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CULTIVAR

Registration of 'Spur' Hard Red Winter Wheat

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Abstract

'Spur' (Reg. No. CV-1139, PI 683537) hard red winter wheat (*Triticum aestivum* L.) was developed and released by the Montana Agricultural Experiment Station (MAES) and licensed to the Crop Research Foundation of Wyoming in 2016. Spur was derived from the cross, MT02113*4/MTS0359. MT02113 ('Karl 92'/UT190) and MTS0359 ('Rampart'/'Mironovskaya 61') are unreleased breeding lines developed by the MAES. Spur resulted from a marker-assisted backcross program for stem solidness and was selected as a solid-stem F_4 headrow. Spur was tested under the experimental number MTS1024 in Montana yield trials from 2010 to 2014 and in Wyoming from 2014 to 2016. Spur is a high-yielding, semidwarf hard red winter wheat cultivar with intermediate stem solidness, medium to late maturity, and acceptable milling and baking quality characteristics. Spur's semisolid stem provides some host-plant resistance to wheat stem sawfly.

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'Spur' (Reg. No. CV-1139, PI 683537) hard red winter wheat (*Triticum aestivum* L.) was developed and released by the Montana Agricultural Experiment Station (MAES) in 2016. Crop Research Foundation of Wyoming licensed Spur due to an increasing presence of wheat stem sawfly (*Cephus cinctus* Nort.) in southeastern Wyoming. Previously released solid and semisolid stem wheats incur a greater yield penalty than Spur in the absence of wheat stem sawfly cutting in Wyoming. In trials, Spur has also shown resistance to current leaf diseases, stripe rust (caused by *Puccinia striiformis* Westend. f. sp. *tritici* Erikss.) and tan spot [caused by *Pyrenophora tritici-repentis* (Died.) Drechler], present in southeastern Wyoming. Spur was released for its combination of semisolid stems, which mitigates damage by wheat stem sawfly, and adaptation to winter wheat production areas of Wyoming.

Methods

Pedigree and Breeding History

Spur is derived from the cross MT02113*4/MTS0359. MT02113 is an unreleased high-yielding hollow-stem line ('Karl 92' [PI 564245; Sears et. al., 1997]/UT190 [1993 Western Regional Hard Red Winter Wheat Nursery entry 3, complex pedigree]). MTS0359 is an unreleased solid-stem line of the pedigree 'Rampart' (PI 593889; Bruckner et al., 1997)/'Mironovskaya 61' (PI 592062). Spur resulted from a marker-assisted backcross program for stem solidness conducted from 2003 to 2006 at Montana State University using two simple sequence

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Abbreviations: IT, infection type; MAES, Montana Agricultural Experiment Station; Pgt, *Puccinia graminis* f. sp. *tritici*.

repeat markers for solid-stem genes located on wheat chromosomes 2B (*cdf233*) and 3B (*gwm340*; Cook et al., 2004). Two (of 21) BC_3F_1 plants (cross 05X428) positive for both the *cdf233* and *gwm340* markers were selected in the 2005 greenhouse. The BC_3F_2 populations derived from the marker-selected plants were grown in the greenhouse and harvested in bulk in 2006. The F_3 bulk population was grown at Williston, ND, in 2007 and was characterized as segregating for stem solidness at a high frequency. The F_4 headrows (116) from the Williston bulk 05X428 were grown at Bozeman in 2008. Headrow 05X428aC34 and six other population cohorts were selected and harvested in bulk based on visual criteria for uniformity, stem solidness, stripe rust resistance, productivity, and acceptable agronomic type.

Line Selection and Evaluation

In 2009, 05X428aC34 was tested and selected from the Montana Sawfly Observation Nursery grown at Bozeman, Havre, North Havre, and Fort Ellis. In 2010, 05X428aC34 was designated MTS1024 and subsequently tested in the Montana Sawfly Trial from 2010 to 2014, in the Montana Advanced Trial planted in 2011, in the Montana Intrastate Trial from 2012 to 2014, and in the Montana Off-station Trial planted in 2013 and 2014. Quality was evaluated in multilocation Montana trials from 2010 to 2014. After 2014, MTS1024 was discarded from further testing and release consideration due to the release of 'Warhorse' (PI 670157; Berg et al., 2014), a solid-stem winter wheat adapted to Montana, even though yield potential in the state was high (Table 1). MTS1024 has been tested in Wyoming since 2014.

The Montana Intrastate Trial consisted of 49 entries arranged in a 7 × 7 partially balanced, incomplete block, triple lattice design (Cochran and Cox, 1957). Plot size, row number, and row spacing varied by location to accommodate local plot seeding equipment. Seeding rate was approximately 2.15 million kernels ha^{-1}. The Montana Off-station Trial consisted of 25 entries planted on-farm arranged as a 5 × 5 partially balanced, incomplete block, triple lattice design, planted at 2.15 million kernels ha^{-1}. Grain yield, volume weight, plant height (distance from ground to top of spike excluding awns), and grain protein concentration were measured in all environments. The number of days to heading (50% of heads in plots completely visible) was recorded in most trials. Winter survival (% spring stand), lodging (% plants lodged), and stripe rust (% severity) were recorded in environments where there was differential expression for these traits. Stem solidness was determined in selected environments using five stems per plot, sampled randomly near crop maturity using a method similar to that reported by McKenzie (1965). Five internodes per stem were cross-sectionally cut and visually rated on a semiquantitative scale of 1 to 5, where 1 designates a hollow (normal) stem and 5 designates a solid stem. Internode scores were summed for each stem and averaged over five stems, resulting in composite stem solidness scores of 5 (hollow) to 25 (completely solid).

Milling and baking characteristics were determined by the Montana State University Cereal Quality Laboratory using methods approved by the American Association of Cereal Chemists International (2000). Grain protein concentration was determined using an Infratec 1241 Grain Analyzer (Foss Analytical). Kernel hardness was determined using a single kernel characterization system (SKCS-4100, Perten Instruments). Composite grain samples harvested from eight environments (2012–2013) of the Montana Intrastate Trial were milled on a Brabender Quadrumat Sr. mill (C.W. Brabender), and the flour was used to determine bake absorption, mix time, and loaf volume (AACCI Method 10-10B; American Association of Cereal Chemists International, 2000).

Analysis of variance was conducted on data from individual environments and across environments using SAS version 9.2 (SAS Institute, 2009). Mean comparison of traits using a protected LSD ($\alpha = 0.05$) test was made to identify significant differences among genotypes. The genotype × environment mean square was used to estimate the standard error of differences when comparing genotype means across environments.

Characteristics

Spur is an awned, white-glumed, semisolid stemmed, hard red winter wheat with medium-late heading date, 168 d to heading from 1 January, slightly later than MAES-released cultivars currently grown in Montana (Table 1). In 10 Wyoming environments, Spur headed 3 d later than 'SY Wolf' (PVP 201100390) and 2 d later than 'Cowboy' (PI 668564, Haley et al., 2014) (Table 2). Spur is semidwarf (77 cm, $n = 67$), significantly shorter than 'Yellowstone' (PI 643428; Bruckner et al., 2007), 'Judee' (PI 665227; Carlson et al., 2013a), and Warhorse and similar in height to 'Bearpaw' (PI 665228; Carlson et al., 2013b) (Table 1). Spur has a semisolid stem, averaging 18.0 on the 5 (hollow) to 25 (solid) stem solidness scale, significantly less solid than Judee, Bearpaw, and Warhorse (Table 3).

Field Performance

In 69 location years of testing in the Montana winter wheat nurseries, average yield of Spur (4690 kg ha^{-1}) was similar to that of Yellowstone (the current predominant hollow-stem cultivar grown in Montana) but higher than solid-stem cultivars

Table 1. Mean performance of Spur hard red winter wheat and Montana Agricultural Experiment Station check cultivars in 69 Montana environments, 2010–2014.

Cultivar	Grain yield	Volume weight	Winter survival	Heading date	Plant height	Grain protein	Stripe rust
	kg ha^{-1}	kg m^{-3}	%	d from 1 Jan.	cm	g kg^{-1}	% severity
Spur	4690	753	12	168	77	126	34
Yellowstone	4676	763	28	168	84	130	30
Warhorse	4273	768	28	167	78	134	17
Judee	4206	772	9	166	80	134	17
Bearpaw	4072	764	23	166	77	134	60
LSD (0.05)	168	6	13	1	1	2	16
No. of environments	69	69	2	39	67	68	5

Table 2. Mean performance of Spur hard red winter wheat and check cultivars in 10 Wyoming environments, 2014–2016.

Cultivar	Grain yield	Volume weight	Heading date	Plant height
	kg ha^{-1}	kg m^{-3}	d from 1 Jan.	cm
Spur	3978	743	164	61
Warhorse	3648	762	164	60
Judee	3756	784	164	58
Bearpaw	3333	764	163	58
SY Wolf	4199	782	161	59
Cowboy	4085	767	162	59
LSD (0.05)	343	17	1	2
No. of environments	10	9	5	5

Table 3. Mean stem solidness and cutting by wheat stem sawfly of hard red winter wheat Spur and Montana Agricultural Experiment Station check cultivars grown in Montana environments, 2010–2014.

Cultivar	Stem solidness	Cutting by wheat stem sawfly
	5–25†	%
Spur	18.0	12
Yellowstone	7.0	18
Warhorse	21.6	3
Judee	20.0	9
Bearpaw	21.6	9
LSD (0.05)	0.6	7
No. of environments	32	12

† Scale: 5 = hollow; 25 = completely solid.

Warhorse, Judee, and Bearpaw (Table 1). In Wyoming, grain yield of Spur was intermediate to that of adapted hollow-stem cultivars, SY Wolf and Cowboy, and the solid stem cultivars, Judee, Warhorse, and Bearpaw (Table 2). Volume weight of Spur (mean 753 kg m^{-3} [Montana] and 743 kg m^{-3} [Wyoming]) was lower ($P < 0.05$) than that of all check cultivars (Tables 1 and 2). Grain protein concentration of Spur was lower ($P < 0.05$) than all MAES check cultivars in Montana trials (Table 1).

Disease and Insect Resistance

Characterization of Spur for disease and insect resistance included Montana trials and cooperative evaluations by the USDA–ARS. Spur is moderately resistant to cutting by wheat stem sawfly (Table 2). Spur is moderately resistant to stem rust (caused by *Puccinia graminis* Pers.:Pers. f. sp. *tritici* Erikss. & E. Henn. [Pgt]) based on field evaluations conducted at Bozeman, MT, using Pgt race TMLKC and seedling and field stem rust evaluations conducted by the USDA–ARS Cereal Disease Laboratory in 2011. In seedling evaluations at St. Paul, MN, Spur was resistant to Pgt races QFCSC, QTHJC, RKQQC, and TPMKC but susceptible to TTTTF. Spur was also resistant to major races in the Ug99 race group (TTKSK, TTKST, and TTTSK) but susceptible to TRTTF. It is postulated that Spur possesses stem rust resistance gene *SrTmp*.

Spur is resistant to stripe rust as indicated by field observations in Montana (Table 1) and screening at Pullman and Mount Vernon, WA, from 2011 to 2014. All field nurseries in Washington were under natural infection of *P. striiformis*, except the Pullman location in 2014 that was inoculated with a mixture of predominant races PSTv-14 and PSTv-37 in late March when plants were at tillering stage (Zadoks 26). Infection type (IT; based on a 0-to-9 scale where IT 0 to 3 is considered resistant, 4 to 6 intermediate, and 7 to 9 susceptible; Line and Qayoum, 1992) and severity (0–100%) were recorded for each entry once at the Pullman location from flowering (Zadoks 60) to soft dough (Zadoks 85) and twice at Mount Vernon, at stem elongation (Zadoks 32–37) and heading-milk (Zadoks 55–75). Susceptible check PS279 had a susceptible reaction (IT 8) in all years and locations, 100% severity in Pullman, and 50 to 80% severity at the early observation and 80 to 100% severity at the second observation in Mount Vernon, indicating adequate levels of stripe rust epidemics for reliable evaluations. Spur had resistant to susceptible reaction (ITs 3–8) with severity 5 to 30% in the 4 yr at Pullman. When it had IT 8 in 2014, its severity was low (20%), which can be considered moderately susceptible. At Mount Vernon, Spur also had ITs 3 to 8 and severity 25 to 40% in the early observation but had reduced ITs (2–5) and severity 5 to 30% at the second observation, indicating a moderate level of high-temperature adult-plant resistance.

End-Use Quality

Based on experimental milling using a Brabender Quadrumat Sr. mill, flour yield of Spur is relatively low, with moderate flour ash content and low flour protein (Table 4). Spur has strong dough mixing characteristics similar to Yellowstone, with high water absorption and relatively long mixing time. Baking qualities of Spur are within acceptable ranges with high loaf volume similar to currently deployed Montana cultivars (Table 4).

Seed Purification and Increase

Purification and increase of Spur was initiated in 2012 when 121 F_7–derived F_8 headrows were grown with selection for visual uniformity, retaining 84 line rows. Individual line rows were evaluated for stem solidness in 2013, and the 42 line rows with the highest stem solidness were bulked as breeder seed.

Table 4. Average milling and baking quality attributes of hard red winter wheat Spur and Montana Agricultural Experiment Station check cultivars grown in eight Montana environments, 2012–2013.

Cultivar	SKCS hardness†	Flour yield	Flour protein	Flour ash	Baking mix time	Baking absorption	Loaf volume
		g kg^{-1}			min	g kg^{-1}	cm^3
Spur	86	654	114	4.3	15.6	752	1120
Yellowstone	83	680	119	4.4	15.0	755	1104
Warhorse	95	668	123	4.3	6.7	723	1101
Judee	81	666	127	4.3	8.2	730	1189
Bearpaw	86	677	120	4.3	6.0	703	1043
LSD (0.05)	4	10	4	ns	1.9	17	50

† Single kernel characterization system.

Breeder seed of Spur was transferred to the University of Wyoming Foundation Seed program in fall 2015 for increase in 2016 at Powell. Spur has been genetically uniform and stable over three generations of seed increase containing tall plant variants (<200/10,000).

Availability

Spur winter wheat is licensed to the Crop Research Foundation of Wyoming, which will maintain breeder seed of Spur. US Plant Variety Protection for Spur has been filed. All seed requests should be sent to the corresponding author during the period of protection by the Plant Variety Protection Certificate. Seed of Spur has been deposited in the USDA–ARS National Plant Germplasm System, where it will be available after the expiration of the Plant Variety Protection for research purposes, including development and commercialization of new cultivars.

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