Registration of 'UI SRG' Wheat

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ABSTRACT

Developing wheat (*Triticum aestivum* L.) cultivars with high yield, desirable end-use quality, and resistance to prevalent diseases are the major goals for the breeding programs in the Pacific Northwest region of the United States and the world. 'UI SRG' (Reg. No. CV-1066, PI 660546) hard red winter wheat was developed by the Idaho Agricultural Experiment Station using a modified backcross breeding procedure. UI SRG was derived from a BC_1F_7 line from the backcross 'Utah 100'*2/'Boundary' and tested under experimental numbers A971065W-J-4 and IDO656. UI SRG was released in 2010 for its improved resistance to stripe rust (caused by *Puccinia striiformis* Westend f. sp. *tritici*) combined with superior yield and resistance to dwarf bunt (caused by *Tilletia contraversa* Kühn) and stem rust (caused by *P. graminis* Pers: Pers. f. sp. *tritici* Eriks. & E. Henn) (local and TTKS races). UI SRG is best adapted to rainfed production in the intermountain zone of the western United States and is targeted to replace the stripe rust–susceptible cultivar 'Deloris' and the lower-yielding older cultivars Utah 100 and 'Finley'. Milling and baking quality of UI SRG is not significantly different from that of the best-quality check cultivars 'DW' and Deloris.

The hard red winter wheat cultivar 'UI SRG' (Reg. No. CV-1066, PI 660546) has high yield, good bread-baking quality, high-temperature adult-plant (HTAP) resistance to stripe rust (caused by *Puccinia striiformis* Westend. f. sp. *tritici* Eriks.), and resistance to dwarf bunt (caused by *Tilletia contraversa* Kühn) and stem rust (caused by *P. graminis* Pers: Pers. f. sp. *tritici* Eriks. & E. Henn). UI SRG is tall and best adapted to rainfed production in the intermountain zone of the western United States and is targeted to replace the stripe rust–susceptible cultivar 'Deloris' (PI 631447; Hole et al., 2004) and lower-yielding older cultivars 'Utah 100' (PI 594920; Hole et al., 1997), 'Boundary' (PI 603039; Souza et al., 1999), and 'Finley' (PI 586756; Donaldson et al., 2000). The grain yield of UI SRG was significantly greater than that of the check cultivars Boundary and Finley used in the Western Regional Hard Winter Wheat Nurseries (WRHWWN) in 31 locations across 3 yr (2006, 2007, and 2009). The bread-baking quality of UI SRG was not significantly different from that of the best-quality checks, hard red winter cultivars 'DW' (PI 620629; Souza et al., 2004), Deloris, and Finley.

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Abbreviations: HTAP, high-temperature adult-plant; IT, infection type; SEV, severity; UIEYT, University of Idaho Elite Yield Trial; WRHWWN, Western Regional Hard Winter Wheat Nurseries.

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Methods

Pedigree and Breeding History

UI SRG was derived from a BC_1F_7 line of the backcross Utah 100*2/Boundary. Utah 100 hard red winter wheat is resistant to dwarf bunt and was released by the Utah Agricultural Experiment Station in 1996. Boundary hard red winter wheat is a high-yielding cultivar that was released in 1997 by the Idaho Agricultural Experiment Station. It is moderately resistant to dwarf bunt and has HTAP resistance to stripe rust. It is also resistant to leaf rust (caused by *P. triticina* Eriks.) and powdery mildew [caused by *Blumeria graminis* (DC) Speer f. sp. *tritici* emend. É. J. Marchal], and moderately tolerant to snow molds (caused by *Microdocium*

nivale and *Typhula* spp.), similar to 'Manning' (CItr 17846) (Souza et al., 1999).

The initial cross was made between Utah 100 and Boundary in 1996. The F_1 was backcrossed to Utah 100 in the field in 1997, and the BC_1F_1 (A971065W, 11 seeds) was grown in the field in a single 1.2-m headrow in 1998, from which individual plants were harvested (designated A971065W-A through A971065W-K). Grain from the 11 harvested plants was planted into 4.5-m^2 plots in the fall of 1998, and approximately 100 heads selected from each plot. Remnant grain from the plots was evaluated for SDS-sedimentation (Guttieri et al., 2004), and 50 heads from one plot A971065W-J with high SDS-sedimentation volume were replanted in the field as 1.2-m headrows in 1999 using seed inoculated with common bunt [caused by *Tilletia tritici* syn. *T. caries* (DC) Tul. & C. Tul.]. Out of 50 headrows, 6 (A971065W-J-2, 4, 8, 17, 18, and 19) were selected based on uniformity and resistance to common bunt. Selected families were planted in a nonreplicated observation nursery in Aberdeen, ID in fall 2000. One line, A971065W-J-4 ($BC_1F_{2:4}$), was selected based on agronomic characteristics and was advanced to yield-trial evaluations.

Line Selection and Evaluation

A971065W-J-4 was evaluated for agronomic and bread baking quality in the University of Idaho's replicated preliminary yield trials in Aberdeen in 2001 and 2002. It was evaluated in the University of Idaho Elite Yield Trials (UIEYTs) under irrigation and rainfed conditions in multiple location-years from 2003 to 2009. The irrigated UIEYTs were grown at three locations (Aberdeen, Hazelton, and Kimberly, ID), while rainfed trials were grown at four locations (Preston, Rockland, Arbon Valley, and Tetoni, ID). Deloris and DW were used as checks in the UIEYTs.

A971065W-J-4 was evaluated under the designation IDO656 in the WRHWWN trials in 2006, 2007, and 2009 at 12 locations each year across the states of Idaho, Oregon, Montana, and Washington. The cultivars Finley and Boundary were used as checks in the WRHWWN trials.

Both the WRHWWN and UIEYT trials consisted of three replicated plots planted in a partial lattice design. In irrigated trials at Aberdeen, Hazelton, Kimberly, and Parma, plots consisted of seven rows that were 3.05 m long, 1.5 m wide, and 0.25 m apart with a seeding rate of 2.47×10^6 seeds ha^{-1}. The rainfed plots grown in Preston, Rockland, Arbon Valley, and Tetonia consisted of four rows that were 3.05 m long, 1.5 m wide, 0.35 m apart and seeded at 1.98×10^6 seeds ha^{-1}.

Grain yield, volume weight, days to heading (50% of heads in the plot completely visible), and plant height (distance from ground to top of spike excluding awns) were measured in most locations, while lodging (0–9; 0 = no lodging; 9 = 100% plants lodged) was recorded only when significant lodging was present in the field.

Milling and baking quality were evaluated as previously described (Guttieri and Souza, 2003) for composite grain samples harvested from four irrigated locations (Aberdeen 2009, Hazelton 2008, Kimberly 2008, and Parma 2009) and five rainfed locations (Rockland 2009, Preston 2008, Arbon Valley 2009, Tetonia 2008, and Moscow 2008). Near-infrared analysis was performed with a Perten 8611 (Perten Instruments, Springfield, IL) according to the American Association of Cereal Chemists method 39-10 (AACC, 2000) to determine flour protein concentration with values calibrated by combustion analysis of total nitrogen content with a LECO Model FP-428 (LECO Corp., St. Joseph, MO) and corrected to 120 g kg^{-1}.

Disease Resistance

UI SRG was evaluated as a single row plot (1.0 m long) for resistance to stripe rust under natural field infections in both Pullman and Mt. Vernon, WA in 2008–2010 in two nurseries, the UIEYT and the WRHWWN. Stripe rust races prevalent at these locations during those years included PST-114, PST-116, PST-127, and PST-139 (Chen et al., 2010; Chen, unpublished data, 20X11. Stripe rust resistance was evaluated twice at the Feekes growth stages 5–6 and 10.1–10.5 in Mt. Vernon and once at stage 10.1–10.5 in Pullman when the susceptible check 'PS 279' had about 30% severity at the early stage and greater than 80% severity at the late stage. Infection type (IT) was recorded based on the 0–9 scale as described by Line and Qayoum (1992), and severity (SEV) was recorded as percentage of foliage infected. In addition, UI SRG was evaluated in the greenhouse with selected races PST-37, PST-45, PST-100, PST-116, and PST-127 in the seedling stage at a low-temperature profile (diurnal temperature cycle gradually changing from 4°C at 0200 h to 20°C at 1400 h) with 16 h light, and with races PST-100, PST-116, and PST-127 in adult-plant stages (boot to flowering) at a high-temperature profile (diurnal temperature cycle gradually changing from 10°C at 0200 h to 30°C at 1400 h) (Chen and Line 1995).

The reaction of UI SRG to dwarf bunt compared with the reaction of the susceptible cultivar 'Cheyenne' (CItr 8885; Clark, 1931) was tested in Logan, UT in two replicate 1.5-m rows in the field in 2005, 2006, 2007, and 2009. The nursery was artificially inoculated with a composite of common pathogenic races of *T. contraversa*. The percentage of diseased spikes of Cheyenne and UI SRG in those years was determined at plant maturity.

Statistical Analysis

Data were analyzed using SAS Version 9.1 (SAS Institute, Gary, NC). Analyses of variance for grain yield and volume weight, days to heading, plant height, lodging, quality traits, and resistance to stripe rust were performed across location-years using only entries common among the trials. The LSD test ($\alpha = 0.05$) was used to determine the significance of mean differences among genotypes for the traits evaluated.

Seed Purification and Increase

Seed-increase plots were planted each year from 2005 to 2008 in parallel with yield trials. In spring 2008, 400 heads were selected from a seed-increase plot. These were threshed individually and planted into headrows in the fall of 2008. Uniform headrows were selected and harvested individually in summer 2009. The harvested headrows

were then evaluated for grain protein content. Seeds from 50 headrows with protein content of 130–145 g kg^{-1} were then bulked and planted in Aberdeen in the fall 2009. In 2010 summer, 150 kg of breeder seed was harvested. Ten kg of breeder seed was planted in Tetonia for pre-foundation-seed production and 70 kg of breeder seed were used in the PNW Quality Council Evaluation. Further seed increases and requests were handled by the University of Idaho, Foundation Seed Program, at Kimberly Research and Extension Center, Kimberly, ID.

Characteristics

Agronomic Characteristics

UI SRG's juvenile plant growth is semierect. At the boot stage, UI SRG's plants are blue-green and have semierect to erect flag leaves. The width of the flag leaf is smaller than that of both parents, and the length of the flag leaf is longer than that of Utah 100 but similar to that of Boundary. The coleoptiles are white, and the anthers are yellow. Stem internodes are hollow, and peduncles are erect. UI SRG has awned, bronze-chaffed, fusiform, middense, and inclined spikes, similar to those of the recurrent parent Utah 100. UI SRG's kernel is ovate, with rounded cheeks, a midwide and deep seed crease, and the brush length is medium and similar to both parents. On the basis of three observation years (2008–2010), UI SRG was found to have an average kernel weight 37.5 mg, which is heavier than that of Boundary (32.1 mg), DW (32.5 mg), and Deloris (35.6 mg) (data not shown).

Spike emergence (days to heading from 1 January) of UI SRG was an average 154 and 163 d in the WRHWWN and UIEYT's, respectively (Tables 1 and 2), which is the same as Boundary but 1 d later than Finley (Table 1) and 1 d earlier than Deloris and DW under rainfed conditions (Table 2). UI SRG had an average height of 97 cm in both WRHWWN and UIEYTs, so it is taller than Boundary (79 cm) but shorter than Finley (103 cm) (Table 1). In the UIEYTs, UI SRG was

Table 1. Grain yield, volume weight, days to heading, and plant height of UI SRG hard red winter wheat compared with other cultivars evaluated under rainfed and irrigated conditions in the Western Regional Hard Winter Wheat Nurseries in 2006, 2007, and 2009.†

	All		Rainfed		Irrigated		All		
Cultivar	Grain yield	Yield rank	Grain yield	Yield rank	Grain yield	Yield rank	Volume weight	Days to heading	Plant height
	kg ha^{-1}		kg ha^{-1}		kg ha^{-1}		kg hL^{-1}	d	cm
				2006					
UI SRG	6316.2	5	6316.2	5	—	—	78.6	154.1	107.3
Boundary	5704.0	17	5704.0	17	—	—	78.3	154.6	88.5
Finley	5119.7	21	5119.7	21	—	—	79.9	153.6	113.1
Mean of 23 entries	5829.1		5829.1				79.1	152.2	92.4
LSD (0.05)	647.4		647.4				4.3	1.7	6.2
No. of sites	8		8				7	5	8
				2007					
UI SRG	6288.2	2	6218.3	3	6637.6	2	77.1	153.0	73.9
Boundary	5601.0	14	5724.0	12	4986.1	21	76.8	153.9	61.5
Finley	5021.8	24	4737.9	24	6441.1	5	79.4	152.6	81.9
Mean of 26 entries	5550.0		5529.4		5652.4		78.2	151.5	68.3
LSD (0.05)	720.0		772.7		1701.2		1.4	2.1	10.5
No. of sites	12		10		2		9	9	7
				2009					
UI SRG	6337.9	1	5707.2	2	8019.7	1	80.4	155.1	105.7
Boundary	5702.6	8	5532.4	4	6156.4	13	80.0	155.2	83.2
Finley	5188.1	15	4836.9	15	6124.6	14	82.2	153.8	109.7
Mean of 17 entries	5615.3		5253.1		6581.3		81.0	154.3	92.0
LSD (0.05)	551.6		509.2		1275.3		1.3	1.3	5.1
No. of sites	11		8		3		8	7	10
				All years					
UI SRG	6313.0	1	6091.1	1	7466.9	1	78.7	154.0	96.5
Boundary	5663.6	2	5658.9	2	5688.3	2	78.3	154.5	78.7
Finley	5106.1	3	4885.9	3	6251.2	2	80.5	153.2	104.1
Mean of 4 entries	5340.5		5229.2		5919.2		79.1	153.7	96.5
LSD (0.05)	384.2		381.5		1168.9		0.7	0.7	4.6
No. of sites	31		26		5		24	21	25

†Complete data summaries can be found at http://www.ars.usda.gov/Services/docs.htm?docid=3712 (verified 8 Sept. 2011).

Table 2. Grain yield, volume weight, days to heading, plant height, and lodging of UI SRG hard red winter wheat compared with two check cultivars evaluated under rainfed (RF) and irrigated (IRR) conditions in the University of Idaho Elite Yield Trials in 2006, 2008, and 2009.

	Grain yield			Volume weight		Days to heading		Plant height		Lodging
Cultivar	All	RF	IRR	RF	IRR	RF	IRR	RF	IRR	IRR
	kg ha^{-1}			kg hL^{-1}		d		cm		0–9
UI SRG	6155.1	3467.2	9052.3	78.5	78.9	163	163	80.8	112.9	4.2
Deloris	5991.8	3548.3	8744.3	79.1	79.9	164	162	78.5	114.5	3.4
DW	5700.7	3095.9	8708.1	79.2	78.9	164	163	69.1	97.7	4.1
Mean of 6 entries	5727.2	3278.9	8439.0	78.7	79.6	164	163	75.7	108.7	3.9
LSD (0.05)	829.6	704.4	1359.8	1.7	1.1	1	2	3.7	10.6	2.4
No. of sites	13	7	6	3	6	6	5	6	5	3

taller than DW but of similar height as Deloris under both rainfed and irrigated conditions (Table 2).

Grain-Yield Performance

In the WRHWWN trials (Table 1), UI SRG ranked among the top five cultivars for grain yield, with a 3-yr average (2006, 2007, 2009) of 6091 kg ha^{-1} in rainfed and 7467 kg ha^{-1} in irrigated tests, respectively. The average grain volume weight of UI SRG (79 kg hL^{-1}) was significantly ($P < 0.05$) less than that of Finley (80.5 kg hL^{-1}) but not significantly different from that of Boundary (78 kg hL^{-1}). UI SRG was evaluated across 13 locations in the UIEYTs, and its average yield and volume weight were not significantly different than those of the two check cultivars (Table 2).

Quality Characteristics

UI SRG has good end-use quality for a hard red winter wheat. The bread-baking volume of UI SRG was not significantly different than those of the best-quality checks DW and Deloris; moreover, it was significantly greater than Boundary's. The flour protein and mix tolerance of UI SRG were also not significantly different than those of all the checks used in this study. The flour yield of UI SRG was significantly less than that of Deloris but not significantly different from that of the other check cultivars ($P < 0.05$) (Table 3).

Table 3. Mean flour protein content, flour yield, mixograph tolerance, and baking volume for UI SRG hard red winter wheat compared to three check cultivars grown in nine farm trials located in Aberdeen, Preston, and Rockland in Southern Idaho during the 2006 to 2009 crop years.

Cultivar	Flour protein	Flour yield	Mix tolerance	Baking volume
	g kg^{-1}		degree	cm^3
UI SRG	116	692	72.4	1125.0
Boundary	110	693	76.1	998.3
DW	118	687	75.3	1191.7
Deloris	117	716	72.3	1172.2
Mean of 6 entries	116	699	74.2	1116.3
LSD (0.05)	8	13	4.7	83.2
No. of sites	9	9	9	9

Disease Reactions

UI SRG has a combination of race-specific all-stage and non-race-specific HTAP resistances to stripe rust. In field tests at nine environments across 3 yr (2008–2010), UI SRG had IT scores ranging from 2 to 3 in six environments and of 8 in three environments and SEV ratings ranging from 2 to 30%, while the susceptible check PS 279 had IT scores of 8 and SEV ratings of 80–90% in the adult-plant stage at all environments. In greenhouse tests, seedlings of UI SRG were resistant (ITs of 0 and 2) to races PST-37, PST-45, PST-100, and PST-127, but susceptible (IT 8) to PST-116 at the low-temperature cycle. The interaction pattern to the races indicated that UI SRG has *Yr10* (Chen et al., 2010) for resistance to some of the U.S. stripe rust races. Adult-plants of UI SRG were resistant to PST-100, PST-116, and PST-127 (ITs of 2, 2, and 0, respectively) at the high-temperature profile. The contrast responses to PST-116 in the greenhouse tests, together with the contrast responses to stripe rust in the early and late growth stages in the field at Mt. Vernon during 2010 indicated that UI SRG has HTAP resistance. On the basis of six location-years of evaluation (Table 4), the mean disease IT (3.5) and SEV (13.7%) of UI SRG were significantly lower than those of Deloris; moreover, the differences of UI SRG with the other two resistant lines, DW and Boundary, were not significant. UI SRG also has excellent resistance to dwarf bunt. The percentage of diseased spikes in the susceptible cultivar Cheyenne and UI SRG tested in Logan, UT during 2005, 2006, 2007, and 2009 was 50% and

Table 4. Mean stripe rust infection type and severity for UI SRG hard red winter wheat compared with four check cultivars grown in two locations Pullman and Mt. Vernon, WA in 2008–2010.

Cultivar	Infection type	Severity
	0–9[†]	%
SRG	3.5	13.7
Deloris	5.7	26.7
DW	2.3	6.7
Boundary	2.8	6.8
PS 279	8.0	76.7
Mean of 12 entries	4.2	23.5
LSD (0.05)	2.1	10.7

[†]Infection type described by Line and Qayoum (1992).

0%, 44% and 0%, 99% and 3%, and 93% and 0%, respectively On the basis of field disease-severity ratings from Kenya in 2007, UI SRG is moderately resistant (5–30%) to stem rust (data not shown). In seedling tests conducted by the USDA-ARS Cereal Disease Laboratory in 2009, UI SRG showed resistant reactions (1 to 2+) to all *P. graminis f. sp. tritici* races except for TPMK and TTTT, suggesting that UI SRG carries the *SrTmp* gene for resistance to TTKS. UI SRG also showed a resistant reaction to a bulked isolate of stem rust collected from the Palouse region and southern Idaho tested under controlled greenhouse conditions in 2010 (Chen and Bonman, unpublished data, 2010). UI SRG was observed to have high levels of infection to black chaff [caused by *Xanthomonas campestris pv. translucens* (J. J. & R.) Dye] on leaves under irrigation in summer 2010.

Availability

Breeder and foundation seed of UI SRG will be maintained by the Idaho Foundation Seed Program under direction of the Idaho Agricultural Experiment Station, University of Idaho, Moscow, ID 83844. U.S. Plant Variety Protection will be sought for UI SRG. Seed of US SRG has been deposited in the National Plant Germplasm System, where it will be available for distribution upon expiration of Plant Variety Protection, 20 yr after the date of publication. 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.

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