

Registration of 'Muir' Spring Feed Barley

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Abstract

'Muir' (Reg. No. CV-357, PI 674172) is a two-row, spring, hulled feed barley (*Hordeum vulgare* L.) cultivar developed and evaluated as 07WA-601.6, and released in 2013 by Washington State University (WSU). Muir was derived from the cross 'Baronesse'/'Bob' and selected through single-seed descent from F₂ to F₄ and pedigree breeding methods from F₅ to F₆. Muir was tested in multi-environment trials at 8 to 10 locations per year by the WSU Variety Testing Program from 2011 to 2014. In the low rainfall (<400 mm annual precipitation) testing locations, Muir had a mean grain yield (4787.0 kg ha⁻¹) that was higher than those of check cultivars Baronesse, Bob, and Lyon. Muir showed head emergence significantly earlier than Baronesse, Bob, and 'Lenetah' and was 3.3 cm taller than Baronesse and 5.5 cm shorter than 'Champion' across low rainfall zone locations. Muir is resistant to currently prevalent races of the stripe rust pathogen (*Puccinia striiformis* Westend. f. sp. *hordei* Erikss.); by comparison, commonly grown cultivars Baronesse, Bob, and Champion are rated as moderately resistant, 'Harrington', Lenetah, and Lyon are rated as moderately susceptible, and 'CDC Copeland' and 'CDC Meredith' are rated as susceptible. Muir was released on the basis of its excellent stripe rust resistance, high grain yield, and agronomic qualities suitable for a feed barley cultivar in low rainfall zones of Washington.

'MUIR' (Reg No. CV-257, PI 674172) is a two-row, spring, hulled feed barley (*Hordeum vulgare* L.) cultivar released in 2013 by Washington State University (WSU). The feed barley market class comprises approximately 90% of the spring barley acreage statewide. Specifically targeted to drought-stressed dryland grain production systems of eastern Washington, Muir is a high-yielding, stripe rust (caused by *Puccinia striiformis* Westend. f. sp. *hordei* Erikss.) resistant cultivar in regions with 250 to 400 mm annual precipitation. Muir was evaluated using the experimental designation 07WA-601.6 across Washington in the WSU Variety Testing State Uniform Nursery. Muir was released on the basis of its excellent stripe rust resistance, high yield in low rainfall zones, and agronomic qualities suitable for a feed barley cultivar.

Muir is a derivation from the cross of 'Baronesse'/'Bob'. The parentage of Baronesse (PI 568246) is 'Mentor'/'Minerva'/'Vada' mutant/4/'Carlsberg'/'Union'/'Opavsky'/'Salle'/3/'Ricard o'/5/'Oriol'/6153P40. Baronesse is a two-row, rough-awned feed-type spring barley cultivar developed in Germany by the Nordsdatt Company in 1988 and marketed by the US Westbred, LLC since 1992. Baronesse has been widely grown in dryland cropping systems of Washington due to its stable yields, high test weight, and above-average straw strength. The ancestry of Bob (PI 629288) is A308/Baronesse. A308 is a reduced-height somaclonal variant of 'Lewis', a two-row feed barley released in 1985 by the USDA-ARS and Montana Agricultural Research Station (Hockett et al., 1985). Bob is a two-row spring feed barley developed by the Barley Improvement Program at WSU Agricultural Research Center and released in 2002 (Ullrich et al., 2003). Muir shows the potential to equal or exceed the yields of all currently grown varieties in the lower rainfall regions of Washington State and would be an important contribution to Washington barley production. Muir is named in honor of Carl Muir, former graduate student of WSU wheat breeder Orville Vogel, long-time barley researcher, and codeveloper of 'Stepteo' barley (Muir and Nilan, 1973). Muir will be released

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Abbreviations: IT, infection type; WSU, Washington State University.

as a nonexclusive, public barley variety intended specifically for the feed market class.

Methods

Parentage, Breeding History, and Line Selection

Muir was developed using single-seed descent in a greenhouse facility followed by pedigree line development in nonirrigated headrows and plots at WSU's Spillman Agronomy Farm in Pullman, WA. Muir spring barley was derived from the cross between Baronesse and Bob (designated X04069) that occurred in July 2004. F₁ seed was grown in square pots (0.15 by 0.15 m) in the greenhouses at WSU at daytime temperatures of 22°C and nighttime temperatures of 16°C. F₁ heads were harvested and planted in 72 cell flats. Subsequent F_{2,3} and F_{3,4} seed was produced under the same conditions. F₂ seed was harvested and planted in 72 cell flats. The resulting F₃ heads were individually harvested, and one seed per head from 300 heads was randomly selected and planted in cones as F₃ seed. F₄ heads were then selected from the segregating population on the basis of short straw length, early maturity, and desirable head type and size. These heads were individually threshed and planted as separate 1.5-m headrows at Spillman Farm in Pullman, from which the final headrow selection was made in 2007 and designated 07WA601.6, before single plot planting in 2008.

Evaluation in Replicated Yield Trials

A total of 27 rows were selected and harvested from the initial Baronesse/Bob cross and were planted in single 1.4-m by 6-m plots with 18-cm row spacing at a seeding rate of 108 kg ha⁻¹ (dimensions and seeding density remained the same for all subsequent testing) in a nonreplicated field trial with repeating check cultivars. Muir (07WA-601.6) was selected for further analysis in replicated advanced field trials at Spillman Agronomy Farm in 2009 and 2010 based on high grain yield, stripe rust resistance, and favorable agronomic characteristics.

Muir was evaluated in the WSU Variety Testing Program at 8 to 10 locations from 2011 to 2014. Each location represented one of the three major precipitation zones found in eastern Washington, including low, intermediate, and high rainfall zone designations (annual precipitation <400, 400–500, and >500 mm, respectively).

Yield evaluations were based on grain harvested from 7.4-m² plots. The percentage of plump kernels was evaluated by

calculating the percentage by weight of the kernels that did not pass through a 0.24-cm by 1.9-cm sieve. All statistical analyses were performed using Agrobases Generation II SQL version 36.5.1 (Agronomix Software, 2004). Analysis of variance for yield, test weight, plump kernels, heading date, plant height, and protein was performed across locations within years. Genotypes and locations were treated as fixed effects. Mean comparisons of traits using a protected LSD ($P < 0.05$) test were made to identify significant differences among genotypes.

Seed Purification and Increase

In 2013, a 1.5-m by 18-m increase strip was sown at the Spillman Agronomy Farm in Pullman for examination of segregating types. Approximately 2000 single heads were randomly selected from the F₈ strip, individually threshed, and planted as headrows by the Washington State Crop Improvement Association. Rows that appeared uniform and clean were subsequently harvested and bulked, creating F₉ breeder seed.

Characteristics

Agronomic Performance and Yield

Comparisons of Muir to other barley cultivars currently grown in the Pacific Northwest region are reported. These include 'Lyon' (Murphy et al., 2015; WSU), 'Champion' (WestBred), 'Lenetah' (Obert et al., 2008; University of Idaho), Baronesse (WestBred), 'Harrington' (Harvey and Rosnagel, 1984; University of Saskatchewan), and Bob (Ullrich et al., 2003; WSU). With the exception of the new WSU high rainfall zone cultivar Lyon, these cultivars are widely grown and adapted in Washington and represent the majority of hectares planted.

Grain yield, plant height, and heading date were evaluated from 2011 to 2014 in the Washington State Variety Testing Yield Trials in approximately 10 locations per year. Of these, two locations, Almira and Lamont, are considered low-rainfall zones in eastern Washington, with a mean annual precipitation of <400 mm. From 2011 to 2014, across six location-years in the low rainfall zone, Muir had significantly higher yields than Lyon, Bob, and Baronesse and similar grain yield to Lenetah and Champion (Table 1). Muir was taller than Lyon and Baronesse, shorter than Champion, and equal to Bob and Lenetah (Table 1). Muir had similar days to heading as Lyon and Champion and was slightly earlier than Baronesse, Bob, and Lenetah (Table 1).

Table 1. Agronomic performance of Muir and check cultivars in Washington State Variety Testing Yield Trials, from 2011 to 2014, in low rainfall (<400 mm) locations (Almira and Lamont) of Washington (six location-years).

Cultivar	Grain yield	Test weight	Plant height	Protein	Heading date†
	kg ha ⁻¹	kg m ⁻³	cm	%	d from planting
Muir	4787.0	648.1	80.1	13.5	63.9
Baronesse	4317.2	643.8	76.8	13.6	64.4
Bob	4326.9	663.8	82.2	13.7	64.4
Champion	4660.0	679.3	85.6	12.5	63.8
Lenetah	4720.0	665.3	81.8	13.0	65.7
Lyon	4527.1	646.5	77.6	13.2	63.6
CV (%)	9.9	2.3	6.7	9.7	0.9
LSD (0.05)	243.0	9.8	3.3	0.9	0.4

† Three location-years data.

The low rainfall, dryland cropping region of Washington is the primary target area for Muir.

Five locations, Dayton, Mayview, Reardan, St. John, and Walla Walla, represent the intermediate rainfall (400–500 mm) zone. Although the intermediate rainfall zone is not its intended target region, Muir had higher grain yield than Bob, similar grain yield to Baronesse and Lyon, and slightly lower grain yield than Champion and Lenetah when tested in WSU Barley Variety Trial Nursery from 2011 to 2014 (Table 2). Muir was taller than Lyon, similar in height to Baronesse, Bob, and Lenetah, and shorter than Champion (Table 2). Muir had similar days to heading as Bob, was earlier than Baronesse and Lenetah, and was slightly later than Lyon and Champion (Table 2).

Although Muir typically exhibits lower yields in the high rainfall zone of eastern Washington, the Pullman location is often an exception. When tested from 2011 to 2014 in the

Washington State Variety Testing Yield Trials in Pullman, Muir had higher grain yield than ‘CDC Copeland’, Harrington, and ‘Merese’ and similar grain yield to Baronesse, Bob, Champion, and Lyon (Table 3).

Across three location-years on certified organic farm ground at the WSU Mount Vernon Research Center, a high rainfall location in western Washington (average annual precipitation >800 mm), Muir ranked higher than Baronesse, Bob, Champion, and Lyon, with significantly higher yields than Lenetah (Table 4). When grown on certified organic farm ground in Pullman in 2012, Muir was the highest-ranked variety in the trial, with significantly higher grain yield than Baronesse, Bob, and Champion (Table 4).

Table 2. Agronomic performance of Muir and check cultivars in Washington Variety Testing Yield Trials, from 2011 to 2014, in intermediate rainfall (400–500 mm) locations (Dayton, Mayview, Reardan, St. John, and Walla Walla) of Washington (17 location-years).

Cultivar	Grain yield	Test weight	Plant height†	Protein	Heading date‡
	kg ha ⁻¹	kg m ⁻³	cm	%	d from planting
Muir	4941.6	677.7	76.0	12.4	71.9
Baronesse	4962.5	680.0	75.2	12.2	73.1
Bob	4636.3	689.3	76.8	12.7	71.6
Champion	5176.5	698.5	79.0	11.8	71.3
Lenetah	5219.3	690.8	76.3	11.8	73.6
Lyon	5086.9	677.8	72.2	12.4	71.3
CV (%)	9.4	1.4	5.7	5.0	1.4
LSD (0.05)	163.7	3.7	1.6	0.3	0.4

† 15 location-years data.

‡ 14 location-years data.

Table 3. Agronomic performance of Muir and check cultivars in Washington Variety Testing Yield Trials, from 2011 to 2014, in Pullman, WA (location years: *n* = 4 for yield, test weight, protein, and percentage plump kernels; *n* = 3 for plant height).

Cultivar	Grain yield	Test weight	Plant height	Protein	Plump kernels
	kg ha ⁻¹	kg m ⁻³	cm	%	%
Muir	5237	679.0	97.9	10.0	86.9
Baronesse	5098	665.6	106.6	10.2	82.7
Bob	5168	690.2	na	10.2	90.7
CDC Copeland	4759	646.4	na	10.5	86.4
Champion	5334	696.8	100.1	10.1	85.8
Harrington	4513	655.9	97.8	11.0	85.3
Merese	4007	725.4	93.1	12.3	62.0
Lyon	5141	678.8	na	9.9	84.8
CV (%)	12.2	2.7	15.5	7.95	12.0
LSD (0.05)	481	15.0	11.3	0.67	8.0

Table 4. Agronomic performance of Muir and check cultivars on certified organic farm ground, from 2012 to 2014, in Mount Vernon (MV) and in Pullman (PUW) in 2012.

Cultivar	Grain yield		Test weight		Plant height	Protein	Heading date
	MV	PUW	MV	PUW	MV	MV	MV
	kg ha ⁻¹		kg m ⁻³		cm	%	Julian
Muir	5809	4050	643	661	84	9.9	166
Baronesse	5443	2909	641	677	79	10.2	167
Bob	5268	3753	646	654	86	10.2	166
Champion	5117	3142	650	681	84	10.0	164
Lenetah	4866	4183	636	694	84	11.0	164
Lyon	5467	na	625	na	80	10.7	164
LSD (0.05)	822	246	35.6	14.2	5.5	1.86	8.8

Test Weight, Plump Kernels, and Protein Content

When tested from 2011 to 2014 in low and intermediate rainfall environments across 23 location-years, Muir had test weights similar to Baronesse and Lyon and lower than Champion, Bob, and Lenetah (Tables 1 and 2). When tested across 4 yr in the high rainfall zone of Pullman, Muir had higher test weight than CDC Copeland, similar test weight to Baronesse, Bob, Harrington, and Lyon, and lower test weight than Champion and Meresse (Table 3). Meresse is a hulless food barley with typically high test weights, low percentage plump kernels, and elevated β -glucan content (Rey et al., 2009). Muir had similar protein content to Lyon, Bob, Baronesse, and Lenetah and higher protein content than Champion across six location-years in low rainfall environments (Table 1). Across 17 location-years in the intermediate rainfall zone, Muir had higher protein content than Champion and Lenetah and similar protein content to Baronesse, Bob and Lyon (Table 2). Across four location-years in Pullman, Muir had higher percentage plump kernels than Meresse and similar percentage plump kernels to Baronesse, Bob, Champion, CDC Copeland, Harrington, and Lyon (Table 3).

Disease Evaluations

Muir was evaluated for resistance to barley stripe rust in fields under natural infection in various nurseries from 2011 to 2014. In 2011, Muir was tested in the WSU Barley Variety Trial Nursery and the National Stripe Rust Nursery at Pullman (Spillman and Whitlow Farms) and Mount Vernon. Other named cultivars tested included 'Bentley' (Juskiw et al., 2009), 'Morex' (Rasmusson and Wilcoxson, 1979), and 'Radiant' (von Wettstein et al., 2004). Stripe rust was generally low and not uniform at the testing locations. At Spillman Farm in Pullman, Muir had an infection type (IT) of 2 and a severity rating of 1%, similar to Bob and lower than Baronesse, Bentley, Champion, Lyon, Meresse, and Radiant (Table 5). In Whitlow Farm, Muir had an IT of 2 and a severity of 2%, similar to Bob and Baronesse and lower than Bentley, Champion, Lyon, Meresse, and Radiant (Table 5). In Mount Vernon, Muir was rated with an IT of 0 and 0.0% severity at both stem elongation and grain milk stages. This was similar to Bob, Lyon, and Baronesse and lower than Champion, which had an IT of 8 and 20% severity at both the stem elongation and the milk stages (Table 6).

In 2012, Muir was tested in the WSU Barley Variety Trial Nursery and the National Stripe Rust Nursery at Pullman and Mount Vernon. Stripe rust was low and not uniform in all

Table 5. Stripe rust (*Puccinia striiformis* f. sp. *hordei*) evaluations, including infection type (IT) and percentage infection, from 2011 to 2014 at two locations in Pullman, WA: Spillman Farm and Whitlow Farm. Dates of evaluation are presented at various barley growth stages. Field summary and overall ranking are shown for five locations (Spillman Farm, Plant Pathology Farm, and Whitlow Farm near Pullman and Washington State University Mount Vernon Research Center ($n = 2$) in Washington in 2014.

Cultivar	Spillman Farm								Whitlow Farm						Five locations	
	25 July 2011		10 July 2012		12 July 2013†		7 July 2014		19 July 2011		10 July 2012		9 July 2014		2014	
	Soft dough		Flowering		Milk		Milk		Flowering		Flowering		Milk		Field summary	Overall rating
	IT	%	IT	%	IT	%	IT	%	IT	%	IT	%	IT	%		
Muir	2	1	0	0	0	0	2	1	2	2	0	0	2	1	R	1
Baronesse	8	5	0	0	0	0	8	5	2	5	0	0	8	2	MR	4
Bob	2	1	0	0	0	0	8	2	2	1	0	0	2	1	MR	3
Champion	8	15	0	0	0	0	8	5	8	20	0	0	8	5	MR	4
Lyon	8	30	8	5	0	0	8	10	3	40	0	0	8	1	MS	6
Meresse	8	5	0	0	0	0	8	10	8	10	0	0	8	5	MS	6
Morex	na	na	8	30	8	2	8	20	na	na	8	1	8	40	S	9

† Barley stripe rust was low and not uniform in 2013. Entries with IT 8 should be considered susceptible no matter the severity, whereas entries with IT 0 should not necessarily be considered resistant.

Table 6. Stripe rust (*Puccinia striiformis* f. sp. *hordei*) evaluations, including infection type (IT) and severity (%), from 2011, 2012, and 2014 at the Washington State University Mount Vernon Research Center. Leaf rust (*P. hordei*) evaluations are presented for 2013. Dates of evaluation are presented with the growth stage of the barley plant (seedling, stem elongation, milk, and soft dough).

Cultivar	27 June 2011		15 July 2011		20 June 2012		19 July 2012		9 July 2013†	4 June 2014	
	Stem elongation		Milk		Stem elongation		Milk		Soft dough	Seedling	
	IT	%	IT	%	IT	%	IT	%	%	IT	%
Baronesse	0	0	0	0	5	10	0	0	20	2	2
Bentley	8	5	3	2	8	20	8	5	na	na	na
Bob	0	0	0	0	0	0	0	0	90	2	5
Champion	8	20	8	20	0	0	0	0	80	2	2
Lyon	0	0	0	0	5	20	0	0	20	2	5
Muir	0	0	0	0	0	0	0	0	10	2	2
Meresse‡	0	0	0	0	5	20	0	0	80	2	5
Morex	na	na	na	na	5	30	8	5	80	8	10
Radiant	0	0	0	0	0	0	8	10	na	na	na

† Barley leaf rust caused by *Puccinia hordei* was very severe at Mount Vernon in 2013; therefore, no reliable stripe rust data were available.

‡ Hulless type.

locations. In Pullman, Muir had an IT of 0 and 0.0% severity, similar to Bob but lower than that of Morex and Lyon (Table 5). During stem elongation stage in Mount Vernon, Muir had an IT of 0 and 0.0% severity, similar to Bob, Champion, and Radiant and lower than Bentley, Baronesse, Meresse, Morex, and Lyon. During the milk stage at Mount Vernon, Muir had an IT of 0 and severity of 0.0%, which was lower than Bentley, Morex, and Radiant and similar to Baronesse, Lyon, Bob, and Champion (Table 6).

In 2013, very little rust was present at the two Pullman WSU Barley Variety Trial Nurseries, Spillman Farm or Whitlow Farm (Table 5). In Mount Vernon, severe leaf rust (caused by *P. hordei* G.H. Otth) masked any symptoms of stripe rust. Champion, Bob, Meresse, and Morex were susceptible to leaf rust, with severity of 80 to 90%. Lyon and Baronesse had 20% severity of leaf rust, and Muir showed the most resistance to leaf rust, with 10% severity (Table 6).

In 2014, a field summary and an overall rating for stripe rust were recorded for all barley cultivars in the WSU Barley Variety Trial Nursery across five locations (Table 5). Among the 43 breeding lines and cultivars, Muir was the only barley cultivar categorized as resistant (R), with an overall rating of 1 (1 = resistant; 9 = susceptible). Champion, Baronesse, and Bob were categorized as moderately resistant (MR), with overall ratings of 4, 4, and 3, respectively. Harrington, Lenetah and Lyon were categorized as moderately susceptible (MS), with overall ratings of 6. CDC Copeland, 'CDC Meredith', Morex, Tradition, LCS Vespa, and LCS Genie were categorized as susceptible (S), with overall ratings of 9, 8, 9, 9, 8, and 8, respectively (Table 5).

In 2014, Muir was evaluated for resistance to powdery mildew (*Blumeria graminis* f. sp. *hordei*) and leaf rust in conventionally managed and certified organic trials in Mount Vernon as part of a western Washington variety trial (Table 7). Muir was found to be susceptible to powdery mildew, similar to other common feed barley varieties. In both trials, Muir had significantly higher powdery mildew severity ratings than Harrington, which was known to be resistant to powdery mildew at the time it was released (Harvey and Rossnagel, 1984). In the conventional trial, Muir had significantly lower leaf rust severity ratings than Champion, Lyon, and Harrington. In the organic trial, Muir had significantly lower leaf rust severity ratings than Champion and Harrington. In both trials, Muir had significantly higher leaf

rust severity ratings than 'Full Pint', initially released by Oregon State University as the stripe and leaf rust resistant germplasm BCD47 (Verhoeven et al., 2011). Together, these data indicate that Muir is susceptible to currently prevalent races of powdery mildew and moderately resistant to prevalent races of leaf rust in western Washington.

Availability

Foundation seed is available from the Washington State Crop Improvement Association. Small quantities may be obtained from the corresponding author for up to five years. Due to minor variations in glume color, Muir will not be considered for PVP status. Muir has been deposited in the National Plant Germplasm System and will be available for distribution after five years from the date of this publication.

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Table 7. Percentage infection of powdery mildew (*Blumeria graminis* f. sp. *hordei*) and leaf rust (*Puccinia hordei*) evaluations from conventional and organic trials conducted in 2014 at Washington State University Mount Vernon Research Center.

Cultivar	Conventional		Organic	
	Powdery mildew	Leaf rust	Powdery mildew	Leaf rust
%				
Baronesse	28	28	13	47
Bob	33	13	20	43
Champion	27	35	13	90
Full Pint (BCD47)	43	0	40	10
Harrington	2	77	3	97
Lyon	43	58	18	63
Muir	35	12	18	50
LSD (0.05)	13	19	6	18