Project Title:	The Oregon Barley Improvement Program
Researchers:	Dr. Patrick Hayes, Dr. Alfonso Cuesta-Marcos, Ms. Tanya Filichkin, Mr. Scott Fisk, Ms. Laura Helgerson
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Executive Summary

How the OSU program helps AMBA realize its mission and primary objective:
OSU develops:

- Winter/facultative 2-row malting barley varieties that will provide the malting and brewing industries with an abundant supply of high quality malting barley
- Novel germplasm that will increase diversity in U.S. barley. We are addressing AMBA's primary objective – ensuring that barley is a competitive crop – by incorporating malting quality into high yielding winter/facultative habit varieties that provide growers with profitable and productive cropping options.
- Doubled haploid genomic selection tools that will benefit all barley breeders working to advance the AMBA cause

Major issues, solutions, and expected benefits:
We are into a second year of "just saying no" to 6-rows and focusing on 2-rows. We do have agronomic and malting quality data on 303 elite winter/facultative 6-rows from the Oregon and Minnesota breeding programs, should there be a renewed interest in 6-rows. We have implemented doubled haploid (DH) genomic selection (GS) for malting quality in winter 2-rows, with a training population (404 DH lines) planted at three locations. The expected benefits are a stream of agronomically competitive winter 2-row malting varieties, and 6-rows – should there be a need for them.

One-year objectives and outcomes:
Our objective for 2013 was to implement an effective winter/facultative 2-row breeding program. Agronomic results are online at (http://barleyworld.org/breeding-genetics/data). By way of example, the O2Malt trial consisted of 18 winter/facultative DH experimental lines and 4 checks and these were tested at Corvallis, OR; and two locations in Idaho (Rupert and Hazelton, in cooperation with BARI). Averaged over these locations, our most advanced DH – 10.0777 – had a yield of 8146 lbs/acre (170 bu/acre). This is a 35% advantage over Charles and a 7% advantage over Wintmalt. Wintmalt and Charles are the parents of 10.0777. Malting quality data on all advanced 2-row DHs are yet to be received from the CCRU and the AMBA Pilot testing program. These will be posted as they are available. 2013 harvest malting data were received from BARI and are shown in Table 1. Our DH production facility has produced nearly 5,000 DH (seed to seed) since its inception in 2012. We are offering DH production services on a cost-recovery basis. Our expected annual production capacity for DH seed is ~ 5,000 lines. In 2013 we tested ~ 1,700 malt DH lines and of these ~ 600 were advanced to additional testing. Approximately 900 new malt DH lines were put into field trials in the fall of 2013 and winter of 2014.

Most significant accomplishments:

- Malting data on the first winter/facultative 2-row DH (2013 harvest) are encouraging (Table 1).
- Two winter 2-row DH (10.0777 and 10.0860) are in the AMBA Plant Scale program.
- The DH lab is in production and consistently achieving greater efficiencies.
- Over 1,500 DH lines are in field testing for 2014 harvest (Table 2).
- We have implemented doubled haploid genomic selection (DHGS).
- Systematic introgression of European 2-row alleles into Oregon winter germplasm. Our key cooperators are Ackermann, Breun, KWS, Limagrain and SECOBRA.
- Generating interest in winter/facultative barley throughout the barley research and production communities. At every opportunity we promote the merits of winter/facultative barley.
- A global understanding of the implications of low temperature tolerance and facultative growth habit. We will be able to rigorously and definitively test this hypothesis in the upcoming T-CAP supported association mapping of cold tolerance in a sample of the world's winter and facultative germplasm (including our own germplasm). This panel consists of 941 accessions and is being tested at 13 locations around the world.

Detailed Report on Objectives, Methodology and Results – AMBA Funded Project

Objectives:

Our objective is to develop superior varieties that meet AMBA specifications based on an understanding of the genetic basis of target traits. In winter/facultative barley, our primary traits of interest are: malting quality, productivity, winter hardiness and disease resistance. All our efforts are directed at 2-row.

Methodology:

Progress in our program depends on extensive collaboration. Dr. Kevin Smith, University of Minnesota is a key cooperator. BARI has provided agronomic testing at Fort Collins, Colorado and test sites in South Idaho. Bob Brunick (MillerCoors) also tests our germplasm in south Idaho. Dr. Gonghse Hu (USDA/ARS; Aberdeen, Idaho) provides data from Aberdeen. Dr. Juliet Marshall includes our advanced lines in the Idaho Extension nurseries. Dr. Kevin Murphy at Washington State University grows our material at Pullman, Washington. At Pendleton, Oregon we work with Dr. Stephen Machado and at Hermiston, Oregon with Matt Kolding. Dr. David Hole, Utah State, screens varying numbers of lines at Logan, Utah. We exchange germplasm with European companies. Our field trials are nearly all DH.

Our winter/facultative barley breeding is entering a DHGS scheme that will increase the frequency of favorable alleles and produce a steady stream of variety candidates. These variety candidates will enter replicated multi-environment testing. The 2013/2014 winter nurseries are summarized in Table 2. Our DH laboratory program directly supports the winter/facultative malting barley genomic selection program. Malting quality assessments are conducted by the USDA/ARS and Dr. Cynthia Henson and colleagues collaborate on additional quality assays.

Results:
We await CCRU data on our 2-row winter/facultative germplasm, as well as results from the AMBA Pilot Scale Program. As shown in Table 1 (2013 crop, with thanks to BARI), the two AMBA Pilot submissions have attractive, balanced malt profiles. These selections, and others, are in regional testing at seven locations (Table 2), planted in fall, 2013. We established a DH production facility that has produced ~ 5,000 DH lines since its inception in 2012. We are offering DH production services on a cost-recovery basis. Our expected annual production capacity for DH seed is ~ 5,000 lines, with ~ 2,000 of these produced for our own breeding initiatives.

We completed final assessment of 6-row malting germplasm (303 accessions) developed with prior AMBA support under the auspices of the T-CAP project (in a Nitrogen Use Efficiency trial). Selected lines are in our Statewide trial and will potentially be released as feed varieties. Full agronomic and malting quality data are presented in the online annual report (http://barleyworld.org/breeding-genetics/data).

Other Barley Research and Future Direction of Program

In addition to winter malting barley development, the Oregon Barley Project is engaged in a number of other endeavors:

- Genetic dissection of malting quality
- Winter hardiness physiology and genetics
- Association mapping of nitrogen use efficiency, water use efficiency, stripe rust resistance and low temperature tolerance
- Winter barley for human nutrition
- Genetic dissection of quantitative resistance to barley stripe rust
- Breeding for UG99 resistance

The human nutrition program has expanded, with support from the Oregon Wheat Commission and Idaho Barley Commission.

Project Personnel

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Alfonso Cuesta-Marcos, Research Assistant Professor
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Publications (2013 - 2014)

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2. Locatelli, A. A. Cuesta-Marcos, L. Gutiérrez, P.M. Hayes, K.P. Smith, and A. Castro. 2013. Genome-wide association mapping of agronomic traits in relevant barley germplasm in Uruguay. Mol. Breeding. 31:631-634.
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4. Chutimanitsakun, Y, A. Cuesta-Marcos, S. Chao, A. Corey, T. Filichkin, S. Fisk, M. Kolding, B. Meints, Y. Ong, J.I. Rey, A.S. Ross, and P.M. Hayes. 2013. Application of marker assisted selection and genome wide association scanning to the development of winter food barley germplasm resources. Plant Breeding. 132:563-570.
5. Jeknic, Z., K. Pillman, T. Dillon, J. Skinner, O. Veisz, A. Cuesta-Marcos, P.M. Hayes, T.H.H. Chen, and E. Stockinger. 2014. Hv-CBF2A overexpression in barley accelerates COR gene transcript accumulation and acquisition of freezing tolerance during cold acclimation. Plant Mol. Biol. 84:67-82.
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Table 1. Malting quality data (courtesy of USDA/ARS-CCRU, Madison, WI) on winter doubled haploid lines grown at Rupert and Hazelton, ID. Experiments and data courtesy of BARI.

Line Name	Location	Malt Extract (%)	Barley Protein (%)	S/T (%)	Diastatic Power (^{o}ASBC)	Alpha Amylase (20DU)	Wort Beta-Glucan (ppm)	FAN (ppm)
ENDEAVOUR	RUPERT	83.0	11.7	49.7	153.2	83.6	103.3	242.9
VIOLETTA	RUPERT	81.8	11.8	43.0	179.6	50.2	263.6	168.1
WINTMALT	RUPERT	80.1	12.2	34.6	160.3	54.3	117.5	153.3
10.0777	RUPERT	83.9	11.9	50.4	183.2	94.8	58.9	273.4
10.0860	RUPERT	82.3	10.4	51.6	133.3	70.5	56.1	234.0
ENDEAVOUR	HAZELTON	81.2	13.5	58.1	165.7	92.6	79.5	291.5
VIOLETTA	HAZELTON	79.6	13.4	46.2	197.8	61.1	196.5	206.0
WINTMALT	HAZELTON	78.5	14.6	41.9	182.6	63.8	134.1	203.4
10.0777	HAZELTON	81.2	14.1	58.0	216.1	106.2	52.4	338.4
10.0860	HAZELTON	80.9	13.8	44.5	169.9	73.5	111.4	234.4

Table 2. Oregon State University winter barley nurseries: 2013-2014. The summary is divided into "Malting", "Food", "Forage/Feed", and "Genetics". In reality, these areas of endeavor are tightly integrated. This is especially true for feed barley as we generally don't breed specifically for this end-use however feed barley lines may stem from any of the other breeding areas. The emphasis of the program is on facultative growth habit in order to provide maximum flexibility in planting date (for growers) and breeding (for research and variety development). The list does not include all 2014 spring-planted trials, as these are still under development.

Winter Malting Barley

Overview:

Number of advanced and fixed lines: 1609

- 499 in yield trial plots
- 1110 in single, double or mini-plots (doubled haploids)

Number of populations/families in early generations:

- 7 F1's

Details:

Oregon Winter/Facultative Barley Statewide Yield Trial; Fall-planted; 44 entries

- Corvallis, OR 3 rep, RCBD
- Lewis Brown Farm (Organic) 3 rep, RCBD
- Hermiston, OR 3 rep, RCBD
- Pendleton, OR 3 rep, RCBD
- Lexington, OR 3 rep, RCBD
- Mt. Vernon, WA 3 rep, RCBD
- Pullman, WA 3 rep, RCBD

Oregon Malting Barley Training Population; Fall-planted; 404 entries

- Corvallis, OR Type 2 Augmented Design (Yield Trial Plots)
- Mt. Vernon, WA Type 2 Augmented Design (Single Row Plots)
- St. Paul, MN Type 2 Augmented Design (Single Row Plots)

Winter Malting Barley Trial; Fall-planted; 29 entries from US and International Cooperators

- Corvallis, OR 3 rep, RCBD

Winter Barley Germplasm Nursery; Fall-planted; 22 entries from US Cooperators

- Corvallis, OR 3 rep, RCBD

Observational Drill Strips (Corvallis); Fall-planted; 3 entries

- OSU Lines

Oregon Otter; Fall-planted; 28 entries

- Dundee, Scotland Unreplicated Nursery with checks

Malt Doubled Haploid Mini-Plots (Corvallis)

- Fall-planted 108 Lines; Unreplicated Nursery with checks
- Winter-planted 22 Lines; Unreplicated Nursery with checks

Malt Doubled Haploid Double Rows (Corvallis)

- Fall-planted 285 lines; Unreplicated Nursery with checks
- Winter-planted 21 Lines; Unreplicated Nursery with checks

Malt Doubled Haploid Single Rows (Corvallis)

- Fall-planted 637 lines; Unreplicated Nursery with checks
- Winter-planted 37 Lines; Unreplicated Nursery with checks

F1 (Corvallis); Fall-planted

- 7 Pedigrees

Winter Food Barley

Overview:

Number of advanced and fixed lines: 1287

- 48 in yield trial plots
- 1239 in single, double or mini-plots (doubled haploids & F5's)

Number of purification head rows:

- 2400

Number of populations/families in early generations:

- 17 F1's
- 13 F2's

Details:

International Food Barley Trial

- Corvallis, OR
  - Fall-planted 15 entries, 2 rep, RCBD
  - Winter-planted 30 entries, 2 rep, RCBD
- Pullman, WA
  - Fall-planted 15 entries, 2 rep, RCBD
- Dundee, Scotland
  - Fall-planted 30 entries, 2 rep, RCBD
- Lleida, Spain
  - Fall-planted 30 entries, 2 rep, RCBD

EurOregon 2-row Food Barley Trial; Fall-planted; 18 entries

- Corvallis, OR 3 rep, RCBD
- Mt. Vernon, WA 3 rep, RCBD
- Pullman, WA 2 rep, RCBD

Black Beaut F5 (Corvallis); Winter-planted

- 28 entries; unreplicated nursery

Food Doubled Haploid Mini-Plots (Corvallis); Winter-planted

- 154 Lines; Unreplicated Nursery with checks

Food Doubled Haploid Double Rows (Corvallis); Winter-planted

- 288 Lines; Unreplicated Nursery with checks

Food Doubled Haploid Single Rows (Corvallis)

- Fall-planted 249 lines; Unreplicated Nursery with Checks
- Winter-planted 520 lines; Unreplicated Nursery with Checks

Purification Head Rows (Corvallis); Fall-planted

- Streaker 1800 rows (600 each from 3 Farmer's Fields)
- 09OR-86 600 rows

F2 (Corvallis); Fall-planted

- 13 Populations

F1 (Corvallis); Fall-planted

- 17 Pedigrees

Observational Drill Strips (Corvallis); Fall-planted; 3 entries

- OSU Malt & European Lines

Forage & Feed*

Overview:
Number of advanced and fixed lines: 11

- 8 in yield trial plots
- 3 in Drill Strips

Details:
Spring Forage Barley Trial; 8 entries

- Corvallis, OR — 3 rep, RCBD; February Planting
- Lebanon, OR — 2 rep, RCBD; March Planting
- Clarksburg, CA — 2 rep, RCBD; December planting
- Maxwell, CA — 2 rep, RCBD; January Planting
- Riverdale, CA — 2 rep, RCBD; November Planting

Observational Drill Strips (Corvallis); Fall-planted; 3 entries

- OSU & European Feed Lines

*Not an inclusive list as feed lines are integrated within other breeding classes. All lines grown have potential as a possible feed variety.

Genetics

Overview:
Number of advanced and fixed lines: 3816

- 262 in yield trial plots
- 3816 in single, double or mini-plots

Number of populations/families in early generations:

- 65 F2's

Details:
Barley Stripe Rust Nursery (Corvallis); Winter-planted; Type 2 Augmented Design

- OSU-TCAP NSGC Winter Barley Core — 374 entries
- ARS BSR Mapping Populations — 207 entries
- Lenetah/GZ Population — 153 entries
- Cali-sib/Bowman Population — 120 entries
- ORO (BCD-47/Baronesse) Population — 407 entries
- 2-row Spring Barley Association Mapping Panel — 248 entries
- 6-row Spring Barley Association Mapping Panel — 253 entries
- 2-row Spring Barley Nested Association Mapping Parents — 102 entries
- Beer Flavor Panel; Winter-planted — 92 entries
- Oregon Winter/Facultative Statewide Trial — 44 entries
- Oregon Malting Barley Training Population — 404 entries

OSU-TCAP Low Temperature Tolerance Panel; Type 2 augmented design

- Corvallis, OR — 941 entries, Winter-planted (BSR Nursery)
- St. Paul, MN — 941 entries, Fall-planted

- Aberdeen, ID 941 entries, Fall-planted
- Wooster, OH 941 entries, Fall-planted
- Lincoln, NE 941 entries, Fall-planted
- Dundee, Scotland 941 entries, Fall-planted
- Irlbach, Germany 384 entries, Fall-planted
- Kurashiki, Japan 384 entries, Fall-planted
- Martonvasar, Hungary 941 entries, Fall-planted
- Freising, Germany 941 entries, Fall-planted
- Zaragoza, Spain 941 entries, Fall-planted
- Lacombe, AB Canada 941 entries, Fall-planted
- Maule, France 941 entries, Fall-planted
- Champagne, France 941 entries, Fall-planted

Low Temperature Tolerance Panel (subset) Yield Trial; Fall-planted; 262 entries

- Moro, OR Type 2 augmented design

Minnesota Genomic Selection; Fall-planted; 266 entries

- Corvallis, OR Type 2 augmented design

Oregon Promise Population

- Corvallis, OR
    - Winter-planted 205 entries, 2 rep, Alpha Lattice
- Dundee, Scotland
    - Spring-planted 153 entries, 2 rep

UG99 F2 (Corvallis); Fall-planted

- 50 Populations

LTT F2 (Corvallis); Winter-planted

- 15 Populations