**Project Title:** Accelerated development of two-row facultative/winter malting barley

# Researchers: Dr. Patrick Hayes, Mr. Scott Fisk, Ms. Laura Helgerson, Dr. Brigid Meints, Ms. Tanya Filichkin

# Department: Crop and Soil Science

# Institution: Oregon State University, Corvallis, OR 97331

**Executive Summary**

In order to assist AMBA in meeting its mission and to realize its primary objectives, at OSU we develop facultative/winter doubled haploid 2-row covered malting barley varieties. The emphasis is on facultative, but all good winters will be given full opportunity! These varieties will provide the malting and brewing industries with an abundant supply of high quality malting barley meeting the quality specifications of AMBA members. Recognizing the different specifications required by adjunct and all-malt brewers, we are developing both types of varieties. These varieties will have outstanding yield potential, making them attractive alternatives to competing crops. Our work is conducted within a larger framework of developing doubled haploid molecular breeding tools that will benefit all barley breeders working to advance the AMBA causes of mitigating risks and increasing acceptance rates.

The major issue for the OSU program is ensuring rapid and efficient development of facultative/winter 2-row malting barley varieties. Our major objectives are to use doubled haploids, molecular breeding tools, and collaborative phenotyping to quickly and efficiently address this issue.

*One-year objectives and outputs:*

* Submit promising new varieties to the AMBA approval system: ORW1-- a winter-- is in the AMBA Plant Scale program, following a successful seed increase in Idaho under the auspices of Great Western Malting (2017 crop). Commercial malt results are expected within spring 2018. Foundation seed, with an experimental designation, was planted in the fall of 2017. ORW2 is shelved for now, as ORW1 appears to have the greatest agronomic benefit. As shown in Table 2, we have two submissions in the AMBA Pilot program (2017 crop) and drill strips of four potential submissions are planted at cooperating locations (2018 crop). These selections are included in the 2017-2018 Winter Malting Barley Trial and/or Winter Barley Germplasm Nursery.
* Develop new germplasm: We generated new facultative/winter doubled haploids and advanced them to regional/advanced/preliminary trials. The agronomic and malting quality profiles of these selections are promising.
* Targeting facultative growth habit: We systematically characterize facultative growth habit of elite breeding material in the greenhouse and in spring-sown plantings.
* Develop germplasm meeting all-malt brewer specifications: Developed doubled haploids specifically to meet these quality specifications.
* Doubled haploid collaborations: The DH production facility is now focused on the needs of the US Wheat and Barley Scab Initiative (USWBSI) and the Small Grains Genomics Initiative (SGGI) and our own program needs.

*Most significant accomplishments:*

* Moving ORW1 towards release as a variety.
* Two doubled haploids (one winter, one facultative) submitted for AMBA evaluation (2017 crop) and assessment in regional nurseries (2018 crop).
* Four additional doubled haploids in the AMBA Western Winter Barley Pilot Scale Nursery at cooperating locations for possible submission to the AMBA Pilot Program (2018 crop) and assessment in regional nurseries (2018 crop).
* Development of lodging resistant and semi-dwarf growth habit facultative/winter 2-row malting barleys.
* Systematic introgression of European winter 2-row malting barley alleles into U.S.-adapted germplasm.
* Generating interest in winter/facultative barley throughout the barley research and production communities.

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

***Objectives and Expected Benefits:***

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

***Methodology:***

* All germplasm is doubled haploid.
* Corvallis, OR is our principal test site. As germplasm advances, it is tested regionally, nationally, and internationally. The 2017/2018 nurseries are summarized in Table 1.
* Malting quality assessments are conducted by the USDA/ARS and Dr. Cynthia Henson and colleagues collaborate on additional quality assays. Great Western Malting, Canada Malting, and Rahr Malting provides additional malting quality data on special projects and selections. The OSU Malthouse is online and is playing an increasingly important role in generating malts on elite breeding lines and potential varieties.
* Progress in our program depends on extensive collaboration. Kevin Smith at University of Minnesota is a key cooperator for providing winterhardiness data, as is Steve Baenziger at University of Nebraska-Lincoln. Mark Sorrells, Cornell University, tests for winterhardiness and scab resistance. Gongshe Hu (USDA/ARS; Aberdeen, Idaho) provides data from Aberdeen, Idaho and satellite locations. Juliet Marshall includes our advanced lines in the Idaho Extension nurseries. Kevin Murphy at Washington State University grows our material at Pullman, Washington. David Hole, Utah State University, screens varying numbers of lines at Logan, Utah. We exchange germplasm with European companies.

***Results:***

In the interest of space, in this report we provide only summary data on our AMBA Pilot Scale submissions and potential AMBA submissions in the AMBA Western Winter Barley Pilot Scale Nursery being grown throughout the Pacific Northwest.

As shown in Table 2, Full Pint figures in the pedigrees of four submissions. Full Pint was selected as a parent in order to develop facultative types with simultaneous opportunities to select for disease resistance, lodging resistance, and for non-production of epiheterodendrin (EPH). EPH non-producers are sought by distillers for their low/no glycosidic nitrile content. There are two non-producers in the set. One (DH140963) has not been tested for EPH, but based on parentage it is likely a producer. Two of the selections are in the AMBA Pilot program (2017 crop). DH130939 is in a second year of assessment. The 2016 crop sample was rated unsatisfactory, but a second year of testing was allowed. DH120304 is a first year submission: this selection may be of particular interest since both parents are reported to make unique contributions to beer flavor. All of the six selections are in regional nurseries: the nursery organizers specifically request that entries not be duplicated across nurseries.

Tables 3 – 8 show all available data for each of the selections compared to the checks – Endeavor and Wintmalt. Integrating information from these tables, all of the selections have a clear yield advantage (a minimum of 20 bushels/acre) over both checks. All selections have excellent kernel plumpness. Lodging is better or equal to the checks, as is resistance to stripe rust. There are substantial improvements in scald tolerance. Winter survival is equal, or comparable, to the checks except for DH130939, which is better than Endeavor but 9% lower than Wintmalt.

In terms of malting quality, all selections meet grain protein and malt specifications for adjunct, all-malt, and distillers 2-row. Malt extracts are generally better than the highest check and always higher than Wintmalt. Four of the selections are within adjunct or all malt specifications for S/T; DH120304 and DH131679 are above the adjunct and all-malt specs but meet the distillers specification. All selections, except DH140963, meet the diastatic power specifications for adjunct and all-malt 2-row. DH140963 reaches the minimum specification for all-malt 2-row. This selection, with a bit more modification could surpass the minimum specification for diastatic power. Alpha amylase values are high for all selections, except for DH140963, which is within the all-malt specification. Beta glucans are within specifications, or nearly so, except for DH130939. To its credit, this selection does have a lower beta glucan than the Endeavor check. All selections meet or are nearly at FAN specifications for adjunct 2-row, except for DH140693, which is within the all-malt specification. In summary, no selection meets all criteria for distillers malt – although DH120304, DH130910, and DH 131679 could likely break through the diastatic power bar and achieve truly impressive yields with higher nitrogen fertilization. The most promising selections for the all-malt category are DH130910 and DH140963. Additional data are needed to determine the potential of these selections for adjunct 2-row; so far most indicators are positive for this application and the potential yields could justify the additional assessments and evaluations.

Table 9 shows malting quality and agronomic data on the selections and checks from the 2016-2017 trials grown in the Willamette Valley of Oregon: while limited in scope, these results show the potential of the selections.

We are pursuing field trialing of facultative types under spring-planted conditions for those selections accepted into the AMBA pilot program from fall-planted trials. The preliminary data obtained to date are encouraging. The potential to fall-plant or spring-plant the same variety would be a powerful tool to deal with the vagaries of climate change.

**Other Barley Research and Future Direction of Program**

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

* Higher resolution analysis of the components of facultative growth habit.
* Testing the hypothesis that barley can contribute to beer flavor.
* The Barley World malt-house, producing ~ 200 lb. batches of malt from advanced lines and new varieties.
* Multi-use naked barley.
* Genetic dissection of quantitative resistance to barley stripe, leaf, and stem rust and deployment of resistance genes in adapted germplasm.

The Oregon Barley Program will continue its dual roles of stimulating economic development and contributing to the body of fundamental knowledge.

**Project Personnel**

##### Patrick Hayes, Professor

* Brigid Meints, Post-Doc
* Tanya Filichkin, Senior Research Assistant
* Scott Fisk, Research Assistant
* Laura Helgerson, Research Assistant

**Graduate students**

* Javier Hernandez, Graduate Research Assistant (PhD). Thesis research focuses on facultative growth habit and resistance to multiple rusts.

**Publications (2017-2018)**

1. Hisano, H., B. Meints, M.J. Moscou, L.Cistue, B.Echávarri, K.Sato and P. M. Hayes. 2017. Selection of transformation efficient barley genotypes based on *TFA* (transformation amenability)haplotype and higher resolution mapping of the *TFA* loci. Plant Cell Reports. DOI 10.1007/s00299-017-2107-2.
2. Castro, A., A. Cuesta-Marcos, P. Hayes, A.Locatelli, M. Macauly, N. Mastandrea, M. Silveira, W. Thomas, and L. Viega. 2017. The completely additive effects of two barley phenology related genes (*eps2S* and *sdw1*) are explained by specific effects at different periods within the crop growth cycle. Plant Breeding. DOI: 10.1111/pbr.12509
3. Herb, D.W., Meints, B.M., Jennings, R., Romagosa, I., Moscou, M., Carey, D., Cistue, L., Filichkin, T, Fisk, S.P., Helgerson, L., Martens, C., Monsour, R., Thiel, R., Tynan, S., Thomas, W.T.B., Vinkemeier, K., Hayes, P.M. 2017. Effects of Barley (*Hordeum vulgare* L.) variety and growing environment on beer flavor. J. Amer. Soc. Brew. Chem. 75:345-353,
4. Herb, D.W., Benson, A., Carey, D., Cistue, L., Filichkin, T, Fisk, S.P., Helgerson, L., Jennings, R., Li, Y., Meints, B.M., Monsour, R., Moscou, M., Nguygen, A., Onio, A., Romagosa, I., Thiel, R., Thomas, W.B., Tynan, S.P., Vega, V., Vinkemeier, K., Hayes, P.M. 2017. Malt modification and its effects on the contributions of barley genotype to beer flavor. J. Amer. Soc. Brew. Chem*.* 75:354-362
5. Belcher, A.R., A. Cuesta-Marcos, K.P. Smith, C.C. Mundt, X. Chen, and P. M. Hayes. 2018. TCAP FAC-WIN 6 elite barley GWAS panel QTL. I. Barley stripe rust (*Puccinia striiformis* f.sp. *hordei*) resistance QTL in facultative/winter 6-rowed malt barley breeding programs identified via genome-wide association studies. Crop Sci. 58:103-119
6. Belcher, A.R., A. Cuesta-Marcos, K.P. Smith, and P. M. Hayes. 2018. TCAP FAC-WIN 6 elite barley GWAS panel QTL. II. Malting quality QTL in elite North American facultative/winter 6-rowed barley identified via genome-wide association studies. Crop Sci. 58:120-132.
7. Meints, B., A. Corey, C. Evans, T. Filichkin, S. Fisk, L. Helgerson, A.S. Ross, and P. M. Hayes. 2018. Registration of ‘Buck’ Naked Barley, J. Plant Reg.12:1-6.

**Table 1. Oregon State University barley nurseries: 2017-2018.** The summary is divided into “Malting”, “Naked” and “Genetics”. Malting types are all covered and that is the focus of AMBA and Great Western funding. We view naked types as having multiple uses (malt, food, and feed), but research on the naked class is funded by other sources.

**Malting Barley**

***Overview:***

***Number of advanced and fixed lines: 982***

* 247 in yield trial plots
* 735 in single rows or mini-plots (doubled haploids)

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

* 36 F1s

***Details:***

***Oregon Winter/Facultative Barley Elite Yield Trial***

* Corvallis, OR Fall-planted 30 entries, 3 rep, RCBD
* Lebanon, OR Fall-planted 30 entries, unreplicated w/checks
* Logan, UT Fall-planted 30 entries
* Aberdeen, ID Fall-planted 30 entries
* Wooster, OH Fall-planted 30 entries
* Rupert, ID Fall-planted 30 entries
* Ithaca, NY Fall-planted 30 entries
* West Lafayette, IN Fall-planted 30 entries
* Blacksburg, VA Fall-planted 30 entries
* St. Paul, MN Fall-planted 30 entries

***Oregon Malting Barley Advanced Line Yield Trial***

* Corvallis, OR Fall-planted 39 entries, 2 rep, RCBD
* Lebanon, OR Fall-planted 39 entries, unreplicated w/checks

***Oregon Malting Barley Preliminary Yield Trial***

* Corvallis, OR Fall-planted 64 entries, unreplicated w/checks

***Oregon Malting Barley Mini-Plot Preliminary Yield Trial***

* Corvallis, OR Fall-planted 130 entries, unreplicated w/checks

***Romp of Otters Yield Trial***

* Corvallis, OR Fall-planted 12 entries, 2 rep, RCBD
* Lebanon, OR Fall-planted 12 entries, unreplicated w/checks

***Winter Malting Barley Trial (US and International Cooperators)***

* Corvallis, OR Fall-planted 27 entries, 3 rep, RCBD

***Winter Barley Germplasm Nursery (US Cooperators)***

* Corvallis, OR Fall-planted 20 entries, 3 rep, RCBD

***AMBA Drill Strips***

* Corvallis, OR Fall-planted 13 entries (OSU & USDA-ARS)
* Lebanon, OR Fall-planted 13 entries (OSU & USDA-ARS)
* Aberdeen, ID Fall-planted 13 entries (OSU & USDA-ARS)
* Filer, ID Fall-planted 13 entries (OSU & USDA-ARS)

***Purification Head Rows***

* Corvallis, OR Fall-planted 13 entries

***Malt Doubled Haploid Mini-Plots***

* Corvallis, OR Fall-planted 422 entries, unreplicated w/checks

***Malt Doubled Haploid Single Rows***

* Corvallis, OR Fall-planted 183 entries, unreplicated w/checks

***Malt F1s***

* Corvallis, OR Fall-planted 36 entries

***Spring/Facultative Malting Barley Yield Trial***

* Lebanon, OR\* Spring-planted 45 entries, unreplicated w/checks

***Oregon Promise Yield Trial***

* Lebanon, OR\* Spring-planted 10 entries, 3 rep, RCBD
* Madras, OR\* Spring-planted 10 entries, 2 rep, RCBD
* Lostine, OR\* Spring-planted 12 entries, 2 rep, RCBD

***World Core Exotic Flavor Drill Strips***

* Lebanon, OR\* Spring-planted 4 entries

\*Not yet planted as of 2/22/18

**Naked Barley**

***Overview:***

***Number of advanced and fixed lines: 281***

* 31 in yield trial plots
* 250 in single rows

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

* 36 F2s

***Details:***

***OREI Fall Regional Yield Trial (Organic)***

* Corvallis, OR Fall-planted 20 entries, 3 rep, RCBD
* LaConner, WA Fall-planted 20 entries
* St. Paul, MN Fall-planted 20 entries
* Mt. Vernon, WA Fall-planted 20 entries
* Ithaca, NY Fall-planted 20 entries
* Madison, WI Fall-planted 20 entries

***Observational Drill Strips/Seed Increase***

* Corvallis, OR Fall-planted 5 entries

***Purification Head Rows***

* Corvallis, OR Fall-planted 10 entries

***Naked Multi-use Barley F2s***

* Corvallis, OR Fall-planted 36 entries

***BB99 Drill Strips***

* Lebanon, OR\* Spring-planted 3 entries
* Lostine, OR\* Spring-planted 3 entries

***OREI Spring Regional Yield Trial (Organic)***

* Corvallis, OR\* Spring-planted 20 entries, 3 rep, RCBD
* Pullman, WA\* Spring-planted 20 entries, 3 rep, RCBD
* St. Paul, MN\* Spring-planted 20 entries, 3 rep, RCBD
* Mt. Vernon, WA\* Spring-planted 20 entries, 3 rep, RCBD
* Ithaca, NY\* Spring-planted 20 entries, 3 rep, RCBD
* Madison, WI\* Spring-planted 20 entries, 3 rep, RCBD

***OREI Naked Barley Diversity Panel (Organic)***

* Corvallis, OR\* Spring-planted 250 entries, Type-2 Modified Aug. Design
* St. Paul, MN\* Spring-planted 250 entries, Type-2 Modified Aug. Design
* Mt. Vernon, WA\* Spring-planted 250 entries, Type-2 Modified Aug. Design
* Ithaca, NY\* Spring-planted 250 entries, Type-2 Modified Aug. Design
* Madison, WI\* Spring-planted 250 entries, Type-2 Modified Aug. Design

\*Not yet planted as of 2/22/17

**Genetics**

***Overview:***

***Number of advanced and fixed lines: 1248***

* 1248 in single rows

***Details:***

***Barley Stripe Rust Nursery (Corvallis); Spring-planted***

* Barley Stripe Rust Screening Trial 60 entries, 2 rep, RCBD
* 95SR316A/Lenetah Population 350 entries, 2 rep, RCBD
* Uniform Barley Winter-hardiness Nursery 28 entries, 2 rep, RCBD
* Bison 1H x Baronesse 42 entries, 2 rep, RCBD

***AMBA Low Temperature Tolerance Doubled Haploid Cooperative***

* Corvallis, OR Spring-planted 397 entries, 2 rep, RCBD

***Multi-Rust Cycle 2 Doubled Haploid Germplasm Array***

* Corvallis, OR Winter-planted 371 entries, 2 rep, RCBD

**Other**

***Adaptive Symbiotic Technologies Drill Strips***

* Corvallis, OR Spring-planted 2 entries, 2 Trtmnts, 4 rep
* Corvallis, OR Spring-planted (Organic) 1 entry, 3 Trtmnts, 6 rep

Table 2.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Selection** | **Pedigree** | **Growth Habit** | **EPH** | **AMBA Status** | **Regional Trial Submissions** |
| DH130939 | Full Pint/Violetta | Facultative | Non-Producer | Pilot Submission 2017 Crop (Second Year) | WMBT 2016-17, 2017-18 |
| DH120304 | Maris Otter/Full Pint | Winter | Producer | Pilot Submission 2017 Crop (First Year) | WMBT 2017-18 |
| DH130910 | Short11-7/Herz 29494/2991 | Facultative | Producer | Potential Pilot Submission 2018 Crop (First Year) | WMBT 2016-17, 2017-18 |
| DH140088 | Violetta/Charles//Full Pint | Facultative | Non-Producer | Potential Pilot Submission 2018 Crop (First Year) | WMBT 2017-18 |
| DH131679 | Full Pint/Violetta | Winter | Producer | Potential Pilot Submission 2018 Crop (First Year) | WBGN 2016-17, 2017-18 |
| DH140963 | 04\_028\_36/Archer | Winter | ? | Potential Pilot Submission 2018 Crop (First Year) | WBGN 2017-18 |

Table 3.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Kernel** | **Grain** | **Malt** | **Wort** |  | **Diastatic** | **Alpha** | **Beta-** |  |  |  | **Plant** | **Winter** |  |  |
|  | **Plumpness** | **Protein** | **Extract** | **Protein** | **S/T** | **Power** | **Amylase** | **Glucan** | **FAN** | **Yield** | **Lodging** | **Height** | **Survival** | **BSR** | **Scald** |
|  | **(on 6/64")** | **(%)** | **(%)** | **(%)** | **(%)** | **(°L)** | **(20° DU)** | **(ppm)** | **(ppm)** | **bu/acre** | **(1-9†)** | **Inches** | **(%)** | **(%)** | **(%)** |
| STA. YRS. | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 8 | 7 | 8 | 5 | 7 | 7 |
| DH130939 | 97.2 | 11.4 | 82.4 | 5.04 | 46.9 | 151 | 105.2 | 130 | 259.4 | 142 | 1 | 40 | 76 | 3 | 18 |
| *Endeavor* | 77.6 | 10.5 | 81.7 | 4.86 | 50.8 | 167 | 104.0 | 182 | 236.5 | 105 | 3 | 39 | 67 | 2 | 72 |
| *Wintmalt* | 95.5 | 10.5 | 81.0 | 4.02 | 41.2 | 143 | 56.8 | 71 | 170.1 | 110 | 2 | 38 | 85 | 5 | 48 |

Table 4.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Kernel** | **Grain** | **Malt** | **Wort** |  | **Diastatic** | **Alpha** | **Beta-** |  |  |  | **Plant** | **Winter** |  |  |
|  | **Plumpness** | **Protein** | **Extract** | **Protein** | **S/T** | **Power** | **Amylase** | **Glucan** | **FAN** | **Yield** | **Lodging** | **Height** | **Survival** | **BSR** | **Scald** |
|  | **(on 6/64")** | **(%)** | **(%)** | **(%)** | **(%)** | **(°L)** | **(20° DU)** | **(ppm)** | **(ppm)** | **bu/acre** | **(1-9†)** | **Inches** | **(%)** | **(%)** | **(%)** |
| STA. YRS. | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 1 | 6 | 6 |
| DH120304 | 96.6 | 11.1 | 82.1 | 5.60 | 52.5 | 174 | 84.2 | 48 | 302.7 | 147 | 2 | 44 | 100 | 12 | 1 |
| *Endeavor* | 77.6 | 10.5 | 81.7 | 4.86 | 50.8 | 167 | 104.0 | 182 | 236.5 | 116 | 2 | 38 | 85 | 2 | 70 |
| *Wintmalt* | 95.5 | 10.5 | 81.0 | 4.02 | 41.2 | 143 | 56.8 | 71 | 170.1 | 122 | 1 | 38 | 100 | 6 | 41 |

Table 5.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Kernel** | **Grain** | **Malt** | **Wort** |  | **Diastatic** | **Alpha** | **Beta-** |  |  |  | **Plant** | **Winter** |  |  |
|  | **Plumpness** | **Protein** | **Extract** | **Protein** | **S/T** | **Power** | **Amylase** | **Glucan** | **FAN** | **Yield** | **Lodging** | **Height** | **Survival** | **BSR** | **Scald** |
|  | **(on 6/64")** | **(%)** | **(%)** | **(%)** | **(%)** | **(°L)** | **(20° DU)** | **(ppm)** | **(ppm)** | **bu/acre** | **(1-9†)** | **Inches** | **(%)** | **(%)** | **(%)** |
| STA. YRS. | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 8 | 7 | 8 | 5 | 7 | 7 |
| DH130910 | 98.0 | 11.4 | 81.3 | 4.53 | 41.8 | 167 | 41.9 | 68 | 191.9 | 135 | 2 | 44 | 96 | 3 | 5 |
| Endeavor | 77.6 | 10.5 | 81.7 | 4.86 | 50.8 | 167 | 104.0 | 182 | 236.5 | 105 | 3 | 39 | 67 | 2 | 72 |
| Wintmalt | 95.5 | 10.5 | 81.0 | 4.02 | 41.2 | 143 | 56.8 | 71 | 170.1 | 110 | 2 | 38 | 85 | 5 | 48 |

Table 6.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Kernel** | **Grain** | **Malt** | **Wort** |  | **Diastatic** | **Alpha** | **Beta-** |  |  |  | **Plant** | **Winter** |  |  |
|  | **Plumpness** | **Protein** | **Extract** | **Protein** | **S/T** | **Power** | **Amylase** | **Glucan** | **FAN** | **Yield** | **Lodging** | **Height** | **Survival** | **BSR** | **Scald** |
|  | **(on 6/64")** | **(%)** | **(%)** | **(%)** | **(%)** | **(°L)** | **(20° DU)** | **(ppm)** | **(ppm)** | **bu/acre** | **(1-9†)** | **Inches** | **(%)** | **(%)** | **(%)** |
| STA. YRS. | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 2 | 6 | 6 |
| DH140088 | 98.4 | 11.2 | 81.5 | 4.96 | 46.4 | 132 | 98.1 | 101 | 256.4 | 153 | 1 | 42 | 94 | 2 | 18 |
| *Endeavor* | 77.6 | 10.5 | 81.7 | 4.86 | 50.8 | 167 | 104.0 | 182 | 236.5 | 116 | 2 | 38 | 89 | 2 | 70 |
| *Wintmalt* | 95.5 | 10.5 | 81.0 | 4.02 | 41.2 | 143 | 56.8 | 71 | 170.1 | 122 | 1 | 38 | 99 | 6 | 41 |

Table 7.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Kernel** | **Grain** | **Malt** | **Wort** |  | **Diastatic** | **Alpha** | **Beta-** |  |  |  | **Plant** | **Winter** |  |  |
|  | **Plumpness** | **Protein** | **Extract** | **Protein** | **S/T** | **Power** | **Amylase** | **Glucan** | **FAN** | **Yield** | **Lodging** | **Height** | **Survival** | **BSR** | **Scald** |
|  | **(on 6/64")** | **(%)** | **(%)** | **(%)** | **(%)** | **(°L)** | **(20° DU)** | **(ppm)** | **(ppm)** | **bu/acre** | **(1-9†)** | **Inches** | **(%)** | **(%)** | **(%)** |
| STA. YRS. | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 1 | 4 | 4 |
| DH131679 | 95.0 | 10.8 | 83.2 | 5.40 | 53.7 | 177 | 108.2 | 27 | 284.4 | 155 | 1 | 33 | 100 | 0 | 8 |
| *Endeavor* | 77.4 | 10.2 | 82.2 | 4.78 | 51.8 | 166 | 106.5 | 173 | 239.1 | 116 | 2 | 37 | 85 | 0 | 71 |
| *Wintmalt* | 96.4 | 9.9 | 81.9 | 4.03 | 43.3 | 138 | 58.4 | 61 | 173.2 | 124 | 1 | 37 | 100 | 0 | 49 |

Table 8.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Kernel** | **Grain** | **Malt** | **Wort** |  | **Diastatic** | **Alpha** | **Beta-** |  |  |  | **Plant** | **Winter** |  |  |
|  | **Plumpness** | **Protein** | **Extract** | **Protein** | **S/T** | **Power** | **Amylase** | **Glucan** | **FAN** | **Yield** | **Lodging** | **Height** | **Survival** | **BSR** | **Scald** |
|  | **(on 6/64")** | **(%)** | **(%)** | **(%)** | **(%)** | **(°L)** | **(20° DU)** | **(ppm)** | **(ppm)** | **bu/acre** | **(1-9†)** | **Inches** | **(%)** | **(%)** | **(%)** |
| STA. YRS. | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 3 |
| DH140963 | 98.6 | 10.0 | 82.7 | 3.92 | 41.9 | 111 | 37.3 | 106 | 149.0 | 174 | 1 | 38 | 100 | 0 | 3 |
| *Endeavor* | 81.3 | 10.3 | 82.4 | 4.78 | 51.7 | 161 | 109.0 | 186 | 236.7 | 118 | 1 | 40 | 85 | 0 | 64 |
| *Wintmalt* | 97.1 | 10.1 | 82.3 | 4.16 | 44.9 | 138 | 59.4 | 64 | 173.3 | 120 | 1 | 36 | 100 | 0 | 38 |

Table 9.Malting Quality and Agronomics of OSU AMBA Pilot Scale Candidates from Corvallis & Lebanon, OR 2017.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Kernel** | **Grain** | **Malt** | **Wort** |  | **Diastatic** | **Alpha** | **Beta-** |  |  |  | **Plant** | **Winter** |  |  |
|  | **Plumpness** | **Protein** | **Extract** | **Protein** | **S/T** | **Power** | **Amylase** | **Glucan** | **FAN** | **Yield** | **Lodging** | **Height** | **Survival** | **BSR** | **Scald** |
|  | **(on 6/64")** | **(%)** | **(%)** | **(%)** | **(%)** | **(°L)** | **(20° DU)** | **(ppm)** | **(ppm)** | **bu/acre** | **(1-9†)** | **Inches** | **(%)** | **(%)** | **(%)** |
| STA. YRS. | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| DH130939 | 99.2 | 11.0 | 83.4 | 4.8 | 46.3 | 122.0 | 107.4 | 81.9 | 238.2 | 143 | 1 | 38 | 100 | 0 | 9 |
| DH120304 | 99.0 | 10.4 | 83.1 | 4.9 | 48.5 | 146.6 | 81.5 | 18.7 | 260.7 | 135 | 1 | 42 | 100 | 0 | 1 |
| DH130910 | 99.1 | 10.7 | 82.1 | 4.3 | 42.4 | 142.3 | 42.7 | 45.0 | 177.5 | 153 | 1 | 44 | 100 | 0 | 1 |
| DH140088 | 99.3 | 11.3 | 82.0 | 4.9 | 44.9 | 125.0 | 97.5 | 63.3 | 245.3 | 142 | 1 | 41 | 100 | 0 | 6 |
| DH131679 | 98.1 | 10.1 | 84.3 | 5.0 | 53.0 | 142.9 | 101.6 | 11.5 | 249.0 | 147 | 1 | 30 | 100 | 0 | 14 |
| DH140963 | 99.3 | 9.6 | 83.0 | 3.9 | 43.2 | 104.2 | 36.9 | 90.4 | 147.5 | 161 | 1 | 39 | 100 | 0 | 4 |
| *Endeavor* | 90.6 | 9.6 | 83.1 | 4.4 | 53.8 | 130.3 | 113.0 | 99.8 | 208.3 | 134 | 1 | 41 | 100 | 0 | 53 |
| *Wintmalt* | 98.9 | 10.0 | 82.5 | 4.0 | 43.3 | 133.5 | 62.2 | 38.6 | 159.7 | 124 | 1 | 37 | 100 | 0 | 16 |