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

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**Executive Summary**

The Oregon State University Barley Project develops winter and facultative doubled haploid 2-row covered malting barley varieties seeks to assist AMBA in meeting its mission and objectives. Winter growth habit is a relatively straightforward target. Facultative growth habit is a multi-dimensional that we address through phenotyping and genotyping. Winter and facultative varieties will provide the malting and brewing industries with an abundant supply of high quality malting barley meeting the quality specifications of AMBA members. We are developing varieties for both adjunct and all-malt brewers, and distillers. These varieties will have outstanding yield potential, making them attractive alternatives to competing crops – such as corn and wheat. 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 response variety development: we use doubled haploids, molecular breeding tools, and collaborative phenotyping to efficiently address this issue.

*One-year objectives and outputs:*

* Submit promising new varieties to the AMBA approval system:
  + Thunder is on the AMBA-approved list and is in commercial production. Great Western Malting has been the principal driver behind the commercialization of the variety.
  + DH120304 (provisional name “Kuske”), approved for AMBA Plant Scale, will be tested by Proximity Malt, Origin Malt, and perhaps Admiral Malting with a fall planting in 2021.
  + Lightning (tested as DH130910) is a facultative 2-row malting type that we released in 2020. Lightning is still in the AMBA testing program – the early release is based on the novelty of facultative growth habit, excellent disease resistance, solid agronomic performance, and overall performance in the AMBA Pilot program.
  + As shown in the accompanying tables, we have four submissions (besides Lightning) in the AMBA Pilot program (2020). Drill strips of these selections, and two new potential submissions, are in increase blocks at cooperating locations (2021 crop). Pedigrees and other data are provided in Table 1.
  + All AMBA Pilot scale entries have been, or are in, the Winter Malting Barley Trial.
* Develop new germplasm: We continue to generate new winter/facultative doubled haploids and advance them to preliminary, advanced, elite, and regional trials (trials are listed in Table 2). The agronomic and malting quality profiles of these selections are promising. Most malting and malt analysis are conducted in collaboration with the Cereals Crops Research Unit (alas, delayed due to COVID for the 2020 crop). A subset of advanced lines and experimental materials are malted at the OSU Malt House and analyzed at the Hartwick Center for Craft Food and Beverage.
* Genotyping and phenotyping facultative growth habit: We have expanded phenotyping of elite breeding material for facultative growth habit in spring-sown plantings and developed a set of allele-specific markers for vernalization and photoperiod genes.
* Develop germplasm meeting all-malt and adjunct brewer specifications: We have developed doubled haploids specifically to meet these contrasting quality specifications.
* Doubled haploid collaborations: The DH production facility is now focused on simultaneously meeting the needs of the OSU Barley Project, the US Wheat and Barley Scab Initiative (USWBSI), and the Small Grains Genomics Initiative (SGGI).

*Most significant accomplishments:*

* Thunder, an AMBA-recommended variety, is in commercial production.
* DH120304 (provisional name “Kuske”) was approved for AMBA Plant Scale (2018 crop) and will be tested by Proximity Malt, Origin Malt, and possibly Admiral Malting (2022 crop).
* Lightning (DH130910) was released as a variety in 2020 and is currently in the AMBA Pilot Program (2018 crop satisfactory; 2019 crop unsatisfactory; 2020 crop pending).
* DH140963 and DH141132 are second year submissions (2020 crop) to the AMBA Pilot Program. They were rated unsatisfactory in their first year of assessment (2019 crop).
* DH141222 and DH141225 are first year submissions (2020 crop) to the AMBA Pilot Program.
* Development of high yielding, lodging resistant winter/facultative 2-row malting barley germplasm with exciting malting quality profiles.
* Systematic introgression of novel alleles into U.S.-adapted germplasm 2-row malting 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. This development process is 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 AMBA-funded efforts are directed at winter/facultative 2-row covered barley. The expected benefit is assisting AMBA in meeting its mission and primary objectives.

***Methodology:***

* Accelerate generation time via doubled haploids and speed breeding.
* Corvallis, Oregon is our principal test site. As germplasm advances, it is tested regionally, nationally, and internationally. The 2020/2021 nurseries are summarized in Table 2.
* Malting quality assessments are conducted by the USDA/ARS CCRU. Dr. Cynthia Henson and colleagues collaborate on additional quality assays. Great Western Malting provides support for, and on-farm testing of, our AMBA pilot scale submissions.
* The OSU Malt House is online and is playing an increasingly important role in generating malts on elite breeding lines and potential varieties. Malt analyses are conducted at the Hartwick Center for Craft Food and Beverage.
* Progress in our program depends on extensive collaboration. Kevin Smith at University of Minnesota is a key cooperator for providing winterhardiness data and coordinating the WMBT. 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 University of Idaho Extension nurseries and is collaborating on management trials. We test for winterhardiness, malting quality and disease resistance with Wynse Brooks at Virginia Tech, Eric Stockinger at Ohio State University, and Lucia Gutierrez at the University of Wisconsin. Winterhardiness trials will optimistically be resumed with Dr. Stephen Baenziger’s successor at the University of Nebraska. Alicia del Blanco, at University of California, Davis, tests selections for stripe rust via the Barley Stripe Rust Screening Trial.

***Results:***

In the interest of space, in this report we provide only summary data on our AMBA Plant Scale prospects, Pilot Scale submissions, and potential AMBA Pilot Scale submissions.

**DH120304 (provisional name Kuske)**

*Pluses:* Eligible for AMBA Plant Scale. Will be tested by Proximity Malt, Origin Malt, and perhaps Admiral Malt (fall planting 2021 for 2022 crop). Excellent yield and test weight. Taller than average but acceptable lodging resistance. Tolerant of stripe rust and has excellent scald resistance. Winter survival comparable to Endeavor Wintmalt. Excellent plump grain %. Malt extract edging out Endeavor and Wintmalt and approaching Thunder. Plenty of DP and FAN for those interested. Excellent wort beta glucan.

*Minuses*: Higher end of protein compared to checks, but still in range. Upper end of modification (S/T). High enzymes and FAN – issues for all-malt user who might otherwise be interested in heritage?

*Overall Impression:* The pedigree might suggest an opportunity for craft brewers to explore for novel flavors. However, the malt profile could be interesting for adjunct brewers desiring plenty of enzymes. This one may get the home(s) it deserves.

**Lightning (DH130910)**

*Pluses*: Releases as the variety Lightning in 2020, based on excellent agronomics, disease resistance, and facultative growth habit. Well-adapted to Pacific Northwest and New York. Passed first year of Pilot Scale testing. Good yield, outstanding test weight. Taller than average but lodging = checks. Excellent stripe rust and scald resistance. May offer some benefit for Fusarium Head Blight resistance. Better winter survival than checks. Excellent plumps. Malt extract = Endeavor and Wintmalt; lower than Thunder. Approaching an all-malt profile, except perhaps for DP. Low alpha amylase, wort beta glucan, and FAN, with room for a little more modification.

*Minuses*: Acceptable but not extraordinary malt extract. Higher end of protein compared to checks, but still in range. Perhaps on the low side of enzymes for adjunct brewers. Rated Unsatisfactory in 2019 crop Pilot testing.

*Overall Impression*: This is one is out there – there will be certified seed available for fall, 2021 planting. Facultative growth habit a plus for seed production – to date, spring-planted performance is average. If 2020 crop Unsatisfactory, it will be the first feed barley release from our program in some time.

**DH140963**

*Pluses:* Impressive yield. Taller than average but good lodging resistance. Excellent stripe rust and scald resistance. Winter survival comparable to checks. Excellent plumps. Protein and malt extract comparable to checks. Low DP, alpha, FAN – all-malt type.

*Minuses*: Beta glucan on the edge of acceptability. Rated Unsatisfactory in 2019 crop Pilot testing.

*Overall Impression*: Great agronomics. A European parentage transplant worthy of American citizenship? Up or out based on 2020 crop results.

**DH141132**

*Pluses:* Impressive yield. Solid test weight. Taller than average but good lodging resistance. Excellent stripe rust and scald resistance. Winter survival comparable to checks. Excellent plumps. Protein and malt extract comparable to checks. Plenty of DP, modest alpha and FAN.

*Minuses*: Acceptable but not extraordinary malt extract. Beta glucan on the edge of acceptability. Rated Unsatisfactory in 2019 crop Pilot testing.

*Overall Impression*: So much promise, but up or out with this one, based on 2020 crop results!

**DH141222**

*Pluses:* Yield better than checks. Impressive test weight. Taller than average but good lodging resistance. Excellent stripe rust and scald resistance. Winter survival fine to date in Oregon trials – to be determined in regional trials. Excellent plumps. Protein comparable to checks and malt extract higher than checks and Thunder. Plenty of DP, modest alpha and FAN. Low beta glucan.

*Minuses*: They will undoubtedly materialize, but all good for now.

*Overall Impression*: This one might just be a winner!

**DH141225**

*Pluses:* Yield better than checks. Impressive test weight. Taller than average but good lodging resistance. Excellent stripe rust and scald resistance. Winter survival fine to date in Oregon trials – to be determined in regional trials. Excellent plumps. Protein and malt extract comparable to checks. Plenty of DP, modest alpha and FAN. Low beta glucan.

*Minuses*: Difficult to spot them at this point – stay tuned!.

*Overall Impression*: Might be crowd-pleaser, this half-sister of DH141222.

**DH141917**

*Pluses:* Yield better than checks. Impressive test weight. Taller than average but good lodging resistance. Excellent stripe rust and scald resistance. Winter survival fine to date in Oregon trials – to be determined in regional trials. Excellent plumps. Protein comparable to checks and malt extract edging out Thunder. Plenty of DP, modest alpha and FAN. Low beta glucan. Progeny of Thunder.

*Minuses*: Still looking.

*Overall Impression*: Oh my.

**DH150683**

*Pluses:* Yield way over the checks. Impressive test weight. Taller than average but good lodging resistance. Excellent stripe rust and scald resistance. Winter survival fine to date in Oregon trials – to be determined in regional trials. Excellent plumps. Protein comparable to checks and malt extract higher than Thunder. Plenty of DP, alpha and FAN. Low beta glucan.

*Minuses*: Waiting around the corner, for sure.

*Overall Impression*: Oh my x 2.

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

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

* Higher resolution analysis of the components of low temperature tolerance and facultative growth habit, including expanded phenotyping and genotyping.
* Testing the hypothesis that barley can contribute to beer flavor – witness the growing series of publications in JASBC.
* The Barley World Malt House producing ~ 200 lb. batches of malt from advanced lines and new varieties and smaller batches of experimental selections using the CLP.
* 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

* Daniela Carrijo, Assistant Professor, Senior Research
* Brigid Meints, Assistant Professor, Senior Research
* Javier Hernandez, Post-Doc
* Tanya Filichkin, Senior Research Assistant
* Scott Fisk, Senior Research Assistant
* Laura Helgerson, Senior Research Assistant

**Graduate students**

* Sarah Windes, Graduate Research Assistant (MS). Thesis research focuses on barley contributions to beer flavor and prospects for perennial malting barley. (Graduated 2020)
* Campbell Morrissy, Graduate Research Assistant (PhD). Thesis research focuses on barley contributions to beer and spirits flavor.
* Margaret Halstead, Graduate Research Assistant (MS). Thesis research focuses on environmental and management effects on barley contributions to beer flavor.
* Cristiana Vallejos, Graduate Research Assistant (MS). Thesis research focuses on multi-use naked barley for organic systems.

**Publications (2020-2021)**

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3. Hernandez, J., A. del Blanco, T. Filichkin, S. Fisk, L. Gallagher, L. Helgerson, B. Meints, C. Mundt, B. Steffenson, and P.M. Hayes. 2020. A genome wide association study of resistance to *Puccinia striiformis* f.sp. *hordei* and *Puccinia graminis* f.sp. *tritici* in barley and development of resistant germplasm. Phytopathology. 110:1082-1092*.*
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10. Carrijo D.R, T. Filichkin, S. Fisk, L. Helgerson, J. Hernandez, B. Meints, M.E. Sorrells, and P.M. Hayes. 2021. Registration of Lightning barley. J. Plant Reg. *In press*.

**Table 1. Descriptors and status of OSU germplasm in the AMBA Pilot Program.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Selection** | **Pedigree** | **Growth Habit** | **EPH** | **AMBA Status** | **Regional Trial Submissions** |
| DH120304 | Maris Otter/Full Pint | Winter | Producer | Eligible for Plant Scale Testing | WMBT 2017-18, 2018-19 |
| Lightning | Short11-7/Herz 29494/2991 | Facultative | Producer | Pilot Submission 2020 Crop (Third Year) | WMBT 2016-17, 2017-18, 2018-19, 2019-20 |
| DH140963 | 04\_028\_36/Archer | Winter | - | Pilot Submission 2020 Crop (Second Year) | WBGN 2017-18;  WMBT 2018-19, 2019-20, 2020-21 |
| DH141132 | Violetta/Archer | Winter | - | Pilot Submission 2020 Crop (Second Year) | WBGN 2018-19;  WMBT 2019-20, 2020-21 |
| DH141222 | 10.1044/Violetta | Winter | - | Pilot Submission 2020 Crop (First Year) | WMBT 2020-21 |
| DH141225 | 10.1044/04\_028\_36 | Winter | - | Pilot Submission 2020 Crop (First Year) | WMBT 2020-21 |
| DH141917 | 04-028-36/Thunder | Winter | - | Potential Pilot Submission 2021 Crop | - |
| DH150683 | 04-028-36/DH131772 | Winter | - | Potential Pilot Submission 2021 Crop | - |

**Table 2. Oregon State University barley nurseries: 2020-21.** The summary is divided into “Malting”, “Naked” and “Genetics”. In reality, these areas of endeavor are tightly integrated. This is especially true for naked barley as we are viewing naked types for multi-use (malt, food, and feed) rather than for only food.

**Malting Barley**

***Overview:***

***Number of advanced and fixed lines: 1174***

* 119 in yield trial plots
* 1055 in single rows or mini-plots (doubled haploids)

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

* 9 F2s
* 67 F1s

***Details:***

***Oregon Malting Barley Elite Yield Trial***

* Corvallis, OR Fall-planted 28 entries, 3 rep, RCBD
* Lebanon, OR Fall-planted 28 entries, unreplicated
* Pullman, WA Fall-planted 28 entries, 3 rep
* Blacksburg, VA Fall-planted 28 entries

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

* Corvallis, OR Fall-planted 51 entries, 2 rep, RCBD
* Lebanon, OR Fall-planted 51 entries, unreplicated w/checks
* Pullman, WA Fall-planted 47 entries, unreplicated
* Bozeman, MT Fall-planted 43 entries, 3 rep

***Brewers Association Nitrogen Trial***

* Corvallis, OR Fall-planted 7 entries, 4 rep, 2 trtmnts, RCBD
* Aberdeen, ID Fall-planted 7 entries, 4 rep, 2 trtmnts, RCBD
* Tulelake, CA Fall-planted 7 entries, 4 rep, 2 trtmnts, RCBD

***Distiller’s Delight Yield Trial***

* Corvallis, OR Fall-planted 8 entries, 3 rep, 3 trtmnts, RCBD
* Aberdeen, ID Fall-planted 8 entries, 3 rep, 3 trtmnts, RCBD
* Pullman, WA Fall-planted 8 entries, 3 rep, 1 trtmnt, RCBD

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

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

***Malt Drill Strips***

* Corvallis, OR Fall-planted 20 entries (OSU & USDA-ARS)
* Lebanon, OR Fall-planted 12 entries (OSU & USDA-ARS)
* Aberdeen, ID Fall-planted 12 entries (OSU & USDA-ARS)
* Kimberly, ID Fall-planted 12 entries (OSU & USDA-ARS)
* Pullman, WA Fall-planted 12 entries (OSU & USDA-ARS)
* Caldwell, ID Fall-planted 8 entries

***Romp Drill Strips***

* Corvallis, OR Fall-planted 5 entries

***Purification Head Rows***

* Corvallis, OR Fall-planted 2 entries, 240 rows

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

* Corvallis, OR Fall-planted 1011 entries, unreplicated w/checks

***Malt Doubled Haploid Single Rows***

* Corvallis, OR Fall-planted 44 entries, unreplicated w/checks

***Malt F2 Bulk Plots***

* Corvallis, OR Fall-planted 9 entries, unreplicated

***Malt F1 Head Rows***

* Corvallis, OR Fall-planted 67 entries, unreplicated

**Naked Barley**

***Overview:***

***Number of advanced and fixed lines: 141***

* 121 in yield trial plots
* 20 in single rows or mini-plots

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

* 35 F5s
* 15 F2/F3

***Details:***

***OREI Fall Regional Yield Trial***

* Corvallis, OR Fall-planted 20 entries, 2 rep, RCBD
* Corvallis, OR Fall-planted (Organic) 20 entries, 4 rep, RCBD
* Lamberton, MN Fall-planted (Organic) 20 entries, 3 rep, RCBD
* Freeville, NY Fall-planted (Organic) 20 entries, 3 rep, RCBD
* Madison, WI Fall-planted (Organic) 20 entries, 3 rep, RCBD
* Davis, CA Fall-planted (Organic) 20 entries, 3 rep, RCBD

***Naked Preliminary Yield Trial***

* Corvallis, OR Fall-planted 32 entries, 2 rep, RCBD
* Corvallis, OR Fall-planted (Organic) 30 entries, 2 rep, RCBD

***Virginia Tech Preliminary Yield Trial***

* Corvallis, OR Fall-planted 24 entries, unreplicated
* Corvallis, OR Fall-planted (Organic) 21 entries, unreplicated

***UC Davis Preliminary Yield Trial***

* Corvallis, OR Fall-planted (Organic) 20 entries, unreplicated

***Naked Multi-use F5 Head Rows (Organic)***

* Corvallis, OR Fall-planted 26 pedigrees, 48 rows each
* Corvallis, OR\* Spring-planted 9 pedigrees, 48 rows each

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

* Corvallis, OR\* Spring-planted 20 entries, 3 rep, RCBD
* Lamberton, MN\* 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
* Tulelake, CA\* Spring-planted 20 entries, 3 rep, RCBD

***Spring Naked Preliminary Yield Trial (Organic)***

* Corvallis, OR\* Spring-planted 25 entries, 2 rep, RCBD

***Naked F2/F3 Bulk Plots (Organic)***

* Corvallis, OR\* Spring-planted 15 entries, unreplicated

\*Not yet planted as of 1/21/21

**Genetics**

***Overview:***

***Number of advanced and fixed lines: 2128***

* 25 in yield trial plots
* 2103 in single rows

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

* 26 F1s

***Details:***

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

* Barley Stripe Rust Screening Trial 56 entries, 2 rep, RCBD
* UC Tahoe/UC 1390 Population 191 entries, 2 rep, RCBD
* Cycle IV DH Germplasm Array 661 entries, Augmented Design

***Uniform Barley Winter-Hardiness Nursery***

* Corvallis, OR Fall-planted 30 entries, 2 rep, RCBD

***TTKSK F1 Head Rows***

* Corvallis, OR Fall-planted 26 entries, unreplicated

***Vernalization Sensitivity Nursery (Corvallis, OR); Spring-planted***

* Cycle III DH Germplasm Array\* 386 entries, Augmented Design
* Cycle IV DH Germplasm Array\* 661 entries, Augmented Design
* KASP Array\* 96 entries, Augmented Design
* Pullman Validation Panel\* 96 entries, Augmented Design
* Successor\* 333 entries, Augmented Design

***Successor Project***

* Corvallis, OR Fall-planted 17 entries, 2 rep, RCBD
* Corvallis, OR\* Spring-planted 22 entries, 3 rep, RCBD
* Pendleton, OR\* Spring-planted 22 entries, 2 rep, RCBD
* Ione, OR\* Spring-planted 22 entries, 2 rep, RCBD
* Kent, OR\* Spring-planted 22 entries, 2 rep, RCBD
* Corvallis, OR\* Spring-planted 6 entries, 2 rep, 8 trtmnts, RCBD

***Naked Promise***

* Corvallis, OR\* Spring-planted 3 entries, 2 rep, RCBD

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

* Corvallis, OR\* Spring-planted 254 entries, Type-2 Modified Aug. Design

\*Not yet planted as of 1/21/21

**Other**

***Drone Fertility Trial***

* Corvallis, OR Fall-planted 2 entries, 4 rep, 7 trtmnts

Table 3. Agronomic data of OSU selections in the AMBA Pilot Program, compared to checks.

**DH120304 (Provisional name Kuske).**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Entry | Yield | Test Weight | Plant Height | Lodging | Stripe Rust (%) | Scald (%) |
| (bu/acre) | (lbs/bu) | (in) | (%) |
| *Station yrs.* | *9* | *10* | *10* | *10* | *5* | *10* |
| DH120304 | 148 | 52.6 | 44 | 21 | 19 | 1 |
| Endeavor | 121 | 51.6 | 39 | 21 | 6 | 67 |
| Wintmalt | 126 | 51.4 | 39 | 19 | 22 | 42 |
| Thunder | 124 | 51.6 | 38 | 31 | 21 | 54 |

Table 4. Agronomic data of OSU selections in the AMBA Pilot Program, compared to checks.

**Lightning.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Entry | Yield | Test Weight | Plant Height | Lodging (%) | Stripe Rust (%) | Scald (%) |
| (bu/acre) | (lbs/bu) | (in) |
| *Station yrs.* | 13 | 14 | 14 | 13 | 8 | 13 |
| Lightning | 136 | 53.9 | 44 | 27 | 5 | 5 |
| Endeavor | 107 | 51.2 | 39 | 32 | 4 | 71 |
| Wintmalt | 113 | 50.2 | 39 | 24 | 19 | 48 |
| Thunder | 113 | 50.7 | 39 | 34 | 16 | 56 |

Table 5. Agronomic data of OSU selections in the AMBA Pilot Program, compared to checks.

**DH140963.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Entry | Yield | Test Weight | Plant Height | Lodging (%) | Stripe Rust (%) | Scald (%) |
| (bu/acre) | (lbs/bu) | (in) |
| *Station yrs.* | *8* | *9* | *9* | *9* | *5* | *9* |
| DH140963 | 180 | 51.9 | 43 | 13 | 4 | 3 |
| Endeavor | 114 | 51.5 | 40 | 32 | 5 | 68 |
| Wintmalt | 118 | 50.8 | 39 | 26 | 24 | 45 |
| Thunder | 122 | 51.2 | 39 | 32 | 23 | 50 |

Table 6. Agronomic data of OSU selections in the AMBA Pilot Program, compared to checks.

**DH141132.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Entry | Yield | Test Weight | Plant Height | Lodging (%) | Stripe Rust (%) | Scald (%) |
| (bu/acre) | (lbs/bu) | (in) |
| *Station yrs.* | *8* | *9* | *9* | *9* | *5* | *9* |
| DH141132 | 176 | 53.1 | 43 | 21 | 2 | 4 |
| Endeavor | 114 | 51.5 | 40 | 32 | 5 | 68 |
| Wintmalt | 118 | 50.8 | 39 | 26 | 24 | 45 |
| Thunder | 122 | 51.2 | 39 | 32 | 23 | 50 |

Table 7. Agronomic data of OSU selections in the AMBA Pilot Program, compared to checks.

**DH141222.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Entry | Yield | Test Weight | Plant Height | Lodging (%) | Stripe Rust (%) | Scald (%) |
| (bu/acre) | (lbs/bu) | (in) |
| *Station yrs.* | *8* | *9* | *9* | *9* | *5* | *9* |
| DH141222 | 154 | 54.9 | 44 | 9 | 2 | 2 |
| Endeavor | 114 | 51.5 | 40 | 32 | 5 | 68 |
| Wintmalt | 118 | 50.8 | 39 | 26 | 24 | 45 |
| Thunder | 122 | 51.2 | 39 | 32 | 23 | 50 |

Table 8. Agronomic data of OSU selections in the AMBA Pilot Program, compared to checks.

**DH141225.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Entry | Yield | Test Weight | Plant Height | Lodging (%) | Stripe Rust (%) | Scald (%) |
| (bu/acre) | (lbs/bu) | (in) |
| *Station yrs.* | *8* | *9* | *9* | *9* | *5* | *9* |
| DH141225 | 159 | 54.2 | 44 | 18 | 3 | 7 |
| Endeavor | 114 | 51.5 | 40 | 32 | 5 | 68 |
| Wintmalt | 118 | 50.8 | 39 | 26 | 24 | 45 |
| Thunder | 122 | 51.2 | 39 | 32 | 23 | 50 |

Table 9. Agronomic data of OSU selections in the AMBA Pilot Program, compared to checks.

**DH141917.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Entry | Yield | Test Weight | Plant Height | Lodging (%) | Stripe Rust (%) | Scald (%) |
| (bu/acre) | (lbs/bu) | (in) |
| *Station yrs.* | *6* | *7* | *7* | *7* | *5* | *7* |
| DH141917 | 148 | 53.2 | 42 | 26 | 6 | 5 |
| Endeavor | 112 | 51.2 | 40 | 39 | 5 | 69 |
| Wintmalt | 115 | 50.2 | 40 | 32 | 24 | 43 |
| Thunder | 116 | 51.0 | 40 | 37 | 23 | 47 |

Table 10. Agronomic data of OSU selections in the AMBA Pilot Program, compared to checks.

**DH150683.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Entry | Yield | Test Weight | Plant Height | Lodging (%) | Stripe Rust (%) | Scald (%) |
| (bu/acre) | (lbs/bu) | (in) |
| *Station yrs.* | *6* | *7* | *7* | *7* | *5* | *7* |
| DH150683 | 163 | 52.9 | 42 | 26 | 0 | 1 |
| Endeavor | 112 | 51.2 | 40 | 39 | 5 | 69 |
| Wintmalt | 115 | 50.2 | 40 | 32 | 24 | 43 |
| Thunder | 116 | 51.0 | 40 | 37 | 23 | 47 |

Table 11. Winter survival of entries and checks in the AMBA Pilot program where (1) there was differential survival in the trial and (2) all entries were present in the same trial.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Entry | Winter survival | Entry | Winter survival | Entry | Winter survival | Entry | Winter survival |
| (%) | (%) | (%) | (%) |
| DH120304 | 63 | Lightning | 78 | DH140963 | 77 | DH141132 | 86 |
| Endeavor | 53 | Endeavor | 69 | Endeavor | 76 | Endeavor | 81 |
| Wintmalt | 68 | Wintmalt | 69 | Wintmalt | 58 | Wintmalt | 64 |
| *Station yrs. 8* | | *Station yrs. 23* | | *Station yrs. 10* | | *Station yrs. 7* | |

Table 12. Malting quality data of OSU selections in the AMBA Pilot Program, compared to checks. **DH120304.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Entry | Plump kernels (%) | Malt extract (%) | Barley protein (%) | Wort protein (%) | S/T | DP | Alpha amylase | Beta glucan | FAN |
| (%) | (0ASBC) | (20°DU) | (ppm) | (ppm) |
| *Station yrs.* | *9* | *9* | *9* | *9* | *9* | *9* | *9* | *9* | *9* |
| DH120304 | 96.6 | 82.2 | 11.1 | 5.7 | 53.4 | 172 | 82 | 49 | 297 |
| Endeavor | 79.5 | 81.9 | 10.4 | 4.9 | 51.9 | 164 | 102 | 201 | 232 |
| Wintmalt | 96.1 | 81.4 | 10.2 | 4.1 | 43.5 | 140 | 56 | 64 | 169 |
| Thunder | 94.6 | 82.9 | 10.3 | 5.2 | 53.6 | 151 | 115 | 36 | 259 |

Table 13. Malting quality data of OSU selections in the AMBA Pilot Program, compared to checks. **Lightning.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Entry | Plump kernels (%) | Malt extract (%) | Barley protein (%) | Wort protein (%) | S/T | DP | Alpha amylase | Beta glucan | FAN |
| (%) | (0ASBC) | (20°DU) | (ppm) | (ppm) |
| *Station yrs.* | *11* | *11* | *11* | *11* | *11* | *11* | *11* | *11* | *11* |
| DH130910 | 97.9 | 81.5 | 11.3 | 4.7 | 44.4 | 167 | 42 | 81 | 191 |
| Endeavor | 80.8 | 81.8 | 10.6 | 5.1 | 51.8 | 165 | 100 | 195 | 233 |
| Wintmalt | 94.3 | 81.3 | 10.3 | 4.2 | 43.9 | 141 | 56 | 58 | 168 |
| Thunder | 94.1 | 82.7 | 10.7 | 5.4 | 53.7 | 159 | 116 | 35 | 266 |

Table 14. Malting quality data of OSU selections in the AMBA Pilot Program, compared to checks. **DH140963.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Entry | Plump kernels (%) | Malt extract (%) | Barley protein (%) | Wort protein (%) | S/T | DP | Alpha amylase | Beta glucan | FAN |
| (%) | (0ASBC) | (20°DU) | (ppm) | (ppm) |
| *Station yrs.* | *7* | *7* | *7* | *7* | *7* | *7* | *7* | *7* | *7* |
| DH140963 | 98.6 | 82.3 | 10.4 | 4.3 | 43.7 | 120 | 37 | 114 | 150 |
| Endeavor | 84.2 | 82.2 | 10.6 | 5.1 | 52.8 | 161 | 100 | 203 | 231 |
| Wintmalt | 94.3 | 82.0 | 10.0 | 4.4 | 47.0 | 138 | 57 | 49 | 168 |
| Thunder | 95.2 | 83.2 | 10.6 | 5.4 | 55.5 | 154 | 117 | 35 | 264 |

Table 15. Malting quality data of OSU selections in the AMBA Pilot Program, compared to checks. **DH141132.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Entry | Plump kernels (%) | Malt extract (%) | Barley protein (%) | Wort protein (%) | S/T | DP | Alpha amylase | Beta glucan | FAN |
| (%) | (0ASBC) | (20°DU) | (ppm) | (ppm) |
| *Station yrs.* | *7* | *7* | *7* | *7* | *7* | *7* | *7* | *7* | *7* |
| DH141132 | 97.7 | 81.9 | 10.4 | 4.7 | 48.9 | 173 | 48 | 114 | 185 |
| Endeavor | 84.2 | 82.2 | 10.6 | 5.1 | 52.8 | 161 | 100 | 203 | 231 |
| Wintmalt | 94.3 | 82.0 | 10.0 | 4.4 | 47.0 | 138 | 57 | 49 | 168 |
| Thunder | 95.2 | 83.2 | 10.6 | 5.4 | 55.5 | 154 | 117 | 35 | 264 |

Table 16. Malting quality data of OSU selections in the AMBA Pilot Program, compared to checks. **DH141222.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Entry | Plump kernels (%) | Malt extract (%) | Barley protein (%) | Wort protein (%) | S/T | DP | Alpha amylase | Beta glucan | FAN |
| (%) | (0ASBC) | (20°DU) | (ppm) | (ppm) |
| *Station yrs.* | *6* | *6* | *6* | *6* | *6* | *6* | *6* | *6* | *6* |
| DH141222 | 98.1 | 83.5 | 10.2 | 4.8 | 51.2 | 189 | 57 | 32 | 203 |
| Endeavor | 84.4 | 82.5 | 10.4 | 5.0 | 53.4 | 159 | 103 | 206 | 232 |
| Wintmalt | 94.3 | 82.1 | 10.0 | 4.3 | 46.5 | 138 | 57 | 50 | 169 |
| Thunder | 95.9 | 83.3 | 10.2 | 5.3 | 55.6 | 149 | 117 | 36 | 259 |

Table 17. Malting quality data of OSU selections in the AMBA Pilot Program, compared to checks. **DH141225.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Entry | Plump kernels (%) | Malt extract (%) | Barley protein (%) | Wort protein (%) | S/T | DP | Alpha amylase | Beta glucan | FAN |
| (%) | (0ASBC) | (20°DU) | (ppm) | (ppm) |
| *Station yrs.* | *7* | *7* | *7* | *7* | *7* | *7* | *7* | *7* | *7* |
| DH141225 | 97.9 | 83.2 | 10.6 | 5.1 | 51.1 | 210 | 57 | 38 | 203 |
| Endeavor | 84.2 | 82.2 | 10.6 | 5.1 | 52.8 | 161 | 100 | 203 | 231 |
| Wintmalt | 94.3 | 82.0 | 10.0 | 4.4 | 47.0 | 138 | 57 | 49 | 168 |
| Thunder | 95.2 | 83.2 | 10.6 | 5.4 | 55.5 | 154 | 117 | 35 | 264 |

Table 18. Malting quality data of OSU selections in the AMBA Pilot Program, compared to checks. **DH141917.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Entry | Plump kernels (%) | Malt extract (%) | Barley protein (%) | Wort protein (%) | S/T | DP | Alpha amylase | Beta glucan | FAN |
| (%) | (0ASBC) | (20°DU) | (ppm) | (ppm) |
| *Station yrs.* | *5* | *5* | *5* | *5* | *5* | *5* | *5* | *5* | *5* |
| DH141917 | 98.3 | 83.3 | 10.8 | 5.1 | 50.5 | 160 | 52 | 31 | 198 |
| Endeavor | 87.8 | 82.4 | 10.6 | 5.2 | 54.8 | 149 | 97 | 191 | 224 |
| Wintmalt | 93.6 | 82.0 | 10.0 | 4.4 | 48.0 | 135 | 56 | 35 | 166 |
| Thunder | 95.8 | 83.1 | 10.7 | 5.6 | 56.6 | 159 | 117 | 27 | 260 |

Table 19. Malting quality data of OSU selections in the AMBA Pilot Program, compared to checks. **DH150683.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Entry | Plump kernels (%) | Malt extract (%) | Barley protein (%) | Wort protein (%) | S/T | DP | Alpha amylase | Beta glucan | FAN |
| (%) | (0ASBC) | (20°DU) | (ppm) | (ppm) |
| *Station yrs.* | *5* | *5* | *5* | *5* | *5* | *5* | *5* | *5* | *5* |
| DH150683 | 97.6 | 83.7 | 10.9 | 5.6 | 54.6 | 189 | 87 | 34 | 272 |
| Endeavor | 87.8 | 82.4 | 10.6 | 5.2 | 54.8 | 149 | 97 | 191 | 224 |
| Wintmalt | 93.6 | 82.0 | 10.0 | 4.4 | 48.0 | 135 | 56 | 35 | 166 |
| Thunder | 95.8 | 83.1 | 10.7 | 5.6 | 56.6 | 159 | 117 | 27 | 260 |