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| Project Title: | The Oregon Barley Improvement Program |
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Executive Summary

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

The OSU program seeks to help AMBA realize its mission by developing (1) winter malting barley varieties that provide the malting and brewing industries with an abundant supply of high quality malting barley, (2) molecular breeding tools that will benefit all barley breeders working to advance the AMBA cause, (3) 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 have developed a winter malting barley germplasm base that delivers a sustained stream of submissions to the AMBA Pilot program. Molecular breeding tools will allow us to make judicious infusions of new genes into this delivery stream.

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 received - to date - from 2009 crop samples are very encouraging. The principal thrust of our research is standard winter six-row: essentially a Midwestern Manchurian type with winter hardiness. However, we have diversified the portfolio to include diversity in plant height, hull type, and row type.

Most significant accomplishments:

- Application of genomics tools to practical breeding. These tools are provided by the Barley CAP, the Enhanced Barley Through Genomics Project (EBTG) and the USDA-NIFA-AFRI_ORNE project on winter hardiness + malting quality.
- Systematic introgression of European alleles into Oregon winter germplasm.
- Systematic introgression of winter hardiness alleles from Nebraska feed barley into Oregon winter germplasm.
- Stimulus of interest in winter barley throughout the barley research and production communities.
- A global understanding of the implications of facultative growth habit.

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:

We work cooperatively. Dr. Blake Cooper, BARI, provides winter hardiness screening at Fort Collins, Colorado and in Montana. Dr. Don Obert (USDA/ARS, Aberdeen, Idaho) provides data from Aberdeen and/or Filer, Idaho. Dr. Juliet Windes includes some of our advanced lines in the Southeast Idaho Extension nurseries. Dr. Steve Ullrich grows our material at Pullman, Washington. At Pendleton, Oregon we work with Dr. Steve Petrie. BARI has arranged for testing of advanced selections in Colorado and Montana. Drs. Kevin Smith, University of Minnesota and Eric Stockinger, Wooster, Ohio both continued winter barley screening. Dr. David Hole, Utah State, screens varying numbers of lines at Logan, Utah. We exchange germplasm with the Martonvasar Research Institute in Hungary and three Germany-based companies (Lochow-Petkus, Breun and Achermann &Co).

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 2009/2010 winter nurseries are summarized in Table 7. Our laboratory program directly supports the winter malting barley breeding program. Malting quality assessments are conducted by Mr. Al Budde, 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 2010 (Tables 1 – 5). Pedigrees of OR76, OR81, OR813, and OR818 are shown in Table 1.

Quality: Long-term quality data are summarized in Table 2A and 2B. The comparisons are not balanced, since Charles was added as a check in 2008. Key factors to bear in mind when considering these data are (i) six-row experimental lines are being compared to a two-row check, and (ii) the averages are based on very diverse environments. Space limitations preclude an in-depth treatment of the individual environment data in this report: complete data are available at <http://barleyworld.org/wintermalting.php>. In the past, Oregon winter six-rows have been described as “too plump”. A notable feature in the online data are the low plumps (but high test weights) that were obtained at Corvallis and Pendleton in the 2009 harvest. The 2009 data reveal that high temperatures at anthesis and a short grain filling season can “pucker up” an otherwise too-plump six-row.

Winter hardiness: Winter hardiness is a very difficult trait to measure. In many years and at many target production locations, there is 100% survival. This indicates that our germplasm has commercial potential in these target environments and would be eligible for the new crop insurance packages for winter barley that are available. There are years and locations where there is 100% mortality, e.g. Fairfield, Montana in 2008-2009. Montana, North

Dakota and Minnesota are strong spring barley states but not likely prospects for immediate conversion to winter barley. Longer term, this may be feasible due to (i) genetic improvement in cold tolerance, and (ii) changes in agronomic practices to maximize the likelihood of winter survival, and (iii) climate change. When winter injury occurs, rankings are not always consistent (Table 3), underscoring the need for as many environments of testing as possible. Overall, the Oregon selections have levels of winter hardiness similar, or close to, Eight - Twelve. In the Oregon germplasm, we have emphasized facultative growth habit (meaning their maturity is comparable to spring barley under spring-sown conditions) whereas Eight-Twelve and Charles are both vernalization sensitive (meaning that they are much later than spring barley under spring-sown conditions). We will fully characterize the facultative trait in the summer of 2010, in collaboration with Kevin Smith (University of Minnesota), via the EBTG project.

Agronomics: As shown in Table 4A and 4B, the yield potential of winter barley is impressive. OR76 and OR81 are agronomically competitive. Oregon selections have excellent grain sizing, although as mentioned earlier in this report, excessive plumpness is not always perceived as desirable in a six-row. Average data give an overall idea of potential, but meaningful comparisons can only be made for target environments. The attentive and interested reader is referred to the online data at <http://barleyworld.org/wintermalting.php>. The cause of achieving the potential of winter malting barley would be well-served by a winter barley nursery that included germplasm from all interested programs (including those based in Europe) that would be grown at a range of representative locations. We will work with Kevin Smith (University of Minnesota), who is also keen on this idea, to make this nursery a reality in 2010-2011.

Disease resistance: OR76, OR81, OR813, and OR818 are all resistant to stripe rust and moderately susceptible to scald (Table 5 and 6). Charles is apparently resistant to stripe rust. However, this observation needs to be confirmed in the absence of scald. At Corvallis it was not possible to rate stripe rust accurately on Charles because the intense scald infection leaves no green tissue for the rust to attack.

Table 1. Pedigrees of Oregon numbered lines that will be submitted to the AMBA Pilot Scale Program in 2010.

| Oregon numbered lines | Selection History | Pedigree |
|------------------------------|---------------------------------------|----------------------------------|
| OR76 | Stab47/Kab51-20 | Stab 47/Kab 51 |
| OR81 | Stab113-08_2_8_FP_RS | Strider/88Ab536 |
| OR813 | Stab47/Kab 51-20 OR76-075 | Stab47/Kab 51 |
| OR818 | Bu 27/Stab 47(F1)/3/Maja/Stab 47-49-4 | Bu 27/Stab 47(F1)/3/Maja/Stab 47 |

Table 2A. Malting quality data for OSU winter six-row malting lines and check varieties. Data are averages of 2005, 2006, 2007, and 2008 crop years from multiple locations; malt data were generated by the CCRU.

| Variety/ Selection | Plump seed (% on 6/64) | Malt Extract (%) | Barley Protein (%) | Wort Protein (%) | S/T (%) | DP (°ASBC) | Alpha amylase (20°DU) | Beta-glucan (ppm) |
|---------------------------|-------------------------------|-------------------------|---------------------------|-------------------------|----------------|-------------------|------------------------------|--------------------------|
| Charles | 98.2 | 82.9 | 11.4 | 5.2 | 49.1 | 119.2 | 93.1 | 129.6 |
| | 2* | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| OR76 | 91.7 | 80.1 | 11.7 | 4.7 | 42.1 | 124.2 | 67.1 | 172.3 |
| | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| OR81 | 81.0 | 80.9 | 10.6 | 4.3 | 42.4 | 121.6 | 52.4 | 97.4 |
| | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |

* # station years

Table 2B. Malting quality data for OSU winter six-row malting lines and check varieties. Data are averages of 2008 crop from multiple locations; malt data were generated by the CCRU.

| Variety/ Selection | Plump seed (% on 6/64) | Malt Extract (%) | Barley Protein (%) | Wort Protein (%) | S/T (%) | DP (°ASBC) | Alpha amylase (20°DU) | Beta-glucan (ppm) |
|---------------------------|-------------------------------|-------------------------|---------------------------|-------------------------|----------------|-------------------|------------------------------|--------------------------|
| Charles | 92.3 | 79.9 | 10.6 | 4.5 | 43.4 | 120.8 | 74.1 | 296.8 |
| | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| OR813 | 97.7 | 81.7 | 11.4 | 4.6 | 42.8 | 109.9 | 76.8 | 123.6 |
| | 3* | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| OR818 | 94.8 | 80.4 | 10.5 | 4.6 | 45.6 | 122.6 | 78.2 | 220.4 |
| | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

* # station years

Table 3. Winter survival data for Oregon winter malting barley selections compared to checks

| Variety/ Selection | Winter survival (%) Hermiston , Oregon 2010* | Winter survival (%) Pullman, Washington 2009** | Winter survival (%) Pullman, Washington 2008 | Winter survival (%) Pendleton, Oregon 2007 | Freeze test survival (%) at -13.5°C Martonvasar, Hungary 2007 |
|-------------------------------|-------------------------------------------------------------------------|---------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| Charles | 93 | 83 | 90 | NA | NA |
| Eight-Twelve | 100 | 95 | 93 | 66 | 82 |
| OR76 | 100 | 93 | 97 | 78 | 93 |
| OR81 | 100 | 93 | 95 | 66 | 78 |
| OR813 | 100 | 95 | NA | NA | NA |
| OR818 | 93 | 83 | NA | NA | NA |

*Hermiston, OR 2010 Feb 2, 2010 average of 3 reps

**Pullman, WA 2009 average of 3 reps

Aberdeen, ID 2009 no differential reported

Pendleton 2008, 2009 no differential reported

Table 4A. Agronomic data summary for Oregon winter malting barley selections compared to checks for Pendleton (OR), 2008 and 2009, Pullman (WA), 2009, Aberdeen (ID), 2009 and Corvallis (OR), 2009.

| Variety/ Selection | Yield (lbs/A) | Plump seed (% on 6/64) | Test weight (lbs/bu) | Heading (days > Jan. 1) | Height (in) | Lodging (%) |
|---------------------------------------|--------------------------|-----------------------------------|---------------------------------|-------------------------------------------|------------------------|------------------------|
| OR818 | 6235 A | 80 ABC | 53 A | 142 A | 39 B | 0 A |
| OR81 | 6167 A | 67 BC | 53 A | 140 AB | 38 B | 13 A |
| Charles | 6008 A | 91 A | 50 AB | 140 AB | 33 C | 10 A |
| OR813 | 5812 A | 80 ABC | 53 A | 137 B | 43 A | 6 A |
| OR76 | 5766 A | 88 AB | 53 A | 137 B | 41 A | 0 A |
| Eight-Twelve | 5251 A | 62 C | 48 B | 140 AB | 37 B | 5 A |
| <i>Number of Environments</i> | 5 | 5 | 5 | 3* | 4** | 4** |
| <i>LSD ($\alpha=0.05$)</i> | 1267 | 21 | 4 | 5 | 2 | 16 |

*Data from Pendleton 2008 and 2009 N/A

**Data from Aberdeen 2009 N/A

Table 4B. Agronomic data summary for Oregon winter malting barley selections compared to checks for 2005-2009. Data from Corvallis and Pendleton (Oregon); Pullman (Washington); and Aberdeen, Filer, Parma (Idaho).

| Variety/ Selection | Yield (lbs/A) | Plump seed (% on 6/64) | Test weight (lbs/bu) | Heading (days > Jan. 1) | Height (in) | Lodging (%) |
|-------------------------------|--------------------------|-----------------------------------|---------------------------------|-------------------------------------------|------------------------|------------------------|
| OR818 | 6542 | 83 | 53 | 140 | 39 | 0 |
| | 7* | 7 | 6 | 5 | 6 | 4 |
| OR81 | 6257 | 76 | 53 | 138 | 38 | 15 |
| | 15 | 15 | 14 | 12 | 13 | 9 |
| OR76 | 6232 | 90 | 53 | 134 | 42 | 8 |
| | 15 | 15 | 14 | 12 | 13 | 9 |
| Eight-Twelve | 6022 | 67 | 49 | 138 | 36 | 8 |
| | 15 | 15 | 14 | 11 | 13 | 10 |
| OR813 | 5757 | 85 | 53 | 136 | 45 | 6 |
| | 7 | 7 | 7 | 5 | 6 | 4 |
| Charles | 5673 | 90 | 50 | 143 | 32 | 8 |
| | 8 | 6 | 6 | 6 | 5 | 5 |

* # station years

Table 5. Stripe rust (% disease severity) for Oregon winter malting barley selections compared to checks.

| Barley stripe rust (% disease severity) | | | | | | | | | | | | | |
|------------------------------------------------|-------------|-------------|--------------------|-----------------------------|------------------------------|------------------------------|---------------------|-----------------------------|------------------------------|---------------------|---------------------|-------------|----------------|
| Corvallis | | | | | | | | | | | | | |
| | 2006 | 2007 | 2008 | 2008 | 2008 | 2008 | 2008 | 2008 | 2008 | 2008 | 2009 | 2009 | Average |
| | | | OBYT CB | Tapa fria CB | Tapa fria Vrn | AMBA DS 1-13E | CAP11 CB | CAP11 2-8 YT | CAP11 2-12 YT | OBELT YT | OBELT CB | | |
| Eight-Twelve | 93 | 30 | 10 | 40 | 15 | NA | NA | NA | NA | 83 | 80 | 46 | |
| Charles | NA | NA | 0 | 5 | 5 | 0 | 0 | 1 | 0 | 23 | 20 | 6 | |
| OR 76 | 3 | 30 | 5 | 5 | 0 | 0 | NA | NA | NA | 5 | 0 | 3 | |
| OR81 | 6 | 10 | 10 | 10 | 0 | NA | NA | 10 | 0 | 0 | 5 | 5 | |
| OR813 | NA | NA | NA | NA | NA | NA | 0 | 1 | 0 | 15 | 0 | 3 | |
| OR818 | NA | NA | NA | NA | NA | NA | 0 | 1 | 0 | 0 | 0 | 0 | |

Table 6. Scald (1 – 9 scale) for Oregon winter malting barley selections compared to checks.

| Scald (1 = resistant; 9 = lesions on flag leaf) | | | | | | | | | | | | |
|--------------------------------------------------------|-------------|-------------|-------------|--------------|--------------|--------------|--------------|--------------|--------------|-------------|-------------|----------------|
| Corvallis | | | | | | | | | | | | |
| | OBYT | Tapa | Tapa | AMBA | CAPII | CAPII | CAPII | OBELT | OBELT | | | |
| | CB | fria | fria | DS | CB | 2-8 | 2-12 | YT | CB | | | |
| | | CB | Vrn | 1-13E | | YT | YT | | | | | |
| | 2006 | 2007 | 2008 | 2008 | 2008 | 2008 | 2008 | 2008 | 2008 | 2009 | 2009 | Average |
| Eight-Twelve | 7 | 9 | 6 | 5 | 6 | NA | NA | NA | NA | 2 | 4 | 5 |
| Charles | NA | NA | 7 | 8 | 9 | 9 | 4 | 6 | 9 | 6 | 1 | 7 |
| OR 76 | 7 | 5 | 5 | 4 | 4 | 7 | NA | NA | NA | 1.5 | 1 | 4 |
| OR81 | 5 | 8 | 4 | 3 | 6 | NA | NA | 4.2 | 5.8 | 0 | 1 | 3 |
| OR813 | NA | NA | NA | NA | NA | NA | 4 | 3 | 6 | 1.5 | 1 | 3 |
| OR818 | NA | NA | NA | NA | NA | NA | 4 | 4 | 6 | 1 | 0 | 3 |

Table 7. 2009/2010 Oregon winter barley nurseries.

OSU AMBA Drill strips

(Charles, OR76, OR81, OR813, OR818)

- Corvallis, Oregon
- Pendleton, Oregon
- Hermiston, Oregon
- Aberdeen, Idaho
- Rupert, Idaho
- Pullman, Washington

OSU elite lines and checks - screening trials

- International
 - Achermann & Co. KG, Germany (11 lines)
 - Cereal Breeding Research Darzau, Germany (3 lines)
 - Zaragoza Spain (OFADV, 30 lines and 4 Elite lines)
 - Winnipeg, MB, Canada (3 lines)
- Domestic
 - Rupert, ID (5 OBELT Elites, 4 AMBA DS)
 - Lawrence, KS (OR76, OR81)
 - St. Paul, MN (30 lines)
 - Logan, UT (11 lines, 3 forage Elites)
 - Washington Island, WI (Elite Bulk)
 - Brooktondale, NY (OR76)
 - St. Paul, MN (OR76, OR77, OR81)
 - Moro, OR (10 OBELT Elite Lines)

OSU-CAPIII; 96 entries; Oregon 2009 CAPIII Lines

Other locations: Food Quality with Mitch Wise, USDA Madison, WI; LOX, and Beta glucanase with Paul Schwarz, NDSU; Food Quality with Byung-Kee Baik, WSU, Pullman, WA; Septoria, Spot Blotch, and Stem Rust (UG99) Screen with Brian Steffenson, UMN, St Paul, MN; Leaf Rust Screen with Carl Griffey, VT, Blacksburg, VA

OSU-CAPIV; 96 entries

Other locations: Septoria, Spot Blotch, and Stem Rust (UG99) Screen with Brian Steffenson, UMN, St Paul, MN

OSU-CAPIV Winters; 100 entries

- Corvallis, OR 3 rep, Lattice Design, 100 entries
- Pendleton, OR 3 rep, Lattice Design, 100 entries
- Hermiston, OR 3 rep, Lattice Design, 100 entries

Tapa Fria; 37 entries; European varieties and checks

- Corvallis, Fall 1 rep, Observation Crossing Block

OBELT; 30 entries

- Corvallis, OR Fall 1 rep, Observation Crossing Block
- Corvallis, OR Spring 2 rep, Observation Crossing Block
- Corvallis, OR Fall 3 rep, Lattice
- Pendleton, OR 3 rep, Lattice
- Hermiston, OR 3 rep, Lattice
- Aberdeen, ID 3 rep, Lattice
- Pullman, WA 3 rep, Lattice
- Ft. Collins, CO 3 rep, Lattice
- MT (BARI) 3 rep, Lattice
- Mt. Vernon, WA 3 rep, Lattice
- Bozeman, MT 3 rep, Lattice
- Wooster, OH 3 rep, Lattice

OBADV; 30 entries; selections from Round2PYT and CAP III

- Corvallis 3 rep, Lattice
- Pendleton 3 rep, Lattice
- Ft. Collins, CO 3 rep, Lattice
- Pullman, WA 3 rep, Lattice
- Aberdeen, ID 3 rep, Lattice

OFADV; 30 entries; selections from Round2PYT and CAP III

- Zaragoza, Spain 3 rep, Lattice
- Aberdeen, ID 3 rep, Lattice

OBPYT; 54 entries; selections from F4 Head Rows

- Pendleton, OR Augmented
- Corvallis, OR Observation head rows

Food Bar PYT

- Pendleton, 25 ent 3 rep, Lattice

Organic Yield Trial 3 entries, 5 treatments (4 companion crops plus control, split-plot design with 3 reps)

- Corvallis, OR – Hyslop Farm
- Corvallis, OR - East Farm
- Pendleton, OR

ORNE DH Yield trial; 36 entries

- Corvallis, OR 3 rep, Lattice

ORNE SSD MAS Exp. 1 NB018199/OR76//OR76; 240 entries

Lincoln, NE 2 rep, Lattice

ORNE SSD MAS Exp. 2 NB03437/OR76//OR76; 240 entries

Lincoln, NE 2 rep, Lattice

ORNE DH; 240 entries

Lincoln, NE 2 rep, Lattice

Early generation segregating Trial from F2's

- Pendleton, OR Malt F2 55 entries
- Wooster, OH Malt F2 55 entries
- Pendleton, OR Food 62 entries

Head Rows (all at Corvallis)

- F3 Head Rows, 15 entries, 36 rows per entry
- F3 Head Rows, 57 entries, 72 rows per entry
- F4 Head Rows, 248 entries, variable rows per entry

31 Malting 6 Row F1 crosses (Corvallis)

15 Malting 2 Row F1 crosses (Corvallis)

11 Food F1 crosses (Corvallis)

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:

Basic research:

- Genetic dissection of malting quality
- Winter hardiness physiology and genetics
- Association mapping
- Genetic dissection of quantitative resistance to barley stripe rust
- Mining drought tolerance genes from *Hordeum vulgare* subsp. *spontaneum*

Applied research

- Winter barley for human nutrition
- Hooded forage barley

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

Project Personnel

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