Registration of 'TAM 401' Wheat

Jackie C. Rudd,* Ravindra N. Devkota, Allan K. Fritz, Jason A. Baker, Don E. Obert, David Worrall, Russell Sutton, Lloyd W. Rooney, Lloyd R. Nelson, Yiqun Weng, Gaylon D. Morgan, Brent Bean, Amir M. Ibrahim, Arthur R. Klatt, Robert L. Bowden, Robert A. Graybosch, Yue Jin, and Brad W. Seabourn

ABSTRACT

'TAM 401' (Reg. No. CV-1056, PI 658500), a hard red winter wheat (*Triticum aestivum* L.) cultivar with the experimental designation TX03M1096, was developed and released by Texas AgriLife Research in 2008. TAM 401 is an F_4-derived line from the cross 'Mason' (PI 594044)/'Jagger' (PI 593688) made at College Station, TX in the fall of 1997. Mason is a soft red winter wheat cultivar released by AgriPro in 1996, and Jagger is a hard red winter wheat cultivar developed and released by Kansas State University in 1996. TAM 401 is an early maturing, apically awnletted wheat suitable for grain-only, dual-purpose, and graze-out systems. TAM 401 was released primarily for its excellent grain yield potential across a wide range of environments in Texas; good fall and early winter forage potential; resistance to leaf rust (caused by *Puccinia triticina* Eriks.) and stripe rust (caused by *P. striiformis* Westend.); and acceptable hard red winter wheat end-use quality. The proposed primary area of adaptation for TAM 401 will be the warmer and more humid areas such as South Texas, the Blacklands, and the Rolling Plains of Texas, where awnletted or apically awnletted hard red winter wheat cultivars with resistance to leaf rust and stripe rust are very limited.

J.C. Rudd, R.N. Devkota, J.A. Baker, and B. Bean, Texas AgriLife Research and Extension Center, 6500 Amarillo Blvd. W., Amarillo, TX 79106; A.K. Fritz, Dep. of Agronomy, 4012 Throckmorton Plant Sciences Center, Kansas State Univ., Manhattan, KS 66506; D.E. Obert, Limagrain Cereal Seeds, 9020 Grant Road, Battle Ground, IN 47920; D. Worrall, AgriPro, 12167 Hwy. 70, Vernon, TX 76385; R. Sutton, L.W. Rooney, L.R. Nelson, G.D. Morgan, and A.M. Ibrahim, Dep. of Soil and Crop Sciences, Texas A&M University, College Station, TX 77843; Y. Weng, USDA-ARS, Horticulture Dep., 1575 Linden Dr., Univ. of Wisconsin, Madison, WI 53706; A.R. Klatt, Dep. of Plant and Soil Sciences, 368 Ag Hall, Oklahoma State Univ., Stillwater, OK 74078; R.L. Bowden, USDA-ARS, 4007 Throckmorton Plant Sciences Center, Kansas State Univ., Manhattan, KS 66506; R.A. Graybosch, USDA-ARS, 314 Biochemistry Hall, East Campus, Univ. of Nebraska, Lincoln, NE 68583; Y. Jin, USDA-ARS, Cereal Disease Lab., 1551 Lindig Ave., Univ. of Minnesota, St. Paul, MN 55108; B.W. Seabourn, USDA-ARS Hard Winter Wheat Quality Lab., 1515 College Ave., Manhattan, KS 66502.
Registration by CSSA. Received 25 Jan. 2011. *Corresponding author (JCRudd@ag.tamu.edu).

Abbreviations: HPD, High Plains dryland; HPI, High Plains irrigated; RP, Rolling Plains; SKCS, single-kernel characterization system; SRPN, Southern Regional Performance Nursery.

Published in the Journal of Plant Registrations 6:1–6 (2012).
doi: 10.3198/jpr2011.01.0045crc
Posted online 19 Sept. 2011.

5585 Guilford Rd., Madison, WI 53711 USA

'TAM 401' (Reg. No. CV-1056, PI 658500), a hard red winter wheat (*Triticum aestivum* L.) cultivar with the experimental designation TX03M1096, was developed and released by Texas AgriLife Research in 2008. TAM 401 is an early maturing, apically awnletted, semidwarf wheat with light red glumes. It has been tested in all wheat-growing areas of Texas but has shown exceptional performance particularly in the warmer and more humid areas such as South Texas, the Blacklands, and the Rolling Plains. TAM 401 has excellent grain yield potential, good resistance to foliar diseases, particularly leaf rust (caused by *Puccinia triticina* Eriks.) and stripe rust (caused by *P. striiformis* Westend.), and acceptable end-use quality. In comparison with wheat with awns, awnletted or apically awnletted wheat is preferred by cattle grazing on wheat pasture after the spikes have emerged from the boot, but very few of these types of hard winter wheat cultivars are available to Texas producers. TAM 401 will be the first apically awnletted wheat released by Texas AgriLife Research since 'Lockett' (PI 604245) in 1998. Its performance has been excellent not only in Texas but throughout the southern Great Plains.

TAM 401 is an F_4-derived line from the cross 'Mason' (PI 594044)/'Jagger' (PI 593688). Mason is a soft-red winter wheat cultivar released by AgriPro in 1996. Jagger is a hard-red winter wheat cultivar developed and released by Kansas State University in 1996 (Sears et al., 1997).

The proposed primary area of adaptation for TAM 401 will be South Texas, the Blacklands, and the Rolling Plains of Texas. TAM 401 will provide an option to producers in these regions for an apically awnletted cultivar suitable for fall and winter grazing.

Methods

Early-Generation Population Development

The cross between Mason and Jagger was made at College Station, TX in the fall of 1997. The F_1 generation was grown in the greenhouse in spring of 1998. The F_2, F_3, and F_4 generations were grown and harvested in bulk during 1999, 2000, and 2001 at the Texas AgriLife Research farm in McGregor, TX. Random spikes were harvested from the F_4 population in 2001 (year of harvest), and these were grown as $F_{4:5}$ headrows of approximately 1 m in length at McGregor during 2002. Both among- and within-population selection was practiced mainly based on disease resistance and visual agronomic characteristics such as uniformity, heading, plant height, straw strength, and plant type. Approximately 5% of the headrows were selected, including the one that was assigned the experimental number TX03M1096.

Evaluation and Selection of Advanced Lines

TX03M1096 was tested consecutively in the South Texas Breeding Nursery in 2003 (310 entries, 1 location), the South Texas Advanced trial in 2004 (40 entries, 5 locations), the Texas Elite Trial in 2005 (40 entries, 20 locations) and 2006 (40 entries, 18 locations), the Southern Regional Performance Nursery (SRPN) in 2006 (50 entries, 28 locations) and 2007 (50 entries, 27 locations), and the Texas Uniform Variety Trial in 2007 (40 entries, 27 locations). Lines were advanced based on agronomic traits, disease resistance (particularly to leaf rust and stripe rust), grain yield, and grain volume weight. As appropriate, additional data on disease and insect resistance from 2006 and 2007 SRPN (http://www.ars.usda.gov/Research/docs.htm?docid=11932; verified 25 Aug. 2011) were also considered for selection. In addition, analysis with the single-kernel characterization system (SKCS) and/or small-scale milling and breadbaking evaluations were performed according to approved methods of the American Association of Cereal Chemists (AACC, 2000) in the cereal quality lab at College Station, TX and the USDA-ARS Hard Winter Wheat Quality Lab at Manhattan, KS.

During the evaluation and selection process, different sets of checks were used for comparison based on the known reaction to the traits and environments being evaluated. Among the TAM-series cultivars released by Texas AgriLife Research, 'TAM W-101' (CItr 15324; Porter, 1974) is the standard long-term check, 'TAM 110' (PI 595757; Lazar et al., 1997) is a popular cultivar resistant to greenbug Biotype E [*Schizaphis graminum* (Rondani)], 'TAM 111' (PI 631352; Lazar et al., 2004) is currently the no. 1 cultivar in the state of Texas, and 'TAM 203' (PI 655960) and 'TAM 304' (PI 655234) are recent releases. 'Sturdy 2K' (PI 636307), also released by Texas AgriLife Research in 2000, is a popular dual-purpose wheat. Jagger, a Kansas State University release, is one of the parents of TAM 401. 'Fannin' (PI 639231), 'Coronado' (PI 591625), and 'Longhorn' (PI 552813) (awnletted) are popular cultivars released by AgriPro.

Seed Purification and Increase

Seed purification started in the fall of 2005 by planting 48 headrows in Yuma, AZ. Following visual evaluation for uniformity, 3 were eliminated, and the remaining 45 rows were harvested in bulk. This seed was used by Texas Foundation Seed Service to plant 0.8 ha in the fall of 2006 to produce breeder seed, which was further planted on 8 ha in the fall of 2007 to produce foundation seed.

Statistical Analysis

Statistical analyses were done with SAS version 9.1 (SAS Institute, Cary, NC). Analysis of variance for individual locations as well as combined analyses across locations and years were performed with a mixed model that had genotypes and environments as fixed and replications within environments as random factors. Least significant difference values at $P = 0.05$ were used to compare means among entries.

Characteristics

Agronomic and Botanical Description

TAM 401 is an early maturing cultivar with an average heading date (d from 1 January) ranging from 102 d on the Texas Rolling Plains (RP) to 125 d on High Plains dryland (HPD) (Table 1). It was earlier than Longhorn (the only awnletted check) and TAM 111 but similar to TAM 110, Jagger, Fannin, and Coronado across all three environments. The long-term standard check TAM W-101 had a similar heading date as TAM 401 on High Plains irrigated (HPI) land but was later on the RP and HPD. TAM 401 is a semidwarf wheat with a height similar to that of Jagger and Fannin and it has good straw strength. The average height of TAM 401 ranged from 68 cm on HPD to 84 cm on the RP (Table 1). On HPI it was shorter than Longhorn but similar to the remaining checks. On HPD it was taller than TAM W-101 and Coronado, shorter than Longhorn, and similar to the rest of the checks. On the RP it was taller than TAM W-101 and TAM 110 but similar to the rest of the checks.

TAM 401 is semierect during the juvenile plant growth stage and is green at the boot stage. It lacks anthocyanin in both the coleoptile and stem. The anthers are yellow. TAM 401 has a waxy bloom with hollow stem internodes, erect and twisted flag leaves, and semierect peduncles. It has a tapering, middense (laxidense), and inclined spike with light red glumes at maturity. The glumes are medium in length and width with an oblique shoulder and an obtuse beak of medium width. TAM 401 is apically awnletted and has hard, red kernels of ovate shape with a medium-size germ, rounded cheeks, and noncollared medium brush.

The plant uniformity of TAM 401 was stable during the last four generations of seed purification and increase (small increase strips at Bushland in 2005; seed purification at Yuma, AZ in 2006; breeder-seed increase at Vernon, TX in 2007; and foundation-seed increase at Vernon in 2008). A variant with the same spike type and glume color but that was 5–10 cm taller than the other plants, and red-glumed and white-glumed awned, off-type plants were observed at a low frequency (<0.05%) and were removed during the

Table 1. Summary of agronomic performance and resistance to leaf and stripe rust of TAM 401 hard red winter wheat and other check cultivars evaluated from 2005 to 2007 within different regions in Texas.†

	Heading			Plant height			Leaf rust‡	Stripe rust‡	
Cultivar	HPI	HPD	RP	HPI	HPD	RP	2005–2007	2005–2007	2010 Castroville
	d from 1 January			cm					
TAM 401	122.8	125.0	102.3	78.0	68.0	84.0	t–5R	tR	20MSMR
TAM W-101	123.2	127.3	107.3	74.3	62.8	73.7	5MR–10S	80S	30MS
TAM 110	120.4	124.8	100.7	75.7	65.4	76.5	60–80S	100S	60S
TAM 111	124.8	126.7	107.5	80.3	70.5	83.3	10MS–40S	10R	tR
Jagger	120.8	124.3	100.7	79.7	69.4	84.5	80S	20MR	40MS
Fannin	123.2	124.4	102.0	80.1	67.7	83.8	tR–20MS	10R	tR
Coronado	122.1	125.6	103.7	73.8	60.4	77.7	5R–20MRMS	60S	20S
Longhorn	127.6	128.8	111.0	83.7	71.8	87.3	tR-tS	80S	N/A
Mean	122.8	125.8	104.3	78.3	66.9	81.8			
CV (%)	1.3	0.9	1.1	4.8	4.9	3.6			
LSD (0.05)	2.6	1.5	2.4	5.4	3.5	6.2			
Location-years	3	4	2	4	7	2	4	2	

†Based on the Texas Wheat Regions Map: HPI, High Plains irrigated; HPD, High Plains dryland; RP, Rolling Plains.

‡Field scores: severity in percent of flag-leaf area infected (t, trace) and reaction (infection type) in the field at soft dough stage; R, resistant; MR, moderately resistant; MS, moderately susceptible; and S, susceptible.

initial stages of seed increase. Both the tall variant and the awned off-types may occur in future generations of seed increase at a low percentage (<0.05%).

Disease and Insect Resistance

Based on natural field infection during various stages of testing over the years 2005–2007 across a wide range of environments, TAM 401 has been consistently resistant to leaf rust and stripe rust (Table 1). The severity of leaf rust for TAM 401 ranged from a trace (t) to 5% with resistant (R) reaction types in contrast to a severity of 80% with susceptible (S) reaction types for TAM 110 and Jagger. In 2005 there were widespread epidemics of stripe rust in Texas, and TAM 401 showed resistance (tR). In 2010 the prevalent race of stripe rust appeared virulent on cultivars postulated to have *Yr17* and that were previously considered resistant. TAM 401 showed an intermediate reaction (20MSMR) to stripe rust in the 2010 rust screening nursery at Castroville, TX, so it may have *Yr17* and one or more adult-plant resistance genes. When TAM 401 was included in the SRPN in 2006 and 2007, it was evaluated for various diseases and insects under the USDA regional testing program (http://www.ars.usda.gov/Research/docs.htm?docid=11932; verified 25 Aug. 2011). Based on the seedling stem rust (caused by *Puccinia graminis* Pers.:Pers f. sp. *tritici* Eriks. & E. Henn.) evaluation conducted by the USDA-ARS Cereal Disease Laboratory at St. Paul, MN, TAM 401 is resistant to the most prevalent stem rust race in Texas and the United States (QFCS) but is susceptible to race TTKSK (Ug99). Also, based on the seedling leaf rust evaluation of 2006 and 2007 SRPN entries at the Cereal Disease Laboratory, it is resistant to the most prevalent races of leaf rust—THBJ, KFMJ, MJBJ, and MCDS—and is postulated to have gene *Lr9* and possibly *Lr24*. Additional data on disease and insect resistance from the 2006 and 2007 SRPN indicated that TAM 401 has intermediate reactions (scores of 2–3 on a scale of 1–4, where 1 = resistant, and 4 = susceptible) to *Wheat soilborne mosaic virus* and *Wheat streak mosaic virus*; however, it is susceptible to greenbug biotype E, Russian wheat aphid [*Diuraphis noxia* (Mordvilko)] biotype 1, and Hessian fly [*Mayetiola destructor* (Say)] Great Plains biotype. Based on natural field infection over the years, it is also susceptible to powdery mildew [caused by *Blumeria graminis* (DC.) E.O. Speer].

TAM 401 was evaluated for resistance to Karnal bunt (caused by *Tilletia indica* Mitra) in the third Winter Wheat Karnal Bunt Screening Nursery, which was planted at Yaqui Valley, Sonora, Mexico, and at Ludhiana, Punjab, India, in 2005. The nursery was not replicated, but the susceptible check 'Karl 92' (PI564245) was replicated 12 times. TAM 401 had significantly lower disease severity than Karl 92 and was as good as or better than the resistant check W485/HD29 (Table 2). It was also evaluated in the fourth, fifth, and seventh Winter Wheat Karnal Bunt Screening Nurseries, but the results were inconclusive mainly because of the inconsistency and/or low level of disease severity across the field.

Table 2. Summary of Karnal bunt resistance data from the third Winter Wheat Karnal Bunt Screening Nursery, planted in Mexico and India in 2005.†

		Mexico	
Name	India	Lights‡	No lights
	Disease severity (%)		
TAM 401	19.8	2.8	0.0
W485/HD29 (resistant check)	19.8	—	0.6
Karl 92 (susceptible check)§	61.4 ± 11.2	8.7 ± 5.2	10.39 ± 7.1
Mean of trial	53.3	6.2	5.8
Entries evaluated	523	493	487

†Screening nursery in Mexico conducted by Guillermo Fuentes of CIMMYT in the Yaqui Valley, Sonora; screening nursery in India conducted by Punjab Agricultural University at Ludhiana, Punjab.

‡Supplemental lights provided to accelerate flowering in photoperiod sensitive lines.

§Karl 92 was repeated 12 times in the nursery; the values represent the mean disease severity followed by SD.

Grain Yield

TAM 401 was tested in Texas across 20 locations in 2005, 18 in 2006, and 27 in 2007, but useful grain yield data were reported only from 10, 8, and 21 locations, respectively. Based on the Texas Wheat Regions Map (p. 2 at http://varietytesting.tamu.edu/wheat/docs/2010/Wheat%20Binder.pdf; verified 25 Aug. 2011), these 39 location-years were grouped into four major regions in which the High Plains accounted for 18 (8 under irrigation and 10 under dryland), the Rolling Plains for 8, the Blacklands for 6, and South Texas for 7. Across these multiple locations over 3 yr, TAM 401 was one of the highest-yielding entries in every production region of Texas, but it performed exceptionally well in the warm and humid areas of South Texas, the Blacklands, and the Rolling Plains, where foliar-disease pressure was high (Table 3). In the South Texas and Blacklands regions, TAM 401 was significantly higher yielding than almost all of the check cultivars. In the Rolling Plains, TAM 401 was significantly higher yielding than TAM W-101, Coronado, and Longhorn but not significantly different than TAM 110, TAM 111, Jagger, and Fannin. In the High Plains (both dryland and irrigated), TAM 401 was either significantly higher yielding or similar to the check cultivars. TAM 401 was significantly higher yielding than the awnletted check Longhorn in all environments except the HPD, where its performance was similar to that of Longhorn. TAM 401 appears to have a wide area of adaptation, not only in Texas but also across the southern Great Plains. The USDA-ARS-coordinated SRPN evaluates the most advanced experimental lines from Great Plains hard wheat breeding programs and is grown across nine states. TAM 401 ranked 27th out of 50 entries across 28 locations in 2006 and 7th out of 50 entries across 27 locations in 2007 (data not shown).

Table 3. Grain yield of TAM 401 hard red winter wheat and other check cultivars averaged over location-years from 2005 to 2007 within different regions in Texas.†

	Grain yield				
Cultivar	HPI	HPD	RP	BKLD	ST
	kg ha^{-1}				
TAM 401	4855	2915	3075	4155	3378
TAM W-101	3851	2724	2300	2724	2529
TAM 110	4310	3100	2737	2597	1712
TAM 111	5215	3192	2898	3137	1994
Jagger	4119	3167	2776	2516	2145
Fannin	3901	2700	2796	4229	2798
Coronado	3855	2917	2561	3555	2902
Longhorn	3710	2674	2289	2662	2316
Mean	4386	3045	2829	3427	2602
CV (%)	12.8	14.7	13.9	14.5	14.2
LSD (0.05)	558	395	388	570	406
Location-years	8	10	8	6	7

†Regions based on Texas Wheat Regions Map: HPI, High Plains irrigated; HPD, High Plains dryland; RP, Rolling Plains; BKLD, Blacklands; ST, South Texas.

Forage Yield

The 2005–2007 yield trials at Claude, TX were grazed until late February, and the grain yield data from these 3 yr at Claude indicated that TAM 401 withstands grazing as well as currently grown cultivars and can be used in a dual-purpose (grazing-plus-grain) system. The 3-yr-average grain yield of TAM 401 (3203 kg ha^{-1}) from Claude was not significantly different from that of TAM 111 (3516 kg ha^{-1}). Forage trials conducted at Overton, TX during the 2006–2007 through 2008–2009 growing seasons (Table 4) indicated that TAM 401 is an excellent forage producer during the fall and early winter but may produce relatively less forage in the spring, most probably as a result of early maturity. Additional forage yield data can be found at http://overton.tamu.edu/forages/ryegrass/index.php (verified 25 Aug. 2011). Compared with awned cultivars, apically awnletted cultivars like TAM 401 are generally preferentially grazed by cattle after heading under graze-out conditions.

End-Use Quality Evaluation

The average grain volume weight of TAM 401 was not significantly different than that of Jagger but was significantly lower than Fannin's across all environments (Table 5). However, the grain volume weights of the remaining checks were either significantly higher or not significantly different than that of TAM 401, depending on the environment. TAM 110 was the only cultivar that had a significantly lower volume weight than TAM 401 in the Blacklands and South Texas region. Based on SKCS analysis, the kernel weight of TAM 401 (Table 6) was not significantly different than Jagger's across all environments, but it was either significantly lower than, or similar to, those of the remaining checks, depending on the environment. The flour protein content (14% moisture basis) of TAM 401 was significantly higher than that of TAM W-101, TAM 110, and TAM 111 in the Blacklands and TAM 110 in HPI; significantly lower than that of Jagger, Fannin, Coronado, and Longhorn in HPD; and similar to that of the checks in RP (Table 6). Kernel hardness index scores based on SKCS analysis ranged from 56 for TAM 111 in HPI to 75 for Jagger in Blacklands; TAM 401 varied from 60 in HPD to 68 in RP (kernels with a score of >50 are categorized as "hard") (Table 6). Mixograph and bread-baking evaluation conducted by the USDA-ARS Hard Winter Wheat Quality Laboratory at Manhattan, KS (p. 4–7 at http://www.ars.usda.gov/SP2UserFiles/Place/54300510/2010%20RPN.pdf; verified 25 Aug. 2011) on 2004 and 2005 Texas Wheat Variety Trials from three Texas High Plains locations (Bushland irrigated, Etter irrigated, and Claude) indicated that TAM 401 had average milling and baking qualities with a relatively short mixing time and low mixing tolerance, but it had an average loaf volume that was similar to that of TAM 111 (Table 7).

Availability

Proposed seed classes will include Breeder, Foundation, Registered, and Certified. TAM 401 was submitted for U.S. Plant Variety Protection (PVP) under Public Law 91-577 with the Certification Only option, and a PVP certificate has been issued (No. 200900486). A small quantity of seed for research purposes may be obtained from the corresponding author for at least 5 yr from the date of this publication abiding by the Wheat Workers' Code of Ethics (Annual Wheat Newsletter, 1995).

Table 4. Dry weight forage yield of TAM 401 hard red winter wheat and other check cultivars harvested during fall, winter, and spring of 2006–2007 through 2008–2009 growing seasons at Texas AgriLife Research in Overton, Texas.†

	Fall	Winter		Spring		
Cultivar	12 Dec. 2006	7 Feb. 2007	5 Mar. 2007	23 Mar. 2007	27 Apr. 2007	Total
	kg ha^{-1}					
TAM 401	557	1136	1474	1056	1596	5818
TAM 111	304	172	1399	1950	1644	5469
TAM 203	67	496	1648	1239	1851	5301
Fannin	327	580	1222	1294	1460	4883
Sturdy 2K	414	364	1189	1822	2326	6116
Mean	376	561	1458	1467	1875	5738
CV (%)	56	39	14	14	21	13
LSD (0.05)	246	258	236	245	880	1754
n	24	24	24	24	24	24

	Fall	Winter		Spring		
Cultivar	20 Dec. 2007	14 Feb. 2008	11 Mar. 2008	7 Apr. 2008	7 May 2008	Total
TAM 401	829	1486	1241	1412	588	5556
TAM 111	963	1107	1632	2137	346	6185
TAM 203	591	921	1398	1600	409	4919
Fannin	959	1111	1308	1172	272	4822
Sturdy 2K	794	993	1583	2344	356	6070
Mean	1127	1167	1364	1551	404	5644
CV (%)	36	24	20	23	45	14
LSD (0.05)	575	392	380	506	254	548
n	40	40	40	40	40	40

	Fall	Winter		Spring	
Cultivar	13 Nov. 2008	20 Jan. 2009	25 Feb. 2009	1 Apr. 2009	Total
TAM 401	2109	1189	1434	1002	5734
TAM 111	1975	467	1359	1889	5690
TAM 203	2043	549	1202	1583	5376
Fannin	1960	1076	1427	1085	5548
Sturdy 2K	1312	692	1051	2228	5282
Mean	1850	786	1401	1574	5612
CV (%)	24	29	23	21	13
LSD (0.05)	526	271	384	398	864
n	26	26	26	26	26

†Source: http://overton.tamu.edu/forages/ryegrass/index.php (verified 13 Apr. 2011).

Acknowledgments

TAM 401 was developed with partial funding from Texas AgriLife Research and Texas Wheat Producers Board.

References

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

Annual Wheat Newsletter. 1995. Wheat worker's code of ethics. Available at http://wheat.pw.usda.gov/ggpages/awn/41/awn41a2.html#report3 (verified 13 Apr. 2011).

Lazar, M.D., W.D. Worrall, G.L. Peterson, A.K. Fritz, D. Marshall, L.R. Nelson, and L.W. Rooney. 2004. Registration of 'TAM 111' wheat. Crop Sci. 44:355–356.

Lazar, M.D., W.D. Worrall, G.L. Peterson, K.B. Porter, L.W. Rooney, N.A. Thuleen, et al. 1997. Registration of 'TAM 110' wheat. Crop Sci. 37:1978. doi:10.2135/cropsci1997.0011183X003700060055x

Porter, K.B. 1974. Registration of 'TAM W-101' wheat. Crop Sci. 14:608. doi:10.2135/cropsci1974.0011183X001400040050x

Sears, R.G., J.M. Moffatt, T.J. Martin, T.S. Cox, R.K. Bequette, S.P. Curran, et al. 1997. Registration of 'Jagger' wheat. Crop Sci. 37:1010. doi:10.2135/cropsci1997.0011183X003700030062x

Table 5. Grain volume weight of TAM 401 hard red winter wheat and other check cultivars averaged over location-years from 2005 to 2007 within different regions in Texas.†

	Grain volume weight				
Cultivar	HPI	HPD	RP	BKLD	ST
	kg m^{-3}				
TAM 401	748	734	755	732	723
TAM W-101	762	757	768	744	716
TAM 110	745	738	751	701	692
TAM 111	785	762	781	743	716
Jagger	750	742	759	723	712
Fannin	775	762	777	778	759
Coronado	750	752	781	753	739
Longhorn	759	759	769	735	721
Mean	760	753	772	740	726
CV (%)	2.3	1.7	1.7	2.8	1.7
LSD (0.05)	19	12	13	30	14
Location-years	7	9	8	6	6

†Based on Texas Wheat Regions Map: HPI, High Plains irrigated; HPD, High Plains dryland; RP, Rolling Plains; BKLD, Blacklands; ST, South Texas.

Table 6. Grain characteristics of TAM 401 hard red winter wheat and other check cultivars evaluated by the Cereal Quality Laboratory at College Station, TX within different regions in Texas from 2005 to 2007.†

	SKCS kernel weight‡				Flour protein§				SKCS kernel hardness index‡			
Cultivar	HPI	HPD	RP	BKLD	HPI	HPD	RP	BKLD	HPI	HPD	RP	BKLD
	mg				g kg^{-1}				score¶			
TAM 401	29.5	26.2	28.9	27.0	134	136	132	130	66	60	68	61
TAM W-101	36.1	31.6	36.5	29.7	131	138	133	123	58	63	63	69
TAM 110	31.8	27.6	31.7	25.0	121	133	128	123	60	65	63	60
TAM 111	33.6	28.4	32.6	25.7	129	138	130	124	56	71	59	60
Jagger	30.4	26.8	30.0	25.6	134	148	126	127	67	69	74	75
Fannin	33.0	28.1	30.5	30.4	137	151	129	128	68	68	73	69
Coronado	30.5	28.0	31.8	29.5	129	152	129	127	61	60	64	60
Longhorn	30.6	27.8	32.6	30.4	129	153	133	133	68	72	68	69
Mean	32.0	27.8	31.9	28.7	131	144	129	126	64	67	68	65
CV (%)	5.3	5.2	5.8	9.0	4.1	3.6	4.1	3.1	5.0	4.9	4.6	6.7
LSD (0.05)	2.0	1.7	2.1	2.9	6.1	5.8	6.0	4.5	3.6	3.5	3.5	5.0
Location-years	5	7	7	6	5	8	7	6	5	8	7	6

†Based on Texas Wheat Regions Map: HPI, High Plains irrigated; HPD, High Plains dryland; RP, Rolling Plains; BKLD, Blacklands.

‡Single-kernel characterization system.

§14% moisture basis.

¶Scores greater than 50 indicate hard kernels.

Table 7. Summary of milling and baking characteristics of TAM 401 hard red winter wheat and other check cultivars evaluated by USDA-ARS Hard Winter Wheat Quality Laboratory, Manhattan, KS from three Texas High Plains locations during 2004 and 2005.†

	Chemical				Mixograph			Bake		
	Wheat		Flour							
Cultivar	Protein‡	Milling yield	Ash‡	Protein‡	Water absorption	Peak time	Tolerance	Water absorption	Mix time	Loaf volume
	%					min	score§	%	min	cm^{-3}
Bushland, irrigated, 2004										
TAM 401	14.4	64.5	0.37	12.2	64.3	2.38	0	60.9	2.50	840
TAM W-101	13.9	66.6	0.33	12.1	63.0	2.63	2	62.2	3.38	900
TAM 111	13.0	67.6	0.36	11.1	62.5	2.23	1	60.4	2.86	840
TAM 203	14.3	66.8	0.39	12.3	64.4	3.25	1	62.3	4.00	895
TAM 304	13.1	67.9	0.37	11.3	62.8	3.44	1	62.5	4.12	870
Mean	13.7	66.7	0.36	11.8	63.4	2.79	1	61.7	3.37	869
SEM	0.3	0.6	0.01	0.2	0.4	0.24	0.3	0.4	0.31	13
Etter, irrigated, 2005										
TAM 401	15.1	66.9	0.36	13.0	64.7	2.13	0	60.6	2.75	950
TAM W-101	14.4	65.5	0.37	12.3	63.4	2.75	1	62.5	3.25	920
TAM 111	15.1	67.0	0.35	13.2	65.0	2.50	1	60.5	3.00	935
TAM 203	16.9	63.8	0.41	14.9	67.7	2.75	0	60.3	3.00	900
TAM 304	14.2	68.3	0.42	12.8	64.2	3.75	0	63.4	4.63	1000
Mean	15.1	66.3	0.38	13.2	65.0	2.78	0.4	61.5	3.33	941
SEM	0.5	0.8	0.01	0.4	0.7	0.27	0.2	0.6	0.34	17
Claude, 2005										
TAM 401	15.2	64.2	0.34	13.3	64.6	4.24	5	64.7	4.63	890
TAM W-101	13.8	64.9	0.38	12.1	62.1	3.63	3	62.4	4.25	925
TAM 111	14.0	66.9	0.36	12.3	63.5	3.88	4	63.6	4.13	885
TAM 203	15.6	64.2	0.37	13.7	65.3	3.63	3	63.3	4.13	870
TAM 304	13.0	69.2	0.39	11.6	61.2	5.69	6	63.3	9.25	865
Mean	14.3	65.9	0.37	12.6	63.3	4.21	4.2	63.5	5.28	887
SEM	0.5	1.0	0.01	0.4	0.8	0.39	0.6	0.4	1.0	11

†Complete evaluation protocols can be found on p. 4–7 at http://www.ars.usda.gov/SP2UserFiles/Place/54300510/2010%20RPN.pdf (verified 25 Aug. 2011).

‡14% moisture basis.

§Resistance of dough to overmixing: 0 = unsatisfactory; 4 = satisfactory; 6 = outstanding.