Published July 25, 2014

JOURNAL OF PLANT REGISTRATIONS

CULTIVAR

Registration of 'Puma' Soft White Winter Wheat

A. H. Carter,* S. S. Jones, X. Cai, S. R. Lyon, K. A. Balow, G. B. Shelton, R. W. Higginbotham, X. M. Chen, D. A. Engle, B. Baik, S. O. Guy, T. D. Murray, and C. F. Morris

ABSTRACT

Resistance to strawbreaker foot rot (caused by *Oculimacula yallundae* Crous & W. Gams and *O. acuformis* Crous & W. Gams), stripe rust (caused by *Puccinia striiformis* Westend. f. sp. *tritici* Eriks.), and Cephalosporium stripe (caused by *Cephalosporium gramineum* Nisikado and Ikata) are important traits for winter wheat (*Triticum aestivum* L.) cultivars produced in the Pacific Northwest region of the United States. The objective of this research was to develop an adapted winter wheat cultivar with effective resistance to these diseases. 'Puma' (Reg. No. CV-1097, PI 670038) soft white winter wheat (*Triticum aestivum* L.) was developed and released in August 2013 by the Agricultural Research Center of Washington State University. Puma was tested under the experimental designations 5J030731, 5J030731–2, and WA008134, which were assigned through progressive generations of advancement. Puma is a semidwarf cultivar adapted to intermediate to high rainfall (>400 mm of average annual precipitation), unirrigated wheat production regions of Washington. Puma is resistant to strawbreaker foot rot, has high-temperature, adult-plant resistance to the stripe rust pathogen, is tolerant to Cephalosporium stripe, is intermediate in height, has midseason maturity, and has a high test weight and grain yield potential. Puma has end-use quality properties similar or superior to those of 'Stephens', 'Brundage 96', and 'Xerpha'.

Strawbreaker foot rot (eyespot, caused by *Oculimacula yallundae* Crous & W. Gams and *O. acuformis* Crous & W. Gams), stripe rust (caused by *Puccinia striiformis* Westend. f. sp. *tritici* Eriks.), and Cephalosporium stripe (caused by *Cephalosporium gramineum* Nisikado and Ikata) are major disease threats of winter wheat (*Triticum aestivum* L.) grown in the Pacific Northwest region of the United States. Relatively few soft white winter (SWW) wheat cultivars currently in commercial production are adapted for the intermediate to high rainfall regions (>400 mm average annual precipitation) that have adequate levels of resistance to stripe rust and foot rot resistance and tolerance to Cephalosporium stripe, especially under heavy disease pressure. The objective of this research was to develop a SWW wheat cultivar that combined more effective resistance to stripe rust, foot rot, and Cephalosporium stripe compared with current cultivars grown in the intermediate- to high-rainfall regions of Washington State.

'Puma' (Reg. No. CV-1097, PI 670038), a SWW wheat, was developed and released in August 2013 by the Agricultural Research Center of Washington State University. Puma was released as an alternative to 'Madsen' (PI 511673; Allan et al., 1989) and 'Tubbs 06' (PI 651023) in unirrigated wheat production systems in the intermediate to high rainfall (>400 mm of average annual precipitation) regions of Washington State. The release of Puma is based on its (i) resistance to strawbreaker foot rot, (ii) high-temperature, adult-plant resistance to local races of stripe rust, (iii) tolerance to Cephalosporium stripe, (iv) improved end-use quality, and (v) high grain-yield potential in the target production regions.

Journal of Plant Registrations
doi: 10.3198/jpr2013.12.0074crc
Received 20 Dec. 2013. Registration by CSSA.
5585 Guilford Rd., Madison, WI 53711 USA
*Corresponding author (ahcarter@wsu.edu)

A.H. Carter, S.S. Jones, S.R. Lyon, K.A. Balow, G.B. Shelton, R.W. Higginbotham, and S.O. Guy, Dep. of Crop and Soil Sciences, Washington State Univ., Pullman, WA 99164-6420; X. Cai, Dep. of Plant Sciences, North Dakota State Univ., Fargo, ND 58108-6050; X.M. Chen, D.A. Engle, and C.F. Morris, USDA–ARS Wheat Genetics, Quality, Physiology, and Disease Research Unit, Pullman, WA 99164-6420; B. Baik, USDA–ARS Corn, Soybean and Wheat Quality Research Unit, Wooster, OH 44691; T.D. Murray, Dep. of Plant Pathology, Washington State Univ., Pullman, WA 99164-6430. Research was funded in part by the Washington State Grain Commission.

Abbreviations: AACC, American Association of Cereal Chemists; ALS, general lattice procedure; IT, infection type; SRC, solvent retention capacity; SWW, soft white winter.

Materials and Methods

Puma, tested under the experimental designations 5J030731, 5J030731-2, and WA008134 (assigned through progressive generations of advancement), is an $F_{3:4}$ head-row selection derived from the cross 'Spitzer'/Madsen//'Rod'/3/Spitzer/Madsen. The final cross for Puma was completed in the greenhouse in Pullman, WA, in 2001. Spitzer (NSL 91403) is a ×*Agrotriticum* spp. developed by Seed Research of Oregon, Inc. Madsen 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'(CItr 17954; Kronstad et al., 1982). Rod (PI 558510; Peterson et al., 1995) is a SWW wheat cultivar released by Washington State University and the USDA–ARS in 1992 with the pedigree 'Luke' (CItr 14586; Peterson et al., 1974)/'Daws' (CItr 17419; Peterson et al., 1977)//Hill 81.

The following modified pedigree bulk-breeding method was used to advance early-generation progeny. Bulked seed (3 g) from F_1 plants, identified as 5J030731, was used to establish a 1-m F_2 row in 2004. Seed from approximately 50 heads within the row were bulk harvested, and a 7-g subsample was used to establish a 1-m F_3 row in 2005. Single heads of approximately 30 F_3 plants were threshed individually to establish $F_{3:4}$ head-row families in 2006. F_1 progeny were advanced at the Plant Growth Facilities on the Washington State University campus in Pullman. F_2 through F_4 progeny were advanced in field nurseries at Pullman.

Following selection among F_4 rows for general adaptation, resistance to natural infection of stripe rust, plant height, and grain appearance, seed from 30 to 50 plants within each selected head-row was bulk harvested to obtain $F_{3:5}$ seed for early-generation quality assessment. Screening methods included high-molecular-weight glutenin profiles (Payne and Lawrence, 1983), seed coat color, and tyrosinase assays (Abrol et al., 1971). Selections with preferred high-molecular-weight glutenin profiles (2+12), white seed coat color, and polyphenol oxidase reactions (light, medium, or dark; AACC, 2008, Approved Method 22-85) were retained and advanced to grain yield assessment trials. Two $F_{3:5}$ head-row selections were individually advanced to a nonreplicated field trial in Pullman and grown in yield plots in 2007. The resulting grain was evaluated for yield, grain volume weight, grain protein concentration, and disease resistance and evaluated again with early-generation quality assessment tools. One line, identified as 5J030731-2, was selected and advanced to F_6 replicated field trials at Pullman and Lind, WA, in 2008. Lines were evaluated for emergence from deep planting, plant height, grain yield, grain volume weight, and disease resistance. Additionally, early-generation quality assessment tools described above were used to evaluate end-use quality.

Using seed generated in a nonreplicated field trial, Puma was evaluated in replicated field trials for 49 location-years in preliminary (2 locations), advanced (15 locations), and western regional (1 location) trials from 2008 through 2013 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 utilized the same data collection strategy with either a randomized complete block design (four replications) (2008) or a general α lattice design (three replications) (2009–2013) (Mason et al., 2003). 5J030731-2, one of the original two F_4 head-row selections, was advanced to preliminary replicated yield trials in Pullman (high precipitation zone) and Lind (low precipitation zone) and evaluated in 2008. This line was entered into advanced replicated trials at multiple locations from 2009 through 2010. Based on these data, 5J030731-2 was selected for testing on a regional basis and assigned the new identification number of WA008134 in 2010. WA008134 was entered in the Washington State University Extension Uniform Cereal Variety Testing Program and tested at 21 locations in both 2011 and 2013 and at 20 locations in 2012 throughout eastern Washington. WA008134 also was evaluated in the Western Regional Nursery Trials from 2011 through 2013. Additionally, WA008134 was retained in the advanced replicated yield trials and tested at multiple locations from 2011 to 2013. From 2006, WA008134 was evaluated for end-use quality by the USDA–ARS Wheat Genetics, Quality, Physiology, and Disease Research Unit, Pullman, according to approved methods of the American Association of Cereal Chemists (AACC, 2008). Samples were tempered to 14% moisture content and milled on a Quadrumat system as modified by Jeffers and Rubenthaler (1979). Grain soundness was evaluated using grain volume weight (AACC Approved Method 55-10). Grain hardness (AACC Approved Method 55–31.01), kernel diameter, and kernel weight were determined using a single-kernel characterization system, SKCS 4100 (Perten Instruments). Flour yield (percentage by weight of the total products recovered as straight-grade white flour), break-flour yield (percentage by weight of the total products recovered as flour off the break rolls of the mill), and flour ash (AACC Approved Method 08-01) were measured to evaluate milling and particle size components. A calculated trait, milling score also was evaluated, calculated as

$$(\{100 - [0.5\times(16 - \text{temper level})] + (80 - \text{flour yield}) + [50\times(\text{flour ash} - 0.30)]\}\times1.274) - 21.602$$

Flour swelling volume (AACC Approved Method 56-21.01), flour sodium dodecylsulfate (SDS) sedimentation volume (Carter et al., 1999), protein content (AACC Approved Method 39-10 adjusted with Dumas combustion method), and flour protein (AACC Approved Method 39-11) were measured to evaluate flour functionality. Solvent retention capacity (SRC) (AACC Approved Method 56-11.02) was conducted on straight grade flour for lactic acid (SRC lactic), sucrose (SRC sucrose), carbonate (SRC carbonate), and water (SRC water). Cookie diameter was evaluated using AACC Approved Method 10-50. WA008134 was evaluated by the Pacific Northwest Wheat Quality Council in 2012.

WA008134 was evaluated for strawbreaker foot rot in inoculated field trials conducted by personnel at Washington State University at the Plant Pathology Farm near Pullman in 2011. The disease index, which is on a scale from 0 to 100, was calculated by multiplying the percentage of infected stems (disease incidence) by the disease severity of infected stems and divided by four. Values ranged from 0 to 100% and represent the mean of four replicate plots (Wetzel and Murray, 2012b). 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 a KASP assay (Wilkinson et al., 2012) following the protocol of LGC Genomics (http://www.lgcgenomics.com/).

WA008134 was tested for stripe rust resistance in naturally infected field trials conducted by the USDA–ARS, Wheat Genetics, Quality, Physiology, and Disease Research Unit, Pullman on the Whitlow and Spillman Farms near Pullman, at the Lind Dryland Research Station near Lind, at Walla Walla and Mt. Vernon, WA, in breeding nurseries in 2010 to 2012, and in various breeding nurseries throughout eastern Washington from 2006 to 2012. Greenhouse seedling tests for stripe rust resistance were conducted from 2010 through 2012 under low-temperature cycles (diurnal temperature cycle gradually changing from 4 to 20°C; Chen and Line, 1992), and adult-plant tests were conducted at high temperatures (diurnal temperature cycle gradually changing from 10 to 30°C; Chen and Line, 1995).

WA008134 was tested for tolerance to Cephalosporium stripe in inoculated field trials conducted by personnel at Washington State University at the USDA–ARS Palouse Conservation Field Station near Pullman in 2011. The disease index, which ranges from 0 to 100, was calculated by multiplying the percentage of infected stems (disease incidence) by the disease severity of infected stems and dividing by four. The plot rating taken is a visual rating for the percentage of plot area with stunted plants and/or white heads per plot and was descriptive of the severity of Cephalosporium stripe. Values ranged from 0 to 100% and represented the mean of four replicate plots (Wetzel and Murray, 2012a).

Breeder seed of WA008134 (Puma) was produced as a reselection, on the basis of phenotypic uniformity, of 1200 $F_{3:9}$ head-rows grown under irrigation in Othello, WA, in 2011. Selected head-rows (2% were discarded) were bulked at harvest, resulting in the production of 967 kg of breeder seed. A 1-ha foundation-seed increase was planted under irrigation in Prosser, WA, in fall 2012.

Data generated from 2010 to 2013 were analyzed with the general lattice (ALS) procedure in Agrobase Generation 2, version 35.15.1 (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 and ranks from 2010 to 2013 were generated via the arithmetic mean of the ALS adjusted mean. The arithmetic means and ALS adjusted means were subjected to analysis of variance, and breeding lines were advanced based on excellent performance within each location, across locations within a region, and across regions within a year. Once Puma was selected for release, the final data analysis used only entries common to the trials across all years. End-use quality data were analyzed by the Student paired *t* test procedure (Cochran and Cox, 1957).

Characteristics

Puma is an intermediate height, semidwarf SWW wheat cultivar. It has a lax, tapering, inclined inflorescence with white awns and white glumes that are long in length and medium in width, with rounded shoulders and medium acuminate beaks. Puma has ovate kernels that are white and soft. The seed of Puma has a midsize germ with a crease width and depth that are 60% and 20%, respectively, of that of the kernel, rounded cheeks, and a medium, collared brush. Puma lacks anthocyanin pigmentation in the coleoptile, displays a semi-erect juvenile plant growth habit, and is green with an erect, twisted, waxy flag leaf at Feekes growth stage 10.0 (Large, 1954). The stem of Puma lacks anthocyanin pigmentation, a waxy bloom is present, the last internode of the rachis is hollow, the auricle lacks pigmentation, pubescence is present, and the peduncle is erect and has an average length of 25 cm. In the lower rainfall regions (<400 mm average annual precipitation) of eastern Washington, the heading date of Puma was similar to Tubbs 06 and significantly ($P < 0.05$) 2 d earlier and 1 d later than that of Madsen and 'WB-528' (PI 643142), respectively (Table 1). The plant height of Puma was similar to Tubbs 06 and significantly ($P < 0.05$) taller than Madsen and WB-528 (Table 1). In the target production region (400–500 mm average annual precipitation), the heading date of Puma was similar to Tubbs 06 and significantly ($P < 0.05$) 2 d earlier and 3 d later than that of Madsen and WB-528, respectively (Table 2). Puma was significantly ($P < 0.05$) taller than Tubbs 06 (3 cm), Madsen (8 cm), and WB-528 (11 cm) (Table 2).

In 2011, Puma was evaluated for resistance to strawbreaker foot rot in an inoculated field trial at the Plant Pathology Farm. Included in this trial were the resistant checks Tubbs 06 and Madsen and the susceptible check 'Skiles' (PI 658154). Madsen carries the *Pch1* gene for foot rot resistance, inherited from the cultivar VPM1, which derives resistance from *Triticum ventricosum* (Tausch). Marker analysis with *Xorw1*

Table 1. Mean heading date, plant height, grain volume weight, and grain yield of soft white winter wheat cultivars from 32 site-years of data from Washington State University Extension Uniform Cereal Variety Performance Trials grown from 2011 through 2013 in eastern Washington.

Cultivar	Heading date		Plant height		Grain volume weight		Grain yield	
	<300 mm†	300–400mm‡	<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} ———	
Puma	150	159	87	103	778	775	3794	6869
WB-528	149	158	82	88	790	793	3523	6005
Madsen	152	161	83	96	778	775	3665	6496
Tubbs 06	150	160	88	103	768	760	3970	6790
LSD (0.05)	0.4	0.6	2	2	2	3	108	206

† Means averaged over trials from 2010 through 2013 in locations receiving <300 mm of average annual precipitation including Connell, Harrington, Horse Heaven, Lind, Ritzville, and St. Andrews, WA (17 site-years).

‡ Means averaged over trials from 2010 through 2013 in locations receiving 300 to 400 mm of average annual precipitation including Almira, Anatone, Creston, Dusty, and Lamont, WA (15 site-years).

Table 2. Mean heading date, plant height, grain volume weight, and grain yield of soft white winter wheat cultivars from 27 site-years of data from Washington State University Extension Uniform Cereal Variety Performance Trials grown from 2011 through 2013 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} ———	
Puma	159	167	110	105	779	775	8755	7893
WB-528	156	163	99	95	792	791	7825	7269
Madsen	161	169	102	97	781	773	8193	7742
Tubbs 06	159	166	107	102	763	761	7869	7576
LSD (0.05)	0.4	0.5	2	0.6	3	2	218	196

† Means averaged over trials from 2011 through 2013 in locations receiving 400 to 500 mm of average annual precipitation including Dayton, Mayview, Reardan, St. John, and Walla Walla, WA (15 site-years).

‡ Means averaged over trials from 2011 through 2013 in locations receiving >500 mm of average annual precipitation including Colton, Farifield, Farmington, and Pullman, WA (12 site-years).

and *Xorw5* (Leonard et al., 2008) and a KASP assay (http://www.lgcgenomics.com/) for *Pch1* indicates that Puma carries strawbreaker foot rot resistance similar to its parent Madsen (data not shown). In this trial, Puma (34.9%) was similar to Tubbs 06 (30.4%) and Madsen (39.9%), indicating a resistant reaction, whereas Skiles (75.5%) demonstrated a susceptible reaction (Wetzel and Murray, 2012b).

Puma, together with its parental cultivar Madsen in addition to other entries, was evaluated for stripe rust resistance in various field locations in Washington State under natural infection and under controlled greenhouse conditions with selected races of *P. striiformis* from 2010 to 2012. In 2010, stripe rust developed to adequate levels in the field for evaluation where the check 'PS 279' was susceptible (infection type [IT] 8; severity 80–100%) in the flowering and soft dough stage. Puma (IT 2–3; severity 20%), 'Stephens' (CI 17596; Kronstad et al., 1978) (IT 3; severity 20%) and Madsen (IT 2; severity 5%) were all rated as resistant. Again in 2011 and 2012, stripe rust developed to adequate levels for field evaluation where PS 279 (IT 8; severity 80–100%), 'Eltan' (PI 536994; Peterson et al., 1991) (IT 3–5; severity 20–40%), and 'Xerpha' (PI 645605; Jones et al., 2010) (IT 5–8; severity 30–70%) displayed moderately susceptible reactions, whereas Puma (IT 2–5; severity 5–30%) and Madsen (IT 2–3; severity 2–10%) displayed resistant reactions. In greenhouse seedling tests conducted in 2010, Puma was resistant (IT 2) to races PST-45, PST-100, PST-114, and PST-127, and moderately susceptible (IT 5) to PST-37. These seedling reactions indicate that Puma has race-specific, all-stage resistance that is not effective against all of the predominant races currently in the region. However, when tested at the adult-plant stage at high temperatures with races PST-45, PST-100, PTS-114, and PST-127 in the greenhouse, Puma was highly resistant (IT 1–2), similar to Madsen and more resistant than Brundage 96 (PI 631486; Zemetra et al., 2003) (IT 1–3). Similar results were obtained in 2011 and 2012 with a broader range of currently grown cultivars, including Eltan and Xerpha.

In greenhouse seedling tests conducted in 2011 and 2012 using PST-45, PST-100, PST-114, and PST-127, Eltan (IT 5–8), Xerpha (IT 8), Madsen (IT 2–8), and Puma (IT 2–8) all indicate the race-specific, all-stage resistance of the four cultivars is not effective against all the predominant races currently in the region. Conversely, when tested at the adult-plant stage at high temperatures with these same races, Madsen (IT 2) and Puma (IT 2) displayed a high level of resistance, whereas Eltan (IT 5) and Xerpha (IT 2–6) exhibited a lower level of resistance. Field results were confirmed through results from greenhouse evaluations, which indicated that Puma has non-race-specific, high-temperature adult-plant resistance to stripe rust similar to Madsen.

In 2011, Puma was evaluated for resistance to Cephalosporium stripe in an inoculated field trial at the Palouse Conservation Field Station (Wetzel and Murray, 2012a). Included in these trials were the susceptible check Stephens, the resistant check Eltan, and one of the parental lines of Puma (Madsen). Disease pressure from Cephalosporium stripe was severe, based on the disease reaction and grain yield of Stephens (88.3%; 3870 kg ha^{-1}). The resistance reaction of Puma (62.8%) was similar to Madsen (63.7%), which was defined as moderately tolerant (Wetzel and Murray, 2012a). Although the disease rating of Puma and Madsen were similar, the grain yield of Puma (8090 kg ha^{-1}) was significantly ($P < 0.05$) higher than that of Madsen (5604 kg ha^{-1}). Conversely, the rating and grain yield for Eltan (44.1%; 10045 kg ha^{-1}) indicates a higher tolerance to Cephalosporium stripe when compared with Puma. Presumably, the tolerance that Puma exhibits was inherited from the parental line Spitzer, via an *Agropyron elongotum* translocation (Cai et al., 1996). These results indicate that Puma is moderately tolerant to Cephalosporium stripe.

Agronomic Performance

When data were averaged over 38 location-years of evaluation in breeding nurseries, the grain yield of Puma was significantly ($P < 0.05$) greater than that of Madsen and similar to that of Brundage 96 (Table 3). The average grain volume weight of Puma was similar ($P < 0.05$) to that of Madsen and Brundage 96 in these breeding trials (Table 3).

Table 3. Grain yield (38 site years) and grain volume weight (32 site years) of soft white winter wheat cultivars from breeding trials in eastern Washington.†

Cultivar	Grain yield	Grain volume weight
	kg ha^{-1}	kg m^{-3}
Puma	5731	778
Madsen	5355	775
Brundage 96	5671	770
LSD (0.05)	121	11

† Agronomic performance evaluated at Pullman, Lind, Kahlotus, Mansfield, Ritzville, and Harrington, WA, 2010 to 2013; Steptoe, WA, 2010 to 2011; Waterville, WA, 2011 to 2013; Walla Walla, WA, 2012 to 2013; and Davenport, WA, 2013.

In 59 rainfed location-years of the Washington State University Extension Uniform Cereal Variety Testing Winter Wheat Performance Trials (http://variety.wsu.edu/) conducted from 2010 through 2013, the grain yields of Puma were greater than those of WB-528 and Madsen and less than Tubbs 06 in the <300-mm precipitation zone (17 location-years; $P < 0.05$; Table 1). In the 300- to 400-mm precipitation zone (15 location-years), Puma produced significantly ($P < 0.05$) more grain than WB-528 and Madsen and had similar grain yields as Tubbs 06 (Table 1). The grain yields of Puma were significantly ($P < 0.05$) greater than those of WB-528, Madsen, and Tubbs 06 in the 400- to 500-mm precipitation zone (15 location-years; Table 2). In the >500 mm precipitation zone (12 location-years), Puma grain yields were not significantly different ($P < 0.05$) than those of Madsen and greater than those of WB-528 and Tubbs 06 (Table 2). Average grain volume weight of Puma was not statistically different ($P < 0.05$) than that of Madsen and was lower than WB-528 and higher than Tubbs 06 in all four precipitation zones (Tables 1–2, 59 location-years).

End-Use Quality

End-use quality of Puma was assessed in early generation tests, and rows were selected for high-molecular-weight glutenin profiles 2+12 at the *Glu-D1* locus, white seed coat color, and polyphenol oxidase reactions of either "light" or medium." End-use quality of advanced generations of Puma were assessed at the USDA–ARS Western Wheat Quality Laboratory in Pullman using grain produced in 35 breeding and commercial variety testing trials in Washington from 2008 through 2012. Stephens, Brundage 96, and Xerpha were used as checks in these evaluations. Grain protein and flour protein content of Puma were similar to those of Stephens, Brundage 96, and Xerpha ($P < 0.01$) (Table 4). Flour yield of Puma was significantly greater than Xerpha ($P < 0.01$) and similar to that of Stephens and Brundage 96 (Table 4). Break flour yield of Puma was significantly lower than Brundage 96 ($P < 0.01$), and significantly ($P < 0.01$) greater than Stephens and Xerpha (Table 4). Flour ash content of Puma was significantly ($P < 0.01$) lower than Brundage 96 and similar to that of Stephens and Xerpha (Table 4). Milling score and cookie diameter of Puma were significantly ($P < 0.01$) higher than those of the three checks (Table 4). Flour swelling volume indicates that Puma has normal starch type, similar to the three checks (Table 4). Mixograph water absorption of Puma was similar to the three checks (Table 4). Limited data ($n = 6$) indicate that Puma (1258 cm^3) did not differ significantly ($P < 0.01$) from Brundage 96 (1296 cm^3) in sponge cake volume. Additionally, when compared with a limited data set ($n = 2$) to Xerpha (1245 cm^3), sponge cake volume of Puma (1248 cm^3) was not significantly different (data not shown).

In 2012, Puma was evaluated by the Pacific Northwest Wheat Quality Council, where commercial millers and bakers concluded that Puma has acceptable milling, dough handling, and baking properties and is equal to or superior to other SWW wheat cultivars that are currently in production in the Pacific Northwest (data not shown).

Availability

Foundation seed of Puma will be maintained by the Washington State Crop Improvement Association under supervision of the Department of Crop and Soil Sciences and the Washington State Agricultural Research Center. Small quantities of seed may be obtained for research purposes by contacting the National Plant Germplasm System. U.S. Plant Variety Protection status for this cultivar is pending.

Acknowledgments

We greatly appreciate the dedicated assistance of the following support personnel who assisted with field testing, quality assessment, and disease screening during the development of this cultivar: Tracy Harris (WSU), Kent Evans (USDA–ARS), and Henry Wetzel (WSU). Molecular marker work was supported by the National Research Initiative Competitive Grants CAP project 2011-68002-30029 from the USDA National Institute of Food and Agriculture. We are grateful to the Washington State Grain Commission and the Washington State Agriculture Research Center for providing funding for this research.

References

Abrol, Y.P., D.C. Uprety, and S. Tikoo. 1971. Rapid test for screening of wheat grains for tyrosinase activity. American Association of Cereal Chemists, St. Paul, MN.

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

Cultivar	Grain protein content	Flour yield	Break flour yield	Flour ash	Milling score	Flour protein content	Flour swelling volume	Cookie diameter	Mixograph water absorption
	g kg⁻¹	——— % ———		g kg⁻¹		g kg⁻¹	mL g⁻¹	cm	g kg⁻¹
Stephens†	98	69.6	41.9	37	85.6	83	20.3	9.3	544
Puma	98	69.6	44.8	36	86.3	83	20.5	9.4	551
LSD (0.01)	4	0.5	0.8	1.0	0.8	5	0.6	0.09	7
Brundage 96‡	101	70.1	48.2	39	85.5	85	19.1	9.3	544
Puma	102	69.9	46.4	37	86.5	87	20.2	9.4	552
LSD (0.01)	3	0.3	0.3	1.0	0.7	3	0.7	0.06	10
Xerpha§	103	68.6	43.9	36	85.4	86	18.4	9.1	549
Puma	103	69.9	46.3	37	86.6	89	20.2	9.3	553
LSD (0.01)	3	0.4	0.5	1.0	0.7	4	0.7	0.07	8

† Data analysis performed on 21 site-years.

‡ Data analysis performed on 28 site-years.

§ Data analysis performed on 26 site-years.

Allan, R.E., C.J. Peterson, G.L. Rubenthaler, R.F. Line, and D.E. Roberts. 1989. Registration of 'Madsen' wheat. Crop Sci. 29:1575–1576. doi:10.2135/cropsci1989.0011183X002900060068x

American Association of Cereal Chemists (AACC). 2008. Approved methods. 11th ed. AACC, St. Paul, MN.

Cai, X., S.S. Jones, and T.D. Murray. 1996. Characterization of an *Agropyron elongatum* chromosomes conferring resistance to Cephalosporium stripe in common wheat. Genome 39:56–62. doi:10.1139/g96-008

Carter, B.P., C.F. Morris, and J.A. Anderson. 1999. Optimizing the SDS sedimentation test for end-use quality selection in a soft white and club wheat breeding program. Cereal Chem. 76:907–911.

Chen, X.M., and R.F. Line. 1992. Identification of stripe rust resistance genes in wheat cultivars used to differentiate North American races of *Puccinia striiformis*. Phytopathology 82:1428–1434. doi:10.1094/Phyto-82-1428

Chen, X.M., and R.F. Line. 1995. Gene action in wheat cultivars for durable high-temperature adult-plant resistance and interactions with race-specific, seedling resistance to stripe rust caused by *Puccinia striiformis*. Phytopathology 85:567–572 doi:10.1094/Phyto-85-567

Cochran, W.G., and G.M. Cox. 1957. Experimental designs. 2nd ed. John Wiley & Sons, New York.

Jeffers, H.C., and G.L. Rubenthaler. 1979. Effect of roll temperature on flour yield with the Brabender Quadrumat experimental mills. Cereal Chem. 54:1018–1025.

Jones, S.S., S.R. Lyon, K.A. Balow, M.A. Gollnick, K.M. Murphy, J.S. Kuehner, T.D. Murray, X.M. Chen, D.A. Engle, and K.G. Campbell. 2010. Registration of 'Xerpha' wheat. J. Plant Reg. 4:137–140. doi:10.3198/jpr2009.06.0306crc

Kronstad, W.E., C.R. Rohde, M.F. Kolding, and R.J. Metzger. 1978. Registration of 'Stephens' wheat. Crop Sci. 18:1097. doi:10.2135/cropsci1978.0011183X001800060060x

Kronstad, W.E., R.J. Metzger, W.L. McCuistion, N.H. Scott, C.R. Rhode, and M.F. Kolding. 1982. Registration of 'Hill 81'wheat. Crop Sci. 22:1266. doi:10.2135/cropsci1982.0011183X002200060062x

Large, E.C. 1954. Growth stages in cereals. Plant Pathol. 3:128–129. doi:10.1111/j.1365-3059.1954.tb00716.x

Leonard, J.M., C.J.W. Watson, A.H. Carter, J.L. Hansen, R.S. Zemetra, D.K. Santra, K.G. Campbell, and O. Riera-Lizarazu. 2008. Identification of a candidate gene for the wheat endopeptidase Ep-D1 locus and two other STS markers linked to the eyespot resistance gene *Pch1*. Theor. Appl. Genet. 116:261–270. doi:10.1007/s00122-007-0664-4

Mason, R.L., R.F. Gunst, and J.L. Hess. 2003. Statistical design and analysis of experiments. 2nd ed. John Wiley & Sons, Hoboken, NJ.

Payne, P.I., and G.J. Lawrence. 1983. Catalogue of alleles for the complex gene loci, *Glu-A1, Glu-B1,* and *Glu-D1* which code for high-molecular-weight subunits of glutenin in hexaploid wheat. Cereal Res. Commun. 11:29–35.

Peterson, C.J., R.E. Allen, G.L. Rubenthaler, and R.F. Line. 1991. Registration of 'Eltan' wheat. Crop Sci. 31:1704. doi:10.2135/cropsci1991.0011183X003100060075x

Peterson, C.J., R.E. Allen, C.F. Morris, B.C. Miller, D.F. Moser, and R.F. Line. 1995. Registration of 'Rod' wheat. Crop Sci. 35:594 doi:10.2135/cropsci1995.0011183X003500020062x

Peterson, C.J., O.A. Vogel, D.W. George, and R.J. Metzger. 1974. Registration of 'Luke' wheat. Crop Sci. 14:129. doi:10.2135/cropsci1974.0011183X001400010047x

Peterson, C.J., O.A. Vogel, D.W. George, G.L. Rubenthaler, and R.E. Allen. 1977. Registration of 'Daws' wheat. Crop Sci. 17:674. doi:10.2135/cropsci1977.0011183X001700040065x

Wetzel, H.C., III, and T.D. Murray. 2012a. Reaction of winter wheat cultivars and breeding lines to Cephalosporium stripe, 2011. Plant Disease Manage. Rep. 6:CF022.

Wetzel, H.C., III, and T.D. Murray. 2012b. Reaction of winter wheat cultivars and breeding lines to eyespot, 2011. Plant Disease Manage. Rep. 6:CF021.

Wilkinson, P.A., M.O.Winfield, G.L.A. Barker, A.M. Allen, A. Burridge, J.A. Coghill, A. Burridge, and K.J. Edwards. 2012. CerealsDB 2.0: An integrated resource for plant breeders and scientists. BMC Bioinf. 13:219.

Zemetra, R.S., M.L. Lauver, K. O'Brien, T. Koehler, E.J. Souza, S.O. Guy, L. Robertson, and B. Brown. 2003. Registration of 'Brundage 96' wheat. Crop Sci. 43:1884. doi:10.2135/cropsci2003.1884