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CULTIVAR

Registration of 'Warhorse' Wheat

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ABSTRACT

'Warhorse' (Reg. No. CV-1096, PI 670157) hard red winter (HRW) wheat (*Triticum aestivum* L.) was developed and released by the Montana Agricultural Experiment Station in September 2013. Warhorse is of unknown pedigree, derived from a composite of three topcrosses made to the same F_1 population in 2000: MT9908//'Nuplains'/MTS9862; Nuplains/MTS9862//MTW0047; and Nuplains/MTS9862//MTS0028. Warhorse was developed using a modified bulk breeding method and selected as an $F_{5:6}$ headrow. Warhorse was tested under the experimental number MTS0808 from 2008 to 2013 in Montana. Quality was evaluated in multilocation Montana trials since 2008. Warhorse is a solid-stem, high-yielding HRW wheat line with medium to high test weight, medium maturity, reduced height (*Rht-B1b*), medium to high grain protein, and acceptable milling and baking quality. Warhorse was released for its improved host plant resistance to wheat stem sawfly (*Cephus cinctus* Nort.) conditioned by stem solidness, along with short stature and improved yield potential relative to existing solid-stem cultivars adapted to Montana.

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'Warhorse' (Reg. No. CV-1096, PI 670157) hard red winter (HRW) wheat (*Triticum aestivum* L.) was developed and released by the Montana Agricultural Experiment Station (MAES) in 2013. The name *Warhorse* denotes a strong, powerful, spirited horse used for military service and also refers to a national wildlife refuge located northeast of Grass Range, MT. Warhorse was released for its combination of stem solidness, short stature, high yield potential, and excellent performance in wheat stem sawfly (*Cephus cinctus* Nort.)–infested production environments of north-central Montana. Wheat stem sawfly is the major biotic limitation to wheat production in Montana, reducing kernel weight and grain yield and increasing harvest losses since stems lodge after mature larvae girdle the stem base (Morrill et al., 1992). Solid stems provide resistance due to antibiosis, whereby larvae are unable to survive in the stem. Warhorse is the 10th solid-stem HRW wheat cultivar released by MAES.

Methods

Pedigree and Breeding History

Warhorse is of unknown pedigree, derived from a composite of three topcrosses made to the same F_1 population in 1992: MT9908//'Nuplains'/MTS9862; Nuplains/MTS9862//MTW0047; and Nuplains/MTS9862//MTS0028. MT9908

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Abbreviations: AACC, American Association of Cereal Chemists; HRW, hard red winter; LY, location years; MAES, Montana Agricultural Experiment Station; NRPN, Northern Regional Performance Nursery; RCBD, randomized complete block design.

(MT85200/'Redwin' [CItr 17844]) and MTW0047 ('Judith' [PI 584526; Taylor et al., 1995]/PI 262605//S86-740) are unreleased hollow-stem breeding lines developed by MAES. Nuplains (PI 605741) is a hollow-stem, semidwarf hard white winter wheat line developed by USDA–ARS and University of Nebraska. MTS9862 (MT91366/MTS92137) and MTS0028 (Vanguard [PI 593891; Carlson et al., 1997]//MTSF1570/Norstar [CI 17735]) are unreleased solid-stem breeding lines developed by MAES. The F_1 populations were grown at Bozeman, MT, in 2001. The F_2, F_3, F_4, and F_5 bulk populations were grown at Fort Ellis, Loma, Loma, and North Havre, MT, in 2002 to 2005, respectively, using a modified bulk-breeding method, with mass selection for survival, reduced plant height, favorable head morphology, stem solidness, and kernel plumpness. One hundred-thirteen heads selected from the F_5 population in 2005 were grown as F_6 headrows at Fort Ellis in 2006. Headrow 00X182cE39 was selected based on evaluation of stem solidness and visual criteria for uniformity, productivity, and acceptable agronomic type and harvested in bulk. 00X182cE39 was subsequently tested in the 2007 Sawfly Observation Nursery grown at Bozeman, Havre, North Havre, and Fort Ellis.

Line Selection and Evaluation

In 2008, 00X182cE39 was designated MTS0808 and subsequently tested in the Montana Sawfly Yield Trial from 2008 to 2013 (22 location-years [LY]), in the Montana Advanced Trial planted in 2009 (6 LY), in the Montana Intrastate Trial from 2010 to 2013 (28 LY; Montana State University Agricultural Experiment Station, 2013), and in the Montana Off-Station Nursery planted from 2011 to 2013 (47 LY). Quality has been evaluated in multilocation Montana trials since 2008. In 2012, MTS0808 was an entry in the USDA Northern Regional Performance Nursery (NRPN) planted at approximately 20 sites across the Northern Great Plains (http://www.ars.usda.gov/Research/docs.htm?docid=11932).

The Montana Intrastate Trial consisted of 49 entries planted in a partially balanced lattice or randomized complete block design (RCBD) with three replications. The Montana Off-station Nursery consisted of 24 entries planted in on-farm trials in a RCBD with three replications. The Montana Sawfly trial consisted of 49 entries planted in a partially balanced lattice or RCBD with two replications. Plot size, row number, and row spacing varied by location due to variable plot seeding equipment. The seeding rate in all trials was approximately 2.15 million kernels ha^{-1}. Grain yield, volume weight, plant height (distance from ground to top of spike excluding awns), and grain protein were measured in all harvested trials. Days to heading (50% of heads in plots completely visible) were recorded at most on-station trials. Winter survival (% plants surviving), lodging (% plants lodged), sawfly cutting (% stems cut by wheat stem sawfly), and stripe rust (caused by *P. striiformis* Westend. f. sp. *tritici* Eriks.) (% severity) were recorded in environments where there was differential expression for these traits. Stem solidness was determined in selected environments using five stems per plot, pulled randomly near crop maturity. Five internodes per stem were cross-sectionally cut and visually rated on a quantitative scale of 1 to 5, where 1 designates a hollow (normal) stem and 5 designates a solid stem. Internode scores were summed for each stem, resulting in composite stem solidness scores of 5 (hollow) to 25 (completely solid).

Milling and baking characteristics were determined by the Montana State University Cereal Quality Laboratory using methods approved by the American Association of Cereal Chemists (2000). Grain protein was determined using an Infratec 1225 Grain Analyzer (Foss Analytical). Kernel hardness was determined using a single-kernel characterization system (SKCS-4100, Perten Instruments). Composite grain samples harvested from various locations of the Montana Intrastate and Sawfly Trials from 2008 to 2012 were milled on a Brabender Automat Mill and the flour then used to determine bake absorption, mix time, and loaf volume (AACC Method 10-10B).

Analysis of variance was conducted on data from individual environments and across environments using SAS version 9.2 (SAS Institute). Mean comparison of traits using a protected LSD ($P = 0.05$) test was made to identify significant differences among genotypes, using the genotype environment mean square to estimate the standard error of differences between genotype means across environments.

Seed Purification and Increase

Purification and increase of Warhorse was initiated in 2010 when 120 F_5–derived F_{10} headrows were selected for stem solidness and visual uniformity, retaining 90 linerows. Individual linerows were grown in 2011 and 87 were bulked on the basis of visual uniformity, as a source of breeder seed. Breeder seed of MTS0808 was increased in 2012. Foundation seed of Warhorse was grown and allocated to seed growers of Montana in fall 2013.

Characteristics

Agronomic Characteristics

Warhorse is an awned, solid-stem, semidwarf HRW wheat. It has medium maturity, 169.5 d heading from 1 January, similar to predominant Montana solid-stem cultivars, 'Genou' (PI 640424; Bruckner et al., 2006) and 'Rampart' (PI 593889; Bruckner et al., 1997) (Table 1). Warhorse is semidwarf (*Rht-B1b*) and medium-short (78 cm, $n = 85$), similar to 'Decade' (PI 660291; Riveland et al., 2011), 'Judee' (PI 665227; Carlson et al., 2013a), and 'Bearpaw' (PI 665228; Carlson et al., 2013b), and about 9 cm shorter than Genou and Rampart. Straw strength of Warhorse is good. Warhorse is solid stemmed, averaging 21.3 on the 5 (hollow) to 25 (solid) stem-solidness scale, significantly more solid than Judee (19.6) and Genou (18.2) and similar in stem solidness to Rampart (21.0) and Bearpaw (21.4) (Table 2). Winterhardiness of Warhorse is intermediate, less than the hardiness of Decade but marginally better than that of solid-stem cultivars Rampart, Genou, Judee, and Bearpaw (Table 1).

Warhorse has been genetically uniform and stable over three generations of seed increase. It contains tall plant variants at a frequency less than 20 per 10,000 plants and dark chaff variants at a frequency less than 5 per 10,000 plants.

Table 1. Mean performance of wheat cultivar Warhorse and check cultivars in 83 Montana environments, 2010–2013.

Cultivar	Grain yield	Volume weight	Winter survival	Heading date	Plant height	Lodging	Grain protein	Stripe rust
	kg ha^{-1}	kg m^{-3}	%	d from 1 Jan.	cm	%	g 100 g^{-1}	% severity
Warhorse	4025	761	36	169.5	78	10	13.5	17
Decade	3917	758	50	167.1	79	11	13.4	49
Judee	3863	764	27	168.5	79	17	13.5	18
Bearpaw	3790	757	34	168.3	78	24	13.4	43
Rampart	3440	763	26	169.1	87	28	14.0	36
Genou	3427	758	27	169.2	87	28	13.7	43
LSD (0.05)	181	ns	9	0.4	1	10	0.2	14
No. of environments	83	83	5	37	85	17	78	10

Table 2. Mean stem solidness and performance of wheat cultivar Warhorse and check cultivars in 10 Montana wheat stem sawfly–infested environments, 2010–2013.

Cultivar	Stem solidness	Sawfly-infested environments	
		Grain yield	Sawfly cutting
	5–25†	kg ha^{-1}	%
Warhorse	21.3	3554	4
Rampart	21.0	3118	9
Bearpaw	21.4	3440	13
Judee	19.6	3648	14
Genou	18.5	3292	16
Decade	–	3608	29
LSD (0.05)	0.7	275	9
No. of environments	25	10	10

† 5 = hollow; 25 = completely solid.

Field Performance

In 83 LY of testing in the Montana Winter Wheat Intrastate, Off-station, and Sawfly nurseries, average yield of Warhorse (4025 kg ha^{-1}) was high, similar to the yield of Decade and Judee and about 17% higher than predominantly grown solid-stem cultivars Genou and Rampart (Table 1). Although Warhorse has improved yield potential relative to older solid-stem genotypes, it is not recommended for environments with low levels of wheat stem sawfly since its yield potential is ~7% lower than Montana's predominant hollow-stem cultivar Yellowstone (PI 643428; Bruckner et al., 2007) (data not shown).Volume weight of Warhorse (761 kg m^{-3}) was medium to high and similar to other solid-stem cultivars in this set of environments. Grain protein content of Warhorse is lower than Rampart but similar to Genou, Judee, Decade, and Bearpaw (Table 1).

In 10 north-central Montana environments where significant cutting by wheat stem sawfly was observed, grain yield of Warhorse was 8% and 14% higher than Genou and Rampart, respectively (Table 2). Cutting by wheat stem sawfly of Warhorse (4%) was similar to Rampart and lower than Bearpaw, Judee, and Genou.

Disease and Insect Resistance

Warhorse is resistant to wheat stem sawfly and susceptible to Russian wheat aphid (*Diuraphis noxia* Mordvilko) and Hessian fly [*Mayetiola destructor* (Say)]. Warhorse is resistant to multiple races of stem rust (caused by *Puccinia graminis* Pers.:Pers. f. sp. *tritici* Eriks. & E. Henn.) including race TTKSK (Ug 99) based on screening of the 2012 NRPN by the USDA-ARS Cereal Disease Lab. Warhorse is susceptible to leaf rust (caused by *P. triticina* Eriks.) based on screening evaluations of the 2012 NRPN. Field observations in Montana (Table 1) and screening at Pullman and Mount Vernon, WA, indicate that Warhorse is resistant to stripe rust. DNA marker analysis of the 2012 NRPN shows that Warhorse carries diagnostic markers for *AL-4DL*, *Pina-D1b*, *Ppd-D1b* (sensitive), and *Rht-B1b* (short) (data not shown).

End-Use Quality

Experimental milling using a Brabender Automat Mill indicates that flour yield of Warhorse is intermediate to that of Judee and Rampart, with intermediate flour ash content and medium flour protein (Table 3). Warhorse has intermediate dough mixing characteristics with medium mixing tolerance,

Table 3. Average milling and baking quality attributes of wheat cultivar Warhorse and check cultivars in 15 Montana winter wheat yield trials, 2010–2012.

Cultivar	SKCS† hardness	Flour yield	Flour protein	Flour ash	Baking mix time	Water absorption	Loaf volume
		g 100 g^{-1}			min	g 100 g^{-1}	cm^3
Warhorse	92.7	64.2	11.1	0.42	7.2	70.9	1026
Judee	79.7	62.9	11.2	0.41	8.2	70.5	1100
Rampart	83.7	66.1	11.9	0.41	11.3	72.6	1088
Genou	80.8	65.4	11.5	0.41	10.9	72.5	1057
Decade	80.4	64.4	11.0	0.41	14.8	73.7	1036
Bearpaw	83.3	65.6	10.8	0.41	6.8	69.7	971
LSD (0.05)	2.8	0.9	0.4	0.01	1.2	1.2	32

† Single-kernel characterization system.

water absorption, and mixing time. Warhorse has high loaf volume similar to Genou and Decade but lower than Rampart and Judee. Warhorse has relatively high polyphenol oxidase content and average to poor Asian noodle brightness and color stability (data not shown).

Availability

The Montana Agricultural Experiment Station will maintain breeder seed of Warhorse. U.S. Plant Variety Protection for Warhorse will be sought. A research fee will be assessed on all registered and certified seed sales. All seed requests should be sent to the corresponding author during the period of protection by the Plant Variety Protection Certificate. Seed of this release is deposited in the National Plant Germplasm System, where it will be available after the expiration of the Plant Variety Protection for research purposes, including development and commercialization of new cultivars. It is requested that appropriate recognition be made if this germplasm contributes to the development of new germplasm or cultivars.

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References

American Association of Cereal Chemists. 2000. AACC approved methods. 10th ed. American Association of Cereal Chemists, St. Paul, MN.

Bruckner, P.L., J.E. Berg, G.D. Kushnak, R.N. Stougaard, J.L. Eckhoff, G.R. Carlson, D.M. Wichman, K.D. Kephart, N. Riveland, and D.L. Nash. 2006. Registration of 'Genou' wheat. Crop Sci. 46:982–983. doi:10.2135/cropsci2005.07-0188

Bruckner, P.L., J.E. Berg, N. Riveland, J.L. Eckhoff, D.M. Wichman, K.D. Kephart, G.R. Carlson, G.D. Kushnak, R.N. Stougaard, D.L. Nash, W.E. Grey, A.T. Dyer, Y. Jin, and X. Chen. 2007. Registration of 'Yellowstone' wheat. J. Plant Reg. 1:18–19. doi:10.3198/jpr2006.12.0788crc

Bruckner, P.L., G.D. Kushnak, J.E. Berg, D.M. Wichman, G.R. Carlson, G.F. Stallknect, R.N. Stougaard, J.L. Eckhoff, H.F. Bowman, W.L. Morrill, E.A. Hockett, and K.A. Tilley. 1997. Registration of Rampart wheat. Crop Sci. 37:1004. doi:10.2135/cropsci1997.0011183X003700030052x

Carlson, G.R., J.E. Berg, K.D. Kephart, D.M. Wichman, P.F. Lamb, J.H. Miller, R.N. Stougaard, J.L. Eckhoff, N.R. Riveland, D.L. Nash, W.E. Grey, Y. Jin, J.A. Kolmer, X. Chen, G. Bai, and P.L. Bruckner. 2013a. Registration of 'Judee' wheat. J. Plant Reg. 7:191–194. doi:10.3198/jpr2012.07.0015crc

Carlson, G.R., J.E. Berg, R.N. Stougaard, J.L. Eckhoff, P.F. Lamb, K.D. Kephart, D.M. Wichman, J.H. Miller, N.R. Riveland, D.L. Nash, W.E. Grey, Y. Jin, J.A. Kolmer, X. Chen, G. Bai, and P.L. Bruckner. 2013b. Registration of 'Bearpaw' wheat. J. Plant Reg. 7:180–183. doi:10.3198/jpr2012.07.0009crc

Carlson, G.R., P.L. Bruckner, J.E. Berg, G.D. Kushnak, D.M. Wichman, J.L. Eckhoff, K.A. Tilley, G.F. Stallknect, R.N. Stougaard, H.F. Bowman, W.L. Morrill, G.A. Taylor, and E.A. Hockett. 1997. Registration of Vanguard wheat. Crop Sci. 37:291. doi:10.2135/cropsci1997.0011183X003700010060x

Montana State UniversityAgricultural Experiment Station. 2013. 2013 winter wheat varieties: Performance evaluation and recommendations. http://plantsciences.montana.edu/Crops/2013data/2013%20Winter%20Wheat%20Varieties.pdf (accessed 14 Nov. 2013).

Morrill, W.L., J.W. Gabor, and G.D. Kushnak. 1992. Wheat stem sawfly (Hymenoptera: Cephidae): Damage and detection. J. Econ. Entomol. 85:2413–2417.

Riveland, N.R., J.E. Berg, K.D. Kephart, D.M. Wichman, G.R. Carlson, G.D. Kushnak, R.N. Stougaard, J.L. Eckhoff, D.L. Nash, M. Johnston, W.E. Grey, Y. Jin, X. Chen, and P.L. Bruckner. 2011. Registration of 'Decade' wheat. J. Plant Reg. 5:345–348. doi:10.3198/jpr2011.04.0191crc

Taylor, G.A., H.F. Bowman, D.M. Wichman, G.R. Carlson, J.L. Eckhoff, C.F. McGuire, G.F. Stallknect, G.D. Kushnak, V.R. Stewart, G.D. Jackson, E.A. Hockett, and P.L. Bruckner. 1995. Registration of 'Judith' wheat. Crop Sci. 35:1512–1513. doi:10.2135/cropsci1995.0011183X003500050060x