



2017 BREWERS ASSOCIATION FUNDED RESEARCH GRANTS

BARLEY

ALL-MALT BEER - BARLEY DEVELOPMENT PROJECT (ONGOING)

- **Partner(s):** Brewers Association, North Dakota State University, United States Department of Agriculture Agricultural Research Service, ID (USDA-ARS Aberdeen), Briess Malt & Ingredients Co.
- **Primary goal(s):** Identify and commercialize malting barley varieties better suited to all-malt brewing for cultivation in the U.S.
- **Background:** Craft brewers represent a 36% customer for U.S. malt consumption as of 2016. And yet, there are currently no malting barley varieties specifically bred for all-malt brewing in production in the U.S. Craft brewers currently use malt made from barley varieties bred for adjunct brewing, with negative stability outcomes in packaged beer.
- **Additional Information:** Study will continue development of test plots of spring and winter lines at Aberdeen; small batch malting of an advanced line at Briess Malt and Ingredients and Oregon State University; brewery trials with working group participant breweries.

UNDERSTANDING THE GENETICS OF BARLEY CONTRIBUTIONS TO BEER FLAVOR:

- **Partner(s):** Oregon State University
- **Researcher:** Pat Hayes
- **Primary goal(s):** Mapping the genetic determinants of barley contributions to beer flavor using two very different types of germplasm and mapping strategies.
- **Background:** There is an increasing awareness of the contributions barley variety can make to beer flavor. Brewers Association funding will allow for mapping the genetic determinants of barley contributions to beer flavor using two very different types of germplasm and mapping strategies.
- **Additional Information:** In strategy 1, we will build on ongoing work that has identified statistically significant differences in components of beer flavor between doubled haploid progeny of the cross between Golden Promise and Full Pint. This strategy – using progeny of a single cross – is called bi-parental mapping. In strategy 2 we will use a panel of very diverse and exotic barleys selected from the USDA World Collection to effectively sample the total genetic diversity in barley. This strategy – using a panel of unrelated lines – is called a Genome Wide Association Study (GWAS). The strategies are complementary and together will yield key information about flavor genetics that will allow breeders to use molecular markers to breed for flavor.

METABOLITE PROFILING OF HEIRLOOM BARLEY TO BREED FOR FLAVOR AND SUSTAINABILITY

- **Partner(s):** Colorado State University
- **Researcher:** Adam Heuberger
- **Primary goal(s):** This research will perform metabolite profiling of heirloom barley breeding lines developed at Montana State University (MSU) to facilitate breeding for flavor.
- **Background:** Investigating the relationship between barley chemical composition and beer flavor is an important area of research. Some craft brewers have preference for malts from older, 'heirloom' varieties, although the chemical basis for this preference is unclear. Further, heirloom varieties are not adapted to many U.S. growing regions, and barley growers would be hesitant to adopt them for their poor agronomic performance, yield and malting quality.
- **Additional Information:** A Montana State University (MSU) effort led by Dr. Jamie Sherman established two new goals to support the craft brewing industry: (1) improve sustainability in barley production by adapting new varieties to dryland agriculture (non-irrigated) and (2) improve the malting and flavor quality of new varieties, specifically for all-malt and craft brewing. This effort is part of the proposed Rocky Mountain Malting Barley Cooperative, a collaboration with Dr. Sherman that seeks to develop new barley varieties that are demonstrated to provide flavor and are adapted for dryland production in the Rocky Mountain West.

STABLE AND SUSTAINABLE DRYLAND PRODUCTION OF HIGH QUALITY MALT BARLEY

- Partner(s): Montana State University
- Principal: Jamie Sherman
- Primary goal(s): This proposal will establish the best practices required to sustainably produce high quality malt to meet the needs of the all malt industry that is shifting towards dryland production in the Western U.S.
- 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.
- 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. This research will facilitate regional production of malt for brewing in the Rocky Mountain region.

SUSTAINABLE GROWER PRODUCTION PRACTICES: 2-ROW BARLEY AND NITROGEN USAGE (ONGOING)

- Partner(s): University of Idaho
- Researcher: Christopher Rogers
- Primary goal(s): Identification of two-row-barley cultivars with the best fit for all-malt brewing, and development of best practices for sustainable cultivation of those varieties.
- Background: This proposal plays a key role in the evaluation, selection, and development of best management practices for all-malt barley cultivars that are agronomically, economically, and environmentally sustainable.
- Additional Information: This research continues the screening of winter and spring barley cultivars as well as the development of fertilizer nitrogen best management practices that maximize plant uptake, yield, and quality and minimize disease and potentially negative environmental impacts.

EASTERN UNITED STATES SPRING BARLEY NURSERY (ESBN) (ONGOING)

- Partner(s): North Dakota State University
- Researcher: Richard Horsley
- Primary goal(s): Identify spring malting barley varieties adapted to the Eastern U.S.
- Background: The craft malting and brewing industries across the U.S. wish to source locally produced grains for making their products.
- Additional Information: The 2017 ESBN includes 25 barley varieties from ten different breeding programs being grown in Indiana, Maine, Maryland, Massachusetts, Michigan, New Jersey, New York, Ohio, Pennsylvania, and Vermont. Trial data will be available for use by local university/extension personnel to educate growers and other stakeholders on varieties that perform best in their region. Trial data will also be used by barley breeding programs to identify other varieties or advanced breeding lines that may be candidates for production in the region.

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

- Partner(s): University of Minnesota
- Researcher: Kevin Smith
- Primary goals(s): The University of Minnesota will organize a coordinated project with 14 breeders/researchers across 12 states/provinces to evaluate two-row spring malting barley lines in the upstream stages of breeding.
- Background: Rapid changes in the craft brewing industry have increased the demand for locally produced malting barley. By identifying the breeding lines that perform well in individual locations, breeders can develop superior varieties that are tailored to the local growing conditions of craft brewers across the United States.
- 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.

BARLEY BREEDING FOR ALL-MALT BREWING

- Partner(s): USDA-Agricultural Research Service, Aberdeen, ID
- Researcher: Gongshe Hu
- Primary goal(s): Evaluation of low protein germplasm lines for use in development of barley varieties suitable for all-malt brewing.
- 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.
- 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.

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

- Partner(s): University of Minnesota, Department of Plant Pathology
- Researcher: Brain Steffenson
- Primary goal(s): The overall goal of this research is the establishment of a sustainable Midwest winter barley industry for U.S. craft brewers. This requires the development of cultivars with acceptable malt quality profiles and adaptation to the climate.
- 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: The long-term aim is to exploit the extraordinary winter hardiness of Russian germplasm for development of adapted two-rowed malting barley cultivars. The specific objectives of this research are to: 1) generate breeding populations made from crosses between selected accessions of the Vavilov collection and two-rowed breeding lines with superior malting characteristics; 2) establish regional trials across the Midwest to broadly assess the winter hardiness of the Vavilov accessions and their malting quality profile; and 3) conduct outreach events at field trials to demonstrate the potential of winter barley production to producers and end-users.

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

- Partner(s): Virginia Tech: Crop & Soil Environmental Sciences Department
- Researcher: Carl Griffey
- Primary goals(s): The ultimate goal of this project is to identify and map 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) to develop superior winter malt barley cultivars.
- Background: Markers will be used to facilitate and expedite the process of developing high quality, high yielding malt barley varieties for the Mid-Atlantic and eastern regions of the U.S.
- Additional Information: Unique flavors will be characterized in Thoroughbred, Violetta, Endeavor, Flavia, and potentially Charles. Potential malt type winter wheat cultivars will be characterized and desirable cultivars recommended to interested growers, maltsters, and brewers.

BUILDING A WINTER MALTING BARLEY MARKET FOR THE GREAT PLAINS

- Partner(s): University of Nebraska
- Researcher: Stephen Baenziger
- Primary goal(s): The ultimate outcome and impact will be new cultivars and an expanding barley market for malting barley (as well as feed and forage) in a region with generally few diseases (very little Fusarium head blight), but known for abiotic stresses (harsh winters and heat/drought) and aphid pressure.
- 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: Goals will be accomplished using a two-fold strategy: 1. Evaluating existing winter malting barley germplasm from the US and Europe as a short-term way of meeting the need for malting barley and 2. Developing locally adapted winter barley with excellent malting quality for the future. This approach will provide for an immediate need to diversify malting barley production into new areas and build for a better future.

BREEDING FOR WINTER 2-ROW MALTING BARLEY CULTIVARS FOR THE EASTERN U.S.

- Partner(s): USDA Agricultural Research Service, Raleigh, NC
- Researcher: David Marshall
- Primary goal(s): Our goal is to develop superior malting quality barleys having high grain yield, desirable agronomic qualities, and the disease and insect resistance needed for production in the high-humidity environments of the eastern U.S.
- Background: In response to local agricultural production thrusts throughout the coastal regions of the eastern U.S. (from Georgia to New York), USDA-ARS researchers in North Carolina, and collaborators in the regions' land grant Universities, began breeding barley having malting quality in 2010.
- Additional Information: The USDA-ARS small grains research program in Raleigh, NC has conducted collaborative research in barley for about the last 50 years, with colleagues in private industry and public Universities. We continue to organize, distribute, and analyze barley germplasm in the Uniform Barley Yield Trial and the Uniform Barley Winter Hardiness Nursery. Since the 2013-14 growing season, we have participated in the evaluation of the University of Minnesota – coordinated Uniform Winter Malting Barley Nursery.

ENSURING MALT QUALITY FROM THE FIELD TO THE MALTHOUSE

- Partner(s): North American Craft Maltsters Guild
- Principal: Janelle Buxton
- Primary goal(s): The Craft Maltsters Guild would like to develop a guide for barley producers outlining storage and handling best practices for malting quality grain.
- Background: Craft malt has a critical role to play in the development of the craft brewing industry. As the key linkage in business and supply chain transparency, craft malt passes along a positive, place-based story that commands a premium in today's craft products market. Craft malts have the potential to explode opportunity for brewers to differentiate their products in an increasingly competitive market.
- Additional Information: In 2017, we would like to continue to improve the quality of craft malts available to brewers, as well as to remain proactive in maintaining the safety of our industry and staying ahead of shifting regulatory environments.

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): Determine how nitrogen application timing affects hop cone yield and quality factors, the disease powdery mildew, and nitrate accumulation in cones.
- 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: There is a fundamental limit to how much nitrogen fertilizer can be reduced without negatively affecting yield, there is a need to also understand how the timing of nitrogen application may influence nitrate accumulation in cones, yield, and other factors. This project builds on previous research and proposes to conduct commercial-scale, on-farm studies to determine how nitrogen application timing interacts with important production concerns for growers and cone quality issues for brewers. Multiple levels of outreach and education will help to disseminate information from this project to growers and brewers, thus speeding adoption of best management practices.

NITRATE RESIDUES IN AND ON HOPS (ONGOING)

- Partner(s): Washington State University
- Researcher: Douglas Walsh
- Primary goal(s): Evaluate the interactions of plant nutrition with arthropod pest abundance and disease severity. Quantify nutrient carryover into cones and subsequent beers brewed.
- Background: Craft brewers use innovative methods to incorporate hops in the brewing process, including dry hopping after the boil, wet hopping with fresh hops, adding hops later in the boil, and dry hopping with whole cones or pelletized hops. Most all-malt beer brands incorporate a substantially greater quantity of hops on a per unit basis than traditional American Pilsner-type adjunct lager beers.
- Additional Information: The overall objective is to help determine optimal nitrogen fertilization rates for hop growers. This will help ensure growers produce economically sustainable yields while providing craft brewers with hops that have optimal brewing properties.

IMPACT OF DISSOLVED OXYGEN ON DRY-HOPPED FLAVOR STABILITY IN BEER

- Partner(s): Oregon State University
- Researcher: Thomas Shellhammer
- Primary goal(s): This project is focused on improving beer quality and seeks to understand the impact of dissolved oxygen on the analytical and sensory profiles of hop aroma in dry-hopped beers during storage.
- Background: It is widely understood that dissolved oxygen has a negative impact on the flavor stability of beer but there is little published work on oxygen's impact on hop aroma stability. However, it is generally recognized within the brewing industry that hop aroma/flavor in beer changes throughout distribution.
- Additional Information: The main questions this project answers are: How does DO concentration impact the sensory and chemical stability of dry-hopped beers? What are acceptable shelf lives for dry-hopped beers? What are chemical markers of dry-hop flavor stability and oxidation? What role do metal ions from hops and their interaction with dissolved oxygen play in flavor deterioration in dry-hopped beers?

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

- Partner(s): USDA Agricultural Research Service, OR
- Researcher: John Henning
- Primary goals(s): 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.
- Background: 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. There is the potential for significant losses to growers through yield loss and the increased cost of irrigation water.

STRATEGIES TO MANAGE SOIL QUALITY AND SUSTAINABILITY IN COMMERCIALY MANAGED HOP FARMS

- Partner(s): Idaho Hop Commission
- Researcher: Michelle Gooding
- Primary goals(s): This project focuses on the sustainable growing practices of hops in the Pacific Northwest region. More specifically the goal is to determine how soil fertility can be maintained in a sustainable manner while commercially producing hops.
- Background: The Pacific Northwest (Idaho, Oregon and Washington) plays host to approximately 97% of annual hop production in the United States. Many of these farms have existed for generations and have intensively managed their soils (i.e., high nutrient inputs, low organic matter return) for equally as long. Signs of degradation are growing (e.g., erosion, compaction, decreased organic matter content) and the need for improved soil health in these lands is becoming increasingly evident to hop farmers.
- Additional Information: This project will build upon established relationships with farmers and seek to increase awareness of soil quality issues and integrate novel soil fertility practices in the conventional hop-farming model. In addition to currently active farmers, this work will engage younger generations and incorporate the local community through youth education in K-12 course curricula, presentations and direct involvement of FFA students.

IDAHO HOP COMMISSION PUBLIC BREEDING PLOT: EVALUATING FUTURE CULTIVARS AND SUSTAINABLE COVER CROP PRACTICES

- Partner(s): Idaho Hop Commission
- Researcher: Michelle Gooding
- Primary goals(s): This project seeks to find the next prolific public hop variety in Idaho while also examining different cover crop options.
- Background: Idaho has a strong history with the public breeding program and wants to further contribute to this cause. The growers of the Idaho Hop Commission have a desire to see the public breeding program thrive while gain new insights into sustainable practices through cover cropping.
- Additional Information: The experiment will be conducted on the Idaho Hop Commission (IHC) test plot located in Wilder, Idaho. Two different cover crops will be planted in the plot (spring wheat and hairy vetch). Cover crop effectiveness will be determined based on the evaluation of soil physical parameters.