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CULTIVAR

Registration of 'Loma' Hard Red Winter Wheat

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Abstract

'Loma' (Reg. No. CV-1126, PI 680576) hard red winter wheat (*Triticum aestivum* L.) was developed and released by the Montana Agricultural Experiment Station in 2016. Loma was derived from the cross 'Yellowstone'//MTS0112/MTS0125. It was developed using a modified bulk breeding method and selected as an $F_{6:7}$ head row. Loma was tested under the experimental number MTS1224 in Montana yield trials from 2012 to 2016. Like the predominant cultivar Yellowstone, Loma is a high-yielding, winter-hardy wheat cultivar with medium to late maturity, medium to high grain protein concentration, and acceptable milling and baking quality characteristics. Loma was released for its excellent performance in winter wheat production environments of north-central Montana, reduced plant height, and its semisolid stem, which provides some host plant resistance to wheat stem sawfly (*Cephus cinctus* Nort.).

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'Loma' (Reg. No. CV-1126, PI 680576) hard red winter wheat (*Triticum aestivum* L.) was developed and released by the Montana Agricultural Experiment Station in 2016. Loma was named in recognition of a small town located in north-central Montana, where a primary winter wheat phenotypic selection and evaluation site for resistance to wheat stem sawfly (*Cephus cinctus* Nort.) has been situated since 1998. Loma was released for its excellent combination of winter wheat production characteristics suited for north-central Montana, including reduced plant height and increased stem solidness, compared with the predominant cultivar Yellowstone.

Methods

Pedigree and Breeding History

Loma is derived from the cross Yellowstone (PI 643428; Bruckner et al., 2007)//MTS0112/MTS0125. Unreleased solid-stem experimental line MTS0112 has the pedigree 'Lew'(CI 17429; McNeal and Berg, 1977)/'Tiber' (PI 517194; Kisha et al., 1992)//'Redwin' (CI 17844; Taylor et al., 1983)/3/2*'Erhardt'(PI 564761; Wichman et al., 1997). MTS0125 is an unreleased experimental line with high stem solidness derived from a composite of four crosses, all made between Lew/Tiber//Redwin derivatives and Idaho germplasm (including ID454, 'Blizzard', and 'Meridian'). The F_1 and F_2 populations were grown near Bozeman, MT, in 2004 and

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Abbreviations: AACCI, American Association of Cereal Chemists International; IT, infection type; LY, location-years; NRPN, Northern Regional Performance Nursery; *Pgt*, *Puccinia graminis* f. sp. *tritici*; *Pst*, *Puccinia striiformis* f. sp. *tritici*; RCBD, randomized complete block design.

2005. The F_3, F_4, and F_5 bulk populations were grown as part of a selection nursery north of Havre, MT, from 2006 to 2008. Segregating populations were advanced using a modified bulk breeding method, with mass selection for stem solidness, winter survival, reduced plant height, favorable head morphology, disease resistance, and kernel plumpness. Sixty-two heads were selected from the F_5 population in 2008 and grown as F_6 head rows at Bozeman in 2009. Headrow 03X137E41 was selected on the basis of visual criteria for uniformity, stem solidness, stripe rust (caused by *Puccinia striiformis* Westend. f. sp. *tritici* Erikss. [*Pst*]) resistance, productivity, and acceptable agronomic characteristics. Heads were harvested for a second round of head row selection, and F_7 head rows were evaluated in 2010. Head row 03X137E41-3 was selected and harvested in bulk. Selection 03X137E41-3 was subsequently tested and selected from the 2011 Sawfly Observation Nursery grown at Bozeman, Havre, and Fort Ellis, MT.

Line Selection and Evaluation

In 2012, 03X137E41-3 was designated MTS1224 and subsequently tested in the Sawfly yield trial (21 location years [LY]) from 2012 to 2016, in the Advanced Trial planted in 2013 (six LY), in the Montana Intrastate trial from 2014 to 2016 (21 LY), and in the Off-Station Nursery planted in 2015 and 2016 (31 LY). Quality has been evaluated from samples grown in multilocation Montana trials since 2012. Loma was an entry in the 2016 USDA-ARS coordinated Northern Regional Performance Nursery (NRPN), planted at ~20 sites across the Northern Great Plains. Loma was also evaluated by the Hard Winter Wheat Quality Council in 2015.

The Montana Intrastate Trial consisted of 49 entries planted in partially balanced lattice or randomized complete block designs (RCBD) with three replications. Plot size, row number, and row spacing varied by location to accommodate local plot seeding equipment. Seeding rate was ~2.15 million kernels ha^{-1}. The Montana Off-Station Nursery consisted of 25 entries planted on farm as five-by-five partially balanced lattice or RCBD trials with three replications, 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 (% plants surviving), 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. Five internodes per stem were cross-sectionally cut and visually rated on a quantitative 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 (AACCI, 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 19 environments (2012–2015) of the Montana Intrastate and Sawfly trials 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). Polyphenol oxidase activity was determined using a modification of the AACCI 22-85.01 method (four kernel samples, 1 mL L-DOPA, microassay plate, no Tween-20, 45 min shaking).

Analysis of variance was conducted on data from individual environments and across environments using SAS version 9.2 (SAS Institute, 2008). 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

Loma is an awned, white-glumed, semisolid-stemmed, hard red winter wheat with medium-late heading date, 162 d to heading from 1 January, slightly later than currently deployed Montana cultivars (Table 1). Loma is semidwarf (*Rht B1b* [marker analysis, 2016 NRPN]; 78 cm, $n = 73$), significantly shorter than currently deployed solid-stem cultivars 'Judee' (PI 665227; Carlson et al., 2013a), 'Bearpaw' (PI 665228; Carlson et al., 2013b), 'Warhorse' (PI 670157; Berg et al., 2014), and the parental cultivar Yellowstone (Table 1). Winter hardiness of Loma was superior to that of Judee and 'Rampart' (PI 593889; Bruckner et al., 1997) in two environments with differential winter injury (Table 1). Loma has a semisolid stem, averaging 18.8 on the 5 (hollow) to 25 (solid) stem solidness scale, significantly less solid than Judee, Rampart, Bearpaw, and Warhorse (Table 2).

Field Performance

In 73 LY of testing in the Montana winter wheat nurseries, average yield of Loma (4542 kg ha^{-1}) was lower than that of Yellowstone (the current predominant hollow-stem cultivar grown in Montana) but higher than solid-stem cultivars Warhorse, Bearpaw, Rampart, and Judee (Table 1). Volume weight of Loma (759 kg m^{-3} over 72 LY) was medium to high, similar to Yellowstone and Warhorse but lower ($P < 0.05$) than that of Judee (Table 1). Grain protein concentration of Loma was higher ($P <$ \0.05) than Yellowstone, similar to that of Judee, 'Decade' (PI 660291; Riveland et al., 2011), and Bearpaw, and lower than that of Warhorse and Rampart (Table 1).

Disease and Insect Resistance

Characterization of Loma for disease and insect resistance included Montana trials and cooperative evaluations by the USDA-ARS. Loma is moderately resistant to cutting by wheat stem sawfly (Table 2) and susceptible to Russian wheat aphid (*Diuraphis noxia* Mordvilko) and Hessian fly [*Mayetiola destructor* (Say)].

Loma is resistant to stem rust (caused by *Puccinia graminis* Pers.:Pers. f. sp. *tritici* Erikss. & E. Henn. [*Pgt*]) according to field evaluations conducted at Bozeman using *Pgt* race TMLKC and seedling and field stem rust evaluations conducted by the USDA-ARS Cereal Disease Laboratory in 2013 (Montana

Table 1. Mean performance of Loma and check wheat cultivars in 73 Montana environments in 2012–2016.

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
Loma	4542	759	89	162.4	78	125	11
Bearpaw	3897	752	84	159.7	80	126	56
Decade	4139	758	86	159.3	82	125	55
Judee	4166	771	40	160.0	81	127	10
Rampart	3769	763	69	160.7	90	132	29
Warhorse	4220	762	79	161.2	82	128	8
Yellowstone	4784	759	94	161.0	87	122	21
LSD (0.05)	195	5	19	0.4	1	2	14
No. of environments	73	72	2	43	73	71	7

Advanced Trial) and 2016 (NRPN). In seedling evaluations at St. Paul, MN, Loma was resistant to all tested *Pgt* races from the United States, including QCCSM, QFCSC, QTHJC, MCCFC, RCRSC, RKQQC, TPMKC, and TTTTF. Loma was also resistant to major races in the Ug99 race group (TTKSK, TTKST, TTTSK, and TTKTT) and other races of foreign origin with broad virulence combinations, including TRTTF (Yemen), TKTTF (Ethiopia), and TKTTF and TKKTP (Germany). Field evaluations at the adult plant stage using a bulk of races MCCFC, QFCSC, QTHJC, RCRSC, RKQQC, and TPMKC in 2013 and 2016 at St. Paul indicated that Loma was highly resistant. Based on infection types (ITs) in seedling tests and infection responses at the adult plant stage, it is postulated that Loma possesses stem rust resistance genes *Sr24* and *Sr36* (*Sr24* postulation supported by marker analysis, 2016 NRPN). Black pigmentation was observed on the internode of Loma, suggesting that the adult plant stem rust resistance gene *Sr2* also might be present. According to seedling evaluations of the 2016 NRPN for leaf rust (caused by *P. triticina* Erikss.) resistance, Loma is resistant to races TBBGS, TCRKG, MBDSD, MCTNB, and PLBRG but susceptible to races TNRJJ, TNBGJ, KFBJG, MFJSB, and MJBJG. Loma is postulated to carry *Lr24* on the basis of its response to races and marker analysis (2016 NRPN).

Loma is resistant to stripe rust based on field observations in Montana (Table 1) and screening at Pullman and Mount Vernon, WA, from 2012 to 2016 All field nurseries in Washington were under natural infection of *Pst*, 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 the tillering stage (Zadoks 26). Infection type on a 0-to-9 scale 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 evaluation. Loma had resistant to moderately resistant reactions (ITs 2–5), with low levels of severity (2–15%) in 2012 to 2016 at Pullman. In Mount Vernon, Loma had ITs 3 to 5 with severity 30 to 50% at the early observation, but reactions and severity were reduced at the late observation (ITs 2–5, severity 1–30%), indicating a high to moderate level of high-temperature adult-plant resistance. Loma is moderately tolerant to Cephalosporium stripe (caused by *Cephalosporium gramineum* Y. Nisik. & Ikata) according to field trials in Pullman in 2015 and 2016.

Table 2. Mean stem solidness and cutting by wheat stem sawfly of Loma and check wheat cultivars in Montana environments in 2012-2016.

Cultivar	Stem solidness	Cutting by wheat stem sawfly
	5–25†	%
Loma	18.8	12
Bearpaw	20.8	9
Judee	20.0	11
Rampart	20.5	8
Warhorse	21.2	2
Yellowstone	7.1	26
LSD (0.05)	0.9	11
No. of environments	21	10

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

End-Use Quality

After experimental milling using a Brabender Quadrumat Sr. mill, flour yield of Loma is high, with moderate flour ash content and flour protein (Table 3). Loma has strong dough mixing characteristics, with high water absorption and a relatively long mixing time. Baking qualities of Loma are within acceptable ranges, with high loaf volume similar to Judee and superior to many currently deployed Montana cultivars (Table 3). Loma has relatively low polyphenol oxidase activity (Table 2) but poor Asian noodle brightness (L24) and color stability (data not shown). Loma carries the 1 subunit at the *Glu-A1* locus, the 7+8 subunits at the *Glu-B1* locus, and the 5+10 subunits at the *Glu-D1* locus (Flour Protein Analysis, 2015 Hard Winter Wheat Quality Council). Loma does not carry the T1BL·1RS or T1AL·1RS translocation (marker analysis, 2016 NRPN).

Seed Purification and Increase

Purification and increase of Loma was initiated in 2014 when 120 F_{10}–derived F_{11} head rows were grown with selection for visual uniformity, retaining 83 line rows. Individual line rows were bulked as breeder seed and increased at Bozeman in 2015. Foundation seed of Loma was produced in 2016. Loma has been genetically uniform and stable over three generations of seed increase containing tall (<10/10,000), awnless (<5/10,000), and dark chaff (<20/10,000) plant variants.

Table 3. Average milling and baking quality attributes of Loma and check wheat cultivars in 19 Montana environments in 2012–2015.

Cultivar	Polyphenol oxidase	SKCS hardness†	Flour yield	Flour protein	Flour ash	Baking mix time	Baking absorption	Loaf volume
	Δ475			g kg^{-1}		min	g kg−1	L
Loma	0.173	81	708	119	4.1	16.6	752	1.149
Bearpaw	0.255	82	696	122	4.2	7.4	719	1.038
Decade	0.276	75	685	123	4.1	20.9	764	1.096
Judee	0.264	80	685	125	4.1	10.1	729	1.180
Warhorse	0.261	91	685	124	4.3	8.1	735	1.091
Yellowstone	0.213	81	693	118	4.2	15.6	747	1.089
LSD (0.05)	0.026	2	6	4	0.1	2.2	11	0.031

† Single Kernel Characterization System.

Availability

The Montana Agricultural Experiment Station will maintain breeder seed of Loma. US Plant Variety Protection for Loma has been filed. 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 National Plant Germplasm System, where it will be available immediately after the expiration of the Plant Variety Protection for research purposes, including development and commercialization of new cultivars. It is requested that appropriate recognition be made if this germplasm contributes to the development of new germplasm or cultivars.

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