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Registration of 'Antero' Wheat

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ABSTRACT

'Antero' (Reg. No. CV-1093, PI 667743) hard white winter wheat (*Triticum aestivum* L.) was developed by the Colorado Agricultural Experiment Station and released in August 2012 through a marketing agreement with the Colorado Wheat Research Foundation. In addition to researchers at Colorado State University (CSU), USDA–ARS researchers at Manhattan, KS, St. Paul, MN, and Pullman, WA, participated in its development. Antero was selected from the cross KS01HW152-1/'TAM 111' made in 2003 at Fort Collins, CO. TAM 111 (PI 631352) is a hard red winter wheat cultivar released by Texas A&M University in 2002 with the pedigree 'TAM 107'//TX78V3630/'Centurk 78'/3/TX87V1233. KS01HW152-1 is an experimental line from Kansas State University with the pedigree 'Trego' (PI 612576)/'Betty' (PI 612578) Sib. Antero was selected as an $F_{3:4}$ line in July 2007 and assigned experimental line number CO07W245. Antero was released because of its superior grain yield under nonirrigated and irrigated production conditions in eastern Colorado, its resistance to stripe rust (caused by *Puccinia striiformis* Westend. f. sp. *tritici* Eriks.) and stem rust (caused by *Puccinia graminis* Pers.:Pers. f. sp. *tritici* Eriks. & E. Henn), and its milling quality attributes. The name Antero was chosen in recognition of Mount Antero (also known as Antero Peak), one of Colorado's 53 mountains above 4267 m (14,000 ft) elevation.

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Methods

Antero was developed using a modified bulk-breeding method. All early-generation population and line development was done in the greenhouse or at an irrigated field-testing location at Fort Collins, CO. The cross, designated as X030584, was made in the greenhouse in spring 2003. The F_1 seed was harvested in June 2003 and was grown in a winter nursery in Yuma, AZ, in 2004. The F_1 plants were hand harvested in bulk in May 2004, and the F_2 seed was planted in an unreplicated field

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Abbreviations: CSU, Colorado State University; GI, germination index; HWW. hard white winter wheat.

nursery in September 2004. In July 2005, the F_2 population was harvested in bulk with a small-plot combine. Bulk seed from the population was enriched for hard white winter wheat (HWW) seeds using a Satake optical color sorter (Satake USA, Inc.) at the USDA–ARS Engineering & Wind Erosion Research Unit in Manhattan, KS. The HWW fraction of the bulk, designated as population X030584W, was planted in September 2005 in an unreplicated F_3 field nursery under sprinkler irrigation at Fort Collins and under nonirrigated conditions at Akron, CO. In July 2006, the bulk population at Fort Collins was randomly sampled for approximately 200 spikes at maturity. The spikes were threshed individually and planted in a sprinkler-irrigated headrow nursery at Fort Collins in September 2006. On the basis of visual observations of uniformity and agronomic appearance, Antero was selected as an $F_{3:4}$ line in July 2007 and assigned experimental number CO07W245.

Antero was evaluated in eastern Colorado in unreplicated preliminary yield trials in 2008, the advanced yield nursery in 2009, the CSU Elite Trial from 2010 to 2012, statewide nonirrigated variety trials in 2011 and 2012, statewide irrigated variety trials in 2012, the USDA–ARS Coordinated Regional Germplasm Observation Nursery in 2011, and the USDA–ARS Coordinated Southern Regional Performance Nursery in 2012. The advanced yield nursery and CSU Elite Trial were arranged in resolvable, latinized row-column designs (John and Williams, 1995) with two replications, and the state variety trials were arranged in resolvable, latinized row-column designs with three replications.

Seed purification of Antero was done by headrow progeny purification. In summer 2010, 168 single-head selections were made from a seed-increase plot ($F_{3:7}$ generation) of Antero growing under irrigation at Fort Collins. In November 2010, the head selections were planted in a winter seed increase in Yuma, AZ. On the basis of visual observation and removal of off-type progeny rows in Yuma, and visual confirmation of purity of HWW kernel color among the harvested rows, 156 $F_{7:8}$ progeny rows were bulked to form the breeder seed. Breeder seed was used to plant a 2.4-ha foundation seed increase under irrigation at Fort Collins in September 2011. The foundation seed increase was rouged for tall and red-chaffed variants before harvest.

All statistical analyses were performed with SAS-JMP Pro Version 10.0.0 (SAS Institute). Agronomic, disease resistance, and end-use quality data were analyzed by the Student's paired *t* test procedure. Yield and grain volume weight data from the CSU Elite Trial and statewide variety trials were subjected to combined analyses of variance across years and locations using a mixed model with genotypes as fixed factors and location-year combinations and replications within location-year combinations as random factors. Only entries common to the trials across all location-years were included. Tukey's honestly significant difference test ($\alpha = 0.05$) was used to compare the least squares means for the genotype effects.

Characteristics

General Description

Antero is an awned, white-glumed, hard white winter wheat. It has medium maturity, 140.5 d to heading from 1 January, which is 1.7 d earlier ($P < 0.05$; $n = 20$) than 'Snowmass' (PI 658597; Haley et al., 2011), 1.7 d later ($P < 0.05$) than 'Ripper' (PI 644222; Haley et al., 2007), and similar to 'Byrd' (PI 664257; Haley et al., 2012a) and 'Thunder CL' (PI 655528; Haley et al., 2009). Antero is medium height (75.9 cm; $n = 50$), 3.3 cm taller than ($P < 0.05$) Ripper and Thunder CL and similar to Byrd and Snowmass. The coleoptile length (evaluated according to Hakizimana et al., 2000) of Antero (67.2 mm; $n = 6$) is similar to ($P > 0.05$) that of Snowmass (66.1 mm) and Thunder CL (71.4 mm) and shorter than ($P < 0.05$) that of Byrd (72.3 mm) and Ripper (81.9 mm). Antero's straw strength is medium (4.3 score, $n = 11$; 1–9 scale, where 1 = erect and 9 = flat), similar to ($P > 0.05$) that of Thunder CL (3.5), Ripper (4.1), and Byrd (5.2) and better than ($P < 0.05$) that of Snowmass (7.4). Preharvest sprouting tolerance of Antero, assessed through determination of a germination index (GI; Mares et al., 2005) from field-grown samples, is moderate (GI = 0.57; $n = 7$), similar to ($P > 0.05$) that of Byrd (GI = 0.45), Ripper (GI = 0.48), Snowmass (GI = 0.58), and Thunder CL (GI = 0.63), and greater than ($P < 0.05$) that of 'TAM 112' (PI 643143) (GI = 0.74). No objective data are available for winter hardiness of Antero, but field observations and performance under dry soil conditions during recent winters in Colorado suggest that it is at least adequate for successful production in the central Great Plains region.

Disease and Insect Resistance

Antero has been characterized for disease and insect resistance in Colorado and through cooperative evaluations of the USDA Coordinated Regional Testing Program. In greenhouse seedling evaluations at St. Paul, MN, Antero was resistant to U.S. stem rust races QFCSC, QTHJC, RCRSC, RKQQC, and TPMKC, and moderately susceptible to race TTTTF and African race TTKSK. Field adult-plant evaluations at St. Paul in 2012 confirmed that Antero is highly resistant to the North American stem rust races. Adult plant evaluation at Njoro, Kenya, in 2012 indicated it is susceptible to Ug99-related races.

Greenhouse seedling evaluations with leaf rust (caused by *Puccinia triticina* Eriks.) have shown that Antero is susceptible to moderately susceptible to most common leaf rust races in the United States (TDBGG, TBBGJ, MBDSD, TFBJQ, MHDSB, TGBGG, and MLDSD) and resistant to races KFBJG, TCRKG, and TNRJJ, suggesting the presence of the *Lr17* gene. In 2011, under natural field infection with unknown leaf rust races, Antero showed a moderately susceptible adult-plant reaction at Granite, OK, and Bushland, TX (infection type 6 on a 0–9 scale, where 0 = resistant and 9 = susceptible at both locations). In greenhouse seedling evaluations under a low diurnal temperature cycle that gradually changed from 4°C at 0200 h to 20°C at 1400 h (Chen and Line, 1995), Antero was susceptible (infection type 8 on a 0–9 scale, where 0 = resistant and 9 = susceptible) to races PST-100, PST-114, and PST-127 of stripe rust and moderately susceptible (infection type 5) to races PST-37 and PST-45 (Chen et al., 2010). In greenhouse adult-plant tests under a high diurnal temperature cycle gradually changing from 10°C at 0200 h to 30°C at 1400 h (Chen and Line, 1995; Chen, 2005), Antero was moderately resistant to moderately susceptible (infection type 3–5) to races PST-100, PST-114, and PST-127. The standard low- and high-temperature profiles were used to simulate early- and late-season growing conditions and to distinguish usable high-temperature adult-plant resistance from all-stage resistance (also called seedling resistance; Chen, 2005). In artificially inoculated

field tests at Rossville, KS, in 2012, Antero showed a resistant reaction (infection type 2, severity 0 to 1%); the susceptible check 'TAM 107' (PI 495594; Porter et al., 1987) had infection type 7 and 50% severity. Field observations in 2012 of stripe rust severity at other locations in the central Great Plains were similar, whereas field observations at four locations in Washington suggested a moderate degree of resistance to prevalent races in that region. The susceptibility of seedlings at low temperatures and resistance of adult plants in greenhouse and field tests at higher temperatures suggest that Antero has moderate high-temperature adult-plant resistance to stripe rust combined with other resistance genes, including the *Yr17* gene, as suggested by pedigree (from the Betty sib parent) and confirmed by the presence of the Ventriup-LN2 marker (Helguera et al., 2003).

Other evaluations in Colorado or through the USDA Regional Testing Program have shown that Antero is moderately resistant to *Barley yellow dwarf virus* and *Wheat soilborne mosaic virus*. The reaction of Antero to *Wheat streak mosaic virus* is not known, although it lacks the DNA markers associated with *Wsm1* (Qi et al., 2007) and *Wsm2* (Lu et al., 2012). Antero is heterogeneous for resistance to a collection of endemic biotypes of the Hessian fly [*Mayetiola destructor* (Say)] (Chen et al., 2009), susceptible to greenbug Biotype E [*Schizaphis graminum* (Rondani)], and susceptible to Russian wheat aphid (*Diuraphis noxia* Kurdjumov) Biotypes 1 and 2.

Field Performance

Antero was tested at 27 nonirrigated trial locations of the CSU Elite Trial during 2010 (9 locations), 2011 (8 locations), and 2012 (10 locations). In the combined analysis across years, the grain yield of Antero was the second highest in the trial (3877 kg ha^{-1}), similar to ($P > 0.05$) that of Byrd (4018 kg ha^{-1}), 'Denali' (Haley et al., 2012b) (3669 kg ha^{-1}), Ripper (3661 kg ha^{-1}), and 'Hatcher' (Haley et al., 2005) (3651 kg ha^{-1}) and greater than ($P < 0.05$) that of TAM 112 (3560 kg ha^{-1}), 'Winterhawk' (PI 652927) (3501 kg ha^{-1}), Thunder CL (3416 kg ha^{-1}), and Snowmass (3362 kg ha^{-1}). In these trials, Antero had above-average grain volume weight (769 kg m^{-3}), similar to ($P > 0.05$) that of Winterhawk (774 kg m^{-3}), Denali (773 kg m^{-3}), TAM 112 (771 kg m^{-3}), Byrd (768 kg m^{-3}), Hatcher (764 kg m^{-3}), and Snowmass (763 kg m^{-3}) and greater than ($P < 0.05$) that of Thunder CL (754 kg m^{-3}) and Ripper (749 kg m^{-3}).

Antero was tested at 15 trial locations of the nonirrigated Colorado Uniform Variety Performance Trial during 2011 (6 locations) and 2012 (9 locations). In the combined analysis across years, the grain yield of Antero was the second highest in the trial (3624 kg ha^{-1}), similar to ($P > 0.05$) that of Byrd (3664 kg ha^{-1}), TAM 112 (3437 kg ha^{-1}), Hatcher (3377 kg ha^{-1}), Ripper (3363 kg ha^{-1}), and Denali (3362 kg ha^{-1}) and greater than ($P < 0.05$) that of Winterhawk (3267 kg ha^{-1}), Snowmass (3181 kg ha^{-1}), and Thunder CL (3093 kg ha^{-1}). In these trials, Antero had above-average grain volume weight (778 kg m^{-3}), which was less than ($P < 0.05$) that of TAM 112 (784 kg m^{-3}), similar to ($P > 0.05$) that of Denali (781 kg m^{-3}), Winterhawk (779 kg m^{-3}), Byrd (778 kg m^{-3}), Hatcher (772 kg m^{-3}), and Snowmass (769 kg m^{-3}), and greater than ($P < 0.05$) that of Thunder CL (764 kg m^{-3}) and Ripper (759 kg m^{-3}).

Antero was tested at three trial locations of the Colorado Irrigated Variety Performance Trial during 2012. In the combined analysis across locations, the grain yield of Antero was the fourth highest in the trial (7068 kg ha^{-1}), similar to ($P > 0.05$) that of Byrd (6959 kg ha^{-1}), TAM 112 (6648 kg ha^{-1}), and Thunder CL (6641 kg ha^{-1}) and greater than ($P < 0.05$) that of Denali (6281 kg ha^{-1}) and Hatcher (6255 kg ha^{-1}). In these trials, Antero had average grain volume weight (762 kg m^{-3}), similar to ($P > 0.05$) that of TAM 112 (786 kg m^{-3}), Thunder CL (772 kg m^{-3}), Byrd (770 kg m^{-3}), and Denali (767 kg m^{-3}).

Antero was tested in the 2012 Southern Regional Performance Nursery. Averaged across the hard winter wheat region (28 locations), Antero was the second-highest-yielding entry in the trial (4198 kg ha^{-1}; 44 total entries).

End-Use Quality

The milling and bread-baking characteristics of Antero and common check entries were determined using approved methods of the American Association of Cereal Chemists (AACC, 2000) in the CSU Wheat Quality Laboratory. Multiple location-year samples from the 2009, 2010, and 2011 growing seasons were available to enable comparison between Antero and Byrd, Snowmass, and Thunder CL as check entries. The values for milling-related variables were generally superior for Antero compared with those of the check entries (Table 1). Overall, Antero has large kernels, good grain volume weight, low grain ash concentration, good flour extraction (with the Brabender Quadrumat Senior, C.W. Brabender), and low flour ash concentration. Polyphenol oxidase activity (L-Dopa method; AACC, 2000) of Antero is similar to the three checks, and its grain color (L* brightness, measured with Minolta Chroma Meter CR-310, Minolta Camera Co Ltd.) is brighter ($P < 0.05$) than the hard red winter wheat check Byrd but less bright ($P < 0.05$) than the hard white winter wheat checks Snowmass and Thunder CL. Values for baking-related variables were generally inferior for Antero compared with the checks (Table 1), each of which being known as having overall superior dough mixing and bread baking characteristics. Relative to the checks, Antero had shorter Mixograph (National Manufacturing) mixing time and lower mixing tolerance. In straight-dough pup-loaf baking tests, Antero showed shorter bake mix time, lower bake water absorption, lower loaf volume, and lower crumb grain score than the checks.

DNA marker assays for high molecular weight glutenin subunits (Butow et al., 2004; Liu et al., 2008) have shown that Antero carries the 2* subunit (*Glu-A1b* allele) at the Glu-A1 locus, the 7+8 subunits (*Glu-B1b* allele) at the Glu-B1 locus, and the 5+10 subunits (*Glu-D1d* allele) at the Glu-D1 locus. Antero does not carry either the T1BL-1RS or T1AL-1RS translocation.

Availability

The Colorado Agricultural Experiment Station will maintain breeder seed of Antero. 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, 4026 South Timberline Road, Suite 100, Fort Collins, CO, 80525. Antero 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 foundation, registered, and certified. Small

Table 1. Milling, dough-mixing, and bread-baking characteristics of wheat cultivar Antero and check entries across multiple evaluations from the 2009, 2010, and 2011 growing seasons in Colorado.

Trait	Samples	Antero	Byrd	Snowmass	Thunder CL
SKCS† kernel weight (mg)	29	31.0	26.8*	30.3 ns‡	28.8*
SKCS kernel diameter (mm)	29	2.71	2.52*	2.71 ns	2.63*
SKCS kernel hardness (score)	29	63.7	67.3*	77.9*	68.8*
Grain volume weight (kg m^{-3})	16	777	765	763*	755*
Grain ash (g kg^{-1})	29	14.2	14.4*	14.7*	14.6*
Flour extraction (g kg^{-1})	17	698	714*	665*	685*
Flour ash (g kg^{-1})	25	4.2	4.2 ns	4.6*	4.1*
Polyphenol oxidase§	15	0.53	0.51 ns	0.57 ns	0.52 ns
Grain color (Minolta L*)	15	58.0	56.4*	58.7*	60.0*
Grain protein (g kg^{-1})	28	123	124 ns	125 ns	130*
Mixograph mixing time (min)	24	4.4	6.3*	7.3*	4.8*
Mixograph tolerance (0–6) ¶	16	2.7	5.0*	5.7*	4.1*
Bake mix time (min)	16	4.1	6.2*	7.7*	4.6*
Bake water absorption (g kg^{-1})	16	615	630*	637*	634*
Loaf volume (L)	16	0.85	1.05*	0.98*	1.01*
Crumb grain (0–6) ¶	16	2.9	4.6*	5.4*	4.3*

* Significance of the difference between Antero and the check cultivar based on a Student's paired *t* test procedure at the 0.05 probability level.

† SKCS, single-kernel characterization system.

‡ ns, not significant.

§ L-Dopa polyphenol oxidase assay, reported as absorption units at 475 nm.

¶ Scale for mixograph tolerance and crumb grain scores: 6 = outstanding, 0 = unacceptable.

quantities of seed for research purposes may be obtained from the corresponding author for at least 5 years from the date of publication. Seed of Antero has been deposited with the National Plant Germplasm System, where it will be available for distribution on expiration of Plant Variety Protection, 20 yr after publication.

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