

Registration of 'Endurance' Wheat

'Endurance' (Reg. No. CV-994, PI 639233) hard red winter wheat (*Triticum aestivum* L.) was released to certified seed growers with permission of the Oklahoma Agricultural Experiment Station and the USDA-ARS in 2004. Its name derives from the unique ability to endure and recover from extended and intensive grazing in a dual-purpose management system common to Oklahoma and surrounding states. Endurance is positioned for irrigated and dryland production areas throughout the southern Great Plains.

Endurance originated in the former hard red winter (HRW) wheat breeding program of Pioneer Hi-Bred International, Inc. from the three-way cross HBV756A/'Siouxland'/'2180'. HBV756A and the HRW cultivar, 2180 (PI 532912), were both developed within the Pioneer program. HBV756A is an unreleased germplasm with the pedigree, 'TAM 105'//W6465/'Bobito' sib (B. Laskar, personal communication, 2006). Siouxland was developed and released by the University of Nebraska-Lincoln (Schmidt et al., 1985).

The F_1 and subsequent bulk generations were evaluated within the Pioneer program (J. Baker, personal communication, 2004). The line from which Endurance is derived originated as an $F_{4,5}$ head row selected at Manhattan, KS in 1990 and grown in the "Pioneer Short Rows-1" nursery at Manhattan and Hutchinson, KS in 1991 (A. K. Fritz, personal communication, 2004). It was then entered in the 1992 Pioneer Observation Nursery, submitted to cooperating breeding programs in the Great Plains in the fall of 1991 by Dr. R. G. Sears. This nursery contained 140 early-generation lines derived from Pioneer HRW wheat populations. From one of two sister lines both named HBG0624, the line OK94P549 was selected and named in 1994. After 3 yr of multi-environment testing in Oklahoma, 200 heads were selected from a breeder-seed increase plot of OK94P549 in 1996 to identify and re-select lines with improved phenotypic uniformity. OK94P549-11, subsequently released as Endurance, was selected as an F_{11} -derived line that traces to a single head row in 1997. It was evaluated in Oklahoma State Univ. breeder nurseries from 1999 to 2003 and in the Southern Regional Performance Nursery (SRPN) in 2003. OK94P549-11 was named Endurance in 2004 and tested in the Oklahoma Wheat Variety Trials (OWVT) from 2003 to 2005.

Endurance is a moderately tall semidwarf wheat with late arrival to first-hollow-stem (FHS) stage and intermediate maturity. From 2003 to 2005 at Stillwater, OK, Endurance reached FHS stage (1.5 cm hollow stem) 7 d later than 'Ok101' (Carver et al., 2003) and 15 d later than 'Jagger' (Sears et al., 1997). These comparisons corresponded to dates on which Endurance had shorter hollow stem ($P < 0.05$) than Ok101 or Jagger in a given year. Heading date of Endurance, however, is only 2 d later than Ok101 and 3 d later than Jagger. This combination of late FHS stage and intermediate heading date provides a crucial fitness trait for maximizing economic returns from grazing and grain production in a dual-purpose management system. Other fitness traits of Endurance relative to a dual-purpose system include a semi-prostrate fall growth habit (slightly more decumbent than Ok101 but more erect than Jagger), moderately fine canopy texture in the fall (similar to Jagger) with a narrow and short leaf blade, and above-average fall forage production. Based on three Oklahoma clipping trials in 2004, total fall forage yield for Endurance averaged 3850 kg ha⁻¹, which was significantly greater ($P < 0.05$) than the forage yield of Jagger (3190 kg ha⁻¹), a cultivar typically perceived by producers as having desirable forage yield (Edwards et al., 2005).

Flag leaves of Endurance at the boot stage are green, recurved, and twisted. Spikes are white-chaffed, awned, taper-

ing, middense, and recurved at harvest-maturity. Kernels are red, hard textured, ovate, and they have a midwide, middeep crease, rounded cheeks, and midsized germ.

Based on field observations, Endurance is tolerant to low-pH soils with high aluminum saturation and resembles Ok101 in reaction type. It possesses the same allele as 'Atlas 66' at the *ALMT1* locus on chromosome 4DL. In nutrient-solution culture, Endurance showed no reduction in root elongation following exposure to 0.36 mM Al relative to the control treatment with 0 mM Al (Zhou et al., 2005). Jagger and Ok101 showed 29 and 53% reductions in relative growth. Endurance exceeds Ok101 in plant stature by 5 cm and Jagger by 3 cm. Lodging resistance of Endurance is intermediate (score of 2.6, 1 = resistant to 5 = highly susceptible) and similar to Ok101 (2.8 core) but weaker than '2174' (a tolerant cultivar with a 1.3 score).

Based on field observations under natural infection in Oklahoma (2003–2005) and cooperative evaluations in the USDA-ARS regional nursery program (2003), Endurance has adult-plant resistance to wheat leaf rust (caused by *Puccinia triticina* Eriks.) races currently present in Oklahoma (May 2005) and is postulated to carry seedling resistance genes *Lr17* and *Lr26* (J. Kolmer, personal communication, 2004) that result in a moderately susceptible rating to leaf rust in the seedling stage. The most recent adult-plant ratings collected on Endurance at four Oklahoma sites in 2005 produced a consistent score of 1.0 on a 1-to-4 scale, compared to the susceptible check cultivar, 'Chisholm', with a consistent score of 4.0. In 2004 at two Oklahoma sites, adult-plant reaction to stripe rust (caused by *Puccinia striiformis* Westend) in Oklahoma was rated intermediate based on a consistent score of 1.0 on a scale of 0 to 4, in which the susceptible check cultivar, 'Ok102' (Carver et al., 2004) averaged 2.5. During the epidemic in 2005, however, Endurance was rated as moderately susceptible based on a mean score of 1.3 across six Oklahoma sites, in which the susceptible check, Ok102, averaged 3.4. Endurance is moderately susceptible to septoria leaf blotch (caused by *Septoria tritici* Roberge in Desmaz.) and to tan spot [caused by *Pyrenophora tritici-repentis* (Died.) Drechs.], susceptible to powdery mildew [caused by *Blumeria graminis* (DC.) E.O. Speer f. sp. *tritici* Em. Marchal] in the seedling stages but moderately resistant in the adult plant, moderately resistant to *Wheat soilborne mosaic virus*, and moderately susceptible to *Spindle-streak mosaic virus*. It has shown an intermediate reaction to *Barley yellow dwarf virus* with an early planting date in Oklahoma, similar to Ok102. Endurance is susceptible to greenbug (*Schizaphis graminum* Rondani), Russian wheat aphid (*Diuraphis noxia* Mordvilko), and Hessian fly (*Mayetiola destructor* Say).

Across 31 grain-only sites of the 2003 SRPN, Endurance was the second highest yielding entry with a mean yield of 4850 kg ha⁻¹ compared with the long-term checks, 'TAM 107' at 4090 kg ha⁻¹ and 'Trego' at 4510 kg ha⁻¹ (LSD = 290 kg ha⁻¹, $P = 0.05$). In the OWVT (49 site-years), grain yield of Endurance averaged 3500 kg ha⁻¹, compared with 3440 kg ha⁻¹ for Jagger, 3160 kg ha⁻¹ for 2174, and 3140 kg ha⁻¹ for Ok101 (LSD = 90 kg ha⁻¹, $P = 0.05$). Mean grain volume from the same trials was 749 kg m⁻³ (Endurance), 755 kg m⁻³ (Ok101), and 763 kg m⁻³ (Jagger and 2174) (LSD = 3 kg m⁻³, $P = 0.05$). Based on grain yield comparisons at the Expanded Wheat Pasture Unit near Marshall, OK from 2002 to 2004, Endurance suffered a 3% grain yield loss from the grain-only to the dual-management system, whereas Jagger suffered a 22% yield loss during the same period.

Based on single-kernel characterization system (SKCS) data recorded from 18 breeder trials from 2001 to 2003, Endurance averaged 29.4 mg for kernel weight, 2.27 mm for kernel diameter, and 76 for kernel hardness index. Values for Ok101,

known for its above-average kernel size and below-average kernel hardness, were 30.6 mg for kernel weight, 2.38 mm for kernel diameter, and 54 for kernel hardness index. Flour extraction rate in the same environments measured with the Quadromat Senior mill were similar between Endurance (622 g kg⁻¹) and Ok101 (629 g kg⁻¹). Hence, Endurance has acceptable physical quality attributes based on SKCS and experimental milling performance. Also from those 18 environments, mean wheat protein content was 117 g kg⁻¹ for Endurance and 115 g kg⁻¹ for Ok101, both considered below-average.

Dough strength of Endurance based on the mixograph resembles Ok101 more than Ok102, which respectively represent relatively low and high levels of dough strength. From the 18 breeder trials spanning 2001 to 2003, Endurance had a mixing time of 4.9 min, a mixing tolerance score of 4.8 on a 1-to-10 (low-to-high) scale, and mixogram curve width at 2 min past peak development of 8.9 mm. Respective scores for Ok101 were 5.1 min, 4.8, and 9.1 mm, and for Ok102 they were 6.8 min, 5.1, and 15.1 mm. Farinograph characteristics from three multi-environment composite samples from 2001 to 2003 indicated acceptable dough strength for Endurance, with a mean peak development time of 7.5 min and stability of 12.8 min. Values for Ok102, with above-average peak time and stability, were 14.8 min peak time and 18.3 min stability.

Overall milling and baking quality was considered acceptable in the 2003 evaluation program of the Wheat Quality Council. On a 0-to-6 scale, mean scores were 2.94 for Endurance and 3.69 for the check cultivar, Ok102. Straight-grade flour yield of Endurance (with reference to Ok102 as the check sample) was 721 g kg⁻¹ (699 g kg⁻¹) with 3.6 g kg⁻¹ flour ash (4.4 g kg⁻¹). The 13 collaborators noted strengths in crumb grain and color but weakness in bake absorption. Endurance is heterogeneous for the T1BL-1RS translocation (28% frequency) (R.A. Graybosch, personal communication, 2004).

Small quantities of Endurance seed may be obtained from the corresponding author for at least 5 yr for research purposes, including use in development and commercialization of new cultivars. Seed has been deposited in the National Plant Germplasm System. Appropriate recognition is requested if this release contributes to the development of a new breeding line or cultivar. Authorized seed classes are Breeder, Foundation, Registered, and Certified. Foundation seed may be obtained through Foundation Seed Stocks, Dep. of Plant and Soil Sciences, Oklahoma State Univ., Stillwater, OK 74078. The Oklahoma Agricultural Experiment Station will maintain Breeder seed. Application for U.S. Plant Variety Protection (Title V) is pending.

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