# 2020 BREWERS ASSOCIATION FUNDED RESEARCH GRANTS

## BARLEY

### BUILDING A WINTER MALTING BARLEY MARKET FOR THE GREAT PLAINS

- Partner(s): University of Nebraska-Lincoln
- Principal: Stephen Baenziger
- Primary goal(s): Develop winter malting barley cultivars for the Great Plains by linking the two main barley breeding programs for this region, working with other barley breeders to collect germplasm, and expanding testing to 5 multi-state locations. Hence, we propose 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. Furthermore, we will work with local maltsters and brewers to provide useful information on growing malting barley for local and national needs. Simply, our proposal is to agronomically evaluate at 5 locations (eastern and western Nebraska, western KS, and central and southern OK) existing malting barley lines and to create and test locally adapted breeding lines at these same locations.
- Background: There are two winter barley breeding programs in the Southern Great Plains that are creating new barley cultivars, specifically the University of Nebraska (UNL) barley breeding program in Nebraska and the USDA-ARS barley breeding program in Oklahoma. For the past 5 years, the UNL has been supported by AMBA and has been introgressing malting barley germplasm into its program. The USDA-ARS in OK has been supported by AMBA for over 20 years to identify and introgress aphid resistance genes into malting barley germplasm. A third program, Limagrain Cereal Seeds is importing European malting barley seed with some success in the Great Plains, thus developing a local malting barley market. We propose having testing locations in Kansas, Nebraska, and Oklahoma that represent the core productions zones in the Southern Great Plains.
- Additional Information: Barley was once widely grown throughout the Great Plains but almost all those acres have been converted to winter wheat or summer annuals (corn and soybeans). Alternative production areas must have the knowledge base, familiarity with the crop, and maintain the equipment to produce the crop for the alternative production area to be successful.

### IMPACT OF STORAGE ON MALTING QUALITY AND SEED DORMANCY IN PRE-HARVEST SPROUTING (PHS) RESISTANT SPRING BARLEY

- Partner(s): Cornell University Department of Plant Breeding and Genetics
- Principal: Mark Sorrells
- Primary goal(s): Little is known about how malting quality changes with storage time in PHS resistant germplasm. Our goal is to reduce grower and maltster risk by understanding how PHS resistance affects seed dormancy release over time and how the timing of dormancy release impacts malting quality assessment.
- Background: Premature loss of seed dormancy in the field increases the risk of pre-germination or, in more severe cases, pre-harvest sprouting (PHS) when excessive moisture from dew or rain is present. Sprout-damaged barley grain has reduced storage life and in severe cases may be totally unusable for malting. The Midwest and Northeast are seeing increased malting barley acreage as demand for locally produced grain increases from craft maltsters and brewers. These regions often have wet summers and are at high risk for PHS, especially considering many available varieties are highly PHS susceptible. Our goal is to reduce grower and maltster risk by understanding how PHS resistance affects seed dormancy release over time and how the timing of dormancy release impacts malting quality assessment.
- Additional Information: Sustained success of the malting barley effort throughout the Northeast and Midwest (and occasionally in the West) is largely contingent on the release and adoption of varieties that can consistently produce high malting quality grain in wet or humid conditions during grain ripening. Germplasm that shows good PHS resistance often has reduced malting quality, but this may be due more to the timing of malting tests after harvest and standard micro-malting methods that are better suited to barley grown in dry climates for large-scale malting and brewing.

## INTERACTION BETWEEN BARLEY GENETICS AND MALT PROCESS IMPACT ON FLAVOR

- Partner(s): Montana State University
- Principal: Jamie Sherman
- Primary goal(s): Objective 1: Grow 4 chemically diverse barley varieties producing enough material for the project. Objective 2: Malt 400 g of each variety by 9 different treatments and send the 36 samples to Heuberger for metabolomics. Objective 3: Hot steep taste testing of 12 samples from malt made above to determine if chemical differences are perceptible. Objective 4: 12 divergent malt samples will be nano brewed by Rahr and brews chemically analyzed.
- Background: Historically, unique flavors due to malt have been provided by changes in the malt process rather than by differences in barley varieties. Although there is some evidence that barley variety contributes to flavor, the impact on flavor by the interplay between barley variety and malt process is under-investigated. Here we propose to build on our current study and interrogate further the relationship between variety and malt process by analyzing four new chemically diverse varieties.
- Additional Information: Outcomes: Determine the interplay between barley genetics and malt process on flavor potential. If the interaction between genotype and malt process is significant then it will change the way breeders, maltsters and brewers think about flavor. In any case, this study will increase our understanding of factors impacting flavor. Long-term Impacts: This work could provide craft brewers with new tools to develop unique flavored beer.

## WINTER AND SPRING TWO-ROW MALT FOR CONVENTIONAL AND ORGANIC SYSTEMS

- Partner(s): Montana State University
- Principal: Jed Eberly
- Primary goals(s): Objective 1: Test 25 winter barleys in tilled and no-till systems to determine the impact on important traits, including winter survival, yield, and malt quality. Objective 2: Continue building the winter barley breeding pipeline for Montana by making crosses, inbreeding and testing about 8,000 lines resulting from winter crosses for winter survivability and malt quality. Objective 3: Compare spring barley in conventional and organic systems to identify varieties particularly suited to organic management and/or to identify varieties with agronomic and malt stability across conventional and organic management systems.
- Background: Barley is the second most widely grown grain crop in Montana. Initially, barley was grown primarily as an animal feed, but more recently malt barley has dominated the state. Barley also has value as a rotational crop with wheat, sugar beets and, most recently, pulse crops. Spring barley has been the focus in Montana, even though winter barley can have significantly higher grain yields and lower grain protein. Winter barley could provide more sustainable malt production in the state by making better use of early spring moisture and requiring fewer inputs per amount of malt produced.
- Additional Information: Deliverables for 2020: 1. Recommendations for best management for winter survivability. 2. Results shared with end-users and growers to encourage adoption of lines and management practices, as well as shared with the scientific community through presentations and publications. 3. Identification of winter barley lines with best winter survivability, agronomics and malt quality. 4. Continuation of a winter barley breeding pipeline for Montana. 5. Continuation of an organic production barley variety trial for Montana. 6. Submission of an organic barley grant to a USDA panel with the goal of more organic testing involving organic growers.

## USING MARKER-ASSISTED SELECTION TO DEVELOP MALTING QUALITY BARLEY VARIETIES FOR CONVENTIONAL AND ORGANIC AGRICULTURE

- Partner(s): University of California, Davis
- Principal: Alicia del Blanco
- Primary goal(s): Complete the backcrossing cycles for low protein and start selfing and increasing. Complete the four backcrosses for low beta-glucan introgression. Test lines in organic system.
- Background: Grain protein and β-glucan content are important traits for high quality malting varieties and are key traits to improve in two-row spring malting barley germplasm at UC Davis. To achieve grain protein contents lower than 12%, as recommended by AMBA, growers must manage N fertilization carefully, which sometimes can impose limitations to grain yield potential. To reduce grain protein content (GPC) without limiting grain yield we initiated, two-years ago, the introgression of the low GPC allele from 'Karl'.
- Additional Information: The introgression of the low GPC allele from Karl to our elite malting barley genotypes 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. The introgression of the low β-glucan allele will improve the UCD germplasm for this trait.

## CONTINUED SUPPORT FOR THE DEVELOPMENT OF TWO- AND SIX-ROWED WINTER MALT BARLEY VARIETIES FOR THE EASTERN U.S.

- Partner(s): Virginia Polytechnic Institute and State University
- Principal: Carl Griffey
- Primary goals(s): The main objective of this study is to evaluate genetic architecture and identify molecular markers that are linked to novel genes and QTL associated with improved malting quality. This will allow us to accelerate development of malt barley cultivars for the mid-Atlantic and southeastern U.S. regions having superior malting quality.
- Background: To support the craft malt movement in the southeast and mid-Atlantic region, farmers must have access to barley cultivars that are well-adapted to the hot, humid growing conditions (resistance to diseases, pre-harvest sprouting, and lodging, while fitting the soybean double crop rotation) and have superior malting qualities (low β-glucan, balanced enzyme package, low protein, and desirable flavors). Virginia Tech has been releasing barley cultivars since the 1940's, therefore we are poised to take on the challenge of developing cultivars optimized for this new agricultural system.
- Additional Information: Knowledge of this study will be published in a peer reviewed journal such as Crop Science or Cereal Chemistry. Identified QTL and diagnostic markers will be used by the Virginia Tech Small Grains Breeding and Genetics program to advance the development of cultivars with superior malting quality traits. This information will likely be of value to most winter malt barley breeders, as it will further enhance the understanding of genetic components controlling malt quality in barley. Once validated the SNP markers can be applied in other breeding programs.

## DEEPER EXPLORATIONS OF BARLEY AND TERROIR CONTRIBUTIONS TO BEER FLAVOR

- Partner(s): Oregon State University
- Principal: Pat Hayes
- Primary goal(s): Using winter and facultative two-row doubled haploids developed by the Oregon State University program and compared to a control: 1. Integrate fundamental science on barley contributions to beer flavor with development and release of varieties meeting BA all-malt specifications. 2. Explore the basis of terroir in barley contributions to beer flavor by characterizing soil and environmental attributes. 3. Contribute to a deeper understanding of the genetic and biochemical basis of barley contributions to beer flavor.
- Background: The contributions of barley variety and growing environment to the flavor of beer is an expanding area of research, with important fundamental and commercial implications. We have developed a path for developing barley and assessing varieties of potential interest to the craft industry based on unique flavor, quality, and agronomic attributes. The path starts with development of doubled haploid germplasm from cross combinations that allow for simultaneous breeding progress and contributions to fundamental genetics. The path leads to release of new varieties. A key to variety release will be rigorous assessment of flavor across environments.
- Additional Information: This research will: 1. Directly contribute to the release of winter and facultative two-row barley varieties, meeting expectations of the craft industry, with competitive agronomic performance and unique flavor contributions to beer. 2. Generate publicly available agronomic, malting quality, and hot steep and beer sensory data on agronomically relevant winter two-row barley germplasm. 3. Contribute to the fundamental body of knowledge regarding the genetics and biochemistry of barley contributions to beer flavor.

## IDENTIFYING SPRING MALTING BARLEY VARIETIES FOR THE CRAFT BREWING INDUSTRIES

- Partner(s): North Dakota State University
- Principal: Richard Horsley
- Primary goal(s): Support the evaluation of 25 barley varieties in the Eastern Spring Barley Nursery (ESBN) in 2020 in six states in the eastern US (MA, MI, OH, NY, VT, and ME). Researchers at Rutgers University will be growing the trial but using their own funds to support their work. Our goal is to determine if varieties developed outside the region may be adapted for local production.
- Background: Barley used for malting and brewing must meet specific requirements on nearly 20 different end-use quality traits. Barley grown outside of its area of adaptation often fails to meet the specifications needed for malting and brewing, which include grain free of pre-harvest sprouting, grain protein less than 12%, plump kernels > 80%, and germination ≥ 95%. Additionally, un-adapted varieties often have lower yields and are susceptible to local diseases that are not present in the area where they were developed.
- Additional Information: The 25 ESBN varieties/lines are grown in replicated trials in MI, OH, PA, VT, ME, MA, and NY. Data are collected by local experiment station or extension personnel. A composite sample from each entry from every location are sent to North Dakota State University (NDSU) for determining barley quality (kernel plumpness, protein, pre-harvest sprouting damage, and mycotoxin levels). Data from field and lab evaluations are compiled and analyzed at NDSU and a final report is sent back to cooperators.

# HOPS

## MULTIFACETED IMPACTS OF NITROGEN AND SULFUR FERTILITY ON HOP PRODUCTIVITY, QUALITY, AND BREWING CHARACTERISTICS

- Partner(s): US Department of Agriculture; Oregon State University
- Principal: David Gent
- Primary goal(s): Continuation of field, analytical, and brewhouse research to understand how growers' fertility practices related to nitrogen and sulfur impact cone quality, aroma and flavor characteristics, pest management considerations, yield, and nitrate levels in harvested cones.
- Background: Nitrate levels in raw products and beer are recognized as a potential quality defect when levels are excessively high. We have established that there is a strong, positive relationship between the rate and timing of nitrogen fertilization and resulting nitrate levels in hop cones, with subsequent nitrate transfer from hops during brewing proportionate to hopping rate. Further, we have also quantified interactions between nitrogen fertilization and levels of alpha acids, sensorial characteristics of hop cones, and practical aspects of pest management in the field. In this project, we will build on these findings and investigate how nitrogen and sulfur fertilization jointly influence nitrate accumulation in cones and multiple phases of crop yield and quality in the field, laboratory, and brew house.
- Additional Information: Based on the behavior of nitrogen and sulfur in other plant systems, we expect that increasing sulfur fertilization may decrease nitrogen stored as nitrate but potentially alter aroma and flavor characteristics of hops and beer due to changes in thiol containing compounds and other mechanisms.

## MAPPING NOVEL LOCI FOR POWDERY MILDEW RESISTANCE IN HOPS

- Partner(s): University of Minnesota
- Principal: Gary Muehlbauer
- Primary goal(s): 1. Identify wild hop accessions that are resistant to a wide variety of powdery mildew isolates. 2. Characterize a wild hop diversity panel for powdery mildew resistance. 3. Identify genetic loci that control powdery mildew resistance.
- Background: Crop improvement relies on identifying and utilizing genetic variation. In hop (Humulus lupulus L.), most varieties have been derived from only a handful of genotypes resulting in limited genetic variation. Previously, utilization of wild relatives of hop has been a rich source of genetic variation and has since allowed for the development of novel hop varieties that are tolerant or immune to various pathogens.
- Additional Information: To control powdery mildew, growers apply multiple applications of fungicide, resulting in added expenditures along with environmental and consumer concerns. Therefore, "built-in" genetic resistance is the most economical and environmentally-friendly approach to controlling hop powdery mildew. Wild hop collections have a wealth of genetic diversity and have been invaluable sources of novel alleles for disease resistance.

## CONTROLLING HOP ENZYMATIC POTENTIAL – HOP KILNING AND BREWERY TREATMENTS

- Partner(s): Oregon State University
- Principal: Thomas Shellhammer
- Primary goal(s): This project has three objectives: 1. Identifying the links between kilning temperature and hop enzyme potential, 2. Determining the degree to which other processing factors/decisions (such as thermal pasteurization and proteolytic enzyme treatments) reduce the 'hop creep' phenomenon, and 3. Examine practical steps that can be taken in the brewery to mitigate and/or eliminate this phenomenon.
- Background: Building on the hop enzyme project funded by the BA in 2017 and 2018 and additional work we are carrying out with an ongoing hop kilning project funded by the Hop Research Council, we have determined that hops contain dextrin-degrading enzymes at low levels which are capable of converting nonfermentable dextrins into fermentable sugars. This phenomenon is informally described by brewers as "hop-creep" but is more properly defined as 'hop diastatic power (DP)'. In this project we propose to examine how the processing of hops (i.e. kiln temperature) and different techniques in the brewery (pasteurization and enzymes) can be used to control hop DP.
- Additional Information: Re-fermentation of fully-attenuated beer following dry-hopping has been shown to be associated with enzymes that are introduced to the attenuated beer by the hops during dry-hopping. This project will identify factors such as treatment of raw material (i.e. hop kilning) and beer production regimes (i.e. hops & beer pasteurization, enzyme treatments) that exacerbate or minimize the re-fermentation phenomenon. The goal of the proposed research is to eliminate or significantly reduce hop enzymic activity thereby improving beer quality, brewery operational efficiency, and consumer safety.

### ANALYSIS OF VARIOUS METABOLITES IN HOPS AS POTENTIAL KEY PARAMETER FOR THIOL AND ESTER RELEASE BY YEAST DURING BEER FERMENTATION

- Partner(s): Nyseos, Barth-Haas Group
- Principals: Laurent Dagan, Christina Schoenberger
- Primary goal(s): The project includes 3 complementary parts: 1. The measure of hop metabolites in various varieties: glutathione, amino acids, hydroxycinnamic acids, (E)-2-hexenal, thiol precursors (including new forms), lipids and sterols. 2. Preliminary studies on the influence of cultural and technical parameters involved in the process: harvest date, kilning temperature, location in cones. 3. Study of the impact of each metabolite present in hop during fermentation.
- Background: Some aromatic hop varieties contain free and bounded thiols in form of precursors. Their aroma properties are very important to brewers as they impart many different fruity flavours into beer during dry hopping. Analysis of these compounds (3MH, 4MMP and 3MHA) is challenging and currently only offered by very few laboratories. The existence of these compounds and their sensory relevance in hops is relatively new knowledge to the brewing world. In order to have a controlled impact of these compounds in the brewing process a lot of information needs to be gathered.
- Additional Information: The topic of thiols as a resource for fruitiness in craft beers presents many opportunities to develop new beer profiles and a better flavour consistency management of all relevant beer styles as IPA, pale ales, IPL etc. The challenge is to identify and manage the hop samples and the hopping parameters during brewing allowing brewers to optimize the transfer and release of fruity thiols in desired concentrations.

## DRAUGHT BEER QUALITY

### EVALUATION OF BIOFILM GROWTH IN CHEMICALLY TREATED BEER DRAUGHT TUBING

- Partner(s): Montana State University, Center for Biofilm Engineering
- Principal: Darla Goeres
- Primary goal(s): Building on the research completed by the Center for Biofilm Engineering and NSF International, we will determine if beer draught line tubing exposed to the caustic and acidic cleaners recommended in the Draft Beer Quality Manual support more biofilm growth after a simulated 1, 2 and 5 years of cleaning.
- Background: Given how significant of an impact poor draught line hygiene can have, the Brewers Association has endorsed a rigorous and regular cleaning approach for the maintenance of commercial draught lines as outlined in their Brewer's Manual, recommending the type of biocide(s), concentration, flow rate of application, and frequency of the line cleaning. As a universal process to be applied across all systems, it would be accurate to describe this as a one size fits all approach. The Brewers Association has empirical evidence that this cleaning strategy works. Draught beer dispensed from lines cleaned according to this protocol are high quality, which is the goal.
- Additional Information: The results will include: 1. viable plate counts of the bacteria and yeast, 2. images of the tubing after aging and before biofilm growth, and 3. images of the tubing with biofilm. This study will inform the Brewers Association of any negative impacts associated with over cleaning beer draught lines.