Registration of 'Ripper' Wheat

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ABSTRACT

'Ripper' (Reg. No. CV-1016, PI 644222) hard red winter wheat (*Triticum aestivum* L.) was developed by the Colorado Agricultural Experiment Station and released in August 2006 through an exclusive marketing agreement with the Colorado Wheat Research Foundation. In addition to researchers at Colorado State University, USDA-ARS researchers in Manhattan, KS, and St. Paul, MN, participated in the development of Ripper. Ripper was selected from the cross CO940606/TAM107R-2 made in 1996 at Fort Collins, CO. CO940606 is an unreleased sib-selection of KS94WGRC29 (PI 586954), a germplasm release from Kansas State University with the pedigree PI 220127/P5///'TAM-200'/KS87H66, while TAM107R-2 is an unreleased sib-selection of the hard red winter wheat cultivar Prairie Red (PI 605390). Ripper was selected as an $F_{3:4}$ line (F_3–derived line in the F_4 generation) in 2000 and assigned experimental line number CO00016. Ripper was released because of its superior grain yield performance under nonirrigated production in eastern Colorado and superior milling and bread-baking quality.

'Ripper' (Reg. No. CV-1016, PI 644222) hard red winter wheat (*Triticum aestivum* L.) was tested under experimental line number CO00016 and released by the Colorado Agricultural Experiment Station in August 2006 through an exclusive marketing agreement with the Colorado Wheat Research Foundation. Researchers at Colorado State University and USDA-ARS researchers at Manhattan, KS, and St. Paul, MN, participated in the development of Ripper. Ripper was released because of its superior grain yield performance under nonirrigated production in eastern Colorado and superior milling and bread-baking quality. The name Ripper was chosen as a slang term referring to "one that is an excellent example of its kind" (Farlex, 2007).

Ripper was selected from the cross CO940606/TAM107R-2 made in 1996 at Fort Collins, CO. CO940606 is an unreleased sib-selection of KS94WGRC29 (PI 586954), a germplasm release from Kansas State University with the pedigree PI 220127/P5//'TAM-200'/KS87H66 (Martin and Harvey, 1997). TAM107R-2 is an unreleased sib-selection of the hard red winter wheat cultivar Prairie Red (PI 605390; Quick et al., 2001b).

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Methods

Early Generation Population Development

Ripper was developed using a modified bulk breeding procedure. All early generation population and line development was done in the greenhouse or an irrigated field-testing location at Fort Collins, CO. The cross between the two parents, designated as cross population X96172, was made in the greenhouse in fall, 1996. The F_1 seed was harvested in January 1997 and immediately planted in a field nursery in mid-February 1997. Seed from the F_1 plants was harvested in bulk in July 1997 and planted in an unreplicated F_2 bulk nursery planted in September 1997. The F_2 bulk nursery was planted under furrow-irrigation in plots 7.9 m long with two rows, spaced 20 cm apart, planted on top of each of two beds spaced 76 cm apart (effective plot area 11.1 m^2). The F_2 bulk nursery included 300 total cross combinations. In July 1998, the F_2 population was harvested in bulk with a small-plot combine. A nonselected subsample of the grain was planted in September 1998, in an unreplicated F_3 bulk nursery with the same plot size as the F_2 bulk nursery. No among-cross selection was practiced. Of the group of 300 different F_3 populations, population X96172

was among a group of 106 populations selected in July 1999 (35% among-cross selection intensity). Each selected population was advanced by random sampling of approximately 100 spikes; selection criteria for advancement included relative plant height and maturity and visual agronomic appearance of the bulk population at harvest. Selected spikes were threshed individually and planted in a furrow-irrigated headrow nursery in September 1999. Headrow selections were planted in a paired-row arrangement 35 cm wide and 1 m long.

Line Selection and Evaluation

Based on visual appraisal of uniformity and agronomic appearance, Ripper was selected from the headrow nursery as an $F_{3:4}$ line in July 2000 and was assigned experimental number CO00016. Between harvest and planting (August 2000), five grams of grain from the selected headrow and approximately 1700 other headrows were subjected to protein (approved method 39-10; AACC, 2000) and hardness (approved method 39-70A; AACC, 2000) analysis via near-infrared reflectance spectroscopy (NIRS) and a modified whole-meal sodium dodecyl sedimentation (SDS) method (Dick and Quick, 1983).

Based on visual observation of grain properties (size, shriveling, color) and values for NIR protein and hardness and SDS sedimentation, Ripper and 1038 other headrows were selected and planted in preliminary yield trials in September 2000. These trials were planted at five locations in Colorado in a single replication, with 'Alliance' (PI 573096; Baenziger et al., 1995) planted as a common check interspersed at regular intervals throughout the nursery (20% total check occurrence). Plots at each location were planted 3.7 m long, six rows wide, with 23 cm spacing between rows; all six rows were harvested (effective plot area 5.1 m^2). During winter 2000–2001, lines advanced to preliminary yield trials were evaluated in standard greenhouse seedling screening tests (Nkongolo et al., 1989) for resistance to Russian wheat aphid (RWA; *Diuraphis noxia* Mordvilko) and dough mixing properties with the computerized Mixograph (AACC approved method 54-40A; AACC, 2000). To account for spatial variation in the unreplicated trials, grain yield of unreplicated experimental lines was calculated using a moving means function (Clarke et al., 1994) and grain yield relative to nearby check plots.

Based on grain yield, grain volume weight (approved method 55-10; AACC, 2000), plant height (height from the soil surface to the tip of the spikes, excluding the awns), heading date (number of days to 50% heading from January 1), RWA resistance, mixograph mixing time and tolerance, and agronomic appearance, Ripper and 129 other lines (12.5% selection intensity) were selected and planted in advanced yield trials in September 2001. These trials were planted in three replications with the same five locations and plot size as the preliminary yield trials. Trials at three locations were either abandoned or too variable for reliable data interpretation because of severe drought stress during the 2002 growing season.

On the basis of grain yield and grain volume weight from two locations in the advanced yield trials, and other characteristics as described above, Ripper and 16 other lines (13% selection intensity) were selected and planted in the Uniform Variety Performance Trial (UVPT) in September 2002. The UVPT is the official, dryland (nonirrigated) state variety trial for Colorado. Plots at each of 10 locations were replicated three times, with each plot 14 m long, six rows wide, with 23 cm spacing between rows; all six rows were harvested (effective plot area 19.2 m^2). Because of continuing drought conditions, reliable yield and grain volume weight data were obtained from only 6 of these 10 locations. During winter 2002–2003, remnant samples of grain were analyzed for milling and bread-baking properties (using AACC approved methods; AACC, 2000) at the USDA-ARS Hard Winter Wheat Quality Laboratory in Manhattan, KS.

On the basis of grain yield, grain volume weight, and other screening data as described above, Ripper and six other lines (44% selection intensity) were selected and advanced for a second year of testing in the UVPT. Ripper was also entered into the cooperative Hard Winter Wheat Southern Regional Performance Nursery (SRPN) and the Colorado Irrigated Variety Performance Trial (IVPT). The IVPT is the official, irrigated state variety trial for Colorado, planted at three locations with three replications at each location. Plot size for the IVPT was 7.9 m long, six rows wide, with 23 cm spacing between rows; all six rows were harvested (effective plot area 10.9 m^2). The 2004 UVPT was planted at 11 locations, compared with 10 locations in 2003, with the same plot size and number of replications as in 2003. In 2004, because of continuing drought, reliable yield and grain volume weight data were obtained from only 5 out of 11 locations.

Using the same criteria as in 2004, Ripper and three other lines (57% selection intensity) were retained for further testing in the 2005 UVPT. Ripper was also entered for a second year of testing in the 2005 SRPN. The 2005 UVPT was planted at the same locations with the same plot size and number of replications as in 2004. Despite continuing drought, reliable yield and grain volume weight data from the UVPT were obtained from 10 out of 11 locations in 2005. These and other data as described above were used in the decision to advance Ripper for a final year of testing in the 2006 UVPT. The 2006 UVPT was planted at the same locations as in 2005, while plot size was reduced to 12.1 m long (effective plot area 16.7 m^2) and the number of replications was increased to four.

Seed Purification and Increase

Seed purification of Ripper began in the 2003 crop year using visual identification and manual removal of tall and red-chaffed off-types from bulk seed increases grown under irrigation at Fort Collins, CO. Seed harvested from the advanced yield trials at Fort Collins in 2002 was planted in a short, unreplicated strip plot (1.3 m wide, 7.9 m long) in fall 2002. During grain filling and again at harvest, strips were rogued to remove tall and red-chaffed variants. A subsample of seed harvested from these strips was planted in a longer strip plot (1.3 m wide, 44 m long) in fall 2003. This strip was rogued as in 2003. In fall 2004, a subsample of seed from this strip was planted in a Breeder seed ($F_{3:10}$) increase block (7.6 m wide, 73 m long) and rogued as in previous years. In 2006 Foundation seed was produced by planting all of the Breeder seed harvested in 2005 in a 5 ha irrigated seed increase block. The Foundation seed increase block ($F_{3:11}$) was rogued as in previous years.

Statistical Analyses

All statistical analyses were done using SAS-JMP Version 6.0.3 (SAS Institute, Cary, NC). Agronomic data (heading date, plant height, coleoptile length, straw strength) and end-use quality

data were analyzed by the Student's paired *t* test procedure. Yield and grain volume weight data from the UVPT and IVPT were subjected to analysis of variance across locations within years and a combined analysis across location-years. Only entries common to the trials across all years (2003–2006 for UVPT, 2004–2005 for IVPT) were included. Within-year analyses were done according to a mixed model with environments and genotypes as fixed factors and replications within environments as random factors. Across-year analyses were also done according to a mixed model with genotypes and location-year combinations as fixed factors and replications within location-year combinations as random factors. Tukey's HSD test ($\alpha = 0.05$) was used to compare the least squares means for the genotype effects. Linear regression of entry mean yield on location mean yield was used to compare variety response across locations.

Characteristics

Agronomic and Botanical Description

Ripper is an awned, white-glumed, early maturing, semidwarf, hard red winter wheat (Table 1). It has early maturity, 139.8 d to heading from 1 January, similar to Prairie Red, 3.1 d earlier than 'Ankor' (PI 632275; Haley et al., 2004), 3.6 d earlier than 'Hatcher' (PI 638512; Haley et al., 2005), and 5.6 d earlier than 'Prowers 99' (PI 612420; Quick et al., 2001a). Plant height of Ripper is short (60.1 cm), similar to Ankor (59.4 cm), and 1.9 cm taller than Prairie Red (58.2 cm), 3.0 cm taller than Hatcher (57.1 cm), and 6.3 cm shorter than Prowers 99 (66.4 cm). Coleoptile length of Ripper (84.1 mm) is similar to that of Prairie Red (82.9 mm), longer than that of Hatcher (76.9 mm) and Ankor (79.5 mm; $P = 0.07$), and shorter than that of Prowers 99 (99.2 mm). Under irrigated and high-yielding nonirrigated conditions, the straw strength of Ripper was good (2.3 score, 1 = erect to 9 = flat scale, $n = 3$ observations), similar to that of Prairie Red (2.0), Hatcher (3.5), and Ankor (3.8). No information is available relative to winter hardiness of Ripper.

Ripper has a semi-erect juvenile plant growth habit with a green plant color at the boot stage and a coleoptile that lacks anthocyanin pigment. Flag leaves of Ripper are erect, not twisted, and show a waxy bloom at the boot stage. Ripper has middense (laxidense), inclined, and tapering heads with white awns. Ripper has white, nonpubescent glumes that are long and narrow with oblique, narrow shoulders and narrow, acuminate beaks. Ripper has kernels that are ovate, red, and hard textured with a short noncollared brush, a rounded cheek, a wide and shallow crease, a midsize germ, and a dark brown phenol reaction.

Table 1. Agronomic data summary for Ripper and check cultivars of hard red winter wheat tested in the Colorado Variety Performance Trials (2003–2006).

Cultivar	Heading date	Height	Coleoptile length	Straw strength
	days from Jan. 1	cm	mm	score†
Ripper	139.8	60.1	84.1	2.3
Ankor	142.9 (<0.001)‡	59.4 (0.423)	79.5 (0.065)	3.8 (0.107)
Hatcher	143.4 (<0.001)	57.1 (0.001)	76.9 (0.024)	3.5 (0.287)
Prairie Red	139.8 (1.00)	58.2 (0.017)	82.9 (0.771)	2.0 (0.465)
Prowers 99	145.4 (<0.001)	66.4 (<0.001)	99.2 (0.001)	–
Observations	15	67	8	6

†Straw strength score: 1 = completely erect to 9 = completely flat at harvest.

‡*P* values (in parentheses) represent the significance of the comparison between Ripper and the respective check cultivar based on a Student's paired *t* test procedure (SAS-JMP version 6.0.3, SAS Institute, Cary, NC).

Ripper was observed to be uniform and stable during the last four generations of seed increase (small strip increase in 2003, large strip increase in 2004, Breeder seed increase in 2005, and Foundation seed increase in 2006). When sexually reproduced, Ripper remains unchanged in its essential and distinctive characteristics. Variants are limited to (i) slightly taller plants that occur at a frequency of fewer than 1 in 1000 plants and (ii) plants with brown glumes that occur at a frequency of fewer than 1 in 1000 plants. The variants in Ripper as well as the typical plants in Ripper are commercially acceptable.

Disease and Insect Resistance

Seedling screening evaluations through the USDA Regional Testing Program showed Ripper to be moderately resistant to stem rust (caused by *Puccinia graminis* Pers.:Pers. f. sp. *tritici* Eriks. & E. Henn.; composite of races MCCF, QFCS, QTHJ, RCRS, RKQQ, TPMK, and TTTT) and susceptible to leaf rust (caused by *P. triticina* Eriks.; composite of races MLRT, MFBP, TKBP, TDGT, and KBQT). The rating scale of infection responses in these evaluations consisted of four classes: R (resistant), MR (moderately resistant), MS (moderately susceptible), and S (susceptible) determined primarily on the basis of the size of uredinia. Based on natural field infection in Colorado in 2003 and 2005 with unknown races, Ripper is susceptible to stripe rust (caused by *P. striiformis* Westend.; 9.0 score, 1 = resistant and 9 = susceptible, $n = 11$ evaluations). Based on cooperative evaluations through the USDA Regional Testing Program, Ripper is moderately susceptible to wheat streak mosaic virus, susceptible to the Great Plains Biotype of Hessian fly [*Mayetiola destructor* (Say)], and susceptible to greenbug Biotype E [*Schizaphis graminum* (Rondani)]. Ripper is resistant to Russian wheat aphid Biotype 1 and susceptible to Russian wheat aphid Biotype 2. Resistance to Russian wheat aphid Biotype 1 in Ripper is conditioned by the *Dn4* resistance gene from the TAM 107R-2 parent, the resistance gene from PI 220127 in the CO940606 parent (temporarily designated as *Dnx*; Liu et al., 2001), or both. Russian wheat aphid resistance scores for Ripper (1.6 score, 1 = very resistant to 5 = very susceptible, $n = 10$ observations) in standard greenhouse seedling screening tests (Nkongolo et al., 1989) using Biotype 1 are similar to cultivars known to carry *Dn4* including Prairie Red (2.1), Hatcher (1.8), and Ankor (1.9).

Field Performance

Ripper was tested at 32 trial locations of the Colorado Dryland UVPT during 2003 (6 locations), 2004 (5 locations), 2005 (10 locations), and 2006 (11 locations). As is typical of field experiments in dryland (nonirrigated) production regions such as eastern Colorado, where drought stress is a common occurrence, groupings for statistical significance for grain yield differences were rather broad (Table 2). This highlights and reinforces the need for multiple-year, multiple-location yield testing during cultivar development in such regions. For the within-year analyses, yield of Ripper was in the top statistical group in each year tested, ranking third in 2003, second in both 2004 and 2005, and first in 2006 (Table 2). In the combined analysis, grain yield of Ripper (2676 kg ha^{-1}) was higher than that of all other cultivars

Table 2. Grain yield and grain volume weight for Ripper and other hard red winter wheat cultivars tested in dryland (nonirrigated) Colorado Uniform Variety Performance Trials (2003–2006). Cultivars are ranked according to the average grain yield across environments.

Cultivar	Grain yield				2003–2006 Average	
	2003	2004	2005	2006	Grain yield	Grain volume weight
	kg ha^{-1}				kg ha^{-1}	g L^{-1}
Ripper	3602 abc †	3502 ab	2595 a	1868 a	2676 a	735 e
Bond CL	3710 ab	3254 ab	2603 a	1746 ab	2618 ab	728 f
Hatcher	3761 a	3244 ab	2385 ab	1786 ab	2571 abc	748 bc
Above	3546 abc	3454 ab	2212 bc	1711 ab	2484 bcd	745 c
Avalanche‡	3388 cd	3402 ab	2206 bc	1762 ab	2462 cd	759 a
Yuma	3560 abc	3250 ab	2053 cd	1761 ab	2422 de	736 de
Jagalene‡	3132 de	3634 a	2204 bc	1649 b	2411 def	764 ab
Alliance	3394 bcd	3115 bc	2148 bc	1766 ab	2401 def	742 cd
Prairie Red	3370 cd	3228 abc	2210 bc	1655 b	2396 def	742 cd
Ankor	3482 abc	3243 ab	1986 cde	1773 ab	2390 def	736 abcdef
Jagger	3093 de	3179 bc	2185 bc	1753 ab	2362 def	736 de
TAM 111‡	3537 abc	3375 ab	1950 cde	1631 b	2361 def	731 cdef
Trego‡	3552 abc	3204 bc	1750 e	1757 ab	2318 efg	736 abcdef
Akron	3334 cde	3140 bc	1819 de	1732 ab	2280 fg	747 abcdef
Prowers 99	3050 e	2833 c	2088 c	1588 b	2213 g	752 b
Average	3434	3271	2160	1729	2424	743
Locations	6	5	10	11	32	32

†Values within a column followed by the same letter are not significantly different at the $\alpha = 0.05$ probability level according to Tukey's honestly significant difference test.

‡Avalanche (PI 620766; Haley et al., 2003b), Jagalene (PI 631376), TAM 111 (PI 631352; Lazar et al., 2004), Trego (PI 612576; Martin et al., 2001).

tested except for Hatcher (2571 kg ha^{-1}) and 'Bond CL' (2618 kg ha^{-1}; PI 639924, Haley et al., 2006), both of which are medium maturing cultivars released by Colorado State University in 2004. In the combined analyses, Ripper showed relatively low grain volume weight (735 g L^{-1}) but not significantly less than several other widely grown cultivars, including Akron (747 g L^{-1}; PI 584504, Quick et al., 1996), Jagger (736 g L^{-1}; PI 593688, Sears et al., 1997), and Yuma (736 g L^{-1}; PI 605388).

As an early-maturing cultivar, Ripper will be positioned as a replacement for other early-maturing cultivars widely grown in Colorado, particularly 'TAM 107' (PI 495594, Porter et al., 1987) and Prairie Red (a backcross-derivative of TAM 107). These two cultivars were grown on a combined 15% of the planted winter wheat acreage in 2007 (Colorado Agricultural Statistics Service, 2007). To determine if the pattern of yield response of Ripper and Prairie Red is consistent from low- to high-yielding locations, we computed the regression of entry mean yield against location mean yield using the dryland data from the UVPT (32 locations from 2003 to 2006). These analyses (Fig. 1) indicate that the slope of the regression equations was similar between the two cultivars (t value = –0.26, $P = 0.80$) while the intercept of the two regressions was significantly different (t value = 22.08, $P < 0.001$). Thus, based on available dryland data, the grain yield advantage of Ripper relative to Prairie Red (280 kg ha^{-1}, 11.7%) is expected to be consistent from low-yielding to high-yielding environments in its primary area of adaptation where drought stress is a common occurrence.

While not recommended for production under irrigated conditions because of its susceptibility to stripe rust, Ripper was tested at five locations of the Colorado IVPT during 2004 (two locations) and 2005 (three locations) (Table 3). Trials in 2005 experienced a severe stripe rust epidemic, and grain yield and grain volume weight of Ripper were adversely affected. Despite the stripe rust infection, grain yield of Ripper in 2005 was similar to several stripe rust–resistant cultivars in the trials. These include 'Dumas' (PI 619199), 'Wesley' (PI 605742, Peterson et al., 2001), and 'NuHorizon' (PI 619198).

Ripper was tested in the 2004 and 2005 Southern Regional Performance Nursery (SRPN). Across locations in the High Plains region, Ripper was the 6th-highest yielding entry in the trial in 2004 (eight location mean yield 3514 kg ha^{-1}; 50 total entries) and the 34th-highest entry in the trial in 2005 (10 location mean yield 2822 kg ha^{-1}; 50 total entries). The difference in average performance in 2004 compared with 2005 is likely due to the susceptibility of Ripper to stripe rust, which was widespread across the High Plains in 2005 but absent in 2004.

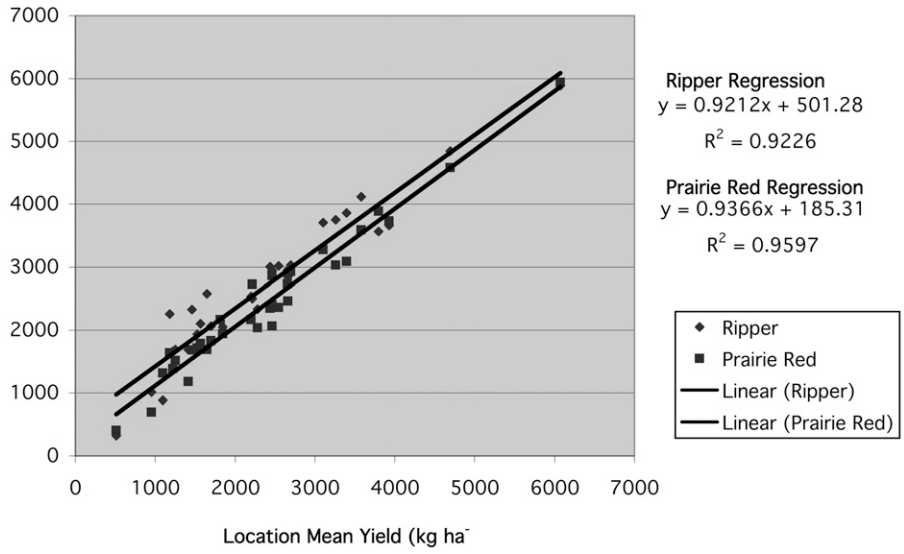

Figure 1. Regression of entry mean on location mean yield for hard red winter wheat (*Triticum aestivum* L.) cultivars Ripper and Prairie Red over 32 dryland (nonirrigated) yield trial locations between 2003 and 2006.

End-Use Quality

Milling and bread-baking characteristics of Ripper were determined from one multilocation composite grain sample in 2002 and six single-location evaluations in 2004 and 2005 ($n = 7$ observations). 'Above' (Haley et al., 2003a), Ankor, and Hatcher were used as checks in these evaluations. Values for milling-related variables were generally superior for Ripper compared with the three check entries

(Table 4). On the basis of Single Kernel Characterization System (SKCS) analysis, Ripper had similar kernel weight (33.0 mg kernel^{-1}) as Above (31.3 mg kernel^{-1}) and Hatcher (30.9 mg kernel^{-1}), higher than Ankor (27.8 mg kernel^{-1}); similar SKCS kernel diameter (2.34 mm) as Above (2.32 mm) and Hatcher (2.24 mm), higher than Ankor (2.13 mm); and similar SKCS kernel hardness index (60.6 score) as Hatcher (62.8 score) and Ankor (60.9 score), lower than Above (67.6 score). Ripper had higher Quadromat Senior flour extraction (663 g kg^{-1}) than Above (648 g kg^{-1}), Hatcher (642 g kg^{-1}), and Ankor (629 g kg^{-1}). Values for baking-related variables were generally superior for Ripper compared to the three check entries (Table 4). Ripper (121 g kg^{-1}) had similar grain protein content as Hatcher (121 g kg^{-1}), Above (122 g kg^{-1}), and Ankor (123 g kg^{-1}). In mixograph tests optimized for water absorption, Ripper had similar water absorption (638 g kg^{-1}) as Above (637 g kg^{-1}), Hatcher (638 g kg^{-1}), and Ankor (638 g kg^{-1}); similar tolerance score (3.0 score; 0 = unacceptable to 6 = excellent scale) as Hatcher (3.4), and higher than Ankor (1.7) and Above (1.5); and similar mixing time (3.2 min) as Hatcher (3.6 min) and Ankor (3.5 min), and longer than Above (2.3 min). In straight-grade pup loaf baking tests, Ripper had similar bake water absorption (632 g kg^{-1}) as Hatcher (629 g kg^{-1}), Ankor (626 g kg^{-1}), and Above (623 g kg^{-1}); similar bake mixing time (4.3 min) as Hatcher (4.7 min) and Ankor (4.3 min), and longer than Above (3.1 min); similar pup loaf volume (0.943 L) as Ankor (0.892 L), and larger than Hatcher (0.872 L) and Above (0.869 L); higher loaf volume:flour protein ratio (7.2 mL g^{-1} kg^{-1}) than Hatcher (6.4 mL g^{-1} kg^{-1}), Ankor (6.4 mL g^{-1} kg^{-1}), and Above (6.3 mL g^{-1} kg^{-1}); and similar loaf crumb grain score (3.6 score; 0 = unacceptable to 6 = excellent scale) as Ankor (3.5), Hatcher (3.1), and Above (2.5). In addition to end-use quality analyses described above, Ripper was entered in the 2006 Wheat Quality Council testing program (2005 crop). Very favorable ratings relative to the check cultivar sample (Ankor) were reported by the Wheat Quality Council cooperators.

Table 3. Grain yield and grain volume weight for Ripper and other hard red winter wheat cultivars tested in the Colorado Irrigated Variety Performance Trials (2004–2005). Cultivars are ranked according to the average grain yield across environments.

Cultivar	Grain yield			Average grain volume weight
	2004	2005	2004–2005 average	
	kg ha^{-1}			g L^{-1}
Bond CL	7583 a	6036 a	6655 a	751 abcd
Hatcher	6826 ab	6026 a	6346 ab	767 ab
Yuma	7701 a	5275 abc	6246 abc	752 abcd
Ankor	7318 ab	5497 ab	6225 abc	746 abcd
NuHills‡	6916 ab	5665 ab	6166 abc	762 abc
Jagalene	6766 ab	5705 ab	6130 abc	774 a
Ripper	7321 ab	5108 abc	5993 abcd	741 bcd
NuFrontier‡	6850 ab	5308 abc	5925 abcd	760 abcd
Ok102‡	7132 ab	5111 abc	5919 abcd	766 ab
Antelope‡	6758 ab	5275 abc	5868 abcd	749 abcd
Overley‡	6900 ab	5157 abc	5854 abcd	764 ab
Dumas	6788 ab	4929 abc	5673 bcd	760 abcd
NuHorizon‡	6688 ab	4812 bc	5562 bcd	768 ab
Wesley	6622 ab	4834 bc	5549 bcd	735 cd
Prairie Red	7228 ab	4327 c	5487 cd	731 d
Platte‡	6215 b	4613 bc	5254 d	761 abc
Average	6976	5230	5928	755
Locations	2	3	5	5

†Values within a column followed by the same letter are not significantly different at the $\alpha = 0.05$ probability level according to Tukey's honestly significant difference test.

‡NuHills (PI 633916), NuFrontier (PI 619089), Ok102 (PI 632635) (Carver et al. 2004); Antelope (PI 633910; Graybosch et al. 2005), Overley (PI 634974), NuHorizon (PI 619198), Platte (PI 596297).

Table 4. Milling and bread-baking characteristics of hard red winter wheat cultivars Ripper, Hatcher, Ankor, and Above across one composite quality evaluation and six individual location evaluations between 2002 and 2005 (*n* = 7 evaluations).

Trait (unit of measurement)	Ripper	Hatcher	Ankor	Above
SKCS† kernel weight (mg)	33.0	30.9 (0.068)‡	27.8 (0.004)	31.3 (0.217)
SKCS kernel diameter (mm)	2.34	2.24 (0.064)	2.13 (0.008)	2.32 (0.570)
SKCS kernel hardness index (score)	60.6	62.8 (0.094)	60.9 (0.897)	65.5 (0.003)
Flour extraction (g kg^{-1})	663	642 (0.038)	629 (0.001)	646 (0.198)
Flour protein content (g kg^{-1})	121	121 (0.932)	123 (0.686)	121 (0.684)
Mixograph water absorption (g kg^{-1})	63.8	63.8 (0.958)	63.8 (0.978)	63.7 (0.937)
Mixograph tolerance (score)§	3.0	3.4 (0.356)	1.7 (0.022)	1.5 (0.011)
Mixograph mixing time (min)	3.2	3.6 (0.070)	3.5 (0.264)	2.3 (0.001)
Bake water absorption (g kg^{-1})	632	629 (0.657)	626 (0.554)	623 (0.097)
Bake mix time (min)	4.3	4.7 (0.109)	4.3 (0.972)	3.1 (0.016)
Loaf volume (L)	0.943	0.872 (0.029)	0.892 (0.060)	0.869 (0.014)
Volume:flour protein ratio (mL g^{-1} kg^{-1})	7.2	6.4 (0.012)	6.4 (0.048)	6.3 (0.003)
Crumb grain score (score)§	3.6	3.1 (0.316)	3.5 (0.708)	2.5 (0.056)

† SKCS, single kernel characterization system.

‡*P* values (in parentheses) represent the significance of the comparison between Ripper and the respective check cultivar based on a Student's paired *t* test procedure (SAS-JMP version 6.0.3, SAS Institute, Cary, NC).

§Mixograph tolerance score: 6 = outstanding, 0 = unacceptable; Crumb grain score: 6 = outstanding, 0 = unacceptable.

Availability

The Colorado Agricultural Experiment Station will maintain Breeder seed of Ripper. Multiplication and distribution rights of other classes of Certified seed have been transferred from the Colorado Agricultural Experiment Station to the Colorado Wheat Research Foundation, 7100 S. Clinton St. Suite 120, Centennial, CO 80112. Ripper has been submitted for U.S. Plant Variety Protection (PVP) under Public Law 91-577 with the Certification Only option. Recognized seed classes will include the Foundation, Registered, and Certified seed classes. A seed sample has been deposited in the USDA-ARS National Center for Genetic Resources Preservation, where it will become available for distribution after expiration of PVP. Small quantities of seed for research purposes may be obtained from the corresponding author for at least five years from the date of this publication. Seed distribution for research purposes will be according to the provisions of the Wheat Worker's Code of Ethics (Annual Wheat Newsletter, 1995).

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