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CULTIVAR

Registration of 'Focus' Hard Red Spring Wheat

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Abstract

Grower and end-user acceptance of new hard red spring wheat (HRSW; *Triticum aestivum* L.) cultivars is heavily influenced by agronomic performance, end-use quality potential, and disease resistance. The objective of this research was to release a new HRSW cultivar with competitive agronomic performance, end-use quality, and disease resistance to serve as a replacement for 'Brick', a HRSW cultivar that has been very popular in South Dakota. 'Focus' (Reg. No. CV-1148; PI 675337) HRSW was developed at South Dakota State University and released by the South Dakota Agricultural Experiment Station in early 2015. The cross SD3943-21/'Brick' was completed during fall 2007, and the resulting population was advanced via an early-generation bulk-testing program, where $F_{4:6}$ seed from the 2010 growing season was included in the 2011 preliminary yield trial, and the line was designated as SD4362. This line was also was tested in the advanced yield trial from 2012 through 2014. Focus was released primarily for its yield potential, high grain volume weight, early maturity, and good level of resistance to Fusarium head blight.

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New hard red spring wheat (HRSW; *Triticum aestivum* L.) cultivar releases generally require desirable agronomic performance, end-use quality, and disease resistance levels to achieve acceptance by potential growers and, ultimately, the support of end-users. The HRSW cultivar Brick (PI 657697; Glover et al., 2010), was released in early 2009 by the South Dakota State University (SDSU) breeding program, and over the years has been very popular in South Dakota primarily because of its yield potential, high grain volume weight (GVW), early maturity, and good level of resistance to Fusarium head blight [FHB; caused by *Fusarium graminearum* Schwabe (teleomorph *Gibberella zeae* (Schwein.) Petch]. The objective of this research was to release a new HRSW cultivar with competitive levels of agronomic performance, end-use quality, and disease resistance to serve as a replacement for Brick, which is quite susceptible to leaf rust (caused by *Puccinia triticina* Eriks.).

'Focus' (Reg. No. CV-1148; PI 675337) HRSW, tested as SD4362, was developed at SDSU and released by the South Dakota Agricultural Experiment Station in early 2015. It was derived as a single F_4 head from within the population SD3943-21/Brick, designated as population 28325, which was created in the HRSW breeding greenhouse at Brookings, SD, during fall 2007. The female parental line SD3943-21 is one of 50 reselections from an unreleased experimental breeding line, SD3943, developed by the SDSU-HRSW breeding program with the pedigree 'Briggs' (Devkota et al., 2007)/SD3623.

Population 28325 was advanced via an early-generation bulk-testing program until 2010, when the single $F_{4:6}$ experimental breeding line selection, designated as SD4362, was

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Abbreviations: AYT, advanced yield trial; DON, deoxynivalenol; FHB, Fusarium head blight; GPC, grain protein concentration; GVW, grain volume weight; HRSW, hard red spring wheat; PYT, preliminary yield trial; RCBD, randomized complete block design; SDSU, South Dakota State University; URN, Uniform Regional Nursery.

tested in the 2011 preliminary yield trial (PYT). Focus also was tested, as SD4362, in the SDSU-HRSW breeding program advanced yield trial (AYT) from 2012 through 2014 and the HRSW Uniform Regional Nursery (URN) during 2014.

Methods

Early Generation Population Development

Before derivation for inclusion in replicated statewide and regional performance trials, population 28325 was advanced via an early-generation bulk-testing breeding method. Five F_1 seeds created in fall 2007 were sown as a single hill in the HRSW breeding greenhouse at Brookings during spring 2008. At maturity, four heads were randomly collected from the hill, threshed individually, and sown as four separate F_2 rows measuring 1.33 m in length in the headrow field located near Brookings during April 2008. Throughout the growing season, headrows were examined visually for various characteristics, such as plant type, height, and lack of disease. Of the four population 28325 rows, a single row was harvested in August 2008, which resulted in bulk F_3 seed. A small sample (approximately 30 seeds) was then sown as a single row at an off-season nursery near Yuma, AZ, during winter 2008–2009. At harvest in the Yuma nursery, F_4 seed of the population 28325 row was bulked, shipped back to South Dakota, and used to sow a single yield trial plot measuring 1.5 by 4.6 m consisting of seven rows (21.4-cm row spacing) at Aurora and South Shore SD, in May 2009. Before harvest of F_4 yield trial plots, 20 individual plant selections were made by hand harvesting heads from within the 28325 plot at Aurora. Selected heads were threshed singly and sown as 2-m $F_{4:5}$ headrows at the Yuma nursery during winter 2009–2010. Of the 20 headrows representing population 28325, five were selected for advancement. Seed of the sib lines, along with 138 additional unrelated selections, was used to sow two $F_{4:6}$ yield trial plots measuring 1.5 by 4.6 m at both Aurora and South Shore during 2010.

Observations of plot uniformity, plant height (height from soil surface to tip of spikes, excluding awns), heading date (number of days to 50% heading after 1 June), and low, or at least acceptable, levels of leaf disease and FHB infection were collected for all F_4 bulk and $F_{4:6}$ plots during the 2009 and 2010 growing seasons. After harvest in both years, grain yield, GVW (approved method 55-10; AACC, 2000), grain protein concentration (GPC) (approved method 39-10; AACC, 2000), and several dough mixing characteristics acquired via a computerized Mixograph (approved method 45-40A; AACC, 2000) were also collected from each plot and compared with results obtained from checks that were uniformly interspersed at each trial location.

Prior to visiting the 2009–2010 Yuma nursery, we considered and used these data to determine whether rows representing population 28325 should be selected for further consideration. Off-season nursery selections were based primarily on desirable plant height and uniformity within rows displaying minimal lodging.

Line Selection and Evaluation

Agronomic performance and disease resistance data as described above were gathered for all $F_{4:6}$ lines during the 2010 growing season, while GVW, GPC, and dough mixing characteristics were collected after harvest. Among the five $F_{4:6}$ sib lines of population 28325 grown in 2010, three were selected for advancement. Bulked $F_{4:7}$ seed gave rise to three experimental lines, designated as SD4360, SD4361, and SD4362, which were included in one of two replicated PYTs during 2011. Two check cultivars, Briggs and 'Oxen' (PI 596770), along with 34 $F_{4:7}$ experimental lines selected from the 2010 growing season, were included within the PYT, which was arranged as a randomized complete block design (RCBD) composed of two replications grown at six South Dakota locations. Agronomic performance and disease resistance data were gathered from each location during the 2011 growing season, and GVW and GPC were again determined after harvest. Additionally, composite grain samples of each PYT entry from three locations were provided to the USDA–ARS Hard Spring Wheat Quality Laboratory in Fargo, ND, for end-use quality analysis using AACC approved methods (AACC, 2000). Based on agronomic, disease resistance, and end-use quality performance observations collected from 2011 PYT entries, SD4361 and SD4362 were among 16 others selected from the two PYTs for inclusion in the 2012 AYT.

Through methods similar to those described for PYT selection from growing season 2011, SD4361 was discarded after the 2012 season, and SD4362 was perpetuated in the three-replication RCBD AYTs grown at seven South Dakota locations from 2012 through 2014. Agronomic performance data from AYTs were consequently collected from 21 location-years over the three seasons. All AYT entries were subjected to molecular marker analysis at the USDA–ARS Cereal Crops Research Unit in Fargo. SD4362 was also included in the URN during 2014 at 13 locations in Minnesota, Montana, North Dakota, and South Dakota. Plot size and row spacings varied with URN cooperators, although all were conducted as a RCBD composed of three replicates that included five checks. All field plots within PYT, AYT, and South Dakota locations of the URN were sown as 1.5- by 6.0-m plots composed of seven rows (21.4-cm row spacing). All plots were trimmed to 4.5 m before heading.

Seed Purification and Increase

Purification of Focus, designated as SD4362, was initiated in 2012. Each AYT entry was sown as four 1.5- by 6.0-m increase and purification plots at Brookings that were trimmed to a length of 4.5 m before heading. On several occasions around heading and immediately before physiological maturity, early-heading, tall, and late-maturing plants were manually removed. After 2012 harvest, approximately 10 kg of breeder seed was sown on 0.2 ha near Brawley, CA. Seed from this increase block was used to sow approximately 5 ha in spring 2013 near Brookings. Finally, prior to release, a 64-ha increase block was sown in spring 2014 for foundation seed production.

Statistical Analysis

Statistical analyses for all parameters were performed using SAS-JMP version 12.0.1 (SAS Institute, 2015). Agronomic data from AYTs were collected on all replicate plots at each location-year. Similar data from URN trials, end-use quality data from AYTs, and deoxynivalenol (DON) concentration values were available only as location means within years. Mixed models were utilized for all analyses. Entries were treated as fixed effects. Locations, years, replications within location-years (where available) and appropriate interactions with entries were considered random effects. Only entries common over years were included in the analyses that took place after first testing for heterogeneity of variance using Levene's test (Levene, 1960). It was determined that location-year variances for grain yield and GVW were heterogeneous. Initial analyses were therefore performed where data were square root transformed to test for significance of effects prior to conducting secondary analyses on nontransformed data used for presentation of entry means. Entry effect mean separation was performed on nontransformed data using an F-protected LSD with $P \leq 0.05$.

Characteristics

Agronomic and Botanical Description

Over 3 yr of AYT observation, (21 location-years), plant height of Focus (89 cm) was significantly ($P < 0.05$) shorter than 'Forefront' (Glover et al., 2013; 91.6 cm) and 'Granger' (Glover et al., 2006; 91.5 cm), similar to 'Traverse' (PI 642780; 88.8 cm), and significantly taller than the nine remaining AYT comparison cultivars (Table 1). Heading date for both Focus and 'Select' (Glover et al., 2011; 21.1 d after 1 June) was significantly ($P < 0.05$) later than that of Brick (20.5 d), but significantly earlier than each of the remaining AYT comparison cultivars (Table 1).

Plant height of Focus (92.5 cm; measured at 13 URN locations) was significantly ($P < 0.05$) shorter than 'Chris' (CItr 13751; 107 cm), 'Keene' (PI 598224; 103.7 cm), and 'Marquis' (CItr 3641; 109.2 cm), similar to '2375' (syn. Pioneer 2375; PI 601477; 90.9 cm), and significantly taller than 'Verde' (Busch et al., 1996; 86 cm) (Table 2). The heading date of Focus (28.8 d after 1 June) was significantly earlier than each of the five URN check cultivars (Table 2).

Focus was observed to have an intermediately prostrate early plant growth habit with no anthocyanin pigmentation. At the boot stage, plants are green in color and flag leaves are inclined, not waxy, and not twisted. After heading, plants possess middense, tapering, and erect heads with white awns, white glabrous medium length glumes, with acuminate beaks, and elevated medium-width shoulders. Kernels are hard-textured, red-colored, oval-shaped, and collared, with rounded cheeks, a medium brush, a midsized germ.

Phenotypic uniformity and stability of Focus were closely monitored during the 2011 and 2012 growing seasons. A single variant plant type is known to occur at a frequency of about 50 in 10,000 plants; it is roughly 10 cm taller than the canopy but otherwise very similar to Focus.

Disease Resistance

Although Focus was not specifically tested for resistance to leaf rust (caused by *Puccinia triticina* Eriks.), analysis of molecular marker csLV34 (Lagudah et al., 2006) revealed that it possesses the slow rusting gene *Lr34*. Focus was evaluated for FHB resistance in inoculated nurseries at Brookings throughout its development (data not shown), where artificial inoculation and overhead mist-irrigation techniques (Rudd et al., 2001) were

Table 1. Agronomic and Fusarium head blight resistance observations for Focus hard red spring wheat and 11 additional cultivars tested in South Dakota State University advanced yield trials from 2012 through 2014.

Cultivar	Grain yield	Grain volume weight	Grain protein	Heading date	Plant height	Disease index†	Fusarium damaged kernels	DON‡
	kg ha^{-1}	kg m^{-3}	g kg^{-1}	d after 1 June	cm	%	%	μg g^{-1}
Focus	3256	777	151.8	21.1	89.0	16.2	16.3	6.8
Advance§	3235	761	144.8	25.3	81.2	22.7	21.9	8.0
Brick	3172	775	148.6	20.5	86.4	18.0	15.9	5.2
Briggs	3047	752	151.4	22.6	84.5	20.4	28.1	7.6
Faller	3351	747	142.4	26.2	86.2	20.5	21.7	9.5
Forefront	3352	772	150.1	22.8	91.6	15.6	19.1	6.1
Granger	3061	757	151.2	24.5	91.5	21.0	31.8	9.3
Knudson	3009	748	146.0	26.1	82.8	26.3	25.5	7.8
Oxen	3008	721	148.4	24.4	80.6	27.1	32.3	5.6
Prevail	3351	760	144.7	24.8	82.7	19.2	20.9	7.5
Select	3268	767	147.3	21.1	87.0	21.8	26.7	6.1
Steele-ND	2976	753	152.2	24.7	86.8	20.5	23.7	9.9
Traverse	3346	725	143.6	23.4	88.8	24.2	30.1	7.8
Mean	3187	755	147.0	23.0	86.0	21.0	24.0	7.0
LSD (0.05)	85	4	1.4	0.5	1.4	5.2	10.7	2.2
CV %	4.7	2.3	2.3	8.3	4.2	16.5	22.9	21.3
Environments	21	21	21	21	21	6	6	6

† Disease index described by Stack et al. (1997).

‡ Deoxynivalenol.

§ Glover et al. (2015).

used to promote disease development. While tested in AYTs, screening of Focus for FHB resistance was continued each year at Brookings and near Volga, SD. On the basis of these six trials, average FHB disease index ratings (Stack et al., 1997) of Focus (16.2%) were similar to Brick (18.0%), Briggs (20.4%), 'Faller' (Mergoum et al., 2008; 20.5%), Forefront (15.6%), Granger (21.0%), 'Prevail' (Glover et al., 2017; 19.2%), and 'Steele-ND' (Mergoum et al., 2005; 20.5%) but significantly ($P < 0.05$) lower, or more resistant, than the remaining five check cultivars (Table 1). The mean Fusarium-damaged kernel percentage of Focus (16.3%) was similar to most check cultivars, although it was significantly ($P < 0.05$) less than those of Briggs (28.1%), Granger (31.8%), Oxen (32.3%), and Traverse (30.1%) (Table 1). The average DON concentration of Focus (6.8 μg g^{-1}) was very similar to the mean of the trials (7.0 μg g^{-1}) and most comparison cultivars, although significantly ($P < 0.05$) less than those of Faller (9.5 μg g^{-1}), Granger (9.3 μg g^{-1}), and Steele-ND (9.9 μg g^{-1}) (Table 1). Analysis of the single nucleotide polymorphism marker *Xsnp3BS-usda* revealed that Focus possesses the *Fhb1* (Pumphrey et al., 2007) quantitative trait locus for FHB resistance.

Entries within the 2014 URN were also evaluated in artificially inoculated and mist-irrigated FHB resistance screening nurseries, where disease index and Fusarium-damaged kernel percentages were collected at three environments in South Dakota and Minnesota. The average disease index rating of Focus (15.1%) was significantly ($P < 0.05$) lower than all check cultivars except for 2375 (22.0%) (Table 2). Average DON concentration of Focus (11.0 μg g^{-1}) was significantly lower than only Chris (25.1 μg g^{-1}) and Keene (19.6 μg g^{-1}) (Table 2).

Field Performance

Over 21 AYT location-years from 2012 through 2014, average grain yield of Focus was 3256 kg ha^{-1}, which was similar to the trial mean and significantly less than Faller, Forefront, Prevail, and Traverse, all of which were in the range of 3346 to 3352 kg ha^{-1} (Table 1). Within the same trials, Focus and Brick were similar in GVW (777 and 775 kg m^{-3}) and were significantly ($P < 0.05$) higher than each of the other check cultivars (Table 1). Likewise, average GPC of Focus (151.8 g kg^{-1}) was among a group with three other cultivars with similarly high values, ranging from 151.2 to 152.2 g kg^{-1}; Table 1).

Within the 2014 URN where grain yield was collected at 13 environments, Focus averaged 5291 kg ha^{-1}, which was similar to that of 2375 (5213 kg ha^{-1}) and significantly higher ($P < 0.05$) than the remaining cultivars (Table 2). Grain volume weight of Focus (770 kg m^{-3}) was significantly higher than all of the URN check cultivars (Table 2). Grain protein concentration of Focus (145.9 g kg^{-1}) was significantly less ($P < 0.05$) than Chris (151.7 g kg^{-1}), similar to most remaining cultivars, but higher than that of Verde (138.1 g kg^{-1}))Table 2).

End-Use Quality

Grain samples collected from 2012 to 2014 AYT harvests were evaluated for milling and bread baking quality by the USDA–ARS Hard Spring Wheat Quality Laboratory in Fargo, ND. Results shown in Table 3 reveal that Focus was not significantly better or worse than trial averages for most end-use quality traits that were measured. Two exceptions are noted, however, for flour protein and flour ash concentration. Flour protein of Focus was 135.8 g kg^{-1} and was significantly ($P < 0.05$) higher than the overall mean of 132.8 g kg^{-1}. Additionally, flour ash concentration of Focus (3.4 g kg^{-1}) was among the lowest values that were measured and significantly lower than the overall flour ash mean of 3.6 g kg^{-1} (Table 3).

Availability

Focus is protected under the US Plant Variety Protection (PVP no. 201600080) Act (P.L. 910577) for foundation, registered, and certified seed. All seed requests should be sent to the corresponding author during the period of protection by the PVP certificate. Seed of Focus has been deposited in the USDA National Plant Germplasm System, where it will be available after PVP expiry for research purposes, including development and commercialization of new cultivars. It is requested that appropriate recognition be made if Focus contributes to the development of new germplasm or cultivars.

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Table 2. Agronomic and Fusarium head blight resistance data for Focus hard red spring wheat and five additional check cultivars tested in 2014 Hard Red Spring Wheat Uniform Regional trial.

Cultivar	Grain yield	Grain volume weight	Grain protein	Heading date	Plant height	Disease index†	Fusarium damaged kernels
	kg ha^{-1}	kg m^{-3}	g kg^{-1}	d after 1 June	cm	%	%
Focus	5291	770	145.9	28.8	92.5	15.1	11.0
2375	5213	757	143.8	33.0	90.9	22.0	15.3
Chris	3753	739	151.7	36.0	107.0	35.8	25.1
Keene	4854	747	146.4	33.7	103.7	31.3	19.6
Marquis	3912	744	146.3	37.0	109.2	27.9	17.9
Verde	4918	743	138.1	34.0	86.0	29.1	17.4
Mean	4657	750	145.4	33.8	98.2	26.9	17.7
LSD (0.05)	318	8	4.0	1.0	3.1	11.7	8.2
CV %	15.3	1.0	2.3	5.5	8.4	21.5	23.0
Environments	13	13	13	13	13	3	3

† Disease index described by Stack et al. (1997).

Table 3. Milling and baking characteristics of Focus hard red spring wheat and 12 additional cultivars tested in South Dakota State University advanced yield trials from 2012 through 2014.

Cultivar	Flour protein	Flour extraction	Flour ash	Envelope peak time	Envelope peak height	Mixograph score†	Bake mix time	Bake water absorbance	Loaf volume
	——— g kg^{-1} ———			min	%	0–7	min	g kg^{-1}	mL
Focus	135.8	644.2	3.4	7.2	61.4	5.5	3.9	570	190.3
Advance‡	129.3	641.9	3.7	7.8	58.4	5.2	4.0	573	188.5
Brick	132.5	636.6	3.6	9.4	60.0	5.7	5.0	580	189.7
Briggs	136.1	648.7	3.6	4.3	58.0	4.1	2.5	571	180.7
Faller	130.6	664.4	3.7	6.6	58.4	4.9	3.3	575	188.7
Forefront	133.6	644.0	3.4	7.1	59.9	5.3	3.7	577	193.6
Granger	136.7	641.2	3.6	4.7	65.3	5.5	3.0	588	188.1
Knudson	130.7	649.5	3.9	10	64.7	6.4	5.5	586	184.4
Oxen	132.5	640.4	3.6	6.9	63.8	6.1	4.0	585	189.7
Prevail	129.5	656.4	3.4	6.6	59.2	5.1	3.3	569	182.2
Select	131.7	624.7	3.9	7.7	58.1	5.2	3.9	579	184.3
Steele-ND	138.4	641.8	3.7	6.1	60.8	5.7	3.5	583	193.6
Traverse	128.6	620.7	4	3.7	58.2	3.8	2.2	571	177.9
Mean	132.8	642.7	3.6	6.8	60.5	5.3	3.7	577	186.6
LSD (0.05)	2.8	13.5	0.1	1.1	2.9	0.5	0.3	90	6.7
CV %	2.4	1.8	5.4	26.8	4.3	13.5	24.3	11.0	2.6
Environments	15	15	15	15	15	15	15	15	15

† Mixograph score scale: 7 = excellent, 0 = unacceptable.

‡ Glover et al. (2015).

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