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CULTIVAR

Registration of 'Jasper' Soft White Winter Wheat

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Abstract

Many soft white winter (SWW) wheat (*Triticum aestivum* L.) cultivars with high yield potential in the US Pacific Northwest lack adequate resistance to stripe rust or are only adapted to specific regions defined by annual precipitation. The objective of this research was to develop a SWW wheat cultivar with improved resistance to current stripe rust races and high yield potential across a wider range of climates. 'Jasper' (Reg. No. CV-1124, PI 678442) SWW wheat was developed and released in September 2014 by the Agricultural Research Center of Washington State University. Jasper was tested under the experimental designations 5J061865-11 and WA8169, which were assigned through progressive generations of advancement. Jasper is a semidwarf cultivar adapted to intermediate to high rainfall (>300 mm of average annual precipitation) wheat production regions of Washington, with acceptable yield potential in the lower rainfall areas (<300 mm of average annual precipitation). It has high-temperature, adult-plant resistance to the current races of stripe rust, is intermediate in height, has midseason maturity, and has an average test weight and high grain yield potential. Jasper has end-use quality properties similar or superior to those of 'Stephens', 'Puma', and 'Otto'.

The state of Washington has many different winter wheat (*Triticum aestivum* L.) production regions based on amount of annual precipitation and other climatic factors. Additionally, the amount of rainfall in a given production region varies widely from one year to the next. Because of this, few soft white winter (SWW) wheat cultivars have strong yield potential across all of Washington's winter wheat production environments. In addition, many high-yielding SWW cultivars do not have adequate levels of disease resistance to stripe rust (caused by *Puccinia striiformis* Westend. f. sp. *tritici* Eriks.), a major disease that threatens winter wheat grown in the Pacific Northwest region of the United States. Stripe rust resistance is particularly important in the intermediate- to high-rainfall regions (>300 mm average annual precipitation), where disease pressure can be heavy. The objective of this research was to develop a SWW wheat cultivar that combines effective resistance to current races of stripe rust with high yield potential across production regions, while maintaining a high standard of end-use quality compared with current cultivars grown in the intermediate to high rainfall regions of Washington State.

'Jasper' (Reg. No. CV-1124, PI 678442), a SWW wheat, was developed and released in September 2014 by the Agricultural Research Center of Washington State University. Jasper was released as an alternative to 'Xerpha' (Jones et al., 2010) in rainfed wheat production systems in the intermediate- to high-rainfall (>300 mm of average annual precipitation) regions of Washington State. Jasper is the 100th cultivar released by Washington State University and is named in honor of the first wheat breeder at the university, William Jasper Spillman. The release of Jasper is based on its (i) high-temperature, adult-plant resistance to current races of stripe rust, (ii) improved end-use quality, and (iii) high grain yield potential across target production regions.

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Abbreviations: IT, infection type; PPO, polyphenol oxidase; SKCS, single kernel characterization system; SWW, soft white winter.

Methods

Breeding Design

Jasper, tested under the experimental designations 5J061865-11 and WA8169, is an $F_{3:4}$ headrow selection derived from the cross 'Sentry'/'Lewjain'//'Madsen'/3/Madsen/4/'Brundage 96'. The final cross for Jasper was completed in the greenhouse in Pullman, WA, in 2006. Sentry (Lebsock, 1965) is a spring durum wheat cultivar jointly released by the USDA-ARS and North Dakota Agricultural Experiment Station in 1954 with the pedigree 'Nugget'/3/'Heiti'/'Stewart'//'Mindum'/'Carleton'. Lewjain (Peterson et al., 1983) is a SWW wheat cultivar released by Washington State University and the USDA-ARS in 1982 with the pedigree 'Luke' (Peterson et al., 1974)/3/'Super Helvia'//'Suwon 92'/CI13645. Madsen (Allan et al., 1989) is a SWW wheat cultivar jointly released by the USDA-ARS, Washington State University, University of Idaho, and Oregon State University in 1988 with the pedigree 'VPM 1'(PI 519303)/'Moisson 951'//2*'Hill 81'(Kronstad et al., 1982). Brundage 96 (Zemetra et al., 2003) is a SWW wheat cultivar released by the Idaho Agricultural Experiment Station in 2001 with the pedigree 'Stephens' (Kronstad et al., 1978)/'Geneva' (Sorrells and Jensen, 1987).

The following modified pedigree-bulk breeding method was used to advance early generation progeny. Bulked seed (3 g) from F_1 plants, identified as population 2J061865, was used to establish a 1-m F_2 row in 2007. Single heads of approximately 30 F_2 plants were threshed individually to establish $F_{2:3}$ headrow families in 2008. Single heads of approximately 30 F_3 plants were threshed individually to establish $F_{3:4}$ headrow families in 2009. F_1 progeny were grown at the Washington State University Plant Growth Facility on the Washington State University Campus in Pullman. F_2 through F_4 progeny were grown in field nurseries at Pullman.

Following selection among $F_{3:4}$ rows for general adaptation, visual resistance to stripe rust, plant height, and grain appearance, seed from 30 to 50 plants within each selected headrow was bulk harvested to obtain $F_{3:5}$ seed for early generation quality assessment. Screening methods included DNA markers for high molecular weight glutenin profile at the *Glu-D1* locus (Liu et al., 2008), seed coat color, and polyphenol oxidase (PPO) enzyme activity using the procedure of Bernier and Howes (1994). Selections with the 2+12 subunit high molecular weight glutenin at the *Glu-D1* locus, white seed coat color, and medium to low PPO reactions were advanced to grain yield assessment trials. Twelve $F_{3:5}$ headrow selections were individually advanced to a nonreplicated yield plot field trial in Pullman in 2010. The lines were evaluated for yield potential, grain volume weight, grain protein concentration, disease resistance, and end-use quality as described below. One line, identified as 5J061865-11, was selected and advanced to F_6 replicated field trials at Pullman and Lind, WA, in 2011. Lines were evaluated for emergence from deep planting (planted 15 cm deep), plant height, grain yield, grain volume weight, disease resistance, and end-use quality.

Using seed generated in a nonreplicated field trial, Jasper was evaluated in replicated field breeding trials for 41 location-years in preliminary (3 locations) and advanced (13 locations) trials from 2010 through 2015 in low- (<300 mm average annual precipitation), intermediate- (300–500 mm average annual precipitation), and high-precipitation zones (>500 mm average annual precipitation) and under irrigation in Washington State. All years of field testing used the same data collection strategy with a general α–lattice design (three replications) (Mason et al., 2003). On the basis of breeding trial data from 2010 to 2012, 5J061865-11 was selected for testing on a regional basis and assigned the new identification number, WA8169. WA8169 was entered in the Washington State University Extension Uniform Cereal Variety Testing Program and tested at 11 locations in 2013 and at 21 and 20 locations in 2014 and 2015, respectively, throughout eastern Washington.

End-Use Quality Screening

Beginning in 2010, WA8169 was evaluated for end-use quality by the USDA-ARS Wheat Health, Genetics, and Quality Disease Research Unit, Pullman, according to approved methods of the American Association of Cereal Chemists (AACC, 2000). End-use quality values for selection were based on the recommendations of the Pacific Northwest Quality Council Quality Targets Steering Committee, which were adopted 25 Jan. 2005, in Portland, OR. Before milling, samples were tempered to 14% moisture content, then milled on a modified Quadrumat system (Jeffers and Rubenthaler, 1979). End-use quality traits included grain volume weight (AACC Approved Method 55-10), grain hardness (single kernel characterization system [SKCS]; AACC Approved Method 55-31.01), total flour yield (g kg^{-1} by weight of the total products recovered as straight-grade white flour), break flour yield (g kg^{-1} by weight of the total products recovered as flour off the break rolls of the mill), and flour ash (AACC Approved Method 08-01), flour swelling volume (AACC Approved Method 56021.01), grain protein concentration (AACC Approved Method 39-10 adjusted with Dumas combustion method), flour protein concentration (AACC Approved Method 39-11), and cookie diameter (AACC Approved Method 10-50). A derived trait, milling score, was calculated as follows:

$$(\{100-[0.5\times(16-\text{temper level})]+(80-\text{flour yield})+[50\times(\text{flour ash}-0.30)]\}\times 1.274)-21.602$$

WA8169 was evaluated by the Pacific Northwest Wheat Quality Council in 2015.

Disease Resistance Screening

WA8169 was evaluated for stripe rust resistance in naturally infected field trials or artificial inoculation and in greenhouses with selected races of the wheat stripe rust pathogen by the USDA-ARS Wheat Health, Genetics, and Quality Disease Research Unit. Field screening locations included the Whitlow and Spillman Farms near Pullman, the Lind Dryland Research Station near Lind, at the Mount Vernon Research and Extension Center in Mt. Vernon, WA, and in a grower's field in Walla Walla, WA. Greenhouse seedling tests for stripe rust resistance were conducted from 2013 through 2014 under low temperature cycles (diurnal temperature cycle gradually changing from 4 to 20°C; Chen and Line, 1992) with races Pstv-4, 14, 37, 40, and 51, and adult-plant tests were conducted at high temperatures (diurnal temperature cycle gradually changing from 10 to 30°C; Chen and Line, 1995) with races Pstv-14, 37, and 40. Data were collected for infection type (IT) on a scale of 1 to 9 (McNeal et al., 1971; Line and Qayoum, 1992) and disease severity on a scale of 0 to 100% (Peterson et al., 1948).

WA8169 was evaluated for strawbreaker foot rot (caused by *Oculimacula yallundae* Crous & W. Gams and *O. acuformis* Crous & W. Gams) in inoculated field trials at the Plant Pathology Farm near Pullman in 2015. Data were collected on disease incidence (percentage of infected stems, 0–100%) and disease severity (visual rating of infected stems, 0–4). The disease index, which is on a scale of 0 to 100, was calculated by multiplying disease incidence by disease severity and dividing by 4, the number of replicate plots. Marker analysis for the *Pch1* gene was conducted using the simple sequence repeat markers *Xorw1* and *Xorw5* following the protocol of Leonard et al. (2008) and the KASP assay wMAS0000023 (Wilkinson et al., 2012) following the protocol of LGC Genomics (http://www.lgcgenomics.com/).

WA8169 was tested for Cephalosporium stripe (caused by *Cephalosporium gramineum* Y. Nisik. & Ikata) in inoculated field trials at the USDA-ARS Palouse Conservation Field Station near Pullman in 2014 (Wetzel and Murray, 2015) and 2015 (unpublished data). Data were collected on disease severity, disease incidence, and disease index as previously described.

Additional data were collected in breeding trials near Waterville and Mansfield, WA, in 2013, 2015, and 2016 for the level of speckled snow mold (caused by *Typhula ishikariensis* Imai var. *idahoensis*) resistance of WA8169 in naturally infested environments. The snow mold rating was recorded as a visual estimate of growth approximately 1 mo after snowmelt, which is based on both percentage recovery and vigor. The scale ranges from 0 to 9, with 0 = no recovery and 9 = complete recovery.

Seed Purification

Breeder seed of Jasper was produced by headrow purification, on the basis of phenotypic uniformity, of 1000 $F_{8:9}$ headrows grown under irrigation in Othello, WA, in 2013. Selected headrows (3% were discarded based on heading date, head type, and plant height) were bulked at harvest, resulting in the production of 392 kg of breeder seed. A 5-ha foundation seed increase was planted under irrigation in Moses Lake, WA, in fall 2014. Foundation fields were rogued for phenotypic uniformity, and 1% of the plants were removed due to differences in plant height and head type.

Statistical Analysis

Data generated from 2011 to 2015 were analyzed with the general lattice procedure, whereas unreplicated data were analyzed using the moving means procedure with replicated check cultivars every 10 plots in Agrobase Generation 2, version 37.2.4 (Agronomix Software). Since four major wheat-producing regions with distinct agroclimatic conditions are present in Washington State, data were analyzed across locations within regions instead of over all locations. Location means from 2011 to 2015 were generated via the arithmetic mean of the general lattice adjusted mean and were subjected to analysis of variance. Breeding lines were advanced on the basis of excellent performance within each location, across locations within a region, and across regions within a year. Once Jasper was selected for release, the final data analysis used only entries common to the trials across all years. For all data except end-use quality, significant differences were determined at $\alpha = 0.05$; for end-use quality, significance was determined at $\alpha = 0.01$. End-use quality data were analyzed using analysis of variance with PROC GLM (SAS v. 9.3; SAS Institute). Data were only analyzed from site-year locations where both Jasper and the respective check cultivar were in the same trial.

Characteristics

General Description

Jasper is an intermediate-height, semidwarf (*Rht-B1b*) SWW wheat cultivar. It has a middense, tapering, and erect inflorescence with white awns and white glumes that are long and narrow, with wanting shoulders and medium-length acuminate beaks. Jasper has ovate kernels that are white and soft (SKCS value 9.6). The seed of Jasper has a midsize germ with a crease width and depth that are 60 and 35%, respectively, of that of the kernel, rounded cheeks, and a medium, noncollared brush. Anthocyanin pigmentation is absent in the coleoptile of Jasper, and its juvenile plant growth habit is semi-erect. Jasper is green with an erect flag leaf that is not twisted and is absent of wax at Feekes growth stage 10.0 (Large, 1954). The stem of Jasper does not contain anthocyanin pigmentation, a waxy bloom is absent, the last internode of the rachis is solid, the auricle lacks pigmentation, pubescence is absent, and the peduncle is erect and has an average length of 25 cm.

Agronomic Performance

Mean heading date and plant height of Jasper are compared to similar SWW cultivars ‘Otto’ (Carter et al., 2013), ‘Puma’ (Carter et al., 2014), and Xerpha in Tables 1 and 2. In the lower rainfall regions (<300 mm average annual precipitation) of eastern Washington, the heading date of Jasper was earlier ($P < 0.05$) than that of Otto and Xerpha, by 2 to 3 d and 1 d, respectively, and later ($P < 0.05$) than Puma by 1 d (Table 1). The plant height of Jasper was shorter than Otto, Puma, and Xerpha by 2 to 5 cm (Table 1). In the intermediate to high rainfall region (400–500 mm average annual precipitation), the heading date of Jasper was similar ($P > 0.05$) to that of Puma and earlier than Xerpha and Otto by 1 d and 4 to 5 d, respectively (Table 2). Jasper was shorter than Puma and Xerpha in the 400- to 500-mm average annual precipitation range by 3 to 7 cm and shorter than Puma and Otto in the >500-mm average annual precipitation range by 6 to 8 cm (Table 2).

The grain yield of Jasper was greater ($P < 0.05$) than that of Xerpha and Brundage 96 when data were averaged over 30 site-years of evaluation in breeding nurseries (Table 3). The average grain volume weight of Jasper was similar ($P > 0.05$) to that of Xerpha and Brundage 96 in these breeding trials (Table 3). In the Washington State University Extension Uniform Cereal Variety Testing Winter Wheat Performance Trials conducted from 2013 through 2015, the grain yields of Jasper were greater than those of Puma and similar to those of Otto and Xerpha in the <300-mm precipitation zone (28 site-years; Table 1). In the 300- to 400-mm precipitation zone (28 site-years), the grain

Table 1. Mean heading date, plant height, grain volume weight, and grain yield of soft white winter wheat cultivars from 28 site-years from Washington State University Extension Uniform Cereal Variety Performance Trials grown from 2013 through 2015 in eastern Washington.

Cultivar	Heading date		Plant height		Grain volume weight		Grain yield	
	<300 mm†	300–400 mm‡	<300 mm	300–400 mm	<300 mm	300–400 mm	<300 mm	300–400 mm
	— d after 1 Jan. —		——— cm ———		——— kg m^{-3} ———		——— kg ha^{-1} ———	
Jasper	143	151	72	89	752	742	3001	5942
Otto	145	154	74	92	776	757	3058	5321
Puma	142	150	75	94	777	763	2747	5669
Xerpha	144	152	75	93	771	760	3061	6143
LSD ($\alpha = 0.05$)	0.5	0.6	2	2	4	3	101	153

† Means averaged over trials from 2013 through 2015 in locations receiving <300 mm of average annual precipitation including Connell, Harrington, Horse Heaven, Lind, Ritzville, and St. Andrews, WA (14 site-years).

‡ Means averaged over trials from 2013 through 2015 in locations receiving 300–400 mm of average annual precipitation including Almira, Anatone, Creston, Dusty and Lamont, WA (14 site-years).

Table 2. Mean heading date, plant height, grain volume weight, and grain yield of soft white winter wheat cultivars from 18 site-years from Washington State University Extension Uniform Cereal Variety Performance Trials grown from 2014 through 2015 in eastern Washington.

Cultivar	Heading date		Plant height		Grain volume weight		Grain yield	
	400–500 mm†	>500 mm‡	400–500 mm	>500 mm	400–500 mm	>500 mm	400–500 mm	>500 mm
	— d after 1 Jan. —		——— cm ———		——— kg m^{-3} ———		——— kg ha^{-1} ———	
Jasper	149	156	94	94	729	734	6043	7329
Otto	153	161	94	100	747	762	4961	6744
Puma	148	156	101	102	754	755	5910	6923
Xerpha	150	157	97	94	753	756	5956	7241
LSD ($\alpha = 0.05$)	0.9	0.6	2	2	5	4	209	213

† Means averaged over trials from 2014 through 2015 in locations receiving 400–500 mm of average annual precipitation including Dayton, Mayview, Reardan, St. John, and Walla Walla, WA (10 site-years).

‡ Means averaged over trials from 2014 through 2015 in locations receiving >500 mm of average annual precipitation including Colton, Fairfield, Farmington, and Pullman, WA (8 site-years).

yields of Jasper were greater than those of Otto and Puma but lower than those of Xerpha (Table 1). The grain yields of Jasper were greater than that of Otto and similar to the grain yields of Puma and Xerpha in the 400- to 500-mm precipitation zone (18 site-years; Table 2). In the >500-mm precipitation zone (18 site-years; Table 2), Jasper grain yields were greater than those of Otto and Puma and similar to those of Xerpha. Average grain volume weight of Jasper was lower than the grain volume weight of Otto, Puma, and Xerpha in all four precipitation zones (Tables 1–2).

Disease Resistance

Jasper was evaluated for stripe rust resistance in various field locations in Washington State under natural infection and under controlled greenhouse conditions with selected races from 2013 to 2014. In 2013, stripe rust developed to adequate levels in the field for evaluation at Spillman Farm, Whitlow Farm, and Mount Vernon, where the check 'WA7821' was susceptible (infection type [IT] 8; severity 95–100%) and Jasper was rated as moderately resistant (IT 2–5; severity 5–20%) at the flowering and soft dough stage. In 2014, stripe rust developed to adequate levels for field evaluation at Spillman Farm, Whitlow Farm, and Mount Vernon, where WA7821 displayed susceptible reactions (IT 8; severity 80–100%) and Jasper again displayed moderately resistant reactions (IT 2–5; severity 5–20%) at the flowering and soft dough stage. In greenhouse seedling tests conducted in 2013 and 2014, Jasper was susceptible (IT 8) to races PSTv-4, PSTv-14, PSTv-37, PSTv-40, and PSTv-51. However, when tested at the adult-plant stage at high temperatures with races PSTv-14, PSTv-37, and PSTv-40 in the greenhouse, Jasper was highly resistant (IT 2) in 2013 and moderately resistant (IT 2–5) in 2014, whereas the check WA7821 was scored as susceptible (IT 8) in both years. These data showed that Jasper has a moderate to high level of high-temperature, adult-plant resistance to stripe rust. The origin of genes controlling the adult-plant resistance to stripe rust is unknown at this time.

In 2015, Jasper was evaluated for resistance to strawbreaker foot rot in inoculated field trials at the USDA-ARS Plant Pathology Farm near Pullman. Included in these trials were the susceptible check 'Eltan' (Peterson et al., 1991) and the resistant check Madsen. The resistance that Madsen carries is inherited from the cultivar VPM1, which derives resistance from *T. ventricosum* (McMillin et al., 1986). Marker analysis using *Xorw1* and *Xorw5* (Leonard et al., 2008) and a KASP assay (www.lgcgenomics.com/) for *Pch1* indicates that Jasper does not carry the *Pch1* gene for strawbreaker foot rot resistance that Madsen carries. In the 2015 trial, the disease index of Jasper (71.4) was

Table 3. Grain yield and grain volume weight of soft white winter wheat cultivars from breeding trials in eastern Washington.†

Cultivar	Grain yield	Grain volume weight
	kg ha^{-1}	kg m^{-3}
Jasper	5254	770
Xerpha	4908	780
Brundage 96	4372	774
LSD ($\alpha = 0.05$)	84	61
n = site-years	30	15

† Agronomic performance evaluated at Pullman and Lind, 2011 to 2015; Waterville, Ritzville and Harrington, 2012 to 2015; Mansfield, 2012 to 2014; Kahlotus, 2012 to 2013; and Davenport, 2013 and 2015.

similar to Eltan (74.2), indicating susceptibility to strawbreaker foot rot based on disease symptoms, whereas Madsen (54.5) demonstrated a resistant reaction. Interestingly, the yield potential of Jasper was similar (1% higher) compared with the yield of the resistant check Madsen in these trials (data not shown) despite its susceptibility rating, suggesting that Jasper may have some tolerance to the strawbreaker foot rot disease.

In 2014 and 2015, Jasper was evaluated for resistance to Cephalosporium stripe in inoculated field trials at the Palouse Conservation Field Station near Pullman (Wetzel and Murray, 2015). Included in these trials were the susceptible check Stephens and the tolerant check 'Bauermeister' (Jones et al., 2007). The Cephalosporium stripe disease pressure was moderate to severe in both years, based on the reaction of Stephens (78.3 in 2014 and 77.7 in 2015). In 2014, Jasper had a disease index value of 79.0, which was similar ($P > 0.05$) to Stephens (78.3) but higher ($P < 0.05$) than the tolerant line Bauermeister (27.8) (Wetzel and Murray, 2015). Even though Jasper had a disease index similar to Stephens, Jasper had a yield 113% of the trial mean and 244% of Stephens. The 2015 results (unpublished) demonstrated a different reaction than in 2014. Jasper had a disease index rating of 40.2, which was not different from tolerant check Bauermeister (43.6) but was lower than the susceptible check Stephens (77.7), indicating some tolerance to the disease. Additionally, in the 2015 trial, Jasper yielded 126% of the trial mean and 194% of Stephens, and was the third highest yielding entry out of the 44 tested. Although the field data is inconclusive on the basis of disease symptomology, Jasper can maintain a high yield potential despite the presence of the disease, suggesting some level of tolerance to Cephalosporium stripe.

Snow mold evaluation trials are conducted near Waterville and Mansfield, WA, every year, and require a minimum of 100 d of snow cover on unfrozen or lightly frozen soils for the disease to develop to adequate levels of infection for data collection. In spring 2013, 2015, and 2016, disease severity was sufficient to evaluate cultivars for snow mold resistance. Jasper was evaluated in these trials along with the resistant cultivars Eltan and Otto and the susceptible cultivar Brundage 96 (a parent of Jasper). Jasper had a rating of 4 in 2013, 2 in 2015, and 5 in 2016. Both Otto and Eltan received scores of 7 in 2013, 6 in 2015, and 7 in 2016, whereas Brundage 96 received scores of 3 in 2013, 2 in 2015, and 4 in 2016. On the basis of visual ratings of recovery after the initial disease resistance score, Jasper is rated as moderately susceptible to snow mold.

End-Use Quality

End-use quality of Jasper was assessed at the USDA-ARS Western Wheat Quality Laboratory in Pullman using grain produced in 17 breeding and commercial variety testing trials in Washington from 2011 through 2014. Stephens, Puma, and Otto were used as checks in these evaluations. Grain and flour protein concentration of Jasper were similar ($P > 0.01$) to those of Stephens, Puma, and Otto (Table 4). Total flour yield of Jasper was similar to that of Puma and greater ($P < 0.01$) than that of Stephens and Otto (Table 4). Break flour yield of Jasper was greater than that of Stephens, Puma, and Otto (Table 4). Flour ash concentration of Jasper was similar to that of Stephens and Puma and greater than that of Otto (Table 4). Milling score, flour protein concentration, and mixograph water absorption were similar in Jasper, Stephens, Puma, and Otto (Table 4). Jasper had greater flour swelling volume and cookie diameter compared with that of Otto but was similar to that of Stephens and Puma (Table 4).

In 2015, Jasper was evaluated by the Pacific Northwest Wheat Quality Council, where commercial millers and bakers concluded that Jasper has acceptable milling, dough handling, and baking properties and is equal to or superior to other SWW wheat cultivars currently in production in the Pacific Northwest (data not shown).

Availability

Foundation seed of Jasper will be maintained by the Washington State Crop Improvement Association under supervision of the Washington State University Department of Crop and Soil Sciences and the Washington State Agricultural Research Center. Small quantities of seed may be obtained for research purposes from the corresponding author for at least 5 yr from the date of publication. A seed sample has been deposited with the National Plant Germplasm System, where it will thereafter be available for distribution. US Plant Variety Protection status for this cultivar is pending.

Table 4. Mean grain protein concentration, flour yield, break flour yield, flour ash concentration, flour protein concentration, milling score, flour swelling volume, cookie diameter, and mixograph water absorption of soft white wheat cultivars from winter wheat trials in eastern Washington.

Cultivar	Grain protein concentration	Total flour yield	Break flour yield	Flour ash concentration	Flour protein concentration	Milling score	Flour swelling volume	Cookie diameter	Mixograph water absorption
	g kg^{-1}						mL g^{-1}	cm	g kg^{-1}
Stephens†	104	666	403	38	90	81.9	18.9	9.1	556
Jasper	98	687	466	40	82	82.9	18.8	9.3	543
LSD ($\alpha = 0.01$)	6	8	18	3	13	2.3	2.4	0.9	19
Puma‡	109	675	436	39	99	82.2	19.2	9.23	561
Jasper	109	681	463	42	93	80.9	18.5	9.24	550
LSD ($\alpha = 0.01$)	8	14	13	3	6	3.0	0.8	0.2	15
Otto†	109	661	447	37	95	80.7	17.8	9.14	557
Jasper	108	682	465	43	93	80.9	18.5	9.24	550
LSD ($\alpha = 0.01$)	9	10	8	2	9	2.2	0.5	0.1	17

† Data analysis performed on 17 site-years.

‡ Data analysis performed on 16 site-years.

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