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REGISTRATION

Cultivar

Registration of 'Bobcat' hard red winter wheat

P. L. Bruckner[1] | **J. E. Berg**[1] | **P. F. Lamb**[2] | **K. D. Kephart**[3] | **J. O. Eberly**[4] | **J. H. Miller**[5] | **C. Chen**[6] | **J. A. Torrion**[7] | **G. P. Pradhan**[8] | **R. Ramsfield**[1] | **D. L. Nash**[1] | **D. L. Holen**[1] | **J. P. Cook**[1] | **S. Gale**[9] | **Y. Jin**[9] | **J. Kolmer**[9] | **X. Chen**[10] | **G. Bai**[11]

[1] Dep. of Plant Sciences & Plant Pathology, Montana State Univ., Bozeman, MT 59717-3140, USA

[2] Northern Agricultural Research Center, 3710 Assinniboine Road, Havre, MT 59501-8412, USA

[3] Southern Agricultural Research Center, 748 Railroad Highway, Huntley, MT 59037, USA

[4] Central Agricultural Research Center, 52583 U.S. Hwy. 87, Moccasin, MT 59462, USA

[5] Western Triangle Agricultural Research Center, 9546 Old Shelby Road, Conrad, MT 59425, USA

[6] Eastern Agricultural Research Center, 1501 North Central, Sidney, MT 59270, USA

[7] Northwestern Agricultural Research Center, 4570 Montana Hwy. 35, Kalispell, MT 59901, USA

[8] Williston Research Extension Center, 14120 Highway 2, Williston, ND 58801, USA

[9] USDA–ARS, Cereal Disease Lab., 1551 Lindig St., St. Paul, MN 55108-6052, USA

[10] USDA–ARS, Wheat Health, Genetics and Quality Research Unit, Pullman, WA 99164-6430, USA

[11] USDA–ARS, Hard Winter Wheat Genetics Research Unit, 4008 Throckmorton Hall, Manhattan, KS 66506, USA

Correspondence
P. L. Bruckner, Dep. of Plant Sciences & Plant Pathology, Montana State Univ., Bozeman, MT 59717-3140, USA.
Email: bruckner@montana.edu

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Abstract

'Bobcat' (Reg. no. CV-1161, PI 693235) hard red winter (HRW) wheat (*Triticum aestivum* L.) was developed and released by the Montana Agricultural Experiment Station in September 2019. Bobcat is of unknown pedigree, derived from a composite of two related single crosses made in 2007: MT0598/98X366-E29-1 and 01X258-C1/MT0598. MT0598 is an unreleased, hollow-stem experimental line, and 98X366-E29-1 and 01X258-C1 are unreleased, Montana solid-stem experimental lines. Bobcat was developed using a modified bulk breeding method and selected as an $F_{5:6}$ head row. Bobcat was tested under the experimental number MTS1588 from 2015 to 2019 in Montana. Quality was evaluated in multilocation Montana trials since 2015. Bobcat is a solid-stem, high-yielding HRW wheat cultivar with medium to high test weight, medium maturity, reduced height (*Rht-B1b*), medium to high grain protein, and acceptable milling and baking quality. Bobcat was released for its improved host plant resistance to wheat stem sawfly (*Cephus cinctus* Nort.) conditioned by stem solidness, along with short stature, and improved yield potential relative to 'Warhorse', the current predominant solid-stem cultivar in Montana.

Abbreviations: HRW, hard red winter; HTAP, high-temperature adult-plant; IT, infection type; LY, location-years; NRPN, Northern Regional Performance Nursery.

1 | INTRODUCTION

'Bobcat' (Reg. no. CV-1161, PI 693235) HRW wheat (*Triticum aestivum* L.) was developed and released by the Montana Agricultural Experiment Station in 2019. Bobcat was chosen as a cultivar name because the bobcat has served as Montana State University's mascot since 1916 (representing cunning intelligence, athletic prowess, and independent spirit). Bobcat was released for its combination of stem solidness, short stature, high yield potential, and excellent performance in wheat stem sawfly infested production environments of north-central Montana. Wheat stem sawfly is the major biotic limitation to wheat production in Montana, reducing kernel weight and grain yield and increasing harvest losses from stem lodging after mature larvae girdle the stem base (Morrill, Gabor, & Kushnak, 1992). Solid stems provide resistance due to antibiosis, whereby larvae are unable to survive in the stem.

2 | METHODS

2.1 | Pedigree and breeding history

Bobcat is of unknown pedigree, derived from a composite of two related single crosses made in 2007: MT0598/98X366-E29-1 and 01X258-C1/MT0598. MT0598 [MT9659/S87-101//Pronghorn (PI 593047; Baenziger et al., 1997)] is an unreleased, hollow-stem Montana experimental line. S87-101 ['Norstar'*2 (CI 17735; Grant, 1980)/Yorkstar (CI 140260; Jensen, 1968)] is an unreleased breeding line developed by the University of Saskatchewan. 98X366-E29-1 [Heyne (PI 612577; Sears et al., 2001)/Rampart (PI 593889; Bruckner et al., 1997)//MT9513] and 01X258-C1 [MTS0023//Pryor (PI 634564)/Genou (PI 640424; Bruckner et al., 2006] are unreleased, solid-stem Montana experimental lines. The F_1 populations were grown in the Plant Growth Center at Bozeman in 2008. Composite F_2, F_3, F_4, and F_5 bulk populations were grown at Fort Ellis in 2009, North Havre in 2010, and Havre, MT, in 2011 and 2012, respectively, using a modified bulk breeding method, with phenotypic mass selection for winter survival, reduced plant height, favorable head morphology, stem solidness, and kernel plumpness. In each generation, individual plants were selected, threshed in bulk, and the seed was sieved using appropriately sized screens to retain the plumpest seed fraction for replanting. Seventy-five heads that were selected from the F_5 population in 2012 were grown as F_6 head rows at Bozeman in 2013. Head row 07X291cE44 was selected based on the evaluation of stem solidness and visual criteria for uniformity, productivity, and acceptable agronomic type and harvested in bulk. 07X291cE44 was tested and selected from the 2014 Sawfly Observation Nursery grown at Bozeman, Conrad, Loma, and Fort Ellis.

2.2 | Line selection and evaluation

In 2015, 07X291cE44 was designated MTS1588 and subsequently tested in the Montana Sawfly Yield Trial from 2015 to 2019 (23 location-years, LY), in the Montana Advanced Trial planted in 2016 (7 LY), in the Montana Intrastate Trial from 2017 to 2019 (25 LY), and in the Montana Off-Station Nursery planted from 2017 to 2019 (43 LY). In 2018, MTS1588 was an entry in the USDA Northern Regional Performance Nursery (NRPN) planted at approximately 20 sites across the northern Great Plains (USDA–ARS, 2018).

The Montana Intrastate Trial consisted of 49 entries arranged in a 7 by 7 partially balanced, incomplete block, triple lattice design (Cochran & Cox, 1957). Plot size, row number, and row spacing varied by location to accommodate local plot seeding equipment. The seeding rate was approximately 2.15 million kernels ha^{-1}. The Montana Off-Station Trial, planted at ~15 locations each year, consisted of 25 entries, arranged as a 5 by 5 partially balanced, incomplete block, triple lattice design and planted at 2.15 million kernels ha^{-1}. The Montana Sawfly Trial, planted at three to six locations each year, consisted of 49 entries, arranged as a 7 by 7 partially balanced, incomplete block, simple lattice with two replications and 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. Days to heading (50% of plot heads completely emerged from boot) were recorded in most on-station trials. Winter survival (percentage of plants surviving) and stripe rust (severity) were recorded in environments where there was a 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 across five stems, resulting in composite stem solidness scores of 5 (hollow) to 25 (completely solid).

Milling and baking quality has been evaluated in multilocation Montana trials since 2015. 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

TABLE 1 Mean performance of Bobcat and check cultivars in 91 Montana environments, 2015–2019

Cultivar	Grain yield	Volume weight	Winter survival	Heading date	Plant height	Grain protein	Stem solidness	Stripe rust
	kg ha^{-1}	kg m^{-3}	%	d from 1 Jan.	cm	g kg^{-1}	5–25[a]	% severity
Bobcat	4,690	788	43	162	71	126	23.2	6
Loma	4,623	776	49	164	72	126	20.1	6
Judee	4,401	792	53	161	76	130	20.2	6
Decade	4,394	779	52	160	77	128	7.9	52
Warhorse	4,381	780	46	162	74	132	21.8	4
LSD (.05)	128	3	ns[b]	0.4	1	1	0.7	15
No. of environments	91	89	2	36	86	91	38	5

[a]Stem solidness score where 5 = hollow to 25= completely solid.
[b]ns = not significant at .05.

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 (2017 and 2018) of the Montana Intrastate Trial and 11 environments from the Montana Sawfly Trial (2015–2018) were milled on a Brabender Quadrumat Sr. mill (C.W. Brabender) and the flour was used to determine bake water absorption, mix time, and loaf volume (AACC Method 10-10B). MTS1588 was also evaluated in the 2018 Hard Winter Wheat Quality Council evaluation (Wheat Quality Council, 2019).

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 ($\alpha = .05$) 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.

2.3 | Seed purification and increase

Purification and increase of Bobcat was initiated in 2017 when 130 F_9–derived F_{10} head rows were evaluated for stem solidness and visual uniformity, retaining 119 line rows, which were bulked as breeder seed. Breeder seed of Bobcat was increased in 2018 and foundation seed was grown and allocated to Montana seed growers in the fall of 2019. Bobcat has been genetically uniform and stable during three generations of seed increase. Bobcat contains tall, hollow stem, and dark chaff variants at frequencies <5, 5, and 5 per 10,000 spikes, respectively.

3 | CHARACTERISTICS

3.1 | Agronomic characteristics

Bobcat is an awned, white-chaffed, solid-stem, semidwarf HRW wheat. Bobcat has medium maturity, 162 d heading from 1 January, similar to the predominant Montana solid-stem cultivar 'Warhorse' (PI 670157; Berg et al., 2014), slightly later than 'Judee' (PI 665227; Carlson et al., 2013), and 2 d earlier than 'Loma' (PI 680576; Bruckner et al., 2017; Table 1). Bobcat is short (71 cm, $n = 86$), semidwarf (*Rht-B1b*; marker analysis, USDA–ARS, 2018), similar in plant height to Loma, and significantly shorter than Warhorse, Judee, and 'Decade' (PI 660291; Riveland et al., 2011). Straw strength of Bobcat is good. Bobcat is solid stemmed, averaging 23.2 on the 5 (hollow) to 25 (solid) stem solidness scale, significantly more solid than Warhorse (21.8), Judee (20.2), Loma (20.1), and the hollow-stem check, Decade (7.9) (Table 1).

3.2 | Field performance

In 91 LY of testing in the Montana Winter Wheat Intrastate, Off-Station, and Sawfly nurseries, the average yield of Bobcat (4690 kg ha^{-1}) was high, similar to the yield of Loma but about 7% higher than the predominantly grown solid-stem cultivar Warhorse (Table 1). Although Bobcat has improved yield potential relative to older solid-stem genotypes, Bobcat is not recommended for environments with low infestation by wheat stem sawfly since its yield potential is still lower than the best hollow-stem cultivars, particularly in high-yielding Montana environments (data not shown). Volume weight of Bobcat (788 kg m^{-3}) was medium to high, slightly lower than that of Judee and higher than Loma, Decade, and Warhorse in this set

TABLE 2 Mean grain yield and stem cutting of Bobcat and check cultivars in 16 Montana environments with moderate to heavy infestations of wheat stem sawfly and in north-central Montana at Conrad and Havre, 2015–2019

	Sawfly-infested environments		NC Montana locations	
			Conrad	Havre
Cultivar	Grain yield	Sawfly cutting	Grain yield	
	kg ha^{-1}	%	kg ha^{-1}	
Bobcat	4,334	8	4,744	4,172
Loma	4,045	31	4,623	3,756
Judee	3,749	39	4,172	3,695
Decade	3,763	42	4,105	3,642
Warhorse	3,588	10	4,045	3,595
LSD (.05)	245	9	195	195
No. of environments	16	16	16	25

of environments (Table 1). Grain protein concentration of Bobcat was lower than that of Warhorse, Judee, and Decade and similar to that of Loma (Table 1).

In 16 Montana environments where moderate to high cutting by wheat stem sawfly was observed (criterion: test mean >10% cutting), grain yield of Bobcat was 16 and 20% higher than Judee and Warhorse, respectively (Table 2). Cutting of Bobcat by wheat stem sawfly (8%) was similar to Warhorse and significantly less than cutting by sawfly in Loma, Judee, and Decade. In north-central Montana, where wheat stem sawfly is endemic, the average grain yield of Bobcat was 17 and 16% higher than the grain yield of the predominant solid-stem cultivar Warhorse at Conrad and Havre, respectively.

3.3 | Disease and insect resistance

Characterization of Bobcat for disease and insect resistance included data from Montana trials and evaluations by the Cooperative USDA–ARS Regional Testing Program. Bobcat is resistant to wheat stem sawfly (Tables 1 and 2) and susceptible to Hessian fly [*Mayetiola destructor* (Say)]. Bobcat is resistant to some races of the stem rust pathogen (*Puccinia graminis* Pers.:Pers. f. sp. *tritici* Erikss. & E. Henn.) including QCCSM, QFCSC, MCCFC, and TPMKC but susceptible to QTHJC, RKRQC, RCRSC, TTTF, and TTKSK (USDA–ARS, 2018). Bobcat is susceptible to prevalent races of the leaf rust pathogen (*P. triticina* Erikss.) based on seedling evaluations of the NRPN (USDA–ARS, 2018).

Bobcat is resistant to stripe rust (caused by *P. striiformis* Westend. f. sp. *tritici* Erikss.) based on field observations in Montana (Table 1), multiyear testing in the Montana winter wheat nursery for reactions to natural infections of stripe rust at Pullman and Mount Vernon, WA, from 2015 to 2019, and also at Walla Walla and Lind, WA, as part of the NRPN evaluation in 2018. Infection type (IT; based on a 0–9 scale where IT 0–3 was considered resistant, 4–6 intermediate, and 7–9 susceptible; Line & Qayoum, 1992) and severity (0–100%) were recorded for each entry. In all Washington field experiments, the susceptible check (PS279) was highly susceptible (IT 8) with 80–100% severity in the late growth season, showing adequate levels of stripe rust for differentiating resistant from susceptible reactions. Across locations and years, the infection type of Bobcat was mostly IT 2 (highly resistant) and severity 2–40%, with intermediate reactions (IT 5–6) observed at Pullman in 2016 (20% severity) and 2017 (40% severity), and at Mount Vernon (80% severity) in the late growth season. In the 2015 test at Mount Vernon, Bobcat had IT 7 (moderately susceptible) and 30% severity in the early season but became highly resistant (IT 2, severity 10%) in the late stage, indicating high-temperature adult-plant (HTAP) resistance. In the 2018 NRPN evaluation, Bobcat was highly (IT 2) or moderately (IT 5) resistant, with 5–15% severity in the late growth season. Based on the reactions, Bobcat was rated 2 (resistant) in the nursery. The high reaction (IT 5, severity 40%) in the early season but low reaction (IT 3, severity 5%) at Mount Vernon again indicated HTAP resistance.

Together with other 2018 NRPN entries and susceptible check PS279, Bobcat was also tested in the greenhouse with six predominant or most virulent races (PSTv-4, PSTv-14, PSTv-37, PSTv-40, PSTv-51, and PSTv198) of the wheat stripe rust pathogen in the seedling stage at a low-temperature cycle (10–20 °C) and with three predominant races (PSTv-14, PSTv-37, and PSTv-40) in the adult-plant stage at a high-temperature profile (10–30 °C). In the seedling low-temperature test, Bobcat was moderately resistant (IT 5) to races PSTv-4 and PSTv-40 and susceptible (IT 8) to PSTv-14, PSTv-37, PSTv-40, and PSTv-198; but in the HTAP test, the line was highly resistant (IT 2–3) to all three tested races. The greenhouse tests clearly

TABLE 3 Average milling and baking quality attributes of Bobcat and check cultivars in 19 Montana winter wheat yield trials, 2015–2018

Cultivar	SKCS[a] hardness	Flour			Bake		
		Yield	Protein	Ash	Mix time	Water absorption	Loaf volume
		g kg^{-1}			min	g kg^{-1}	L
Bobcat	69	720	125	3.9	14.9	783	1.08
Loma	79	720	122	4.0	15.2	785	1.13
Judee	78	704	126	4.0	9.0	759	1.16
Decade	75	703	122	4.0	18.6	793	1.08
Warhorse	87	697	128	4.2	7.9	772	1.12
LSD (.05)	3	5	3	0.1	2.2	14	0.03

[a]Single-kernel characterization system.

showed that Bobcat has a high level of HTAP resistance to stripe rust.

3.4 | End-use quality

Based on experimental milling using a Brabender Quadrumat Mill, flour yields of Bobcat and Loma were similar and significantly higher than those of Judee, Decade, and Warhorse (Table 3). Flour protein concentration and flour ash of Bobcat were similar to the check cultivars. Like Loma and Decade, Bobcat has strong dough mixing characteristics with high water absorption and a relatively long mixing time. Bobcat has loaf volume that is acceptably high like Decade and slightly lower than Warhorse, Loma, and Judee (Table 3). Bobcat carries the 2* high molecular weight glutenin subunit at the *Glu-A1* locus, the 7+8 subunits at the *Glu-B1* locus, and the 2+12 subunits at the *Glu-D1* locus (wheat flour protein analysis; Wheat Quality Council, 2019.

4 | AVAILABILITY

The Montana Agricultural Experiment Station will maintain breeder seed of Bobcat. U.S. Plant Variety Protection for Bobcat will be sought. A research fee will be assessed on all registered and certified seed sales. All seed requests should be sent to the corresponding author during the period of protection by the Plant Variety Protection Certificate. Seed of this release is deposited in the USDA–ARS National Plant Germplasm System, where it will be available for research purposes, including development and commercialization of new cultivars, after the expiration of the Plant Variety Protection.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ORCID

P. L. Bruckner https://orcid.org/0000-0002-5936-8729
J. O. Eberly https://orcid.org/0000-0002-3963-5367
J. P. Cook https://orcid.org/0000-0002-7753-6191
G. Bai https://orcid.org/0000-0002-1194-319X

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