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### Registration of 'Darrell' Wheat

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# Registration of 'Darrell' Wheat

A. M. H. Ibrahim,\* S. D. Haley, P. S. Baenziger, Y. Jin, M. A. C. Langham, J. Rickertsen, S. Kalsbeck, R. Little, J. Ingemansen, O. K. Chung, B. W. Seabourn, G. H. Bai, Ming-Shun Chen, and D. V. McVey

## ABSTRACT

'Darrell' (Reg. No. CV-1024, PI 644224) hard red winter wheat (*Triticum aestivum* L.) was developed by the South Dakota State University–Agricultural Experiment Station and released in 2006 to seed producers by the South Dakota State University–Agricultural Experiment Station and the University of Nebraska Agricultural Experiment Station. Darrell was selected from the cross 2076-W12-11/'Karl 92' (PI 564245)//NE89526. NE89526 is an experimental line from the University of Nebraska with the pedigree 'Lancota' (CI 17389) selection/'Siouxland' (PI 483469)//TX792729. 2076-W12-11 is an unreleased experimental line that originated from a population with an unidentified pedigree. Darrell was selected as an F<sub>3:4</sub> line in 1998 and was assigned experimental line number SD98102. Darrell was released on the basis of its good disease resistance and excellent yield potential in the northern Great Plains.

'**D**arrell' (Reg. No. CV-1024, PI 644224) hard red winter wheat (*Triticum aestivum* L.) was developed by the South Dakota Agricultural Experiment Station and released in 2006 to seed producers by the developing institution and the Nebraska Agricultural

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**Abbreviations:** AACC, American Association of Cereal Chemists; AYT, advanced yield trial; CPT, Crop Performance Testing; EYT, early yield trial; NRPN, Northern Regional Performance Nursery; PYT, preliminary yield trial; WSMV, wheat streak mosaic virus.

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Experiment Station. In addition to researchers at South Dakota State University, researchers at the University of Nebraska as well as the USDA–ARS at Manhattan, KS, and St. Paul, MN, participated in the testing of Darrell. Darrell was selected from the cross 2076-W12-11/'Karl 92' (PI 564245; Sears et al., 1997)//NE89526. NE89526 is an experimental line from the University of Nebraska with the pedigree 'Lancota' (CI 17389; Schmidt et al., 1979) selection/'Siouxland' (PI 483469; Schmidt et al., 1985)//TX792729. 2076-W12-11 is an unreleased experimental line that originated from a population with an unidentified pedigree. Darrell was selected as an F<sub>3:4</sub> line (F<sub>3</sub> derived line in the F<sub>4</sub> generation) in 1998 and was assigned experimental line number SD98102. Darrell was released on the basis of its good disease resistance and excellent yield potential in the northern Great Plains. Darrell was named to honor the late Dr. Darrell Wells, winter wheat breeder at South Dakota State University from 1962 to 1982.

## Methods

### Early Generation Population Development

Darrell was developed using a modified bulk breeding method. The cross (coded XNE94031) was made by P.S. Baenziger at the University of Nebraska in fall 1994. The F<sub>1</sub> plants were grown in spring 1995 in a greenhouse at the University of Nebraska at Lincoln, and the F<sub>2</sub> seed was harvested in bulk in May 1995. The F<sub>2</sub> bulk generation was grown in an unreplicated breeding nursery at Mead, NE, that was planted in September 1995 and harvested in July 1996 with a small plot combine. Each F<sub>2</sub> bulk was planted in a four-row plot with rows 2.4 m long and 30 cm apart. The F<sub>3</sub> seed was shared with South Dakota State University in August 1996, and the population was planted as an F<sub>3</sub> Bulk in September 1996 in

unreplicated breeding nurseries at the Central Crop and Soils Research Station in Highmore, SD, and under irrigation at the Dakota Lakes Research Farm near Pierre, SD. On the basis of pedigree and visual observations at both locations, selection was made to reduce the total number of cross combinations. From each of these selected  $F_3$  bulks, approximately 100 to 200 single heads were selected in August 1997 and were planted as head-rows in September 1997. The head-rows were planted at the Dakota Lakes Research Farm as single rows, in a four-row set, 0.9 m long and 20 cm apart.

### Line Selection and Evaluation

Darrell was selected on the basis of visual appraisal of uniformity and agronomic appearance from the head-row nursery as an  $F_{3,4}$  line in July 1998 and assigned experimental number SD98102. In August 1998, before planting, all head-row harvested seed was visually inspected for kernel plumpness and discoloration indicating diseased or stressed plant growth. Darrell and other experimental lines were planted in the South Dakota Early Yield Trial (EYT) nursery. This unreplicated nursery was planted at Brookings, Selby, and Winner, SD, with 'Arapahoe' (PI 518591; Baenziger et al., 1989) planted as a common check every 10 plots throughout the nursery. Plots at each location were planted 4.0 m long, seven rows wide, and 20 cm apart in September 1998. Over the winter, all of the lines were evaluated in the greenhouse for their resistance to stem rust (caused by *Puccinia graminis* Pers.: Pers. f. sp. *tritici* Eriks. & E. Henn.) using the predominant race TPMK. In August 1999, all seven rows of each plot at each location were cut using a seven-row sickle bar cutter and threshed by a stationary thresher. Harvested seed was subjected to protein analysis via near-infrared reflectance spectroscopy (American Association of Cereal Chemists [AACC] Method 39-10; AACC, 2000). Grain yield of unreplicated experimental lines was calculated based on percentage of the nearby check plots.

Darrell and other experimental lines from the EYT were selected for planting in the South Dakota Preliminary Yield Trial (PYT) in September 1999 on the basis of grain yield, volume weight, protein and protein quality, resistance to leaf rust (caused by *Puccinia triticina* Eriks.) and other diseases prevalent in the field, uniformity, and general agronomic appearance.

On the basis of grain yield, volume weight, protein concentration and protein quality, resistance to stem rust, leaf rust, and tan spot (caused by *Pyrenophora tritici-repentis*), uniformity, and general agronomic appearance, Darrell was selected and planted in the 2000–2001 Advanced Yield Trials (AYT) grown at six sites in South Dakota.

On the same basis, Darrell and five other lines were selected and planted in the South Dakota Crop Performance Testing (CPT) Variety Trial in 15 locations across South Dakota in September 2001. Plot dimensions at Brookings, Britton, Watertown, Platte, Highmore, Selby, Winner, Wall, and Pierre were seven rows wide, 4.0 m long, and 20 cm apart, with four replications. Each plot at

Kennebec, Sturgis, Martin, Bison, Hays, and Oelrichs consisted of six rows, 7.5 m long, and 25 cm apart. The CPT is the official, dryland (nonirrigated) state variety trial for South Dakota. During winter 2002–2003, remnant samples of grain from the CPT trials 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 and volume weight, protein concentration and protein quality, resistance to stem rust, leaf rust, wheat streak mosaic virus (WSMV), and tan spot, uniformity, and general agronomic appearance, Darrell and seven other experimental lines were retained for further testing in the CPT in 2002 to 2005, with remnant samples of grain analyzed for milling and baking properties as described above. The PYT, AYT, and CPT nurseries were laid out in the field in a randomized complete block design with two, three, and four replications, respectively.

Darrell was also entered into the cooperative Hard Winter Wheat Northern Regional Performance Nursery (NRPN) in 2003 and 2004 planted in 18 locations in nine U.S. states (Kansas, Nebraska, South Dakota, Iowa, North Dakota, Montana, Wyoming, Minnesota, and Ohio) and one location in Alberta, Canada.

Days to heading was measured on all yield trials as the number of days from 1 January until 50% of the spikes have emerged from the boots. Plant height was measured at maturity as the average length of the stems from the soil level to the tip of the spike, excluding the awns. Winter survival was measured in 2001 at six South Dakota locations (Brookings, Britton, Selby, Highmore, Wall, and Pierre) as (spring stand/fall stand) × 100%. Resistance to stem rust of Darrell and other lines included in the AYT, CPT, and NRPN was conducted at the seedling stage using six races (QFCS, RCRS, QTHJ, RTQQ, TPMK, and TTTT) and at the adult plant stage using a composite of the first five races by the USDA–ARS Cereal Disease Laboratory, St. Paul, MN. Resistance to Great Plains biotype of Hessian fly [*Mayetiola destructor* (Say)] was done on all lines in the 2003 and 2004 NRPN on the basis of seedling tests conducted at the Department of Entomology, USDA–ARS, Manhattan, KS. An artificially inoculated field nursery was used to evaluate tolerance of Darrell and other lines in the AYT and CPT to WSMV in Brookings, SD, between 2000 and 2005. Two rows each of a control and a treatment, representing each entry, were grown side by side and replicated three times for comparison. Data were obtained on yield losses, plant stunting, and disease severity due to WSMV. Severity was evaluated using a scale of 0 to 5, where 0 = no symptoms; 1 = very mild symptoms, isolated small light green areas of mosaic, no stunting; 2 = mild symptoms, small areas of light green or yellow mosaic, short streaks, mild stunting; 3 = moderate symptoms, predominant yellow mosaic, extensive streaks, moderate stunting; 4 = severe symptoms, severe yellow mosaic, some necrosis, severe stunting; and 5 = severe symptoms, extreme yellowing, necrosis, very severe stunting, and plant death.

## Seed Purification and Increase

Breeder seed of Darrell originated from a purification program between 2003 and 2005 designed to remove off-types by rouging. Seed purification began in 2003 using visual identification and manual removal of variants (primarily red-chaffed off-types and tall white-chaffed variants) from bulk seed increases grown under rainfed conditions at Brookings. Seed harvested from the CPT increases at Brookings in 2002 was planted in a short, unreplicated strip plot (12 m long, seven rows wide, and 20 cm apart) in fall 2002. During grain filling and at harvest, strips were rouged to remove semi-dwarf red-chaffed, tall white-chaffed, and other variants. A subsample of seed harvested from these strips was planted in a longer strip plot (36 m long, seven rows wide, with 20 cm spacing between rows) in fall 2003. This strip was rouged in 2004 as in 2003. In fall 2004, a subsample of seed from this strip was planted at Yuma, AZ, in a Breeder seed ( $F_{3:10}$ ) increase block (approximately 0.5 ha) and rouged as in previous years. In 2006, Foundation seed was produced by planting all of the Breeder seed harvested in 2005, in a 22-ha rainfed seed increase block at Brookings.

## Statistical Analyses

All statistical analyses were done using SAS version 9.1 (SAS Institute, Cary, NC). Data from the CPT 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 (2003–2005) 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. Data for baking and quality attributes have been composited from four locations and measured every year (2003–2005) and an average was taken over the 3 yr based on a randomized complete block design. The LSD test ( $P = 0.05$ ) was used to compare the least squares means for the genotype effects for yield, agronomic, and quality traits.

## Characteristics

### Agronomic and Botanical Description

While considerable data are available from the breeding nurseries during the line development, the majority of data presented here will be from the CPT and NRPN as their complete reports are readily available (USDA–ARS, 2003, 2004).

Darrell is awned and has dark green foliage at anthesis. The spike is tapered, inclined, and mid-dense. At maturity Darrell has white, midlong, and midwide glumes that have wanting shoulders and acuminate tips. Kernels are red, hard textured, and elliptical in shape with collarless short brushes, rounded cheeks, and shallow creases.

In 26 site-years of testing between 2003 and 2006 in the CPT, Darrell was a medium-maturing wheat (152 d to heading from 1 January), 4 d later than 'Expedition' (PI 629060; Ibrahim et al., 2004) and 2 d earlier than 'Harding' (PI 608049; Haley et al., 2000). Plant height obtained from 35 site-years of Darrell (81 cm) is similar to 'Tandem' (81 cm, PI 601817; Haley et al., 1998b) and Arapahoe (79 cm) and 5 cm shorter than Harding ( $LSD_{0.05}$ , 1.2). The winter survival of Darrell, as tested in five South Dakota locations in the very cold winter of 2001, was good to excellent (68%), similar to 'Alliance' (72%; PI 573096; Baenziger et al., 1995) ( $LSD_{0.05}$ , 10%). Darrell has good preharvest sprouting tolerance (2.2) similar to Alliance (1.5) and Expedition (2.1) and better than 'Wendy' (4.2; PI 638521; Ibrahim et al., 2006). Darrell has a medium-long coleoptile similar to Expedition (80 mm,  $n = 6$  observations; 133% of Wendy and 89% of Harding; data not presented). On a scale of 0 to 9 (0 = no lodging to 9 = severe lodging), Darrell has good straw strength (1.8) similar to Alliance (1.8), Expedition (1.7), and 'Trego' (2.2; PI 612576; Martin et al., 2001) and better than Tandem (3.1;  $LSD_{0.05}$ , 0.6).

## Field Performance

In 39 site-years of testing in the CPT, grain yield of Darrell (3692 kg ha<sup>-1</sup>) was greater than Wendy (3557 kg ha<sup>-1</sup>), 'Wesley' (PI 605742; Peterson et al., 2001; 3553 kg ha<sup>-1</sup>), Expedition (3532 kg ha<sup>-1</sup>), Trego (3473 kg ha<sup>-1</sup>), and Arapahoe (3508 kg ha<sup>-1</sup>) and was less than 'Millennium' (3769 kg ha<sup>-1</sup>; PI 613009; Baenziger et al., 2001) ( $LSD_{0.05}$ , 99 kg ha<sup>-1</sup>, Table 1). In 39 site-years of testing in the CPT, Darrell had similar grain volume weight to Expedition (758 kg m<sup>-3</sup>), higher than Wesley (736 kg m<sup>-3</sup>) and lower than Millennium (767 kg m<sup>-3</sup>) and Trego (764 kg m<sup>-3</sup>) ( $LSD_{0.05}$ , 4.2 kg m<sup>-3</sup>).

Darrell ranked fifth (out of 35 lines tested) and fourth (out of 40 lines tested) for grain yield in the NRPN in 2003 and 2004, respectively. Compared with the check cultivars in the NRPN (Table 2), Darrell (4650 kg ha<sup>-1</sup>) was higher yielding than 'Nekota' (4043 kg ha<sup>-1</sup>; Haley et al., 1996) and 'Nu Plains' (4184 kg ha<sup>-1</sup>; PI605741).

Because of its excellent grain yield, disease resistance, and quality, Darrell should be a replacement to both Arapahoe and Alliance in South Dakota.

## Disease and Insect Resistance

Darrell is homogeneous for the 1AL.1RS wheat-rye translocation based on SDS-PAGE gel analysis. Darrell is resistant to stem rust races TTTT, TPMK, RTQQ, RCRS, QTHJ, and QFCS in seedlings tests and highly resistant to a composite of the first five races in adult plant tests conducted by the USDA Cereal Disease Laboratory, St. Paul, MN, in 2003 and 2004. Darrell likely carries *Sr6* and the undesignated stem rust resistance gene located on the 1AL.1RS translocation. Seedling tests show Darrell to be heterogeneous to the Great Plains biotype of Hessian fly. Darrell is moderately susceptible (moderate mosaic and/or moderate stunting) to wheat soil-borne mosaic virus. Darrell was tested in an artificially inoculated WSMV nursery in

**Table 1. Grain yield (GY), volume weight (VW), days to heading (DTH), sprouting tolerance (ST), plant height (PH), and straw strength (SS) for 'Darrell' and other cultivars tested in the South Dakota Crop Performance Variety Trial (2003–2006).**

Entry	Grain yield (GY), volume weight (VW), days to heading (DTH), sprouting tolerance (ST), plant height (PH), and straw strength (SS)					
	GY	VW	DTH	ST <sup>†</sup>	PH	SS <sup>‡</sup>
	kg ha <sup>-1</sup>	kg hL <sup>-1</sup>	d	1–9	cm	0–9
Alice	3602	75.6	148	1.8	71	1.9
Alliance	3558	74.5	149	1.5	75	1.8
Arapahoe	3508	75.0	151	2.5	79	2.2
Crimson	3411	76.7	154	1.8	83	1.1
Darrell	3692	75.8	152	2.2	81	1.8
Expedition	3532	75.9	148	2.1	74	1.7
Harding	3541	75.8	154	2.3	86	1.6
Jagalene	3633	76.9	150	1.3	72	0.8
Jerry	3558	75.2	154	1.3	85	1.6
Millennium	3769	76.7	152	2.2	81	1.2
Nekota	3327	74.9	149	2.1	72	1.7
Tandem	3453	77.3	151	2.0	81	3.1
Trego	3473	76.5	150	2.6	71	2.2
Wahoo	3719	73.5	151	1.5	77	2.3
Wendy	3557	76.4	148	4.2	68	1.3
Wesley	3553	73.6	150	2.1	69	0.9
Mean	3615	75.7	152	2.2	77	1.6
CV%	11.9	2.5	0.8	35.1	4.8	49.7
LSD <sub>0.05</sub>	99	0.4	0.4	1.3	1.2	0.6
No. of site-years	39	39	26	3	35	7

<sup>†</sup>Scale (1 = highly resistant to 9 = highly susceptible).

<sup>‡</sup>Scale (0 = no lodging to 9 = complete lodging).

Brookings between 2002 and 2005. Yield losses of Darrell, Arapahoe, and Millennium due to WSMV were 8.8%, 30.3%, and 24.2%, respectively. Plant stunting due to WSMV of Darrell, Arapahoe, and Millennium was 20.2%, 16.6%, 18.1%, respectively. WSMV disease severity of Darrell, Arapahoe, and Millennium was 1.9, 3.3, and 2.0, respectively. Darrell has a low *Fusarium* head blight (caused by *Fusarium graminearum* Schwabe) disease index rating (12%) tested under severe disease pressure in Brookings during 2003 to 2006, similar to Arapahoe (21%), and lower than 'Crimson' (PI 601818; Haley et al., 1998a; 45%) and 'Jagalene' (57%; LSD<sub>0.05</sub>, 31%).

### End-Use Quality

Composite milling and bread-baking properties of Darrell were determined during cooperative baking tests from 2003 to 2006 conducted by the USDA-ARS Hard Winter Wheat Quality Laboratory in Manhattan, KS (Table 3). Darrell has overall acceptable milling and good baking quality. Relative to the check cultivars Millennium and Arapahoe, Darrell had similar kernel weight (29.1 vs. 29.7 and 29.3 mg, respectively; LSD<sub>0.05</sub>, 3.4 mg). Flour extraction of Darrell, Millennium, and Arapahoe was 665, 674, and 663 g kg<sup>-1</sup>, respectively (LSD<sub>0.05</sub>, 26.5). Flour ash of Darrell was higher (3.9 g kg<sup>-1</sup>) than Millennium (3.6 g kg<sup>-1</sup>) and similar to Arapahoe (3.8 g kg<sup>-1</sup>;

**Table 2. Data on the agronomic performance of four check cultivars and Darrell from the 2003 and 2004 cooperative Hard Winter Wheat Northern Regional Performance Nursery (USDA-ARS, 2003, 2004).**

Line/selection	Grain yield		Volume weight
	Mean	Rank	Mean
	kg ha <sup>-1</sup>		kg hL <sup>-1</sup>
2003			
Kharkof	3209	35	76.7
Roughrider	3501	34	76.5
Nuplains	4059	28	76.9
Nekota	4066	27	75.2
Darrell	4406	5	75.0
Mean	4158		73.9
CV%	12.9		
LSD <sub>0.05</sub>	365		
2004			
Kharkof	3577	40	77.1
Harding	4553	20	75.7
Nuplains	4308	32	77.9
Nekota	4021	35	75.7
Darrell	4894	4	76.5
mean	4477		76
CV%	13		
LSD <sub>0.05</sub>	130		
2003–2004			
Kharkof	3393		76.9
Nuplains	4184		77.4
Nekota	4043		75.5
Darrell	4650		75.8
Mean	4318		75

LSD<sub>0.05</sub>, 0.2). Flour protein of Darrell (11.8%) was similar to both Millennium (11.2%) and Arapahoe (11.4%; LSD<sub>0.05</sub>, 0.9). In bread-baking tests, flour water absorption and loaf volume of Darrell (625 g kg<sup>-1</sup>; 875 L) were both similar to Millennium (614 g kg<sup>-1</sup>; 855 L) and Arapahoe (616 g kg<sup>-1</sup>; 822 L; LSD<sub>0.05</sub>, 14.4 and 62.9, respectively). Darrell had similar mixograph tolerance (4.0) to both Millennium (3.0) and Arapahoe (3.3) (0 = unacceptable, 4 = acceptable, 6 = outstanding; LSD<sub>0.05</sub>, 1.5). Mixograph mix time of Darrell (5.4 min) was similar to both Millennium (4.0 min) and Arapahoe (4.8 min; LSD<sub>0.05</sub>, 0.9).

### Availability

The South Dakota Foundation Seed Stocks Division (Plant Science Department, South Dakota State University, Brookings, SD) had Foundation seed of Darrell available to producers for planting during fall 2006. Seed classes are Breeder, Foundation, Registered, and Certified. Darrell has been submitted for U.S. Plant Variety Protection under P.L. 910577 with the certification option. Small quantities of seed for research purposes may be obtained from the corresponding author for at least 5 yr from the date of this publication.

**Table 3. Milling and baking characteristics of Darrell (D), Millennium (M), and Arapahoe (A) across one composite quality evaluation and four locations during 2003 to 2006.**

Characteristic	D	M	A	Mean	CV%	LSD <sub>0.05</sub>
Mixograph mix time (min)	5.4	4.0	4.8	4.7	7.8	0.9
Flour water absorption (g kg <sup>-1</sup> )	625	614	616	619	1.0	14.4
Flour ash, g kg <sup>-1</sup>	3.9	3.6	3.8	3.8	2.6	0.2
Flour protein, percent (12% mb) <sup>†</sup>	11.8	11.2	11.4	11.5	3.4	0.9
Flour extraction (g kg <sup>-1</sup> )	665	674	663	667	1.8	26.5
Loaf volume (g kg <sup>-1</sup> )	875	855	822	851	3.3	62.9
Mixograph tolerance (0–6 scale)	4.0	3.0	3.3	3.4	19.3	1.5
Kernel wt. (mg)	29.1	29.7	29.3	29.4	5.1	3.4

<sup>†</sup>mb, moisture basis.

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