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Registration of 'Alba' barley

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ABSTRACT

'Alba' (Reg. No. _____) is a winter, six-row barley released by the Oregon Agricultural Experiment Station in 2012. The name “Alba” was chosen due to the bright and attractive appearance of the crop at maturity. In high rainfall environments, it has a notable yield advantage over check varieties and maintains excellent test weight and kernel plumpness. These advantages are, in part, attributable to resistance to barley stripe rust (incited by *Puccinia striiformis* f. sp. *hordei*) and scald (incited by *Rhynchosporium commune*). The principal end-use of Alba grain is as feed, but it could also be used for food (after pearling) and preliminary tests show that it can be successfully malted and used in craft brewing.

'Alba' (Reg. No. _____) is a winter, six-row barley released by the Oregon Agricultural Experiment Station in 2012. The name “Alba” was chosen due to the bright and attractive appearance of the crop at maturity. “Alba” is derived from the Latin word for “white,” and means “dawn” in Spanish. Prior to being named, Alba was tested under the experimental designations ‘OR77’ and ‘TCFW6-002.’ In high rainfall environments, it has a notable yield advantage over some varieties, and it maintains excellent test weight and kernel size. These advantages are, in part, attributable to resistance to barley stripe rust (incited by *Puccinia striiformis* f. sp. *hordei*) and scald (incited by *Rhynchosporium commune*). The principal end-use of Alba grain is as feed, but it could also be used for food (after pearling), and preliminary tests show that Alba can be successfully malted and used in craft brewing.

Alba was derived from a cross made in 1997 between ‘Strider’ (released by the Oregon Agricultural Experiment Station in 1997), and ‘Orca’ (Hayes et al., 2000). Strider is a six-row, compact spike, winter growth habit, feed variety with low temperature tolerance comparable or superior to other commercially available varieties. Strider requires vernalization and long days to transition from the vegetative to the reproductive state. Strider has exceptionally poor malting quality, with almost no detectable enzyme activity in malt (Filichkin et al., 2010). Strider is resistant to stripe rust and moderately resistant to scald, and can show severe symptoms of Barley Yellow Dwarf Virus (BYDV). Orca is a two-row, erect spike, spring growth habit feed cultivar. Orca does not require vernalization to transition from the vegetative to the reproductive state (Hayes et al., 2000). Orca is resistant to stripe rust with mapped adult plant resistance QTL on chromosomes 4H and 5H, moderate resistance to scald, and it has the *Ryd2* gene for resistance to BYDV (Hayes et al., 2000).

Methods

Generation Development and Line Selection

The cross between Strider and Orca was made in 1997. From the F1 generation until head-row purification, all generations were fall-planted under field conditions at the Oregon State University Hyslop Farm, near Corvallis, OR USA. The F2 was planted as a bulk population of approximately 2000 plants. Selected F2 heads were threshed and bulked and grown as an F3 population. Selected F3 heads were grown as F4 head rows. Selected F4 head rows were harvested in bulk and advanced to a preliminary yield trial. Selections moved through subsequent cycles of replicated, multi-environment yield testing in Oregon and in the fall of 2004 one of the selected Strider/Orca sibling lines (F7) was designated as OR77 and tested regionally in replicated yield trials.

Seed Purification and Increase

Five hundred F10 heads were selected from OR77 plots and planted for head row purification and increase in the fall of 2007. Seed from one head from one row (F11) was used for Single Nucleotide Polymorphism (SNP) genotyping under the auspices of the USDA-NIFA Triticeae Coordinated Agricultural Project (http://www.triticeaecap.org/), and these data are available at the T3 database (http://triticeaetoolbox.org/barley/). In the T3 database Alba is designated as TCFW6-002. One thousand F11 heads were harvested from selected rows, threshed individually and transferred to the Washington Crop Improvement Association for production of F12 Breeder’s seed.

Statistical Analyses

All statistical analyses were conducted using R version 3.0.1 (R Core Team, 2014). Alba was compared with 'Maja', Strider, 'Eight-Twelve' (Wesenberg et al., 1992), and 'Charles' (Obert et al., 2006) for agronomic traits in 33 environments over the years 2008-2012, although not all traits were measured in all years. At each location, plot sizes, nutrient management, weed control, and irrigation (if applied) were in accordance with local practice. Varieties were replicated either three or four times at each location, also in accordance with local practice. The mean values from each environment were used in this analysis. The same five varieties were tested for disease resistance in Corvallis, Oregon over the course of five years. For scald, plants were rated using a 1 (resistant) to 9 (susceptible) disease reaction score. For stripe rust, the percentage of leaf area (on a plot basis) that was covered by lesions at anthesis was estimated visually. In 2013 Alba, Maja, and 'Full Pint,' were evaluated for leaf rust resistance at the Northwestern Washington Research and Extension Center, Washington State University, Mount Vernon, WA (WSU Mount Vernon). Leaf rust was rated based on visual estimation of the percentage of leaf area (on a plot basis) that was covered by lesions at anthesis. Alba, Maja, and Strider were tested for low temperature tolerance in controlled freeze tests at the Martonvasar Research Institute (MRI; Hungary) in 2006 and 2008, as described by Skinner et al. (2006). Eight-Twelve and Charles were tested for low temperature tolerance in controlled freeze tests for one year each at the MRI, in 2006 and 2008 respectively. Winter survival was recorded in eight field trials where differential survival occurred. The malt quality of composite samples from Alba, Maja, and Charles was compared in 10 environments over the years 2009-2011, using the methods described by Budde et al. (2008). For the purposes of this report, two trials grown at the same location but in different years, or under substantially different growing conditions, are

considered as different environments. The mean of measurements collected from each environment for each cultivar were used for mean separation based on LSD (p = 0.05) except for the leaf rust data, where there was a single replicated experiment.

Characteristics

Botanical Description

Phenotypic selection for agronomic type and performance in the progeny of this wide cross (winter/spring and two-row/six-row define the principal germplasm groups of barley) resulted in a six-row barley with a lax spike. Alba has winter growth habit: it requires vernalization. Alba has grain with adhering hulls, a white aleurone, short rachilla hairs, and rough awns.

Agronomic Performance

Across all 33 environments, Alba demonstrated a significantly higher yield than Charles. Grain from Alba had significantly higher test weight than all varieties except Maja, and higher plumpness than Maja and Eight-Twelve. Alba was significantly taller than Charles. There were no statistically significant differences in heading date or lodging between varieties (Table 1).

In high-rainfall environments (Brownsville, Corvallis, and Junction City, OR), where the average rainfall is greater than 800 mm $year^{-1}$ (Western Regional Climate Center), Alba had a significantly higher yield than Eight-Twelve and Charles and a similar yield to Maja and Strider. Alba had a significantly higher test weight than Eight-Twelve, but a similar test weight to other varieties. Alba had significantly higher kernel plumpness than Maja, Strider, and Eight-Twelve (all six-rows), but was not significantly different from Charles (a two-row). Alba was

significantly taller than all varieties in this trial except for Eight-Twelve, and later maturing than all varieties in this subset of environments. In the limited number of trials where lodging was observed, no significant difference in lodging was detected between these varieties. Variable within-trial lodging at the limited number of sites where lodging occurred precludes a robust statistical comparison of means (Table 2).

Pendleton, OR and Pullman, WA are classified as dryland locations because no irrigation is applied and the long-term rainfall averages are 420 mm $year^{-1}$ and 540 mm $year^{-1}$ (Western Regional Climate Center). These environments are typical of optimum dryland environments in the Pacific Northwest of the US and results cannot be extended to truly dry areas (e.g. the summer–fallow zones). At the irrigated locations (Hermiston, OR; Aberdeen, Burley, Filer and Kimberly, ID; and Fort Collins, CO) supplemental irrigation is routinely applied in accordance with local practice since average annual rainfall is below 400 mm. Under dryland (Table 3) and irrigated (Table 4) environments, there were no significant differences between varieties for yield. The test weight advantage of Alba over the other varieties was not as apparent under dryland or irrigated conditions as it was under high rainfall. Under dryland and irrigated conditions, there were no significant differences in terms of kernel plumpness. Alba was significantly taller than Charles in irrigated environments. No statistically significant differences in heading date were detected among these varieties in either dryland or irrigated environments. Lodging percentages for the varieties were variable and non-significant, in part reflecting the variability of this trait within environments.

In eight field environments, the winter survival of Alba was not statistically different from that of the other four varieties. Differential winter survival data are very difficult to obtain. The Corvallis location rarely experiences sufficiently low temperatures to cause winter injury in

varieties with some level of cold tolerance. The high survival values in field trials that experienced differential winter survival over four years of testing indicate that Alba has a level of winter survival at least comparable to that of other commercially available winter barley varieties (Table 5). In addition to field data, we present the results from two controlled freeze tests (Table 6). While controlled freeze test data can only approximate field conditions, they do can provide a meaningful ranking of cultivar performance.

Disease Resistance

Alba was significantly more resistant to scald than Maja, Eight-Twelve, and Charles, but not Strider, in five years of testing under intense natural epidemic conditions at Corvallis, OR (Table 7). Alba was significantly more resistant to stripe rust than Eight-Twelve in these same trials. Alba, Maja, and Strider were all developed at Oregon State University and selected for maximum levels of adult plant resistance to stripe rust. Alba is susceptible to leaf rust (incited by *Puccinia hordei)* (Table 8).

Malt Quality

Alba was included in malting quality tests in 10 environments (Table 9). Eight-Twelve and Strider were not included in the malting quality analyses because they had previously been determined to have poor quality. Charles is currently the American Malting Barley (AMBA) winter barley check for malting quality. At the time these tests were conducted, Maja was a six-row facultative growth habit candidate cultivar for AMBA approval. Alba was included in the ten malt analyses because it is a parent of germplasm involved in genetic studies of malting quality.

Key malting parameters are grain protein, malt extract, the ratio of soluble/total protein,

enzyme activity (as measured by alpha amylase and diastatic power) and wort beta glucan. There were no significant differences in grain protein. Alba was significantly lower than Charles for malt extract and soluble/total protein. The diastatic power of Alba was significantly lower than that of both Maja and Charles and the level of alpha-amylase was significantly lower than that of Charles. The wort beta glucan of Alba was significantly higher than that of either Maja or Charles. Therefore, Alba does not meet current standards for malting barley as established by AMBA (AMBA, 2010). However, lower soluble protein and enzyme levels have also been noted by AMBA as a priority for the Craft Brewing industry. Preliminary results from tests involving changes to malting and brewing protocols indicate that Alba grain, produced under high rainfall conditions can produce excellent malt and beer (M. Doehnel and W. Carpenter, Skagit Malting and Brewing, personal communication). In high rainfall environments, the significantly higher yield of Alba may warrant the additional effort required to produce malt and beer from the grain of this variety.

Feed, Forage and Food Quality

The limited data that are available for Alba feed, forage, and food quality can be found at "http://barleyworld.org/breeding-genetics/data".

Availability

Breeder seed is maintained by the Barley Project at Oregon State University, Corvallis, OR 97331. Seed for research purposes will be available on request from the corresponding author for at least 5 years. It is requested that appropriate recognition of source be given when this cultivar contributes to development of new germplasm or cultivars. Alba is a public release

without Plant Variety Protection (PVP) and no licensing restrictions.

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Tables

Cultivar	Yield	Test Weight	Plump	Plant Height	Heading Date	Lodging
	kg ha^{-1}	g L^{-1}	%	cm	Julian Days	%
Alba	7412.2	669	90.3	102.8	149.3	16.4
Maja	6858.9	663	75.6	96.4	145.2	16.2
Strider	7522.7	644	82.4	96.3	146.1	21.0
Eight-Twelve	6804.7	630	74.1	95.3	146.0	21.0
Charles	6262.6	639	92.0	85.4	144.9	26.2
# of trials	33	28	28	28	23	20
LSD (p=0.05)	871.7	21	10.1	7.8	7.0	18.4

Table 1. Agronomic performance of Alba and check cultivars across 33 environments (7 high rainfall, 7 dryland, and 19 irrigated).[t]

[t]Brownsville, Corvallis, Hermiston, Junction City and Pendleton, OR; Pullman, WA; Aberdeen, Burley, Filer and Kimberly, ID; and Fort Collins, CO.

Cultivar	Yield	Test Weight	Plump	Plant Height	Heading Date	Lodging
	kg ha^{-1}	g L^{-1}	%	cm	Julian Days	%
Alba	6846	666	90.6	121.7	137.8	28.0
Maja	5961	640	56.1	106.3	125.6	50.0
Strider	6435	610	67.1	106.1	129.6	48.0
Eight-Twelve	4156	562	42.7	110.0	127.6	50.0
Charles	5008	603	86.6	89.6	120.2	63.0
# of trials	7	7	7	7	5	2
LSD (p=0.05)	1566	57	22.9	12.8	4.1	150.6

Table 2. Agronomic performance of Alba and check cultivars across 7 high rainfall environments.[t]

[t]Brownsville, Corvallis and Junction City, OR.

Cultivar	Yield	Test Weight	Plump	Plant Height	Heading Date	Lodging
	kg ha^{-1}	g L^{-1}	%	cm	Julian Days	%
Alba	6806	673	84.7	101.6	152.3	21.5
Maja	6290	679	76.0	94.3	149.3	19.8
Strider	7084	662	81.3	100.5	150.7	19.5
Eight-Twelve	6204	650	73.1	95.1	149.7	31.5
Charles	6245	645	91.7	87.1	150.0	27.2
# of trials	7	7	7	7	3	6
LSD (p=0.05)	1059	28	20.3	17.1	4.3	38.4

Table 3. Agronomic performance of Alba and check cultivars across 7 dryland environments.[t]

[t]Pendleton, OR and Pullman, WA.

Cultivar	Yield	Test Weight	Plump	Plant Height	Heading Date	Lodging
	kg ha^{-1}	g L^{-1}	%	cm	Julian Days	%
Alba	7844	666	92.9	93.9	152.6	11.8
Maja	7399	668	85.2	92.1	150.9	8.8
Strider	8085	652	90.5	88.8	150.7	17.3
Eight-Twelve	8002	653	90.3	88.1	151.5	10.8
Charles	6731	655	94.8	82.4	152.1	19.6
# of trials	19	14	14	14	15	12
LSD (p=0.05)	1163	20	8.5	8.9	5.7	17.8

Table 4. Agronomic performance of Alba and check cultivars across 19 irrigated environments.[t]

[t]Hermiston, OR; Aberdeen, Burley, Filer and Kimberly, ID; and Fort Collins, CO.

Cultivar	Winter Survival
	% survival
Alba	78.3 (12-96)
Maja	76.1 (33-100)
Strider	73.1 (16-100)
Eight-Twelve	72.5 (23-100)
Charles	60.9 (9-93)
# of trials	8
LSD (p=0.05)	29.43

Table 5. Winter survival at Aberdeen, ID; Pullman, WA; Hermiston and Pendleton, OR; St. Paul, MN; and Bozeman, MT over the years 2008-2011. Ranges are listed in parentheses. Data were only recorded in environments where differential survival was observed.

Cultivar	MRI '06	MRI '08
	% survival	% survival
Alba	85	87
Maja	78	75
Strider	58	98
Eight-Twelve	82	-
Charles	-	31

Table 6. Percent survival in controlled freeze tests at the Martonvasar Research Institute (Hungary), in 2006 and 2008. Charles and Eight-Twelve were not included in the 2006 and 2008 tests, respectively.

Cultivar	Scald	Stripe Rust
	1-9[t]	%
Alba	1.6 (1-3)	0.4 (0-2)
Maja	4.8 (1-7)	2 (0-7)
Strider	2 (1-4)	0 (0-0)
Eight-Twelve	5.4 (3-7)	59.6 (0-97)
Charles	7.4 (4-9)	17.6 (0-63)
# of trials	5	5
LSD (*p*=0.05)	2.3	31.2

Table 7. Disease ratings for scald (*Rhynchosporium commune*) and percent severity for barley stripe rust (*Puccinia striiformis* f. sp. *hordei*) at Corvallis, Oregon, 2008-2012. Ranges are listed in parentheses.

[t]1 = most resistant, 9 = most susceptible

Cultivar	Leaf Rust
	%
Alba	75 (75-75)
Maja	93 (90-95)
Full Pint (BCD47)	0.33(0-1)
# of replicates	
p-value	0.002

Table 8. Percent severity for barley leaf rust (*Puccinia hordei*) from a single replicated trial at WSU Mount Vernon, WA, 2013. Ranges are listed in parentheses.

Cultivar	Malt extract	Barley protein	Wort protein	Soluble/total protein	Diastatic power	α-amylase	β-glucan
	%	%	%	%	°ASBC	D.U.	mg L^{-1}
Alba	78.3 (72.7-81.7)	10.5 (8.3-13.8)	3.6 (3.1-4.2)	36.4 (26.8-48.8)	91.4 (67.0-126.7)	43.3 (34.6-70.6)	466.4 (111.0-720.3)
Maja	79.4 (77.0-81.7)	11.0 (8.7-14.8)	4.1 (3.6-4.7)	40.5 (33.4-47.8)	130.3 (109.0-164.6)	51.6 (38.3-67.9)	102.9 (43.1-179.6)
Charles	81.7 (79.3-83.6)	11.3 (9.8-13.2)	4.9 (4.6-5.5)	47.0 (38.3-57.7)	125.5 (92.8-159.9)	84.1 (73.0-97.0)	165.2 (51.5-310.1)
# of trials	10	10	10	10	10	10	10
LSD (*p*=0.05)	1.7	1.4	0.3	5.0	16.5	8.4	119.9

Table 9. Malting quality profile of Alba compared to other cultivars grown at Corvallis, Hermiston and Pendleton, OR; Aberdeen, ID; and Pullman, WA; over the years 2009-2011.