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| <b>Project Title:</b> | The Oregon Barley Improvement Program                                            |
| <b>Researchers:</b>   | Dr. Patrick Hayes, Dr. Alfonso Cuesta-Marcos, Ms. Ann Corey, Ms. Tanya Filichkin |
| <b>Department:</b>    | Dept. of Crop and Soil Science                                                   |
| <b>Institution:</b>   | Oregon State University, Corvallis, OR 97331                                     |

### **Executive Summary**

**Note: Throughout this report “winter” barley refers to fall-planted barley and does not differentiate between facultative and vernalization-requiring types.**

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

OSU develops:

- winter malting barley varieties that provide the malting and brewing industries with an abundant supply of high quality malting barley
- molecular breeding tools that will benefit all barley breeders working to advance the AMBA cause
- 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 habit varieties that provide growers with profitable and productive cropping options.

#### ***Major issues, solutions, and expected benefits:***

We are in the process of re-focusing the breeding program on 2-row. Without molecular breeding tools and doubled haploids this re-alignment would be impossible. We will apply stringent selection to the 6-row germplasm in the pipeline. Molecular breeding tools allow us to develop our 2-row germplasm base using genomic selection procedures. This will deliver a sustained stream of submissions to the AMBA Pilot program: 6-rows for the next few years and then 2-rows.

#### ***One-year objectives and outcomes:***

We developed, tested, characterized, and selected winter germplasm at multiple locations. We selected lines with excellent yields under irrigated and dryland conditions. These high yielding lines have good disease resistance and attractive malt profiles. We developed markers for target traits and implemented these in our breeding program. Malting data from 2011 crop samples are encouraging for enterprises with uses for 6-row malting varieties.

#### ***Most significant accomplishments:***

- Application of genomics tools to practical breeding. These tools are provided by the Triticeae CAP (T-CAP). The OrNe project (a competitive grant supported by USDA-AFRI) generated exciting germplasm, in terms of cold tolerance and disease resistance. The Nebraska germplasm contributed alleles that set a new record in viscosity: wort beta glucan levels over 1,000 ppm.
- Systematic introgression of European 2-row alleles into Oregon winter germplasm. Our key cooperators are Breun, KWS-Lochow, Limagrain and SECOBRA.
- Systematic introgression of winter hardiness alleles from Nebraska feed barley into Oregon winter germplasm via the OrNe Project. We produced doubled haploid

populations and advanced selected DH lines to yield and cold tolerance trials. In the process we discovered a new cold tolerance QTL. Marker assisted selection was completed.

- Generating interest in winter barley throughout the barley research and production communities. At every opportunity we promote the merits of winter barley.
- A global understanding of the implications of facultative growth habit. Our data indicate that maximum cold tolerance can be achieved with facultative growth habit. The OrNe project provided corroborating evidence. 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.

## **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 barley, our primary traits of interest are: malting quality, productivity, winter hardiness and disease resistance.

### ***Methodology:***

Progress in our program depends on extensive collaboration. Dr. Kevin Smith, University of Minnesota is a key cooperator. BARI has provided winter hardiness screening at Fort Collins, Colorado. Bob Brunick (MillerCoors) tests our germplasm in south Idaho. The USDA/ARS (Aberdeen, Idaho) provides data from Aberdeen. Drs. Juliet Marshall and Brad Brown include our advanced lines in the Idaho Extension nurseries. Kevin Murphy at Washington State University grows our material at Pullman, Washington. At Pendleton, Oregon we work with Dr. Steve Petrie and at Hermiston, Oregon with Matt Kolding. Dr. David Hole, Utah State, screens varying numbers of lines at Logan, Utah. We exchange germplasm with the Martonvasar Research Institute in Hungary and European companies. We now have everything from F1 to doubled haploid generation germplasm derived from crosses with European lines.

Our winter barley field phenotyping efforts are based on regional evaluation of variety candidates, replicated multi-environment testing of advanced lines, screening of preliminary yield trials, advance of segregating generations, and crossing to accumulate favorable alleles. The 2011/2012 winter nurseries are summarized in Table 1. Our laboratory program directly supports the winter malting barley breeding program. Malting quality assessments are conducted by the USDA/ARS and Drs. Cynthia Henson and Mark Schmitt collaborate on additional quality assays.

### ***Results:***

Breeding program results are highlighted in the following tables. The summaries are averages of multi-environment data on selections that will be submitted to the AMBA Pilot program in 2012 (Table 1), except for Maja which will go to Plant Scale. These six-row barleys have excellent resistance to stripe rust, good tolerance to scald, are as (or more) winterhardy than the checks and will yield (on average) 125 bu/acre. The typical quality profile is low protein, extract in the 80s, S/T in the high 40s, DP in the 120s, alpha in the mid-60s and beta glucan in the 150s. In most cases 6-rows will have lower extract and higher beta glucan than 2-rows. Their "ace" is yield.

## 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:

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

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

## Project Personnel

Patrick Hayes, Professor  
Alfonso Cuesta-Marcos, Research Assistant Professor  
Ann Corey, Senior Research Assistant  
Tanya Filichkin, Senior Research Assistant  
Brigid Meints, Graduate Research Assistant  
Araby Belcher, Graduate Research Assistant

## Publications (2011 - 2012)

### **Papers**

1. Cistué, L., A. Cuesta-Marcos, S. Chao, Y. Chutimanitsakun, A. Corey, B. Echávarri, T. Filichkina, N. Garcia-Mariño, I. Romagosa, and P.M. Hayes. 2011. Comparative mapping of the Oregon Wolfe Barley using doubled haploid lines derived from female and male gametes. *Theor. Appl Genet.* 122:1399-1410.
2. Chutimanitsakun, Y., R. Nipper, A. Cuesta-Marcos, L. Cistué, A. Corey, T. Filichkina, E. Johnson, and P.M. Hayes. 2011. Construction and application of a Restriction Site Associated DNA (RAD) linkage map in barley. *BMC Genomics.* 12:4
3. Ramsay, L., J. Comadran, A. Druka, D. F. Marshall, W.T. B. Thomas, M. Macaulay, K. MacKenzie, C. Simpson, J. Fuller, N. Bonar, P. M. Hayes, U. Lundqvist, J. D. Franckowiak, T. J. Close, G. J. Muehlbauer, and R. Waugh. 2011. *INTERMEDIUM-C*, a modifier of lateral spikelet fertility in barley, is an ortholog of the maize domestication gene *TEOSINTE BRANCHED 1*. *Nature Genetics.* 43:169-172.
4. VonZitzewitz, J., A. Cuesta-Marcos, F. Condon, A. Castro, S. Chao, A. Corey, T. Filichkin, S.P. Fisk, L. Gutierrez, K. Haggard, I. Karsai, G. Muehlbauer, K. Smith, O. Veisz, and P. Hayes. 2011. The genetics of winterhardiness in barley: perspectives from association mapping. *The Plant Genome.* 4:76-91
5. Gutiérrez L., A. Cuesta-Marcos, A. J. Castro, J. von Zitzewitz, P. M. Hayes. Association mapping of malting quality QTL in winter barley: positive signals from small germplasm arrays. 2011. *The Plant Genome.* 4:256-272.
6. Muñoz-Amatriaín M., M. J. Moscou, P. R. Bhat, J. T. Svensson, J. Bartoš, P. Suchánková, H. Šimková, T. R. Endo, R. D. Fenton, Y. Wu, S. Lonardi, A. M. Castillo,



- Hermiston, OR 3 rep, Rectangular Lattice
- Pendleton, OR 3 rep, Rectangular Lattice
- Aberdeen, ID 3 rep, Rectangular Lattice
- Pullman, WA 3 rep, Rectangular Lattice
- Ft. Collins, CO 3 rep, Rectangular Lattice
- Burley, ID 3 rep, Rectangular Lattice
- Mt. Vernon, WA 1 rep, Unreplicated Nursery
- St. Paul, MN observation

**European Winter 2 Row Malting Trial; selections from Europe**

- Corvallis, OR- replicated RCBD, 3 rep, 9 entries
- Corvallis, OR - unreplicated 1 rep, 18 entries
- Hermiston, OR - replicated RCBD, 3 rep, 21 entries

**Winter Malting Barley Trial; 28 entries from US and International Cooperators**

- Corvallis, OR 3 rep, RCB

**Winter Barley Preliminary Yield Trial; 107 entries; selections from F6 bulks**

- Corvallis, OR 1 rep, Type 2 Modified Augmented design

**Doubled Haploid HRBIN 2-row plots (Corvallis)**

- 47 lines. Unreplicated nursery with checks

**Doubled haploid single rows (Corvallis)**

- 22 lines. Unreplicated nursery with checks

**Head Rows (Corvallis) 3492 segregating head rows total**

- F3 Head Rows 12 families, 542 rows
- F4 (club) Head Rows 17 families, 306 rows
- F4 (lax) Head Rows 68 families, 1156 rows
- F5 Head Rows 70 families, 1488 rows

**F2 (Corvallis)**

- 28 populations

**F1 (Corvallis)**

- 27 pedigrees

**Purification Head Rows (all at Corvallis)**

- OR818 150 rows; OR101 144 rows

**Oregon Sampler Elite Lines – 12 entries**

- International
  - Spain, 2 locations; France
- Domestic
  - St. Albans, VT; Wooster, OH

**Winter food barley**

**Overview: Number of populations/families in early generations:**

- 16 F2's

**Number of segregating head rows:**

- 2100 (F3 to F5)

**Number of purification head rows:**

- 1290

**Number of advanced and fixed lines: 364**

- 19 in yield trial plots; 345 in single or double row plots (doubled haploids)

**Details: Oregon Winter Food Barley Trial; 16 entries**

- Corvallis, OR 3 rep, RCBD

- LB Farm (organic), OR 3 rep, RCBD
- Hermiston, OR 3 rep, RCBD
- Pendleton, OR 3 rep, RCBD
- Pullman, WA 3 rep, RCBD
- Aberdeen, ID 3 rep, RCBD
- Genesse, ID (WSU) 3 rep, RCBD
- Mt. Vernon, WA 3 rep, RCBD

**Doubled haploid HRBIN (2 row plots); 96 lines total**

- Corvallis, OR Waxy; 60 lines. Unreplicated nursery with checks
- Corvallis, OR Non-waxy; 36 lines. Unreplicated nursery with checks

**Doubled haploid single rows; 249 lines total**

- Corvallis, OR Hull-less; 130 lines. Unreplicated nursery with checks
- Corvallis, OR Food; 5 lines. Unreplicated nursery with checks
- Corvallis, OR Hulled Waxy Food; 12 lines. Unreplicated nursery with checks
- Corvallis, OR Hulled non-waxy; 102 lines. Unreplicated nursery with checks

**Head Rows (Corvallis) 2100 segregating head rows**

- F3 Food Hulless 6 row Head Rows 8 entries, 180 rows
- F4 Food Hulless 2 row Head Rows 18 entries, 828 rows
- F4 Food Hulless colored SSD 156 entries, 936 rows
- F3 Food Hulless colored SSD 156 entries, 156 rows

**Purification Head Rows (Corvallis)**

- OR85, blue 120 rows; 8 pedigrees 1170 rows

**Streaker mix increase (Corvallis)**

- OR85 + OR86 + OR911

**Introductions; 3 entries; Varieties from K.J. Mueller, Germany**

- Corvallis, OR Observation strip; Hermiston, OR 1 plot each

**Genetics**

**Number of advanced and fixed lines tested: 2837**

- 54 in yield trial plots; 2783 in single or double row plots

**OSU-TCAP Facultative 6 row trial; NUE; Hi, Lo N, 396 entries**

- Corvallis, OR–fall planted. Type 2 Modified Augmented design

**OSU-TCAP NSGC Winter Barley Core; LTT, 414 entries**

- Pendleton, OR–fall planted. Augmented design

**OSU-TCAP NSGC Barley core; BSR, 2583 entries**

- Corvallis, OR–fall planted. Type 2 Modified Augmented Design

**Denso gene fertility Trial; 6 entries**

- Corvallis, OR 3 rates

**Uniform Barley Winter Hardiness Nursery; 30 entries**

- Pendleton, OR 2 rep, RCBD

**Oregon/ Nebraska (OrNe) Marker Assisted Selection (MAS) HRBIN**

- Corvallis, OR 48 entries. Unreplicated nursery with checks

**F2 (Corvallis)**

- UG99 resistance 16 populations

Table 2. Malting quality and agronomic data summaries for OSU winter six-rows. Maja is in Plant Scale. The other selections are potential Pilot Scale candidates. Charles (two-row) is the malt check. Eight-twelve (six-row) is the agronomic check.

| Selection<br>Pedigree | Maja (OR81)<br>Strider/88Ab536    |                         |                        |            |                            |                              |                          |                  |                  |                                |                           |
|-----------------------|-----------------------------------|-------------------------|------------------------|------------|----------------------------|------------------------------|--------------------------|------------------|------------------|--------------------------------|---------------------------|
|                       | Kernel<br>Plumpness<br>(on 6/64") | Grain<br>Protein<br>(%) | Malt<br>Extract<br>(%) | S/T<br>(%) | Diastatic<br>Power<br>(°L) | Alpha<br>Amylase<br>(20° DU) | Beta-<br>Glucan<br>(ppm) | Yield<br>bu/acre | Lodging<br>(1-9) | Days to<br>Heading<br>(Julian) | Plant<br>Height<br>Inches |
| Maja                  | 84.4                              | 10.7                    | 79.6                   | 40.4       | 127.2                      | 49.9                         | 108                      | 121.8            | 2.4              | 139                            | 39.8                      |
| STA. YRS.             | 10                                | 12                      | 12                     | 12         | 12                         | 12                           | 12                       | 11               | 5                | 8                              | 9                         |
| Charles**             | 89.2                              | 11.9                    | 81.0                   | 46.3       | 137.4                      | 84.7                         | 171                      | 108.5            | 3.3              | 130                            | 35.8                      |
| STA. YRS.             | 22                                | 21                      | 22                     | 22         | 22                         | 20                           | 22                       | 24               | 13               | 16                             | 19                        |
| Eight-Twelve          | ND**                              | ND**                    | ND**                   | ND**       | ND**                       | ND**                         | ND**                     | 99.0             | 3.0              | 141                            | 39.0                      |
| STA. YRS.             |                                   |                         |                        |            |                            |                              |                          | 14               | 9                | 12                             | 13                        |

| Selection<br>Pedigree | OR818<br>Bu27/Stab47,<br>F1/3/Maja/Stab47 |                         |                        |            |                            |                              |                          |                  |                  |                                |                           |
|-----------------------|-------------------------------------------|-------------------------|------------------------|------------|----------------------------|------------------------------|--------------------------|------------------|------------------|--------------------------------|---------------------------|
|                       | Kernel<br>Plumpness<br>(on 6/64")         | Grain<br>Protein<br>(%) | Malt<br>Extract<br>(%) | S/T<br>(%) | Diastatic<br>Power<br>(°L) | Alpha<br>Amylase<br>(20° DU) | Beta-<br>Glucan<br>(ppm) | Yield<br>bu/acre | Lodging<br>(1-9) | Days to<br>Heading<br>(Julian) | Plant<br>Height<br>Inches |
| OR818                 | 86.6                                      | 10.6                    | 80.4                   | 45.8       | 128.8                      | 75.3                         | 181                      | 123.5            | 1.0              | 140                            | 40.0                      |
| STA. YRS.             | 12                                        | 12                      | 12                     | 12         | 12                         | 12                           | 12                       | 11               | 5                | 8                              | 9                         |
| Charles               | 89.2                                      | 11.9                    | 81.0                   | 46.3       | 137.4                      | 84.7                         | 171                      | 108.5            | 3.3              | 130                            | 35.8                      |
| STA. YRS.             | 22                                        | 21                      | 22                     | 22         | 22                         | 20                           | 22                       | 24               | 13               | 16                             | 19                        |
| Eight-<br>Twelve      | ND**                                      | ND*                     | ND*                    | ND*        | ND*                        | ND*                          | ND*                      | 99.0             | 3.0              | 141                            | 39.0                      |
| STA. YRS.             |                                           |                         |                        |            |                            |                              |                          | 14               | 9                | 12                             | 13                        |

Selection

OR91

Pedigree

Bu27/Stab47,  
F1/3/Maja/Stab47

|              | Kernel Plumpness (on 6/64") | Grain Protein (%) | Malt Extract (%) | S/T (%) | Diastatic Power (°L) | Alpha Amylase (20° DU) | Beta-Glucan (ppm) | Yield bu/acre | Lodging (1-9) | Days to Heading (Julian) | Plant Height Inches |
|--------------|-----------------------------|-------------------|------------------|---------|----------------------|------------------------|-------------------|---------------|---------------|--------------------------|---------------------|
| OR91         | 86.2                        | 10.1              | 80.8             | 48.2    | 117.4                | 74.9                   | 161               | 128.1         | 1.4           | 138                      | 40.4                |
| STA. YRS.    | 8                           | 8                 | 8                | 8       | 8                    | 8                      | 8                 | 9             | 4             | 6                        | 7                   |
| Charles      | 89.2                        | 11.9              | 81.0             | 46.3    | 137.4                | 84.7                   | 171               | 108.5         | 3.3           | 130                      | 35.8                |
| STA. YRS.    | 22                          | 21                | 22               | 22      | 22                   | 20                     | 22                | 24            | 13            | 16                       | 19                  |
| Eight-Twelve | ND*                         | ND*               | ND*              | ND*     | ND*                  | ND*                    | ND*               | 99.0          | 3.0           | 141                      | 39.0                |
| STA. YRS.    |                             |                   |                  |         |                      |                        |                   | 14            | 9             | 12                       | 13                  |

Selection

OR92

Pedigree

Bu27/Stab47,  
F1/3/Maja/Stab47

|              | Kernel Plumpness (on 6/64") | Grain Protein (%) | Malt Extract (%) | S/T (%) | Diastatic Power (°L) | Alpha Amylase (20° DU) | Beta-Glucan (ppm) | Yield bu/acre | Lodging (1-9) | Days to Heading (Julian) | Plant Height Inches |
|--------------|-----------------------------|-------------------|------------------|---------|----------------------|------------------------|-------------------|---------------|---------------|--------------------------|---------------------|
| OR92         | 85.9                        | 10.1              | 80.9             | 46.7    | 121.1                | 75.6                   | 146               | 132.3         | 0.9           | 139                      | 41.0                |
| STA. YRS.    | 8                           | 8                 | 8                | 8       | 8                    | 8                      | 8                 | 9             | 4             | 6                        | 7                   |
| Charles      | 89.2                        | 11.9              | 81.0             | 46.3    | 137.4                | 84.7                   | 171               | 108.5         | 3.3           | 130                      | 35.8                |
| STA. YRS.    | 22                          | 21                | 22               | 22      | 22                   | 20                     | 22                | 24            | 13            | 16                       | 19                  |
| Eight-Twelve | ND*                         | ND*               | ND*              | ND*     | ND*                  | ND*                    | ND*               | 99.0          | 3.0           | 141                      | 39.0                |
| STA. YRS.    |                             |                   |                  |         |                      |                        |                   | 14            | 9             | 12                       | 13                  |



Selection

OR910

Pedigree

Bu 27/Stab 47,  
F1/3Maja /Stab47

|                  | Kernel<br>Plumpness<br>(on 6/64") | Grain<br>Protein<br>(%) | Malt<br>Extract<br>(%) | S/T<br>(%) | Diastatic<br>Power<br>(°L) | Alpha<br>Amylase<br>(20° DU) | Beta-<br>Glucan<br>(ppm) | Yield<br>bu/acre | Lodging<br>(1-9) | Days to<br>Heading<br>(Julian) | Plant<br>Height<br>Inches |
|------------------|-----------------------------------|-------------------------|------------------------|------------|----------------------------|------------------------------|--------------------------|------------------|------------------|--------------------------------|---------------------------|
| OR910            | 83.8                              | 9.9                     | 80.9                   | 48.8       | 120.2                      | 77.4                         | 129                      | 126.5            | 2.3              | 135                            | 41.9                      |
| STA. YRS.        | 7                                 | 7                       | 7                      | 7          | 7                          | 7                            | 7                        | 7                | 4                | 7                              | 7                         |
| Charles          | 89.2                              | 11.9                    | 81.0                   | 46.3       | 137.4                      | 84.7                         | 171                      | 108.5            | 3.3              | 130                            | 35.8                      |
| STA. YRS.        | 22                                | 21                      | 22                     | 22         | 22                         | 20                           | 22                       | 24               | 13               | 16                             | 19                        |
| Eight-<br>Twelve | ND*                               | ND*                     | ND*                    | ND*        | ND*                        | ND*                          | ND*                      | 99.0             | 3.0              | 141                            | 39.0                      |
| STA. YRS.        |                                   |                         |                        |            |                            |                              |                          | 14               | 9                | 12                             | 13                        |