Registration of 'NE05548' (Husker Genetics Brand Panhandle) Hard Red Winter Wheat

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ABSTRACT

Western Nebraska wheat producers and those in adjacent areas want taller wheat cultivars that retain their height under drought. 'NE05548' (Reg. No. _____, PI 670462) hard red winter wheat (*Triticum aestivum* L.) was developed cooperatively by the Nebraska Agricultural Experiment Station and the USDA-ARS and released in 2014 by the developing institutions. NE05548 was released primarily for its superior performance under rainfed conditions in western Nebraska and adjacent areas of the Great Plains and its tall plant stature where it is competitive with 'Pronghorn' and Goodstreak'. NE05548 was selected from the cross NE97426/NE98574 where the pedigree of NE97426 is 'Brigantina'/2*'Arapahoe' and the pedigree of NE98574 is CO850267/'Rawhide'. The cross was made in 1999. The F_1 generation was grown in the greenhouse in 2000 and the F_2 to F_3 generations were advanced using the bulk breeding method in the field at Mead, NE in 2001 to 2002. In 2003, single F_3-derived F_4 rows were planted for selection. There was no further selection thereafter. The $F_{3:5}$ was evaluated as a single four row plot at Lincoln, NE and a single row at Mead, NE in 2004. NE05548 was identified in 2005 as the experimental line, NE05548, and selected for further testing. NE05548 was selected using a modified bulk breeding method as an $F_{3:4}$ line (F_3-derived line in the F_4 generation) in 2003, and in 2005 was assigned experimental line number NE05548. It survives the winter, has acceptable disease reactions to many of the common diseases in its target area, and has acceptable end-use quality for bread making. After extensive testing, it was released in January 2014.

Nebraska is climatically and geographically diverse (Peterson, 1992). Due to year to year and place to place rainfall and temperature variations, wheat (*Triticum aestivum* L.) cultivars with taller plant stature are preferred by western Nebraska wheat producers as a way to provide a wheat crop that is easily harvested when the crop becomes shorter in height due to drought. Popular wheat cultivars in this area included 'Scout 66' (Schmidt et al., 1971), 'Centurk' (Schmidt et al., 1973), 'Buckskin' (Schmidt et al., 1976) 'Centura' (Schmidt et al., 1985), 'Pronghorn' (Baenziger et al., 1997), and 'Goodstreak' (Baenziger et al., 2004), all of which are conventional height lines with no major semi-dwarfing genes. Providing higher yielding, taller wheat cultivars remains a goal of the Nebraska Agricultural Experiment Station and the USDA-ARS cooperative wheat improvement team. Other major goals of the Nebraska Wheat Improvement team include ability to survive the NE winter, resistance to stem rust (caused by *Puccinia graminis* Pers.: Pers. f. sp. *tritici* Eriks & E. Henn.), and make an acceptable loaf of bread (Baenziger et al., 2001).

'NE05548' (PI 670462) hard red winter wheat was tested under experimental line designation NE05548 and was developed and released cooperatively by the Nebraska Agricultural Experiment Station and the USDA-ARS for its tall plant height and adaptation in western NE in January, 2014. NE05548 will be marketed and sold as Husker Genetics Brand 'Panhandle'. The name Panhandle was chosen for the panhandle of Nebraska, the region of Nebraska where this line is adapted and where taller wheat cultivars are still popular.

METHODS

NE05548 was selected from the cross NE97426/NE98574 where the pedigree of NE97426 is 'Brigantina'/2*'Arapahoe' (Baenziger et al., 1989) and the pedigree of NE98574 is CO850267/'Rawhide' (Baenziger et al., 1992). The cross was made in 1999. The F_1 generation

was grown in the greenhouse over the winter of 1999-2000 and the F_2 to F_3 generations were advanced using the bulk breeding method in the field at Mead, NE in 2001 to 2002. Each F_2 bulk was planted in a 2.4 m long 4-row plot with 30 cm between rows at a seeding rate was 66 kg ha^{-1}. After a mild culling selection of less than 15% to remove very poor bulks, usually based upon poor winter survival, though also on poor disease resistance, extreme lateness, or lodging, F_3 bulks were planted in September 2002, in an unreplicated F_3 bulk nursery, each as a 5 m long 4-row plot that was with 30 cm between rows. Approximately 50% of the F_3 populations were visually selected on an estimate of winter survival, disease resistance, and general agronomic appearance based mainly on plant height, flowering date, straw strength, and visually estimated yield potential. Each selected population was advanced by randomly sampling approximately 100 spikes (syn. heads) in July 2003, though especially meritorious bulks had a sample of 200 to 300 spikes selected. The bulk from which NE05548 was selected was considered meritorious and 200 spikes were selected. Selected spikes were threshed individually and planted in a head row nursery in September 2003. Each head row selection (a total of 9 head rows were selected from the population that NE05548 was derived) was planted as a single 0.9 m row in a four row set (e.g. 4 different head rows were planted in the set) with 30 cm between rows using a four-row drill. Head rows were selected visually on the basis of uniformity, agronomic appearance, and on visually selecting for good seed quality after harvest. Seed from the selected head rows were harvested and planted in a rainfed nursery at Ithaca as a single row 3 m long to measure winter survival, and at Lincoln, NE in a single 2.4 m long 4-row plot with 30 cm between rows. Selection in 2004 was based upon the line surviving the winter, being resistant to stem rust, having agronomic merit (standability, grain yield, grain volume weight), and having acceptable end-use quality (Baenziger et al., 2001). In 2005, NE05548 was planted as the 548 entry (where

entries run from 401 to 700) of the Nebraska preliminary yield trial at six locations (Ithaca, Lincoln, Clay Center, North Platte, Sidney, and Alliance). The experimental name was chosen as the last two digits of the year it was entered and entry number of preliminary yield trial. Based upon its performance in the preliminary yield trail, it was advanced to the advanced yield trial with three replications grown at Ithaca, Lincoln, Clay Center, North Platte, Sidney, and Alliance in 2006. In 2007, it was advanced to the elite yield trial and grown at seven locations in Nebraska (Ithaca, Lincoln, Clay Center, North Platte, McCook, Sidney, and Alliance) where it continued to be tested until its release. The trials had four replications at Lincoln, two replications at McCook, and three replications at the remaining locations. Once the line was identified in 2005, the only selection thereafter was roguing to remove obvious off-types.

NE05548 was entered into the USDA-ARS coordinated Northern Regional Performance Nursery (2008 and 2009) (data at http://www.ars.usda.gov/Research/docs.htm?docid=11932), NE05548 was entered in the Nebraska State Variety Trial (NESVT) from 2009-2013 (data available at http://cropwatch.unl.edu/web/varietytest/wheat). The NESVT was planted at 13 to 15 rainfed and two to three irrigated locations with three to six replications in Nebraska or combined with nearby locations in Wyoming. Normally one to three locations are lost yearly due to hail, freezes, drought, or severe disease incidence.

Lines were advanced based upon winter survival (determined at Ithaca, NE), resistance to stem rust and other foliar diseases prevalent in the field, uniformity, and general agronomic appearance (mainly plant height measured from the soil surface to the tip of the spikes, excluding the awns; flowering date measured as the number of days after Jan. 1 to when 50% of the emerged spikes had extruded anthers, straw strength measured using a scale of 1 to 10 with 1 being little to 10% lodging and 10 being 100 % lodged; grain yield, and grain volume weight).

As tall wheat genotypes are needed for western Nebraska, tall wheat type are selected though they may yield lower than our best semi-dwarf wheat lines and cultivars.

Over the winter, all of the lines were evaluated in the greenhouse in Lincoln, NE for their resistance to stem rust using race TPMKC or QFCSC (using methods described in Sidiqi et al., 2009) and at the USDA-ARS Cereal Disease Laboratory using races QFCS, QTHJ, MCCF, RCRS, RKQQ, TPMK, and TTTT, in the greenhouse and a composite of races QFCS, QTHJ, RCRS, RKQQ, and TPMK in the field at St. Paul, MN for the advanced nursery (using methods described in Rouse et al., 2011). In addition, the lines were evaluated in the greenhouse at Lincoln and at the Cereal Disease Laboratory for leaf rust (caused by *P. triticina* Eriks) using methods described in Watkins et al. (2001) and Kolmer (2003) and in the field (data from the regional performance nurseries using naturally occurring isolates) for leaf rust and stripe rust (caused by *P. striiformis* Westendorp f. sp. *tritici*). For *Wheat soilborne mosaic virus*, the lines were screened in the field at Lincoln and in the regional performance nurseries using naturally occurring strains (using methods described in Hunger et al., 1989).

The lines were evaluated in the greenhouse for Fusarium head blight (incited by *Fusarium graminearum* Schwabe). Each spike was artificially inoculated with a spore suspension of an isolate of *F. graminearum* at 1 x 10^5 spores/ml at mid-anthesis using a hand-held bottle sprayer. To obtain the spore suspension, an isolate of *F. graminearum* obtained from a Nebraska wheat field was grown on potato dextrose agar (PDA) plates on a laboratory bench for three weeks. Sterile distilled water (5 ml) was added to each plate and a rubber policeman was used to dislodge spores. The spore suspension was filtered through two layers of cheesecloth into a beaker and the concentration was adjusted to 1 x 10^5 spores/ml with distilled water. Approximately 2 ml of the spore suspension was applied to each spike with a hand-held

bottle sprayer and the spike was then covered with a transparent plastic bag for 7 days following inoculation. FHB severity (%) was visually estimated 14 days after inoculation. In the field, natural infection, inoculated without irrigation, and inoculated with mist irrigation nurseries were used to evaluate the lines (using methods described in Wegulo et al., 2011). The lines were also evaluated for their resistance to Hessian fly (*Mayetiola destructor* Say) by the USDA-ARS Hard Winter Wheat Genetics Research Unit (using methods described in Chen et al., 2009). For end-use quality, the preliminary lines were evaluated using a Mixograph and for protein content (Baenziger, 2001). The advanced lines were evaluated using composited grain samples from western NE (locations other than Lincoln or Ithaca that were harvested for seed). Bread baking properties were evaluated by approved methods (AACC, 2000). Bake mixing time, water absorption, external and internal grain and texture were recorded (AACC, 2000; Baenziger et al., 2001; Baenziger et al., 2008). Mineral content of NE05548 were measured (after release) of NE05548 using the procedures of Guttieri et al. (2015a, 2015b).

Statistical Analyses

The elite and advanced breeding trials were analyzed annually using an incomplete block (incomplete block size = 5) design within blocks (block size = 60; using Agrobase GEN II; Agronomix Software, Inc. Winnipeg, Canada; Stroup et al., 1994). Occasionally, advanced and elite trials with three or more replications were analyzed using the nearest neighbor (NNA) procedure of Agrobase GEN II (Stroup et al., 1994). Because NE has three major wheat producing regions (Peterson, 1992) and our irrigated trials are considered environmentally different from the rainfed trials, the data were analyzed within a location within a region or an irrigation treatment (irrigated or rainfed). Location means and ranks were studied and lines were selected by having excellent performance within a location or irrigation treatment, across

locations within a region, and all locations or irrigation treatments within a year based on the arithmetic mean of the adjusted means, or across locations, irrigation treatments, and years based on the arithmetic mean of the adjusted means. A truncated selection procedure was used as a risk avoidance strategy. Basically if a line did well in one or two years and then poorly in the next year, the line was discontinued because it might perform poorly in a producer's field. For summary data, however, we use the head-to-head cultivar (syn. variety) comparison of Agrobase GEN II which allowed us to compare lines from different sets of trials to each other. Analyses of the NRPN data used SAS (SAS Institute Inc., Cary, NC) for a randomized complete block design within locations and across locations within a year. Entries tested in the NRPN were statistically analyzed only within years due to many entries being tested for only one year. For the NESVT, the trials were analyzed using SAS using a row and column correction (PROC MIXED) for each location and analyzed across years within a region. For NE05548, only the western NE data were considered as its height is not desirable in the other two regions or under irrigation. Only entries common to the trials across years within a region in the NESVT (2009 to 2013) were analyzed using randomized complete block designs.

CHARACTERISTICS

Agronomic and Botanical Description

The coleoptile color of NE05548 is white and the juvenile growth habit is prostrate. The foliage is green with a waxy bloom on the leaf sheath, with little waxy bloom on the spike at anthesis and on the leaves. The leaves are glaborous. The leaves are glaborous. The flag leaf is erect and twisted at the boot stage. After heading, the canopy is moderately closed and erect to inclined. The flag leaf is erect and twisted at the boot stage. The foliage is green with a waxy bloom on the leaf sheath, with little waxy bloom on the spike at anthesis and on the leaves. The

spike is tapering, narrow, mid-long, and middense. The glume is medium long and medium wide, and the glume shoulder is square to elevated. The beak is very long in length with an acuminate tip. The spike is predominantly inclined at maturity with some erect spikes. Kernels are red colored, hard textured, and mainly ovate in shape. The kernel has no collar, a medium brush of medium length, rounded cheeks, midsize germ, and a narrow and shallow crease.

-dwarf cultivar that contains the *RhtB1b* allele.

While considerable data are available from the breeding nurseries during line development, the majority of data presented here will be from the head to head cultivar comparison for grain yield from the Nebraska elite trial (Table 1), the NRPN, and NESVT (Table 2) as the latter two have their complete reports readily available (http://www.ars.usda.gov/Research/docs.htm?docid=11932 and http://varietytest.unl.edu/winterwheat.html, respectively). For grain yield in Nebraska (Table 1), NE05548 was significantly lower yielding than 'Freeman' (NE06545, Baenziger et al., 2014), 'Overland' (NE01643, Baenziger et al., 2008), 'Settler CL' (NH03614CL, Baenziger et al., 2011), and 'Wesley' (Peterson et al., 2001). It was not significantly different from 'Camelot' (Baenziger et al. 2009) and Goodstreak. Of the comparison lines, only Goodstreak was a taller wheat and it is the line that is the key comparison for cultivars of similar plant height (Table 2). Both Goodstreak and NE05548 being taller wheat lines tend to be at a disadvantage in Nebraska except the drier western part of NE known as the panhandle where both lines did well (data not shown). These data are supported by the 2008 and 2009 USDA-ARS Northern Regional Performance Nursery where NE05548 ranked 2 and 6 region-wide of the 31 and 25 entries tested in those years (data available at http://www.ars.usda.gov/Research/docs.htm?docid=11932). In the last five years it has

been tested in western Nebraska in the Nebraska State Variety Trials across 20 environments (Table 2, full data available at http://cropwatch.unl.edu/web/varietytest/wheat). NE05548 (3527 kg/ha) had higher grain yield than comparable tall winter wheat cultivars (Goodstreak, 3393 kg/ha; Pronghorn, 3165 kg/ha; and Buckskin, 3111kg/ha). It was similar in grain yield to Overland (3480 kg/ha), but lower yielding than 'Robidoux'NI04421, 3,709kg/ha, Baenziger et al., 2012) and Settler CL (3595 kg/ha). Based upon these data, NE05548 is adapted to rainfed wheat production in western NE and is highestyielding taller wheat. Using data form the NESVT, NE05548 is significantly shorter than Buckskin, not significantly shorter than Goodstreak and Pronghorn, and significantly taller than Robidoux, Settler CL, Camelot, and Wesley. NE05548 has a grain volume weight and grain protein content that are comparable to most wheat cultivars grown in western NE (Table 2).

Disease and Insect Resistance

Using data predominantly from the 2008 Southern and 2009 Northern Regional Performance Nursery, NE00548 is resistant to *Wheat soilborne mosaic virus*. It is resistant to moderately resistant to moderately susceptible to stem rust in field nursery tests inoculated with a composite of stem rust races (RCRS, QFCS, QTHJ, RKQQ, and TPMK) at St. Paul, MN (Table 3). In greenhouse seedling tests, it is resistant to races QFCS, QTHJ, MCCF, , RCRS RKQQ and TMPK., but susceptible to race TTTT (data provided by Y. Jin at the USDA Cereal Disease Laboratory). It is moderately susceptible (10 – 20 MS/S at Castroville, TX) to leaf rust (caused by *P. triticina* Eriks.) races of the southern Great Plains. It is susceptible to stripe rust (caused by *P. striiformis* Westendorp f. sp. t*ritici*, data obtained from field observations). It is moderately susceptible to Fusarium head blight (caused by *F. graminearum*, data from greenhouse and field observations in Nebraska) and moderately resistant for deoxynivalenol accumulation. NE05548

is moderately resistant to moderately susceptible to Hessian fly ((*Mayetiola destructor* Say., data provided by M.-S. Chen, USDA and Kansas State University). In different tests it has ranged from a score of resistant to 21% of the plants were resistant to the Hessian fly. It is susceptible to *Wheat streak mosaic virus* (data obtained from field observations in NE) and the wheat stem sawfly (*Cephus cinctus* Norton).

End-Use Quality

The milling and baking properties of NE05548 were determined for six years by the Nebraska Wheat Quality Laboratory (Table 4). In these tests, Wesley, an excellent milling and baking wheat, was used for comparison. The average flour protein content of NE05548 (12.5%) was similar to Wesley (12.4%) for the corresponding years (also found in the NESVT, Table 2). The average flour extraction on the Buhler Laboratory Mill for NE05548 (74.7%) was slightly higher than Wesley (74.0 %). The flour ash content (0.43%) was similar to Wesley (0.42 %). Dough mixing properties of NE05548 were acceptable (mixtime peak was 3.72 minutes and mixtime tolerance was scored as 4.1 on a one to 7 scale where 7 is very tolerant) and weaker than Wesley (mixtime peak of 4.39 minutes and mixtime tolerance scored as 4.6). Average Mixograph absorption (61.8 %) was similar to Wesley (61.6%) for the corresponding years. The average loaf volume of NE05548 (822 cm^3) was lower than Wesley (841 cm^3). The scores for the internal crumb grain and texture were 3.7 and 3.7 which were lower than Wesley (4.3 and 4.4, respectively). The overall end-use quality characteristics for NE05548 (scored as 3.8, where 3 is fair, 4 is good and 7 is excellent) was lower than Wesley (4.4) and similar to many commonly grown wheat cultivars. NE05548 should be acceptable to the milling and baking industries. After NE05548 was released, we discovered that it was a low Cd accumulating line

when grown on high Cd soils (Guttieri et al., 2015a,b). Cd is a toxic heavy metal and this line should be preferred in regions where soils high in Cd availability are found.

SEED PURIFICATION AND INCREASE

Seed purification of NE05548 began in 2010 and continued through 2013 using visual identification and manual removal of variants in bulk seed increases grown under rainfed conditions at Lincoln and Ithaca, NE. NE05548 has been uniform and stable since 2010. Less than 0.5 % of the plants were rogued from the Breeder's seed increase in 2010-13. The rogued variant plants were taller in height (5 - 15 cm), were awnless, or had bronze chaff. Up to 2% (20:1000) variant plants may be encountered in subsequent generations.

AVAILABILITY

The Nebraska Foundation Seed Division, University of Nebraska-Lincoln, Lincoln, NE has had foundation seed available under the marketing name Husker Genetics brand Panhandle to qualified certified seed enterprises since 2013. The seed classes are Breeder, Foundation, Registered, and Certified. Registered seed will be a nonsalable class. NE05548 has been submitted for U.S. Plant Variety Protection under P. L. 10577 with the certification option. A research and development fee will be assessed on all certified seed sales. Small quantities of seed for research purposes may be obtained from Dr. P. S. Baenziger and the Department of Agronomy and Horticulture, University of Nebraska-Lincoln for at least 5 yr from the date of this release. A seed sample has been deposited in USDA-ARS National Center for Genetic Resources Preservation and in the USDA-ARS National Small Grains Collection, Aberdeen ID and seed is freely available to interested researchers.

ACKNOWLEDGEMENTS:

The Nebraska Crop Improvement Association provided technical assistance in describing the cultivar characteristics and accomplishing technology transfer. NE05548 was developed with partial financial support from the Nebraska Agricultural Experiment Station and the Nebraska Wheat Development, Utilization, and Marketing Board. Partial funding for P.S. Baenziger is from Hatch project NEB-22-328, USDA- IFAFS competitive grant 2001-04462, USDA, NRICGP 00-353000-9266, 2004-35300-1470, and 2007-51300-0375, USDA, CSREES NRICAP grant number 2006-55606-16629, USDA OREI 2007-51300-03785, AFRI/2011-68002-30029, the CERES Trust Organic Research Initiative, and USDA under Agreement No. 59-0790-4-092 which is a cooperative project with the U.S. Wheat & Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the USDA. Cooperative investigations of the Nebraska Agric. Res. Div., Univ. of Nebraska, and USDA-ARS.

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Table 1. Head to head comparisons of NE05548 to six popularly grown or new cultivars from trials in Nebraska beginning in 2007 until 2013. Data on grain yield was from trials at up to seven rainfed locations (Ithaca, Lincoln, Clay Center, North Platte, McCook, Sidney, and Hemingford) in Nebraska and not every cultivar was grown in the same trial across the state.

Cultivar	Trials (no.)	Grain Yield of Cultivar (kg/ha)	Grain Yield of NE05548 (kg/ha)	% of NE05548	Significance†
Camelot	64	3775	3738	101	n.s.
Goodstreak	62	3700	3768	98	n.s.
Freeman	57	4234	3844	110	**
Overland	72	4067	3897	104	**
Settler CL	55	3966	3798	104	**
Wesley	72	3763	3897	97	**

†n.s.,** Significantly different at the P=0.01 probability level.

Table 2. Grain yield, grain volume weight, grain protein concentratoin, and plant height for western Nebraska from 2009 to 2013 representing 20 location-years of data from rainfed environments.

Brand	Cultivar	Grain Yield	Grain Volume Weight	Grain Protein Concentration	Plant Height
		kg ha^{-1}	kg hl^{-1}	g kg^{-1}	cm
Husker Genetics	Robidoux	3709	76.6	108	74.9
Husker Genetics	Settler CL	3595	76.3	113	73.9
WESTBRED	Winterhawk	3575	77.0	110	74.2
----	NE05548	3527	75.3	116	80.3
Husker Genetics	Overland	3480	76.2	111	76.2
Husker Genetics	McGill	3480	75.6	110	75.7
PlainsGold	Hatcher	3474	76.2	110	70.1
----	Alliance	3467	75.6	109	75.2
----	NW03666	3400	76.1	112	73.9
----	Goodstreak	3393	76.9	112	82.8
----	Infinity CL	3393	76.7	113	76.5
NuPride	Camelot	3386	76.1	114	75.7
----	NE05496	3386	76.0	111	72.9
----	Arrowsmith	3306	75.6	115	80.3
----	Wesley	3245	75.3	115	70.1
----	Pronghorn	3165	77.0	115	84.3
----	Buckskin	3111	76.6	113	85.3
----	Millennium	3104	73.9	114	77.0
----	Scout 66	2795	76.3	116	85.3
----	Mace	2721	72.5	115	67.8
----	Turkey	2674	75.7	118	84.6
Mean†		**3304**	**75.9**	**113**	**77.0**
LSD ‡ (p <0.05)		**269**	**2.0**	**5**	**4.3**

† This value is the average of all the values for the traits for the entries that were in the trial and includes values for many experimental lines not shown in the table.

‡ The L.S.D. (least significant difference $p < 0.05$) was calculated from the analysis of variance using all of the values of the entries that were in the trial including many experimental lines not shown in the table.

Table 3. Seedling stem rust reaction scores of NE06545 hard red winter wheat and other check cultivars evaluated in the 2008 and 2009 Northern Regional Performance Nursery at the USDA-ARS Cereal Disease Laboratory, St. Paul, MN.

Nursery		QFCS	QTHJ	MCCF	RCRS	RKQQ	TPMK	TTTT	Adult plant field response	
	Line/selection	06ND76C	75ND717C	59KS19	77ND82A	99KS76A-1	74MN1407	01MN89A-1-2	St. Paul, MN	Kenya
2008 NRPN	Kharkof	S	-		S	S	S	S	20MS	1S
2008 NRPN	Antelope	0;/2	S		0/S	S	;3-	S	40S	40S
2008 NRPN	Wesley	;1	2		;1-	2/S	;1+	S/2	10S	70S
2008 NRPN	Jerry	;/S	S/0		S/2	S	;1	S/2	20 MS-S	50SMS
2008 NRPN	NE05548	0	2		;2	2	;1-	S	TR	80S
2009 NRPN	Kharkof	S/2	S	S	S	S	S	S		
2009 NRPN	Antelope	0	S	0;	0/;3	S	0;	S/;2		
2009 NRPN	Wesley	0;	S/2-	0;	;	S/;1	0;	1+3/2/S		
2009 NRPN	Jerry	;	2-/S	esc.	;/2-	S/2	;	S/2-		
2009 NRPN	NE05548	0;	2	0;	;1-	2-	0;	S		

Complete data set can be found at http:// http://www.ars.usda.gov/Research/docs.htm?docid=11932 (accessed January 21, 2016). Seedling infection type: 0 = immune response, no sign of infection, 1 = small uredinia surrounded by necrosis; 2 = small uredinia surrounded by chlorosis; 3 = moderate size uredinia without necrosis or chlorosis; 4 = large uredinia without necrosis or chlorosis; + = uredinia larger than normal; - = uredinia smaller than normal; semicolon (;) = hypersensitive chlorotic or necrotic flecks; S = seedlings with scores of 3 or higher.

† Adult plant resistance evaluation from inoculated field nursery at St. Paul., MN or Kenya.

Table 4. Comparison of NE05548 to Wesley from 2006 to 2013 for flour yield, bran score, mill score , flour protein content, , flour protein content, flour ash content, Mixograph water absorption (water abs.), Mixograph mixing time, Mixograph tolerance, loaf volume (loaf vol.) , and external appearance score (ext. score), crumb grain score, crumb texture score, and overall bake score as determined by the Wheat Quality Laboratory at the University of Nebraska (Baenziger et al., 2001). All reported values were measured at a 140 g H_20 1000 g^{-1} flour basis.

Line	Year	Milling			Protein	Flour	Mixograph			Baking				
		Flour Yield	Bran Score†	Mill Type Score†	in Flour	Ash	Water Abs	Mtime	MTol.‡	Loaf Vol.	Ext. Score§	Crumb Grain Score§	Crumb Texture Score§	Overall§
		g kg^{-1}				g kg^{-1}		min		(cm^3)				
NE05548														
	2006	732	3.5	3.5	136	4.30	600	3.55	5.0	800	4.0	4.0	4.0	4.0
	2007	748	3.5	4.0	135	4.50	600	2.80	4.0	765	3.0	3.3	3.0	3.1
	2009	756	3.5	3.5	137	4.20	600	2.43	2.5	773	3.5	3.3	3.3	3.3
	2010	747	3.0	3.0	98	4.10	615	4.38	4.4	870	4.0	3.5	3.3	3.6
	2011	769	3.5	4.5	112	4.50	635	3.88	3.8	828	4.3	4.0	4.0	4.1
	2012	731	3.5	4.5	133	4.10	660	5.26	4.8	893	5.0	4.0	4.3	4.4
Mean		***747.2***	***3.4***	***3.8***	***125.2***	***4.28***	***618.3***	***3.7***	***4.1***	***822***	***4.0***	***3.7***	***3.7***	***3.8***
WESLEY														
	2006	729	3.5	4.0	127	4.30	600	4.95	5.0	903	4.5	5.0	5.0	5.0
	2007	733	3.5	2.5	139	4.30	600	3.55	4.3	800	4.0	4.8	5.0	4.8
	2009	751	3.5	3.5	133	4.10	600	3.02	3.5	860	4.8	4.5	4.5	4.6
	2010	741	3.5	4.5	107	4.00	623	4.93	4.9	870	4.3	4.3	4.5	4.3
	2011	751	3.5	4.5	115	4.60	635	4.01	4.6	835	4.3	3.4	3.6	3.8
	2012	734	4.0	4.5	123	3.90	640	5.85	5.4	775	3.8	3.8	3.8	3.8
Mean		***739.8***	***3.6***	***3.9***	***124.0***	***4.20***	***616.3***	***4.4***	***4.6***	***841***	***4.3***	***4.3***	***4.4***	***4.4***
LSD*		17	0.3	1.0	19.0	0.30	30.0	1.4	1.1	67	0.7	0.7	0.8	0.7

† Scores use a 1 to 5 scale with 5 being very good and 1 being very poor

‡ Scores use a 0 to 7 scale with 7 being very tolerant.

§ Scores use a 0 to 6 scale with 6 being excellent

* Least significant difference (p=0.05) for the mean values of NE05548 and Wesley