2018 BREWERS ASSOCIATION FUNDED RESEARCH GRANTS

BARLEY

CREATION AND DEVELOPMENT OF BETTER GERMPLASM LINES FOR ALL-MALT BARLEY VARIETIES

- Partner(s): USDA-Agricultural Research Service, Aberdeen
- Principal: Gongshe Hu
- Primary goal(s): We will use top low protein germplasm lines identified from previous study for creation of new germplasm lines for craft brewing specific variety development. We plan to start selecting the top 10 low protein germplasm lines as low protein donor parents. The selection standards will be: low protein, better agronomic traits based on field observation. Then to select 10 elite malting lines as agronomic and malting quality donor parents. About 50 crosses will be made and F2 generation will be advanced for those 50 crosses in year of 2018.
- Background: Selecting low protein 2-row barley lines from all over the world will greatly enrich the genetic diversity of barley breeding and germplasm resources; and help ensure a supply of barley varieties suitable for all-malt brewing. In past two years, we have screened germplasm for low protein and identified some lines with lower protein and good agronomic and malting traits. To use those lines in the breeding program by crossing some of those lines with elite malting barley lines, we may be able to create more and better germplasm lines for craft brewing specific barley variety development.
- Additional Information: To improve the genetic background of North American barley lines, genetic sources for stress tolerance, better malting and brewing quality traits, and disease resistance will be introduced to create genetic diversity and improve on current barley qualities for use in all-malt beer production.

BREEDING FOR BARLEY CONTRIBUTIONS TO BEER FLAVOR

- Partner(s): Oregon State University
- Principal: Pat Hayes
- Primary goal(s): Funding is requested to extend our flavor genetics work into our breeding program to expedite the development and release of barley varieties with unique flavor contributions. The proposed research will be fully integrated with ongoing research supported by the American Malting Barley Association (AMBA) and the Barley Flavor Pack (BFP).
  Background: Ongoing research is directed at finer structure genetic mapping of contributors to flavor. The barley germplasm produced to date, the results that will be obtained from the research underway, and insights afforded by collaborations with other researchers provide the essential elements for translating genetics research into commercial varieties. In the proposed project, we will focus on three distinct sets of barley germplasm – generated with prior support from the BFP and AMBA - and we will make extensive use of the malting capability at Oregon State University established with BA funding.
- Additional Information: The BA-supported research is integrated and synergistic with AMBA and BFP-supported research. AMBA supports the overall 2-row malting barley breeding effort, including the development of 2-row winter and facultative varieties suitable for all-malt brewing. The BFP funding is targeted to leverage BA funding and provide sufficient resources for a full-time post-doc devoted to flavor research.

STABLE AND SUSTAINABLE DRYLAND PRODUCTION OF HIGH QUALITY MALT BARLEY

- Partner(s): Montana State University
- Principal: Jamie Sherman
- Primary goal(s): The long-term goal is to develop malt barley varieties with stable quality under dryland production that are suitable for the all-malt brewing industry. Growers will more likely grow the varieties because of reduced risk of rejection, providing a more stable malt supply for end-users. Malt produced from more stable varieties will have more stable and consistent quality. Growers, maltsters and brewers will benefit economically by more sustainable malt production.

- Background: Barley is well adapted to dryland farming, however historic production of malting barley has been in higher moisture to ensure malt quality. In dryland conditions, current barley varieties have an increased risk of rejection due to poor malt quality, resulting in a significant economic loss to farmers. Therefore, growers are often reluctant to plant malting barley due to the increased risk, resulting in an unstable malt barley supply for end-users.
- Additional Information: Currently, most barley breeding is focused on selecting for quality potential instead of quality stability because most programs only test malt quality on barley grown in high production environments, and few efforts exist to improve dryland production. Thus, breeding for quality stability requires testing in multiple environments. Here, we propose the continuation of a three year project to identify genes controlling quality stability that can be incorporated into varieties for the all-malt industry.

MAPPING MALT QUALITY TRAITS TO FACILITATE MARKER ASSISTED BREEDING AND DEVELOPMENT OF WINTER MALT BARLEY

- Partner(s): Virginia Polytechnic Institute and State University
- Principal: Carl Griffey
- Primary goal(s): The primary objectives of this project are to facilitate the development of superior quality winter malt barley for Eastern North America by mapping genes or quantitative trait loci (QTL) for malt quality and flavor traits in elite malt barley varieties for which diagnostic DNA markers can be used in Marker Assisted Selection (MAS). Results will enable barley breeding programs to make crosses and select lines having improved malt quality traits more reliably and faster than using traditional breeding and phenotypic selection methods.
- Background: There is significant demand for productive, locally adapted, and disease resistant winter malt barley cultivars to meet the diverse needs of the rapidly growing craft malting and brewing industries in the eastern U.S. Currently, there are very few well-adapted and high yielding winter malt barley cultivars, and the best winter barley cultivars in the eastern U.S. lack desirable malting characteristics. Once molecular markers diagnostic for specific malt quality traits are identified, breeders can communicate with the larger craft malt houses and brewers in the area to ensure they are developing cultivars that meet their specific needs.
- Additional Information: Virginia Tech recently constructed a pilot research brewhouse in the Department of Food Science & Technology. The pilot brewhouse provides a unique opportunity for researchers to evaluate malt barley lines, train the next generation of brewing scientists, and connect regional craft brewers with plant breeders and local farmers.

BUILDING A WINTER MALTING BARLEY MARKET FOR THE GREAT PLAINS

- Partner(s): University of Nebraska
- Principal: Stephen Baenziger
- Primary goal(s): We hope to develop locally adapted winter malting barley lines for the Great Plains to expand the production area for malting barley into areas with less disease. High quality malting barley from this region will provide the malting and brewing industry with a consistent supply of this critical ingredient.
- Background: Our vision for malting barley expansion in the Great Plains is based upon the emergence of a diverse and expanding barley market for cereal production. Winter barley is known to be more drought tolerant than winter wheat and with water restrictions and changing weather, winter barley has the potential for further expansion. Furthermore, the Great Plains with its dry climate coupled with the potential for irrigation is favorable for the development of malt and food grade grain with minimal disease (e.g. Fusarium head blight).
- Additional Information: Traditionally, winter barley in the Southern Great Plains is grown primarily as a feed grain with grazing potential, or for forage. While neither of these uses are related to malting barley quality, we believe it is critical to have a barley market before you can have a malting barley market. Having a barley market provides a ready market for malting barley grain that does not meet malting quality specifications.

UTILIZING A MULTI-STATE DATASET TO SUPPORT COORDINATED BREEDING OF LOCAL MALTING BARLEY

- Partner(s): University of Minnesota
- Principal: Kevin Smith
- Primary goal(s): We will use the data set from the 2017 project to make environment-specific recommendations for advanced breeding lines. These recommendations will be based on agronomic performance, disease resistance, and malting quality. For each of the target regions across the U.S., we will prepare a summary of predicted performance of 300 breeding lines for all of the traits above. Each participant of our current project will be presented with the prediction report for their specific region and select the best lines for further testing in their own regional trials. These lines will be provided in time to be planted in the spring of 2018. We will evaluate all of the selected lines in Minnesota and collect the data from selected lines with each collaborator to validate our prediction method.

- Background: Craft brewers are increasingly looking to obtain the raw material for their products from local sources. This trend has created a demand for malting barley cultivation in regions and locations proximal to craft breweries. Such a shift in market preference has the obvious benefit of reducing transportation costs from current centers of production, but brewers make also receive a premium for sourcing ingredients within their region. With this change in the industry landscape, barley breeding and cultivation must adapt to fill this demand. The distribution of craft brewers in the United States spans regions with disparate climates, soils, and other environmental conditions. With such dissimilarities, we might expect that a single barley variety will not be the best-suited to all of these regions.
- Additional Information: A common panel of 233 two-row spring barley breeding lines will be grown in 18 different trials in each of the next two years. Researchers at each location will conduct a yield trial of this panel and will oversee each according to best management practices (i.e. fertility, pest control, irrigation, etc.). Through this coordinated effort, we plan to develop a rich, publicly available dataset for use by breeders and researchers nationwide to make informed selections.

IMPROVING MALTING QUALITY IN TWO-ROWED BARLEY BY REDUCING GRAIN PROTEIN CONTENT THROUGH MARKER ASSISTED BACKCROSSING

- Partner(s): University of California, Davis
- Principal: Alicia del Blanco
- Primary goals(s): The objectives of this project are: 1) Introgress, via marker assisted backcrossing, the low GPC allele from malting variety "Karl" to our elite malting barley variety UC Tahoe and advanced line UC1390. 2) Evaluate the BC3F2 selected lines in replicated experiments with different levels of N fertilization and select the top lines. 3) Assess the malting quality of the BC3F2 lines and select the superior genotypes. 4) Start using the selected BC3F2 lines in the regular malting barley program for crossing and variety release.
- Background: The introgression of the low GPC allele from malting cultivar Karl to our elite malting barley lines will improve malting quality characteristics by lowering protein content in the grain. It is also expected an increase of plumpness in the grains given by a delayed senescence of the plant, and a subsequent longer grain filling stage. Lastly, for this late senescence and for allowing a higher N fertilization, it may also result in an improvement in grain yield of the barley genotypes carrying the low GPC haplotype in environments where a long grain-filling period is possible.
- Additional Information: Content of protein in barley grain is an important trait for commercial malt standards. The recommended limit of grain protein content by AMBA is 12%. Protein content above 12% is associated with several undesirable characteristics, including increased steep time and uneven water absorption during steeping, irregular germination during the malting process leading to increased malt losses, excessive enzymatic activity, poorer mellowness, etc . Malting barley exceeding the protein standard is regularly subject to a significant penalty in price, or rejected, at local and international markets. This mandatory limit in protein content also limits the amount of fertilizer that can be applied in barley crops resulting in potential reductions of grain yield.

ALL-MALT BARLEY: NITROGEN AND CULTIVAR MANAGEMENT STRATEGIES FOR IDAHO GROWERS

- Partner(s): University of Idaho
- Principal: Christopher Rogers
- Primary goal(s): Develop data for nitrogen response to application rate and timing for winter and spring malt varieties, emphasizing the specific needs of all-malt brewers in terms of grain quality characteristics for producing all-malt beers. Investigate the physiological response of low-protein breeding lines to drought stress. A detailed understanding of the physiological characteristics of lines that perform well under stress will provide evidence of traits (i.e., yield components and nitrogen partitioning) that can be used as markers for future selections.
- Background: We are continually addressing the improvement of spring and winter two-row malt barley cultivars, fertilizer management, and irrigation practices to meet the quality profiles for all-malt brewers. Screening of breeding lines from the USDA-ARS and University of Idaho research groups in Aberdeen, Idaho has been undertaken in previous years. These lines potentially have unique agronomic trait profiles that are desirable for all-malt brewing. In particular, grain protein requirements for all malt two-row barley cultivars are typically lower than those for adjunct two-row malt barley.
- Additional Information: By providing optimal nitrogen to meet grain needs and malting specifications, we can decrease environmental impacts associated with nitrogen loss and improve the overall sustainability of barley production. Through detailed physiological studies we can improve our understanding of desirable traits that can be quantitatively measured during breeding line screenings, and thus, improve the breeding programs ability to select lines with the best traits for all-malt brewing under increasingly water stressed conditions.

ENHANCEMENT OF WINTER HARDINESS IN TWO-ROWED BARLEY VARIETIES FOR THE CRAFT BREWING INDUSTRY

- Partner(s): University of Minnesota
- Principal: Brain Steffenson
- Primary goal(s): The specific objectives for FY18 are to: 1) develop additional breeding populations between selected accessions of the Vavilov genebank (VIR) collection and two-rowed breeding lines with superior malting characteristics; 2) establish regional trials of VIR accessions and their derived progeny to broadly assess their winter hardiness and malting quality profile; and 3) hold outreach events at field trials to showcase the potential of winter barley production to producers and end-users.
- Background: This project will exploit Russian barley accessions to develop winter two-rowed barley cultivars suitable for growing malt-quality barley in the Midwest; which will provide the Midwest craft brewing industry with more locally grown ingredients.
- Additional Information: Autumn-sown (i.e. "winter") barley has many advantages over traditional spring-sown barley that is currently grown in the northern tier states of the U.S. including higher yield potential, enhanced malting quality, higher nitrogen and water use efficiency, escape from major "summer" diseases, and various ecological services. One of the major challenges of breeding winter barley under the harsh weather conditions of the northern tier states is winter hardiness. The recent discovery of extraordinary winter hardiness in barley germplasm from the N. I. Vavilov genebank in Russia offers great hope for breeding for enhanced levels of this critical trait.

EASTERN UNITED STATES SPRING BARLEY NURSERY (ESBN)

- Partner(s): North Dakota State University
- Principal: Richard Horsley
- Primary goals(s): Funding is requested to support the evaluation of 25 barley varieties in the Eastern Spring Barley Nursery (ESBN) in 2018 in nine states in the eastern U.S. Our goal is to determine if varieties developed outside the region may be adapted for local production.
- Background: The craft malting and brewing industries across the U.S. have an increased desire to use locally produced grains for making their products. The most widely used grain in brewing is barley, which is predominantly produced in Idaho, Montana, and North Dakota in the US; and Alberta, Manitoba, and Saskatchewan in Canada. Each of these areas has large barley-breeding programs developing varieties adapted to their specific growing regions, which are quite different from those in the eastern U.S.
- Additional Information: The barley improvement program at North Dakota State University (NDSU) is coordinating the nursery. The 2018 ESBN will be sown and managed locally by a university or extension person with experience conducting research on small grains. Data will be collected on days to heading, plant height, foliar diseases, lodging, and yield. Following harvest, a sample of each entry from each location will be sent to NDSU where kernel plumpness, grain protein, test weight, pre-harvest sprouting, and deoxynivalenol (DON) content will be determined. Grain from three locations will be malted at NDSU and data will be collected on malt extract, wort color, wort protein, Kolbach Index, wort ß-glucan, diastatic power, α-amylase activity, and free amino nitrogen concentration.

METABOLOMICS OF HOT STEEP MALT EXTRACTS AND INTEGRATION WITH SENSORY DATA

- Partner(s): Colorado State University
- Principal: Adam Heuberger
- Primary goals(s): The goal of this project is to perform chemical and sensory profiling of hot steep malt extracts. This research will perform metabolomics of 10 hot steep malt extracts, and integrate variation in this data with malt sensory profiles to identify chemicals in the hot steep extract that are associated with specific sensory traits.
- Background: The brewing industry has recently established the hot steep (HS) extraction method to evaluate malt flavor. The HS method was developed to provide a more rapid and affordable measure of malt flavor, and lower extraction temperatures and incubation times compared to a Congress Mash extract. The HS method reduces the amount of sugars in the wort and allows for a broader sensory to evaluate flavor. Currently, the industry is working to refine the method, develop a lexicon, and establish quantitative statistics methods to evaluate flavor of the HS extract. While the sensory traits of the extract have not yet been associated to beer flavor, there is still value in understanding the sensory profile of the malt, such as internal quality assurance or quality control.
- Additional Information: The Heuberger laboratory at Colorado State University (CSU) employs a technique referred to as 'metabolomics'. Metabolomics is a comprehensive chemical profiling method that can measure 'what' chemicals and 'how much' is in a given sample, and can include both volatile (aromatics, e.g. terpenes such as linalool) and non-volatiles (e.g. sugars, amino acids, fatty acids and more complex lipids). The methods are high-throughput (a single chemical profile can be generate in ~12-30 minutes) and comparative (can measure quantitative differences among many samples). The Heuberger lab and others at CSU has performed metabolomics on barley, malt, and beer samples, including GC-MS metabolomics of non-volatiles from congress wort. The experiments results in the detection of hundreds to thousands of chemical, for example a single wort sample resulted in the detection of amino acids, organic acids, and fatty acids (unpublished data).

PROSPECTS FOR BREEDING PERENNIAL MALTING BARLEY

- Partner(s): N/A
- Principal: Colin Curwen-McAdams
- Primary goal(s): Produce a literature review and feasibility study of the genetics, economics, environmental and market aspects of breeding perennial malting barley.
- Additional Information: This feasibility study seeks to determine the potential of developing perennial malting barley. It will review perennial relatives of barley, their genetics and potential for domestication or cross pollination with malt barley lines. Disease resistance as it relates to the possibility of broadening the genetic base of barley though the use of exotic germplasm and as it relates to diseases, such as BYDV, that will be important for a perennial crop. A cost analysis for development will be explored along with the potential returns. The market impact of switching to perennial malt barley will be explored as it relates to contracts with growers, sustained production and decreased volatility in supply. The potential environmental impacts, such as carbon sequestration and more efficient use of water and fertilizer, will be considered to identify areas that are best suited for production. Malt quality traits and any known qualities in wild relatives, such as seed dormancy, will be outlined to establish breeding targets. In addition, the genetics of perenniality will be discussed, and the potential to use barley as a model crop for genetic study.

HOPS

NITROGEN APPLICATION TIMING EFFECTS ON NITRATE ACCUMULATION IN HOP CONES, YIELD AND CONE QUALITY FACTORS

- Partner(s): USDA Agricultural Research Service, OR
- Researcher: David Gent
- Primary goal(s): This project will conduct a second and final year of commercial-scale, on-farm studies to determine how nitrogen application timing interacts with important pest management and production concerns for growers and cone quality issues for brewers.
- Background: Nitrate levels in raw products and beer are increasingly scrutinized by brewers and the public. Previous research has established that there is a direct relationship between the amount of nitrogen fertilizer applied in the field and the nitrate content of hop cones at harvest. Excessive nitrogen fertilization also may reduce alpha acids content of cones, increase levels of the disease powdery mildew and certain arthropod pests, and potentially reduce yield.
- Additional Information: Experiments will again be conducted in a commercial yard of cultivar Simcoe in Washington State in 2018 to evaluate the influence of nitrogen application timing to various production and cone quality factors. We have focused the research on Simcoe because of its relevance to craft brewers and its common use in dry hopping. However, it is also susceptible to powdery mildew and the severity of the disease may be influenced by nitrogen fertilization practices. Multiple levels of outreach activities will transfer knowledge to stakeholders. We will provide updates through regular presentations at hop industry and professional meetings whenever invited. Timely updates on findings also will be pushed to friends of the Northwest Hop Information Facebook page.

ASSESSING THE GENOMIC IMPACT OF DROUGHT AND HEAT ON HOP GROWTH AND PRODUCTION

- Partner(s): USDA Agricultural Research Service, OR
- Researcher: John Henning
- Primary goal(s): Genomics, transcriptomics and plant physiological studies will be implemented to ascertain the genetic control and response to heat and insufficient water. Both field and growth chamber studies will be used to generate physiological data, which will then be correlated to genomic response. Genetic markers linked to the heat or drought tolerance will be identified and validated
- Background: Major shifts in global climate are expected to alter growing regions for crops such as hop. Selection for drought and heat tolerance is extremely difficult and time-consuming due to the inability to control environment. Genetic markers and use of molecular-assisted selection would be the most reasonable method to breed for tolerance to these environmental factors.
- Additional Information: Hops require considerable amounts of water and mild temperatures for optimal cone production; high temperatures and drought have repeatedly been associated with low cone yield. As our climate continues to change, the number of days hop-growing regions experience high temperatures and drought conditions will continue to increase. There is the potential for significant losses to growers through yield loss and the increased cost of irrigation water. This multi-state project conducted by USDA Agricultural Research Service scientists associated with the Hop Breeding and Genetics Program will look at the physiological response of hop plants to heat and drought in Washington and Oregon to identify cultivars that have increased tolerance to reduced irrigation and heat.

MAPPING NOVEL LOCI FOR POWDERY MILDEW RESISTANCE IN HOPS

- Partner(s): University of Minnesota
- Principal: Gary Muehlbauer
- Primary goal(s): We propose to develop a diversity panel composed of North American and Eurasian wild hops, genotype the panel with genotyping-by-sequencing–derived markers, and phenotype the panel for response to powdery mildew. The combined genotype and phenotype data will be used to identify markers associated with powdery mildew resistance.
- Background: Powdery mildew of hop is a major problem for commercial hop growers. To control powdery mildew, growers apply fungicides, which results in greater costs, environmental issues, and consumer concerns. Thus, "built-in" genetic resistance is the most cost effective and environmentally-sustainable approach to controlling powdery mildew. Wild hop has been shown to be a rich resource of genetic variation for disease resistance.
- Additional Information: The outcomes of this work will be a hop diversity panel that is genotyped and available to the hop research community for additional genetic studies; (2) wild hop accessions will be identified that exhibit powdery mildew resistance and can be used by breeders to enhance powdery mildew resistance in breeding programs; and (3) markers associated with powdery mildew resistance that can be used to accelerate the development of powdery mildew resistant hop cultivars.

DEVELOPING ECONOMIC AND ENVIRONMENTAL FOCUSED HOP NITROGEN RECOMMENDATIONS FOR TEMPERATE CLIMATES

- Partner(s): University of Vermont
- Researcher: Heather Darby
- Primary goal(s): A nitrogen (N) management trial including rates and timing will be conducted in a newly established hop yard. Results will be broadly shared through outreach events and an online Extension bulletin.
- Background: Over the past 5 years, we have learned very little about hop fertility management in temperate climates. Nitrogen (N) is a major yield-limiting factor for most crops, especially for organic acreage that has limited access to approved N sources. Proper N levels are critical to maximizing yield and quality while minimizing pest pressure and environmental degradation. Hops are a heavy feeder and adequate N application and timing are critical for high yields.
- Additional Information: Given the conflicting reports in the literature and high potential for N loss, hop growers in temperate climates require N application rate and timing recommendations that meet their climatic and environmental needs.
  This project will begin the development of N recommendations that support high yield and quality while protecting the environment in temperate climates.

HOP-DERIVED DEXTRIN-REDUCING ENZYMES FROM DRY-HOPPING

- Partner(s): Oregon State University
- Researcher: Thomas Shellhammer
- Primary goal(s): The proposed project will examine the variation in potential dextrin-reducing enzyme activity in commercial hop varieties and assess processing techniques for either accelerating or mitigating this effect during dry-hopping. The impact of the proposed research will improve craft beer quality and reduce consumer safety risk from package over-pressurization.
- Background: As a result of collaborative studies with the Allagash Brewing Company, we have determined that Cascade hops pellets contain dextrin-degrading enzymes at low levels but which are nonetheless effective at converting non-fermentable dextrins into fermentable sugars. A prominent question is whether the same enzyme activity exists in other hop varieties and well as what to do to control it. The goals of the research outlined in this proposal are to determine if this phenomenon is varietal dependent and to assess various strategies for either accelerating or preventing the dextrin reduction effect in the brewery so that it does not occur in beer after packaging thereby creating a consumer safety hazard due to package over-pressurization. The impact of the proposed research will improve craft beer quality and reduce consumer safety risk from package over-pressurization.
- Additional Information: A broad range of hop varieties consisting of approximately 30 of the most commonly used American and non-American hops will be procured from the leading hop processors. For some common varieties such as, Centennial, Chinook, Amarillo, we intend to examine the same variety grown in different regions to determine if regional variation occurs. Additionally, for a subset of varieties we will examine different product forms, such as whole cones, pellets, concentrated pellets and lupulin, to determine how hops processing impacts its residual enzymatic power.