

Registration of 'Endeavor' Winter Barley

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ABSTRACT

'Endeavor' (Reg. No. CV-341, PI 654824), a two-rowed winter malting barley (*Hordeum vulgare* L.), was developed and submitted for release in 2007 by the USDA-ARS, Aberdeen, ID, in cooperation with the University of Idaho Agricultural Experiment Station. Endeavor is a selection from the cross ORWM8406/'Harrington'. ORWM8406 has the pedigree 'Carstens'/'Riso' mutant 1508 (F₁)/'Cossack'. Riso mutant 1508 is an ethyleneimine-induced mutant of 'Bomi'. Progenitors of ORWM8406 are all European barleys. Harrington is a two-rowed spring malting barley released by the Crop Development Centre, University of Saskatchewan, and is the current western two-rowed malting industry standard. Endeavor was released because of its higher diastatic power compared with 'Charles', the most-advanced two-rowed winter malting barley adapted to Idaho.

'Endeavor' (Reg. No. CV-341, PI 654824), a two-rowed winter malting barley (*Hordeum vulgare* L.), was tested under the experimental number 95Ab2299 and developed by the USDA-ARS, Aberdeen, ID, in cooperation with the University of Idaho Agricultural Experiment Station. Endeavor was publicly released in December 2007 because of its favorable malt profile and higher diastatic power compared with 'Charles' (Obert et al., 2006) winter barley. Endeavor also has superior yield compared with 88Ab536-B (Wesenberg et al., 1998), a six-rowed winter barley germplasm that is the progenitor of most elite six-rowed malt barley lines.

Endeavor is a selection from the cross ORWM8406/'Harrington' (Harvey and Rosnagel, 1984). ORWM8406 has the pedigree 'Carstens'/'Riso' mutant 1508 (F₁)/'Cossack'. Riso mutant 1508 is an ethyleneimine-induced mutant of 'Bomi'. Progenitors of OR8406 are all European barleys.

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Abbreviations: Kwt, 1000 kernel weight.

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Harrington is a two-rowed spring malting barley released by the Crop Development Centre, University of Saskatchewan, and is the current western two-row malting industry standard.

Methods

Early-Generation Population Development

Endeavor was developed using a pedigree selection procedure with all early-generation population and line development done under irrigation at Aberdeen, ID. The cross between the two parents was made in January 1990, and F₁ seed was planted in September 1990 as a single 3.1-m row. F₂ seed was harvested in bulk and 56 g of seed was planted in a 3.1-m by 1.4-m plot with 35-cm row spacing. One hundred random spikes were harvested, individually threshed, and planted as F_{2,3} rows in fall 1991. In 1992, five random spikes from 10 superior rows were harvested, individually threshed, and planted as F_{3,4} rows in fall 1992. Again, five random spikes from 10 superior rows were harvested, individually threshed, and planted as F_{4,5} rows in fall 1993. Selected rows were based on maturity, height, winter survival, and uniform spike type.

Line Selection and Evaluation

A total of 100 random spikes was selected from 10 superior rows in summer 1994, threshed individually, and planted as progeny rows 2 m in length for visual observation in 1995. Endeavor was selected from among F_{5,6} progeny rows on the basis of winter survival, resistance to lodging, suitable maturity, acceptable height and spike characteristics, and plump kernels. Because it was row number 2299, it was assigned the experimental designation 95Ab2299.

For all yield trials, the seeding rate was 105 kg ha⁻¹. All plots were 4.3 m by 1.3 m with row spacing of 17.8 cm. Endeavor entered nonreplicated yield trials in 1996 at Aberdeen and replicated yield trials at Aberdeen from 1997 to 2003. In 2004, it began evaluation in trials in Filer and

Parma, ID, Pendleton, OR, and Pullman, WA. In 2006, it began evaluation in Colby, KS.

Endeavor was evaluated in American Malting Barley Association–sponsored pilot-scale evaluations at Aberdeen, ID, and Pendleton, OR from 2003 to 2005. Quality evaluation plots of an area 15 m by 1.52 m were harvested in bulk, and a 7.7-kg sample was malted by industry partners following standard industry malting procedures specific for the company. Following favorable ratings in 2003 to 2005, it was advanced to plant-scale evaluation for further malting and brewing testing. Endeavor is currently entered in plant-scale evaluation at multiple locations in south-central Idaho.

Malting Quality Evaluation

A 400-g seed sample, consisting of a 1-kg composite sample from two replicates, was cleaned on a Carter Dockage tester, and only the seeds retained on a 1.98-mm screen were malted. Samples (170 g, dry matter basis) were steeped at 16°C for variable time intervals to bring them to 45% moisture by alternating 4 h of wet steep with 4 h of air rest. The steep time intervals were adjusted depending on the mean 1000 kernel weight (Kwt) of the samples according to the formula $Kwt (mg) - 8 = \text{steep hours}$. The steeped samples were weighed, water was removed or added to reach target weights, and the seeds were then placed into germination chambers for 5 d. Germination conditions were 17°C and near 100% humidity, with rotation of samples for 3 min every 30 min. Moisture levels were checked once during germination and adjustments were made if necessary to maintain 45% moisture content. The germinated grain (green malt) was weighed and then kilned for 24 h. The kilning protocol was 49°C for 10 h, 54°C for 4 h, 60°C for 3 h, 68°C for 2 h, and 85°C for 3 h, with 30-min ramps between stages. This malting protocol was used to produce samples that closely resemble those produced in commercial malt houses.

Barley Grain Analyses

Barleys were analyzed as described in the Methods of Analysis of the ASBC (American Society of Brewing Chemists, 1992) for moisture, plumpness, kernel weight, and protein content. Ground barley that was required for moisture and protein analyses was generated with a Labconco Burr mill that was adjusted so that only 35% of the grist remained on a 525- μm sieve after 3 min of shaking and tapping.

Malt Analyses

Malts were analyzed as described in the American Society of Brewing Chemists (1992) for moisture, protein, and diastatic power activity (Skalar Analytical B.V., DE Breda, the Netherlands). Alpha amylase activities were determined on a Skalar SAN plus analyzer by heating the enzyme extract produced for diastatic power to 73°C to inactivate the bulk of other enzymes found in malt. The extract was then analyzed for alpha amylase activity (Skalar Analytical). The grist for moisture, protein, and enzyme determinations was generated with the same mill used for barley moisture and protein analyses. A fine-grind Congress wort was generated and the wort analyzed for extract, color, protein, and β -glucan levels.

Seed Purification and Increase

Seed of Endeavor from the original $F_{5,6}$ progeny row was planted as a single 5.5-m row, examined for off types, and harvested in bulk in 2005. This seed was planted as a single 7-row plot 4.6 m by 1.5 m, and 220 random spikes were harvested and individually threshed. Two hundred progeny rows were planted in 1.8-m rows with 35.5-cm spacing and examined for segregating types; 185 rows were harvested in bulk to produce Breeder seed. Thirty kilograms of Breeder seed was seeded in the fall of 2008 to produce Foundation seed.

Statistical Analyses

All statistical analyses for agronomic and malting quality characteristics were performed using Agrobases Generation II software (Agronomix Software, 2004). Analysis of variance for yield, test weight, plump kernels, heading date, height, and lodging from ARS trials was performed across locations within years, and a combined analysis was performed across location-years using only entries common to all trials from 1997 to 2006. Within-year evaluations had location and genotypes as fixed factors and replicates as a random factor. Analyses across years had location-years and genotypes as fixed factors and replicates as random factors.

Characteristics

Agronomic and Morphological Description

Compared with Charles, Endeavor on average is 3.6 cm taller and heads 2 d later (143 vs. 141 Julian days). Straw strength is similar to Charles, as Endeavor averaged 1.2 vs. 1.1 (0–9) for Charles across 11 location-years where lodging occurred (Table 1). Winter hardiness for Endeavor is similar to Charles, both having inferior winter survivability compared with 88Ab536-B. From 2003 to 2005, mild winter conditions resulted in no winter kill. In 2006 at Pullman, WA, Endeavor and Charles both averaged 98% survivability compared with 100% for 88Ab536-B. In 2007, under severe winter conditions at Pullman, Endeavor had less winter survivability (37%, $P < 0.05$) than Charles (58%). Both had lower survivability ($P < 0.05$) than 88Ab536-B (85%, $LSD = 16.5$).

Endeavor has a semilax spike that nods slightly at maturity. The spike has rough awns, long rachilla hairs, and glume hairs that are banded, tending to covered, with glume awns twice the length of glume. The laterals are sterile, long, and awnless, with barbs at the apex. The kernel has white aleurone, prominent veins without barbs, and a crease that is open, flaring to a V shape. The hull is adher-

Table 1. Agronomic summary for 'Endeavor', 'Charles', and 88Ab536-B barley in trials from 1998 to 2007.

Entry	Heading date	Height	Lodging	Grain yield	Test weight
	Julian days	cm	1–9 [†]	kg ha ⁻¹	g L ⁻¹
Endeavor	143	90.5	1.2	7999	688
Charles	141	81.5	1.1	7795	663
88Ab536-B	137	97.3	1.0	7203	676
$LSD_{0.05}$	1.4	3.4	0.7	489	13.6
Observations	13	14	11	21	16

[†]Lodging score: 1 = none to 9 = completely flat.

ing and slightly wrinkled, tending to smooth. The rachis has numerous hairs along margins.

Disease Reaction

Endeavor was tested for reaction to barley stripe rust (causal agent *Puccinia striiformis* Westend. f. sp. *hordei* Ericks. & Henn.) by Dr. Xianming Chen at the USDA-ARS Wheat Genetic, Quality, Physiology, and Disease Research Unit in Pullman. Ten seedlings of Endeavor were grown in the greenhouse along with a susceptible check 'Steptoe' (Muir and Nilan, 1973) and resistant checks i-Bison 2-22 and i-Bison 129 (Richardson et al., 2006). Seedlings were inoculated with *P. striiformis* f. sp. *hordei* races PSH-14 and PSH-31 (field races collected in Washington), and after 13 d seedling leaves were scored according to the 0 to 9 scale described by Line et al. (1974). PSH-14 is virulent on the barley stripe rust differentials 1, 2, 3, 4, 5, 6, 7, 8, and 9, whereas PSH-31 is virulent on the same differentials as well as the differential line 10 (Chen and Line, 2002). All 10 seedlings of Endeavor were susceptible, with scores ranging from 7 to 9, whereas i-Bison 2-22 and i-Bison 129 were resistant, with scores of 1 and 3, respectively. All seedlings of Steptoe were scored 8 to 9. On the basis of these data, it appears Endeavor is susceptible to field races of *P. striiformis*. The incidence of barley stripe rust in Idaho is rare, and when present, losses have been insignificant. Across all testing locations from 1997 to 2007, no winter line evaluated in yield trials has experienced measurable yield loss due to stripe rust.

In Idaho, Endeavor is expected to be best adapted to the irrigated areas of the southern Snake River plain. It has suitable winter survival at Aberdeen in the absence of snow mold caused by *Microdochium nivale* (ces. Ex Berl. & Vogl.) Samuels & Hallet. Survival is greatly reduced by snow mold when extended snow cover occurs.

Field Performance

Endeavor was evaluated in ARS replicated yield trials across 21 location-years in Idaho, Kansas, Oregon, and Washington from 1997 to 2008 and yielded 102.6% of Charles (Table 1). In the target areas of Idaho and Washington, Endeavor yielded 104.3% of Charles across 17 location-years. Across 14 location-years in Idaho, Endeavor yielded 105.7% of Charles. Endeavor has a higher test weight than Charles, averaging 103.8% of Charles across 16 location-years (Table 1). A direct comparison to spring malting barley, such as Harrington, is not possible, although some conclusions may be drawn. For example, Charles and Harrington were each grown in separate trials in the same field, typically within 50 m, across nine location-years in Aberdeen and Filer, ID, from 2001 to 2007. The mean yield for Charles was 8714 kg ha⁻¹ compared with 6617 kg ha⁻¹ for Harrington. Since, as already noted, Endeavor has averaged 103.8% of Charles for yield, it seems reasonable to conclude that Endeavor is also greatly superior to Harrington for grain yield.

Malting Quality

Endeavor and Charles were evaluated for malting quality across 11 location-years from 1998 to 2006 in Idaho, Oregon, and Washington. The malting profile for Endeavor is

Table 2. Malting quality summary for barley cultivars Endeavor and Charles in trials from 1998 to 2006 (n = 11 observations).

Trait	Endeavor	Charles
Kernel weight (mg)	38.0	42.0
Plump kernels (%)	83.4	92.8*
Malt extract (%)	80.6	80.9
Barley protein (%)	12.0	11.8
Wort protein (%)	5.2	5.0
Soluble/total protein	45.4	45.4
Diastatic power (°ASBC)	137.0*	119.0
Alpha amylase (20°C dextrinizing units)	88.4*	79.5
Beta glucan (µg g ⁻¹)	170.0	193.0

*Significantly different at $P < 0.05$.

very similar to Charles for Kwt, malt extract, barley protein, wort protein, soluble/total protein, and beta-glucan (Table 2), with no differences ($P = 0.05$). Endeavor is inferior to Charles for percentage plump kernels (92.8 vs. 83.4), and superior for diastatic power (137 vs. 119 °ASBC), and alpha amylase (20°C dextrinizing units) (Table 2).

Availability

Breeder and Foundation seed of Endeavor will be maintained by the Idaho Agricultural Experiment Station, Foundation Seed Program. Requests for seed should be directed to the Coordinator, Foundation Seed Program, College of Agriculture, Kimberly Research and Extension Center, 3793 N 3600 E, Kimberly, ID 83341. Seed is also available for research purposes from the USDA-ARS National Small Grains Collection, Aberdeen, ID. It is requested that appropriate recognition of source be given when this cultivar contributes to research or development of new germplasm or cultivar.

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