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Registration of 'NH03614 CL' Wheat

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ABSTRACT

'NH03614 CL' (Reg. No. CV-1051, PI 653833) hard red winter wheat (*Triticum aestivum* L.) was developed cooperatively by the Nebraska Agricultural Experiment Station and the USDA-ARS and released in 2008 by the developing institutions and the South Dakota Agricultural Experiment Station and the Wyoming Agricultural Experiment Station. In addition to researchers at the releasing institutions, USDA-ARS researchers at Manhattan, KS and St. Paul, MN participated in the development of NH03614 CL. NH03614 CL was selected from the cross 'Wesley' sib//'Millennium' sib/'Above' sib that was made in the spring of 1997 to develop new herbicide-tolerant cultivars. NH03614 CL was selected using the bulk breeding method as an $F_{3:4}$ line (F_3–derived line in the F_4 generation) in 2001, and in 2003 was assigned experimental line number NH03164. NH03614 CL was released primarily for its herbicide tolerance to imadazolinone compounds which control many previously difficult-to-control weeds in wheat production systems, and for its superior adaptation to rainfed wheat production systems in Nebraska, Wyoming, South Dakota, and counties in adjacent states.

'NH03614 CL' (Reg. No. CV-1051, PI 653833) hard red winter wheat (*Triticum aestivum* L.) was tested under experimental line designation NH03614 and was developed cooperatively by the Nebraska Agricultural Experiment Station and the USDA-ARS and released in 2008 by the developing institutions and the South Dakota Agricultural Experiment Station and the Wyoming Agricultural Experiment Station. NH03614 CL will be marketed primarily through the NuPride Genetics Network and sold as Husker Genetics brand Settler CL. The name NH03614 CL was chosen because it is a Clearfield resistant wheat that will be used with Beyond herbicide (active ingredient imazamox (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid) (BASF Corp., Research Triangle Park, NC). NH03614 CL was released primarily for its tolerance to imadazoline herbicide compounds, which control many previously difficult-to-control weeds in wheat production systems, and for its superior adaptation to rainfed wheat production systems in Nebraska, Wyoming, South Dakota, and counties in adjacent states.

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Abbreviations: NESVT, Nebraska State Variety Trial; NRPN, Northern Regional Performance Nursery.

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Methods

NH03614 CL was selected from the cross 'Wesley' (Peterson et al., 2001) sib//'Millennium' (Baenziger et al., 2001a) sib/'Above' (Haley et al., 2003) sib. The cross between the Millennium sib (formerly NE94481) and the Above sib (TXGH125888–120*4/FS2) was made in the spring of 1997. The final cross to Wesley sib (formerly N95L164) was made in fall 1997. The F_1 generation was grown in the spring greenhouse in 1998, and the F_2 to F_3 generations were advanced using the bulk breeding method in the field at Lincoln, NE, in 1999 to 2000. The F_2 and F_3 bulks were sprayed in the spring with imazamox herbicide to select for the herbicide-tolerant segregants. The F_2 bulk generation of populations segregating for herbicide tolerance was

grown in an unreplicated breeding nursery at Lincoln, NE that was planted in September 1999 and harvested in July 2000 with a small-plot combine. Each F_2 bulk was planted in a four-row plot with each row being 2.4 m long and with 30 cm between rows. The seeding rate was 66 kg ha^{-1}. After a mild culling selection of less than 15% to remove very poor bulks (usually based on poor winter survival, though also on poor disease resistance, extreme lateness, or lodging), F_3 bulks were planted in September 2000 in an unreplicated F_3 bulk nursery, each as a four-row plot that was 2.4 m long with 30 cm between rows. Approximately 50% of the F_3 populations were visually selected on the basis of winter survival, disease resistance, and general agronomic appearance (mainly plant height, flowering date, standability, and visually estimated yield potential). Each selected population was advanced by random sampling of approximately 100 spikes, although especially meritorious bulks had a sample of 200 to 300 spikes selected in July 2000. Selected spikes were threshed individually and planted in a headrow nursery in September 2000. Headrow selections were planted as a single row in a four-row set that was 0.9 m long with 30 cm between rows. Headrows were selected visually on the basis of uniformity and agronomic appearance. In 2001 to 2002, the line was evaluated as a single plot in an observation nursery. In 2002 to 2003, the line eventually designated as NH03614 CL was grown at six locations in Nebraska, where the H in the designation acknowledges its herbicide tolerance. There was no further selection thereafter.

Beginning in the fall of 2003, NH03614 CL was evaluated in replicated trials in Nebraska: advanced trial, 2003–2004; elite trial, 2004–2009, Northern Regional Performance Nursery (NRPN) in 2005–2007 (data at http://www.ars.usda.gov/Research/docs.htm?docid=11932, verified 4 Aug. 2010); and in the Nebraska State Variety Trial (NESVT) from 2007 to 2009 (data available at http://cropwatch.unl.edu/web/varietytest/wheat, verified 4 Aug. 2010). The NESVT is planted at 13–15 rainfed and 2–3 irrigated locations in Nebraska or combined with close locations in Wyoming. Normally 1–3 locations are lost yearly due to hail, freezes, drought, or severe disease incidence.

Lines were advanced based on winter survival (determined at Mead, NE), resistance to stem rust (caused by *Puccinia graminis* Pers.: Pers. f. sp. *tritici* Eriks & E. Henn.) and other 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 January 1 to when 50% of the emerged spikes had extruded anthers; standability measured on a scale of 1 to 10, with 1 being little to 10% lodging, and 10 being 100% lodged; grain yield; and grain volume weight). Over the winter all of the lines were evaluated in the greenhouse (for their resistance to stem rust using race TPMK) and at the USDA-ARS Cereal Disease Laboratory for the advanced nursery. The lines were also evaluated for their resistance to Hessian fly (*Mayetiola destructor* Say) by the USDA-ARS Center for Grain and Animal Health Research and by Kansas State University. For end-use quality, the advanced lines were evaluated using grain samples from western Nebraska (e.g., those harvested locations other than Lincoln or Mead, which were harvested for seed). The samples were composited and analyzed for milling and bread-baking properties using 100 g pup loaves, where the bake-sample mix time, water absorption, baked-loaf volume, and external and internal grain and texture were measured by approved methods as previously described (AACC, 2000; Baenziger et al., 2001b, Baenziger et al., 2008).

Seed Purification and Increase

Seed purification of NH03614 CL began in 2005 using visual identification and manual removal of variants (primarily tall and red-chaffed off-types) from bulk seed increases grown under rainfed conditions at Lincoln, NE. Seed harvested from the advanced yield trials at Lincoln, NE in 2004 was planted in a short, unreplicated strip plot (1.2 m wide, 15 m long) in fall 2004. During grain filling and again at harvest, strips were rogued to remove tall, red-chaffed, and other variants. A subsample of seed harvested from these strips was planted in a longer strip plot (1.2 m wide, 45 m long) in fall 2005 at Mead, NE. This strip was rogued as in 2005. In fall 2006, a subsample of seed from this strip was planted at Mead, NE in a breeder-seed ($F_{3:9}$) increase block (approximately 0.2 ha), sprayed at the recommended rate of Beyond herbicide, and rogued as in previous years. In 2008, foundation seed was produced by planting breeder seed harvested in 2007. The foundation-seed increase block ($F_{3:10}$) was sprayed and rogued as in previous years. NH03614 CL has been uniform and stable since 2006. Less than 1% of the plants were rogued from the breeder's seed increase in 2006. The rogued variant plants were taller in height (8–15 cm) or darker or had black chaff, which may be due to disease (possibly caused by *Xanthomonas campestris* pv. *translucens*). Up to 2% (20:1000) variant plants may be encountered in subsequent generations.

Statistical Analyses

To analyze data during the development of NH03614 CL, the elite and advanced breeding trials were analyzed using an incomplete block design (incomplete block size = 5) within replication blocks (block size = 60) with 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 procedure of Agrobase GEN II (Stroup et al., 1994). Because Nebraska has three major wheat-producing regions (Peterson, 1992), the data for the advanced and elite trials were analyzed within a location within a region and rarely across locations. Location means and ranks were studied, and lines were selected by having excellent performance within a location, across locations within a region, and at all locations within a year based on the arithmetic mean of the adjusted means, or across locations and years based on the arithmetic mean of the adjusted means. A truncated selection procedure was used as a risk-avoidance strategy (if a line did well in one or two years and then poorly in the next year, the line was not continued because it might perform poorly in a producer's field). 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 owing to the many entries being tested for only one year. Two-yr averages were presented for those entries in common for both years. For the NESVT, the trials were analyzed using SAS using a row and column correction (PROC MIXED) for each location and were analyzed across years within a region. Entries varied greatly across regions, hence analysis across regions and locations was not done using SAS, but the arithmetic means of lines in common were considered. Only entries common to the trials across years within a region in the NESVT (2007 to 2009) were analyzed using randomized complete block designs.

Characteristics

Agronomic and Botanical Description

NH03614 CL is an awned, ivory-glumed, semidwarf (contains *RhtB1b* [formerly *Rht1*]) cultivar. It has a prostrate juvenile growth habit. The flag leaf is erect and twisted at the boot stage. The foliage is gray-green to green with a moderate waxy bloom on the leaves, leaf sheath, and spike at anthesis. The leaves are glabrous, though some plants have very few and very short hairs. The spike is tapering in shape, narrow, midlong, and middense. The glume is long and narrow to midwide, and the glume shoulder is wide and elevated. The beak is medium in length with an acuminate tip. Kernels are red, hard textured, and mainly oval in shape. The kernel has no collar, a large brush of medium length, rounded cheeks, midsized germ, and a narrow and shallow crease. The coleoptile length of NH03614 CL (90 ± 3 mm) is relatively long for a semidwarf cultivar and longer than that of Husker Genetics Brand 'Overland' (NE01643, 81 ± 1 mm; Baenziger et al., 2008), 'Infinity CL' (83 ± 2 mm; Baenziger et al., 2006), and Wesley (68 ± 2 mm), but shorter than that of conventional-height cultivars such as 'Goodstreak' (105 ± 2 mm; Baenziger et al., 2004) and 'Scout 66' (112 ± 1 mm; Schmidt et al., 1971).

Although considerable data is available from the breeding nurseries, the majority of data presented here will be from the NRPN (Table 1) and NESVT (Table 2) because their complete reports are readily available at http://www.ars.usda.gov/Research/docs.htm?docid=11932 (verified 9 Aug. 2010) and http:// cropwatch.unl.edu/web/varietytest/wheat (verified 9 Aug. 2010), respectively. NH03614 CL performed very well in the NRPN (Table 1). In 2006 it was the second highest yielding line (4740 kg ha^{-1}) of 30 lines tested and in 2007 it was the eighth highest yielding line (3577 kg ha^{-1}) of 33 lines tested. Using the 2-yr averages, NH03614 CL (4159 kg ha^{-1}) was higher yielding than 'Harding' (3765 kg ha^{-1}, Haley et al., 2000), 'Kharkof' (2907 kg ha^{-1}, CI 1442), 'Nuplains' (3434 kg ha^{-1}, PI612576), and Wesley (4069 kg ha^{-1}) that are the nursery check cultivars, as well as AgriPro 'Hawken' (PVP200700350). In other measures of performance, NH03614 CL (74.8 kg hl^{-1}) had lower grain volume weight than Harding and Kharkof, but a higher one than Wesley and Nuplains. It matures (148 d after Jan. 1) earlier than Kharkof, Harding, and Nuplains, but about the same time as Wesley. NH03614 CL is a semidwarf wheat and is shorter than Kharkof, Harding, Nuplains, and Wesley.

Table 1. Characteristics in rainfed production systems in the Northern Regional Performance Nursery in 2006 and 2007 and in both years for those lines in common in each year.

Line/selection	Grain yield	Grain volume weight	Days to flowering	Plant height
	kg ha^{-1}	kg hL^{-1}	d after Jan. 1	cm
		2006†		
Kharkof	3201	75.9	155.3	104.5
Harding	4239	75.0	154.2	89.7
Nuplains	4018	76.3	154.4	76.5
Wesley	4628	74.9	151.2	73.4
NH03614 CL	4740	76.0	151.7	76.3
NW03681	4608	77.3	151.7	79.5
Hawken	4638	76.1	150.5	73.5
SD96240-3-1	4350	74.1	152.7	80.7
SD98W175-1	4650	76.9	152.5	81.1
Mean‡	4311	75.6	152.3	81.6
LSD ($p < 0.05$)§	344			
		2007†		
Kharkof	2613	75.7	151.6	81.6
Harding	3292	75.4	150.9	76.9
Nuplains	2849	74.4	150.6	72.0
Wesley	3509	73.6	148.2	72.6
Hawken	3511	74.8	147.4	70.6
NH03614 CL	3577	74.8	148.0	71.0
NW03681	3736	76.0	148.0	70.2
SD96240-3-1	3240	72.4	150.8	69.6
SD98W175-1	3143	76.2	149.7	74.3
Mean‡	3274	74.8	149.5	73.2
LSD ($p < 0.05$)§	410			
		2006–2007		
Hawken	4074	75.4	149.0	72.1
Harding	3765	75.2	152.6	83.3
Kharkof	2907	75.8	153.4	93.1
NE03458	3919	74.3	149.8	71.8
NH03614 CL	4159	75.4	149.9	73.7
Nuplains	3434	75.3	152.5	74.2
NW03681	4172	76.7	149.8	74.8
SD96240-3-1	3795	73.3	151.7	75.1
SD98W175-1	3897	76.5	151.1	77.7
Wesley	4069	74.2	149.7	73.0
Mean‡	2878	74.9	149.7	74.0

†2006, 14 environments; 2007, 11 environments.

‡The mean 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 LSD (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.

In the NESVT (Table 2), NH03614 CL (3930 kg ha^{-1}) has performed well for grain yield across Nebraska and was similar to Infinity CL (3839 kg ha^{-1}), Millennium (3948 kg ha^{-1}),

Table 2. Three-year averages for grain yield by region and state-wide averages for characteristics from the rainfed locations in the Nebraska State Variety Trial from 2007 to 2009 for the lines that were in common all three years.

		Grain yield, regional average				State averages†				
Brand	Cultivar	SE‡	SC‡	WC‡	PH‡	Grain yield§	Grain volume weight¶	Grain protein¶	Lodging¶	Plant height¶
		kg ha^{-1}				kg ha^{-1}	kg hL^{-1}	g kg^{-1} grain	%	cm
NuPride	Camelot	3945	3091	4717	3689	3861	73.4	120	4.8	88.3
—	Infinity CL	4180	3111	4435	3629	3839	74.9	117	8.6	87.1
—	Millennium	4166	3629	4536	3461	3948	75.1	120	3.9	91.1
—	NE01481	4247	3313	4697	3488	3936	73.5	115	8.0	89.6
—	NI04421	3468	3111	4462	3797	3709	72.1	116	6.5	84.5
Husker Genetics	Overland	4476	3783	4657	3588	4126	74.6	119	4.2	87.9
—	Scout 66	2796	2218	3582	3145	2935	68.5	120	24.6	97.3
—	NH03614 CL	3629	3609	4650	3830	3930	74.5	115	6.0	81.5
—	Wesley	3669	3716	4657	3447	3872	72.1	120	4.4	80.5
Average all entries#		3716	3325	4453	3512	3752	73.2	118	7.0	85.1
LSD ($p < 0.05$)††		457	565	393	222	3861	73.4	120	4.8	88.3

†n = 36.

‡SE, southeast (n = 7); SC, south central (n = 3); WC, west central (n = 12); PH, panhandle (western) (n = 14).

§Average across regions across years.

¶Average across locations across years

#The average of all entries 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 LSD (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.

Wesley (3872 kg ha^{-1}), and 'Camelot' (3961 kg ha^{-1}, Baenziger et al., 2009), and lower than Husker Genetics Brand Overland (NE01643, 4126 kg ha^{-1}). In these comparisons, the average across regions was used because Nebraska has diverse ecogeographic zones (Peterson, 1992). The most important cultivar comparison for the intended use of NH03614 CL is Infinity CL, because as they are the only herbicide-tolerant cultivars in these trials. Based on our data, Infinity CL has a slightly better yield record in southeastern Nebraska but tends to be lower yielding in the south central, west central, and panhandle regions of the state. Infinity CL and NH03614 CL have similar grain volume weight, similar grain protein concentration, and similar lodging scores. NH03614 CL averages 6 cm shorter than Infinity CL. In western Nebraska, there are three popular herbicide-tolerant wheat cultivars that are grown: 'Above CL', Infinity CL, and 'Bond CL' (Haley et al., 2006). Using 4-yr averages from the NESVT (n = 17 environments, data not shown) for that region (NH03614 CL was tested there 1 yr before statewide testing due to limited seed), NH03614 CL had higher grain yield and similar or superior grain volume weight (3703 kg ha^{-1}, 76.0 kg hl^{-1}) compared with those for Infinity CL (3562 kg ha^{-1}, 76.5 kg hl^{-1}) and Bond CL (3555 kg ha^{-1}, 74.8 kg hl^{-1}). In Wyoming, Settler CL was comparable with Bond CL in yield. Across 17 trials from 2007 to 2009, NH03614 CL yielded 3870 kg ha^{-1} compared with 3698 kg ha^{-1} for Bond CL. In 12 of these trials Settler CL exceeded Bond CL in mean yield.

Disease and Insect Resistance

NH03614 CL is moderately resistant to stem rust in field nursery tests when inoculated with a composite of stem rust races (RCRS, QFCS, QTHJ, RKQQ, and TPMK) and to *Wheat soilborne mosaic virus*. In greenhouse tests, it had a resistance rating of 2 to 2+ to stem rust races QFCS, RCRS, RKQQ and had a heterogeneous reaction (e.g., some plants are resistant and others are susceptible) to races TPMK and TTTT. It had a low infection rating (2 to 2+) to races TTKSK (Ug99) and TTKST (Ug99 + Sr24 virulence). Resistance to the TTKS lineage is postulated to be due to *SrTmp*. NH03614 CL is moderately resistant to moderately susceptible to Hessian fly. It is moderately susceptible to leaf rust and stripe rust (data obtained from field observations in the Great Plains). NH03614 CL is slightly less susceptible to Fusarium head blight (caused by *Fusarium graminearum* Schwabe) than many widely grown lines, based on disease severity ratings obtained from misted screening nurseries for Fusarium head blight in Nebraska and South Dakota. It is susceptible to wheat streak mosaic virus (data obtained from the 2006 NRPN and field observations in NE).

End-Use Quality

The milling and baking properties of NH03614 CL were determined for 4 yr by the Nebraska Seed Quality Laboratory (Table 3). In these tests, Wesley, an excellent milling and baking wheat cultivar, was used for comparison. All reported values were measured on the basis of 140 g H_2O 1000 g^{-1} flour. The average flour extraction on the Laboratory Mill (Buhler, Uzwil, Switzerland) for NH03614 CL (726 g kg^{-1}) was slightly lower than for Wesley (738 g kg^{-1}). The average wheat and flour protein concentration of NH03614 CL (142 and 117 g kg^{-1}) were similar to those of Wesley (142 and 123 g kg^{-1}) for the corresponding years. The similar grain protein content was confirmed by the NESVT, where NH03614 CL and Wesley

Table 3. Comparison of NH03614 CL to Wesley from 2005 to 2008 for characteristics as determined by the Wheat Quality Laboratory at the University of Nebraska.†

Year	Flour yield	Grain protein	Flour protein	Ash content	Mixograph mix time	Mixograph tolerance	Loaf volume	External	Crumb grain	Crumb texture	Overall bake
	g kg^{-1}				min	score‡	cm^3	score§			
						NH03614 CL					
2005	73.0	116	106	4.60	5.1	4.0	910	4.5	3.5	3.0	3.3
2006	72.0	175	122	4.87	4.7	5.0	833	4.0	4.5	4.5	4.5
2007	71.7	127	125	4.81	4.1	4.8	768	4.0	5.0	5.0	4.9
2008	73.6	150	115	3.86	4.9	5.0	825	4.5	4.0	3.5	3.8
Mean	72.6	142	117	4.54	4.7	4.7	834.0	4.3	4.3	4.0	4.1
SEM	0.44	13.1	4.2	0.232	0.21	0.24	29.2	0.14	0.32	0.46	0.36
						Wesley					
2005	73.1	126	116	4.54	5.0	3.7	965	4.5	4.0	4.0	4.1
2006	72.9	167	127	4.27	5.0	5.0	903	4.5	5.0	5.0	5.0
2007	73.3	140	139	4.33	3.6	4.3	800	4.0	4.8	5.0	4.8
2008	76.0	136	111	5.33	4.0	4.8	880	5.0	5.0	6.0	5.6
Mean	73.8	142	123	4.62	4.4	4.5	887.0	4.5	4.7	5.0	4.9
SEM	0.73	8.7	6.1	0.244	0.36	0.29	34.1	0.2	0.24	0.41	0.32

†All reported values were measured at a 140 g H_20 1000 g^{-1} flour basis.

‡Scores use a 0–7 scale with 7 = very tolerant (Baenziger et al., 2001).

§Scores use a 0–6 scale with 6 = excellent.

were both reported to have 120 g protein kg^{-1}. The flour ash content (45.4 g kg^{-1}) was lower than that of Wesley (46.2 g kg^{-1}). Dough mixing properties of NH03614 CL were acceptable: mix-time peak on the Mixograph (National Mfg. Co., Lincoln, NE) was 4.7 min and mix-time tolerance was scored as 4.7, and both parameters were very similar to those for Wesley (Mixograph mix-time peak of 4.4 min and mix-time tolerance scored as 4.5). Average baking absorption (601 H_2O g kg^{-1}) was similar to that of Wesley (603 H_2O g kg^{-1}) for the corresponding years. The average loaf volume of NH03614 CL (834 cm^3) was lower than that for Wesley (887 cm^3). The scores for the external loaf score, internal crumb grain, and texture ranged from 4.0 to 4.3 (where 6 is excellent and 4 is good), which was less than those for Wesley, which ranged from 4.5 to 5.0. The overall end-use quality characteristics for NH03614 CL (scored as 4.1, where 6 is excellent and 4 is good) was lower than for Wesley (4.9) but superior to many commonly grown wheat cultivars. NH03614 CL should be acceptable to the milling and baking industries.

Availability

NH03614 CL contains a patented herbicide-tolerance trait (CLEARFIELD) owned by BASF Corporation (Florham, NJ) that confers tolerance to imidazolinone herbicides, such as imazamox. Any use of NH03614 CL requires a Material Transfer Agreement (for research use only) or a commercial license to the trait, as well as permission from the originator (University of Nebraska). Seed requests should be sent to the corresponding author who will forward the request for seed to BASF Corporation. No seed will be distributed for 20 yr from the date of release without written permission from both BASF and the University of Nebraska. After 20 yr, the seed can be freely distributed by the USDA collection.

The Nebraska Foundation Seed Division, University of Nebraska-Lincoln, Lincoln, NE 68583 had foundation seed available to qualified certified seed enterprises who were members of the NuPride Genetics Network in 2008. The USDA will not have seed for distribution. The seed classes will be breeder, foundation, registered, and certified. A research and development fee will be assessed on all certified seed sales.

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