. Can. Plant Dis. Surv. **45**: 23–29.

Harder, D. E. 1997. Stem rusts on wheat, barley and oat in Canada in 1995. Can J. Plant Pathol. **19**: 171–175.

Harder, D. E., Dunsmore, K. M. and Anema, P. K. 1994. Incidence and virulence of stem rust on wheat, barley and oat in Canada in 1993. Can. J. Plant Pathol. **16**: 329–334.

Harder, D. E., Dunsmore, K. M., Wilson, R. G. and Salmeron, J. J. 1996. Stem rusts on wheat and barley in Canada, and on oat in Canada and Mexico in 1994. Can. J. Plant Pathol. **18**: 379–383.

Hoffman, 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.

Kolmer, J. A. 1994. Physiologic specialization of *Puccinia recondita* f. sp. *tritici* in Canada in 1993. Can. J. Plant Pathol. **16**: 326–328.

Kolmer, J. A. 1996. Physiologic specialization of *Puccinia recondita* f. sp. *tritici* in Canada in 1994. Can. J. Plant Pathol. **18**: 300–302.

Kolmer, J. A. and Lui, J. Q. 1997. Physiologic specialization of *Puccinia recondita* f. sp. *tritici* in Canada in 1995. Can. J. Plant Pathol. **19**: 166–170.

Long, D. L. and Kolmer, J. A. 1989. A North American system of nomenclature for *Puccinia recondita* f. sp. *tritici*. Phytopathology **79**: 525–529.

MINITAB Inc. 2000. MINITAB statistical software. Release 13.32. MINITAB Inc., State College, PA.

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

Orshinsky, B. R., McGregor, L. J., Johnson, G. I. E., Hucl, P. and Kartha, K. K. 1990. Improved embryoid induction and green shoot regeneration from wheat anthers cultured in medium with maltose. Plant Cell Rep. **9**: 365–369.

Roelfs, A. P. and Martens, J. W. 1988. An international system of nomenclature for *Puccinia graminis* f. sp. *tritici*. Phytopathology **78**: 526–533.