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Determination of Optimum Harvest Date for Winter Malting Quality Barley in Northwest Arkansas

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Determination of Optimum Harvest Date for Winter Malting Quality Barley in Northwest Arkansas

Cover Page Footnote
Thanks the the University of Arkansas Wheat Breeding Program for providing the the field space, work area, and help for this project.
Determination of optimum harvest date for winter malting quality barley in Northwest Arkansas

Meet the Student-Author

I am from White Hall, Arkansas and was homeschooled which allowed me to earn a technical certificate in Metal Inert Gas welding before coming to the University of Arkansas in the fall of 2015. After my first semester as a Crop Science major, I added Animal Science as a second major, with the goal of one day owning a self-sustaining farm. My interest in small grains was sparked after helping Dr. Mason and the wheat breeding program with harvest in 2017. And the next year I was not only helping with harvest but harvesting my own research plots. While at the university, I had the opportunity to study abroad in India to learn about their views on GMOs and their agriculture research system. I also served as an officer in the Crop, Soil, and Environmental Sciences Club, before I graduated cum laude in May 2019 with majors in Crop Science and Animal Science and a minor in Agricultural Business.

I am thankful for the help of Dr. Mason and the University of Arkansas Wheat Breeding Program for their help in guiding me through this project.

After graduation, I am planning to take a year off before pursuing my JD and MBA, with the goal of working as an administrative law judge on the many policy issues that the agriculture sector will face.

Meet the Student-Author

Paul Wolf

Research at a Glance

- Barley is a grain that can be grown across much of the world, but its growth is not tracked in Arkansas.
- The preference of barley for malting makes it a potentially profitable grain for Arkansas.
- Barley is able to meet the germination requirements for malt quality when grown in Arkansas.

Paul collecting barley heading date data in May 2017 at the University of Arkansas System Division of Agriculture’s Agricultural Experiment Station.
Determination of optimum harvest date for winter malting quality barley in Northwest Arkansas

Paul D. Wolf*, David Moon†, and Richard Esten Mason§

Abstract

Due to the strict quality requirements, only 10% of worldwide barley is used for malting. As such, malting quality barley comes with a price increase of up to 50% or greater. With the craft brewery industry growing in Northwest Arkansas there is a growing demand for locally sourced malt quality barley. However, data are lacking regarding production practices for barley in Arkansas. The optimal harvest date for malting quality barley is at physiological maturity. This is because many of the malting traits (such as germination energy) decline as the harvest is delayed, which makes it difficult to meet the criteria for malting quality if the barley is left in the field. The purpose of this study was to evaluate the effects of harvest date on the malting quality of barley grown in Northwest Arkansas, specifically, the effect of harvest date on barley seed quality characteristics that impact malting and the interaction of harvest date and cultivar. Harvest date, cultivar, and in many cases the interaction of harvest date and cultivar were significant for grain yield, test weight, water sensitivity, germination energy, and germination capacity. There was no significant variation between cultivars for protein content. In general, all malting quality traits decreased with delayed harvest and the decrease at 21 days after physiological maturity was statistically significant. Of the cultivars tested, Thoroughbred was closest to meeting the criteria for malting quality, having the greatest grain yield, while maintaining germination energy and capacity into a later harvest date.

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§ Richard Esten Mason, the faculty mentor, is a professor in the Department of Crop, Soil, and Environmental Sciences.
Introduction

Barley is number four in terms of area cultivated in cereal grains in the world at 49.24 million hectares (USDA-FAS, 2019). The major uses of the barley grown is for malting and as a feed source (Jacobs, 2016). Due to the strict quality requirements, approximately 10% of worldwide barley is used for malting, though malting quality barley comes with a price increase of up to 50% or greater. In the United States, 25% of the barley grown is used for malting (Davison et al., 2007). In 2017, 1,004,025 ha of winter and spring barley were planted in the United States, and 790,756 ha were harvested (USDA-FSA, 2018). No barley production for Arkansas was reported to the Farm Service Agency for 2017 (USDA-FSA, 2018).

With the craft brewery industry growing in Arkansas, particularly in the Northwest area of the state where over half of the state’s microbreweries reside, there is a growing demand for locally sourced malt quality barley (Brewers Association, 2018). However, data are lacking regarding production practices for barley in Arkansas. The University of Arkansas System Division of Agriculture’s Agricultural Extension Service offers handbooks and guides for the cereal grains wheat, rice, and oats but data for barley are not present (Cooperative Extension Service, 2019). With winter wheat production declining in Arkansas, malt quality barley could serve as an alternative winter small grain for Arkansas producers (USDA-NASS, 2019).

While many different malting grains are available, barley is considered the best for malting, and thus there is potential for barley to be an economically successful crop for Northwest Arkansas. The malting process consists of steeping, germination, and kilning. When looking at kernel characteristics for malting, germination rate is one of the most important as it leads to protein and carbohydrate hydrolysis during malting that also occurs during early growth (Muñoz-Amatriain et al., 2010; American Malting Barley Association, 2017). When analyzing malt quality, malt factors such as total protein, malt modification, congress wort, and malt enzyme levels are all important (American Malting Barley Association, 2017).

There are currently no recommendations for barley production in Arkansas. The purpose of this study was to determine how harvest date affects the malting quality of barley in Northwest Arkansas. Specifically, we determined the effect of harvest date on barley seed quality characteristics that impact malting and the interaction of harvest date and cultivar. This study provided preliminary data to formulate a recommendation for harvest date in Northwest Arkansas, to suggest variety recommendations, and to aid in future studies on barley in the area.

Materials and Methods

Barley Cultivars and Experimental Design

Five winter malting quality barley cultivars were used for this study including Charles, Endeavor, McGregor, Thoroughbred, and Wintmalt. Of these cultivars, Charles, Endeavor, and Wintmalt are 2-row varieties; McGregor and Thoroughbred are 6-row varieties. The use of both 2- and 6-row varieties was important to evaluate if genetics impacted traits more than the environment. The location in which each cultivar was developed is also important as varieties are bred to perform well in different growing environments and hence affect adaptation to Northwest Arkansas conditions. Charles and Endeavor were developed in Idaho, McGregor was developed in Wisconsin, Thoroughbred in Virginia, and Wintmalt in Europe but adapted to Washington (French, 2012; Obert et al., 2009; Virginia Polytechnic Institute and State University, 2013; Windes and Obert, 2009).

The barley cultivars were drill-seeded in four-row plots at a rate of 250 seed/m² in a randomized complete block design with eight replications on 21 October 2017. Plot dimensions were 1.5 m wide and 1.22 m. Plots were managed using recommended cultural practices for wheat production because there are no current recommendations for barley in Arkansas. Nitrogen fertilizer in the form of urea was applied twice during the study. The first application was 67.25 kg/ha (27 February 2018) and the second was 33.63 kg/ha (21 March 2018).

Trait Measurement

During the season, heading date was recorded on each plot as the day when 50% of the developing barley heads fully emerged from the leaf sheath. A single row from each replication was harvested on four different dates, with the first date beginning at physiological maturity on 1 June 2018 (HD1). Subsequent harvest dates occurred on 8 June (HD2), 15 June (HD3), and 23 June 2018 (HD4). After harvest, samples were oven-dried to a constant moisture of 7.5% and subsequently stored to maintain 7.5% moisture until processing.

In the Fall of 2018 and Spring of 2019, the tests to determine grain yield, test weight, germination capacity, germination energy, and water sensitivity were performed at the University of Arkansas System Division of Agriculture’s wheat breeding program lab located on the Arkansas Agricultural Research and Extension Center, Fayetteville, Arkansas. Protein analysis was outsourced to the USDA Agricultural Research Service – Cereal Crop Research Unit.

Grain yield was measured by weighing the grain harvested from each plot after cleaning. Measurements were taken by weighing the seeds and envelopes used to store the grain after taking an empty 8-ounce spear envelope.
Test weights were measured by taring a 6000-g scale to the weight of a ¼ cup measuring cup. The ¼ cup measuring cup was then overfilled; a straight edge was run across the top of the measuring cup to ensure the seeds were level with the top edge of the measuring cup. The filled ¼ cup measuring cup was weighed and the weight recorded in grams per ¼ cup. Weights were converted using the following formula \[
\text{test weight in kilograms per hectoliter} = \frac{\left(\text{weight in g} \times 1690.7\right)}{1000}
\] resulting in the reported test weight.

Germination capacity, germination energy, and water sensitivity were measured simultaneously using methods adapted from the Simultaneous Determination of Germination Energy, Water Sensitivity, and Germination Capacity in Barley (Kuester et al., 1997). Four Petri dishes were filled with 2 pieces of filter paper each for every sample to be tested. Next, the dishes were labeled A through D for each sample and 100 seeds for each sample were added to each Petri dish. Four milliliters of distilled water was added to each of the dishes labeled A and B, and 8 mL was added to the dishes labeled C and D. The Petri dishes were then stacked and placed at room temperature in plastic boxes to prevent excessive evaporation of water out of the dishes. Each of the dishes was inspected as close to every 24 hours as possible. When being checked the chitted seeds (seeds with the radical extruding) were considered to be germinated and removed to prevent them from continuing to imbibe water. After 72 hours of germination, the total number of seeds germinated for dishes A and B of each sample were averaged resulting in the germination energy for the sample. The water sensitivity was calculated by averaging the seeds germinated in dishes C and D and subtracting it from the average of A and B, with the resulting formula

\[WS(\%) = \frac{A + B}{2} - \frac{C + D}{2}\]

Following the 72 hours of incubation, all germinated seeds were removed and 2 mL of 0.75% H₂O₂ were added to each of the dishes A and B with seeds remaining. They were then left to incubate for another 48 hours after which the seeds germinated for each dish were counted and the average was taken and reported as germination capacity.

### Statistical Analysis

The descriptive statistics mean, median, and standard deviation were calculated in Microsoft Excel. An analysis of variance (ANOVA) was performed in SAS 9.4 with the factors cultivar, harvest date, and the interaction of cultivar and harvest date treated as fixed effects and replication as a random effect (Table 1). Means were separated using Fisher's least significant difference test at \(\alpha = 0.05\).

### Results and Discussion

#### Analysis of Variance

The effects of cultivar and harvest date were significant for grain yield, test weight, water sensitivity, germination energy, and germination capacity. There was no significant variation between cultivars for protein content, which ranged from 16.17% to 12.34% on a dry basis. There was an interaction between cultivar and harvest date for water sensitivity, germination energy, and germination capacity.

#### Barley Grain Yield

Grain yield is important to malting quality barley as greater grain yields result in greater malt being produced from the harvested area. There was a difference in grain yield due to harvest date with HD1 (physiological maturity) at 132 g/plot, greater than all other harvest dates. There was no significant difference observed between harvest dates HD2, HD3, and HD4, which yielded 102, 96, and 106 g, respectively.

Grain yield was also affected by cultivar, with Thoroughbred being the greatest yielding at 185 g and different from all other cultivars. The grain yield of Thoroughbred was nearly double that of Endeavor (96 g), McGregor (95 g), and Wintmalt (95 g). The grain yield of Endeavor, McGregor, and Wintmalt was not different. Charles was lower yielding at 71.97 g (Fig. 1).

#### Germination Energy

Germination is important to the malting process, so a greater germination energy (GE) is better for achieving a superior malting quality. The expectation is that GE is at 98% or greater for malting quality barley (American Malt-
Fig. 1. Effect of cultivar on barley grain yield for cultivars Charles, Endeavor, McGregor, Thoroughbred, and Wintmalt. Means were separated using Fisher’s least significant difference test at $\alpha = 0.05$. Numbers in parentheses indicate whether the cultivar is a 2- or 6-row type barley.

Fig. 2. Effect of cultivar by harvest date interaction on germination energy for five barley cultivars: Charles, Endeavor, McGregor, Thoroughbred, and Wintmalt. Means were separated using Fisher’s least significant difference test at $\alpha = 0.05$. Numbers in parentheses indicate whether the cultivar is a 2- or 6-row type barley. HD1 = Physiological Maturity; HD2 = 1 week after Physiological Maturity; HD3 = 2 weeks after Physiological Maturity; HD4 = 3 weeks after Physiological Maturity.
ing Barley Association, Inc., 2019). Germination energy was affected by harvest date, cultivar, and the interaction of cultivar and harvest date. While HD1, HD2, and HD3 were the same, HD4 was 6% lower in germination capacity.

The differences in germination energy between cultivar and harvest date showed that the 6-row cultivars (McGregor and Thoroughbred) stayed relatively consistent across all harvest dates, with McGregor dropping 1.8% and Thoroughbred dropping 1.3% between HD1 and HD4. Germination energy for the 2-row cultivars (Charles, Endeavor, and Wintmalt) was reduced by greater than 5% between HD3 and HD4. Before that, the germination energy of Endeavor and Wintmalt dropped 2.3% and 1.3%, respectively, between HD1 and HD3. However, Charles held steady at approximately 99% through the first three harvest dates and dropping on the HD4 (Fig. 2).

Germination Capacity
The measure of the number of seeds that germinated after exposure to 0.75% H$_2$O$_2$ quantified germination capacity. This capacity reflects the ability to germinate in non-optimal conditions. Therefore, greater germination capacity is desired for malting quality barley. Overall, the trend for germination capacity was similar to germination energy across harvest dates, cultivars, and cultivar by harvest date (data not shown).

Water Sensitivity
Water sensitivity (germination in 4 mL of water compared to germination in 8 mL water) differed between harvest date, cultivar, and cultivar by harvest date. Harvest date 1 showed the least sensitivity to water, at less than 1%, and HD4 is the most sensitive at 9%. Harvest date 2 and HD3 were not different (Fig. 3). The 6-row varieties, McGregor and Thoroughbred, were lower in water sensitivity than the 2-row varieties making them more desirable for malting (Fig. 3).

Except for Endeavor, all cultivars were at or below 1% water sensitivity for HD1. For HD2, Charles and McGregor were both near 2% with Charles being 2.4% and McGregor being 1.9%. Water sensitivity for Thoroughbred, Endeavor, and Wintmalt also increased for HD2 with Thoroughbred increasing to almost 4%, Endeavor to 4.5%, and Wintmalt to 8%. However, HD3 was different with Thoroughbred staying near 4%, and the 4 other varieties increasing. Charles increased to 5% from 2%, Endeavor to 6.5% from 5%, McGregor to 3% from 2%, and Wintmalt to over 10% from 8%. Harvest date 4 had the greatest sensitivity for 4 of the 5 cultivars. The sensitivity for Charles and Endeavor increased by more than 8%. McGregor increased to 4% and Thoroughbred recorded its greatest water sensitivity at 4%. Wintmalt was the only cultivar for which the sensitivity decreased for the 4th harvest date dropping from 10% to 7.5% (Fig. 3).

![Fig. 3. Effect of cultivar by harvest date interaction on water sensitivity for five barley cultivars with harvest date averages: Charles, Endeavor, McGregor, Thoroughbred, and Wintmalt. Means were separated using Fisher’s least significant difference test at α = 0.05. Numbers in parentheses indicate whether the cultivar is a 2- or 6-row type barley. HD1 = Physiological Maturity; HD2 = 1 week after Physiological Maturity; HD3 = 2 weeks after Physiological Maturity; HD4 = 3 weeks after Physiological Maturity.](image-url)
Conclusions

The optimal harvest date was at physiological maturity for malting quality barley. Many of the malting traits (such as germination energy) declined as harvest was delayed. It is possible to minimize the losses to the malting traits if harvest is completed within 14 (HD1 to HD3) days of maturity but by 21 days after maturity, it is unlikely to meet the criteria for malting quality barley. Of the cultivars tested, the 6-row cultivar, Thoroughbred, performed better than other cultivars. It has the greatest grain yield and thousand kernel weight, also it performed the most consistently across the malting traits maintaining malting quality germination energy and capacity into HD4. Thoroughbred became more sensitive to water by HD4, so harvesting early is still recommended. Of the 2-row cultivars, Wintmalt performed consistently but was more prone to reduced performance as harvest was delayed. McGregor had slightly lower yield but better performance in the malting traits than Wintmalt. For malting quality barley, the recommended cultivars are Thoroughbred and McGregor followed by Wintmalt for the traits evaluated in this study. While Thoroughbred came the closest to meeting the criteria for malting quality, all the cultivars tested failed to meet the requirement for malting quality with protein: Charles and Wintmalt having protein contents of 15%, and McGregor, Thoroughbred, and Endeavor having 14%, all higher than the 13.5% maximum. Further studies to evaluate additional cultivars with genetically lower protein in combination with cultural practices that limit grain protein content, while not sacrificing grain yield, will be important for the production of profitable malting quality barley in the state.

Acknowledgements

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Literature Cited


