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Meet the Student-Author and Research at a Glance

I am from White Hall, AR 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. 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 University I had the opportunity to study abroad in India and serve 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 minoring in Agriculture Business.

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

- Barley is a grain that can be grow 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 .

Abstract

Due to the strict quality requirements, only 10 percent of worldwide barley is used for malting, though malting quality barley comes with a price increase of up to 50 percent or higher. With the craft brewery industry growing in Northwest Arkansas there is a growing demand for locally sourced malt quality barley. However, data is lacking regarding production practices for barley in Arkansas. The optimum harvest date for malting quality barley is at physiological maturity. This is because many of the malting traits (such as germination energy) decline as harvest is delayed, which will make 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 significantly. Of the cultivars tested Thoroughbred was closest to meeting the criteria for malting quality, having the highest grain yield, while maintaining germination energy and capacity into a later harvest date.

Introduction

Barley is number four in terms of area cultivated in cereal grains in the world at 49.24 million hectares (Office of Global Analysis, FAS, USDA, 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 percent of worldwide barley is used for malting, though malting quality barley comes with a price increase of up to 50 percent or higher. In the United States, 25 percent of the barley grown is used for malting (Davison, Schultz, & Widaman, 2007). In 2017, 1,004,025 hectares of winter and spring barley were planted in the United States, and 790,756 hectares were harvested (United States Deparment of Agriculture Farm Service Agency, 2018). No barley production for Arkansas was reported to the Farm Service Agency for 2017 (United States Deparment of Agriculture Farm Service Agency, 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 Assocation, 2018). However, data is lacking regarding production practices for barley in Arkansas. The University of Arkansas Agricultural Extension offers handbooks and guides for the cereal grains wheat, rice, and oats but data for barley is 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: National Agricultural Statistics Service, 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 consist 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-Amatriaín, et al., 2009: American Malting Barley Association, 2017). When analyzing malt quality, malt factors such as total protein, malt modification, congress wort, and malt enzymes 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 effects 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, variety recommendation, and for 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 uses of both 2- and 6-row varieties was important to evaluate if genetics impacted traits more than the environment. The location each cultivar was developed is also important 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 & Obert, 2009)

The barley cultivars were drill-seeded in four-row plots in a randomized complete block design with eight replications on October 21, 2017. Plot dimensions were 1.5 m wide and 1.22 m. Plots were managed using recommended cultural practices for wheat production. Nitrogen fertilizer in the form of urea was applied twice during the study. The first application was 67.25 kg ha-1 (February 27, 2018) and the second was 33.63 kg ha-1 (March 21, 2018).

Trait measurement

During the season, heading date was recorded on each plot as the day when 50% of the developing barley heads were fully emerged from the leaf sheath. A single row from each replication was harvest on four different dates, with the first date beginning at physiological maturity on June 1, 2018 (HD1). Subsequent harvest dates occurred on June 8 (HD2), June 15 (HD3), and June 23, 2018 (HD4) After harvest, samples were oven dried to a constant moisture of 7.5 percent and subsequently stored maintain 7.5 percent 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's wheat breeding program lab located on the Arkansas Agricultural Research and Extension Center and University Campus in Fayetteville, Arkansas. Protein analysis was outsourced.

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 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 g per ¼ cup. Weights were converted using the following formula [((weigh in g) x 1,690.7) / 1000 = test weight in kilograms per hectoliter] resulting in the reported test weight.

Germination compacity, germination energy, and water sensitivity were measured simultaneously using methods adapted from 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 were added to each of the dishes labeled ‘A’ and ‘B’ and 8 ml were 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 ml H_2O_2 was 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

After data collection, 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. Means were separated using a Fisher's Least Significant Difference at an $\alpha=0.05$.

Results

Analysis of Variance

The effect of cultivar and harvest date was 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 percent on a dry basis. There was a significant 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 higher grain yields result in greater malt being produced from harvested area. There was a significant difference in grain yield due to harvest date on HD1 (physiological maturity) at 132 g, significantly higher than all other harvest dates. There was no significant difference observed between harvest dates HD2, HD3, and HD4, which yielded 102, 96, 106 g, respectively.

Grain yield was also affected by cultivar, with Thoroughbred being the highest yielding at 185 g and significantly 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). Grain yield of

Endeavor, McGregor, and Wintmalt were not significantly different. Thoroughbred was statisticly better and Charles being statisticly lower yielding at 71.97 g (figure 1).

Germination Energy

Germination is important to the malting process, so a higher germination energy (GE) is better for achieving a higher malting quality. The expectation is that GE be at 98 percent or higher for malting quality barley (American Malting Barley Association, Inc., 2019). There was a significant difference in germination energy by harvest date, cultivar, and the interaction of cultivar and harvest date.While HD1, HD2, and HD3 were statistically the same, HD4 was 6 percent 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 percent and Thoroughbred dropping 1.3 percent between HD1 and HD4. Germination energy for the 2-row cultivars (Charles, Endeavor, and Wintmalt) was reduced by greater than 5 percent between HD3 and HD4. Before that the germination energy of Endeavor and Wintmalt dropped 2.3 and 1.3 percent, respectively, between HD1 and HD3. However, Charles's held steady at approximately 99 percent through the first three harvest dates dropping in the HD4 (Figure 2).

Germination Capacity

The measure of the number of seeds that germinate after exposure to 0.75 percent H_2O_2 quantifies germination capacity. This capacity reflects the ability to germinate in non-optimal conditions. Therefore, higher 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.

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. HD1 showed the least sensitivity to water, at less than one percent, and HD4 being the most sensitive at 9 percent. HD2 and HD3 were not statistically different (Figure 13). The 6-row varieties, McGregor and Thoroughbred, were statistically lower in water sensitivity then the 2-row varieties (Figure 3).

With the exception of Endeavor, all cultivars were at or below 1 percent water sensitivity for HD1. For HD2, Charles and McGregor were both near 2 percent with Charles being 2.4 percent and McGregor being 1.9 percent. Thoroughbred, Endeavor, and Wintmalt also increase for harvest date 2, with Thoroughbred increasing to almost 4 percent, Endeavor to 4.5 percent, and Wintmalt to 8 percent for HD2. However, HD3 was different with Thoroughbred staying near 4 percent, and the 4 other varieties increasing. Charles increased to 5 percent from 2 percent, Endeavor to 6.5 percent from 5 percent, McGregor to 3 percent form 2 percent, and Wintmalt to over 10 percent from 8 percent. HD4 had the highest sensitivity for 4 of the 5 cultivars. The sensitivity for Charles and Endeavor increased more than 8 percent. McGregor increased to 4 percent and Thoroughbred recorded its highest water sensitivity at 4 percent. Wintmalt was the only cultivar for which the sensitivity decreased for the 4th harvest date dropping from 10 to 7.5 percent (Figure 4).

Conclusions

The optimum 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 highest grain yield and thousand kernel weight, in addition, it preformed the most consistent 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 preformed 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 due to the high protein content. Further studies to evaluate varieties, more adapted to the northwest Arkansas environment and genetically lower protein content would be important to help bring malting quality barley to the state. With the variable weather in the state a study that harvested before maturity could be useful to provide data on whether it is better to harvest early or late.

Acknowledgements

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Figures and Tables

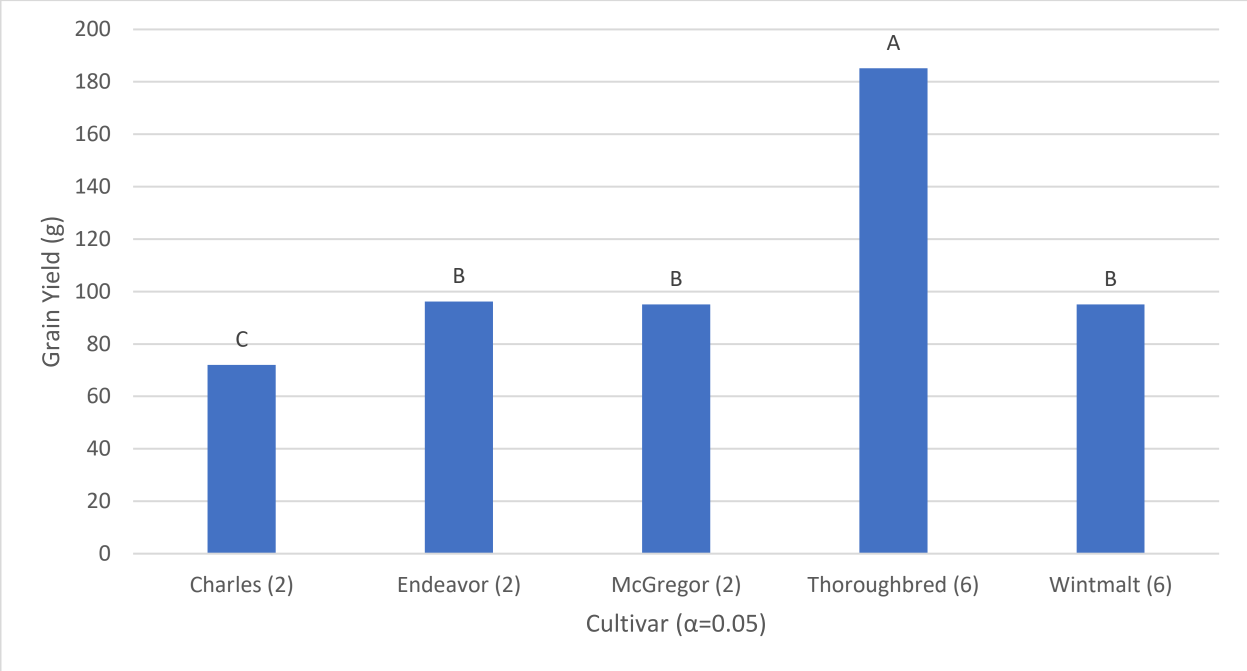

Figure 1. Effect of cultivar on grain yield.

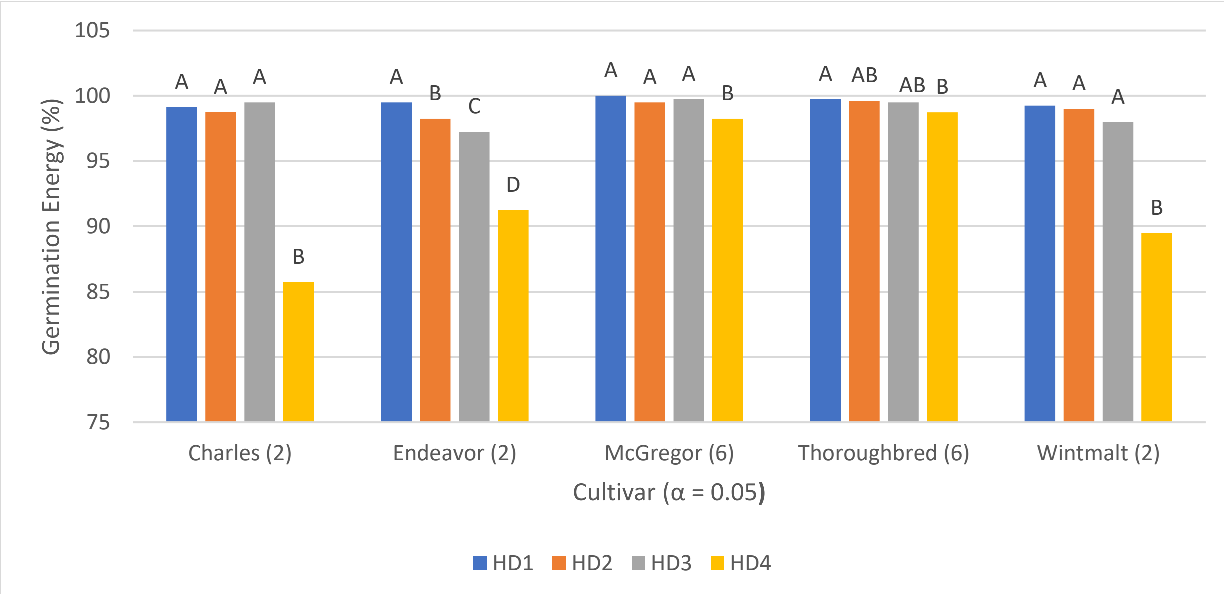

Figure 2. Effect of cultivar by harvest date interaction on germination energy.

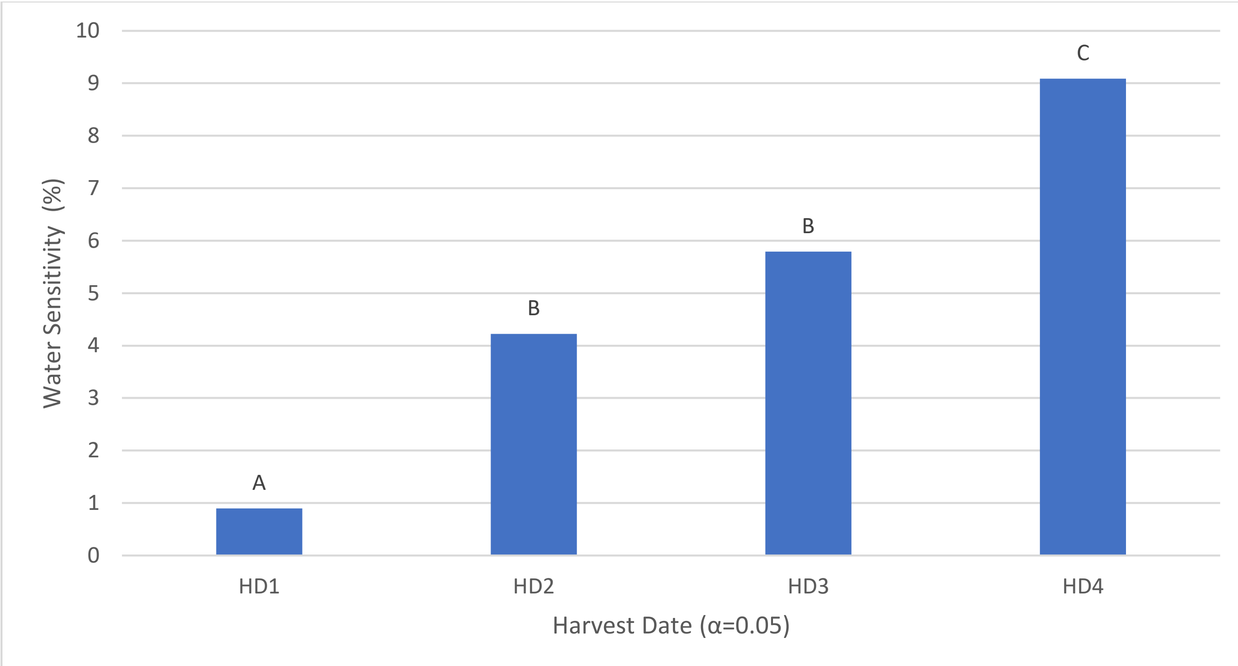

Figure 3. Effect of harvest date on water sensitivity.

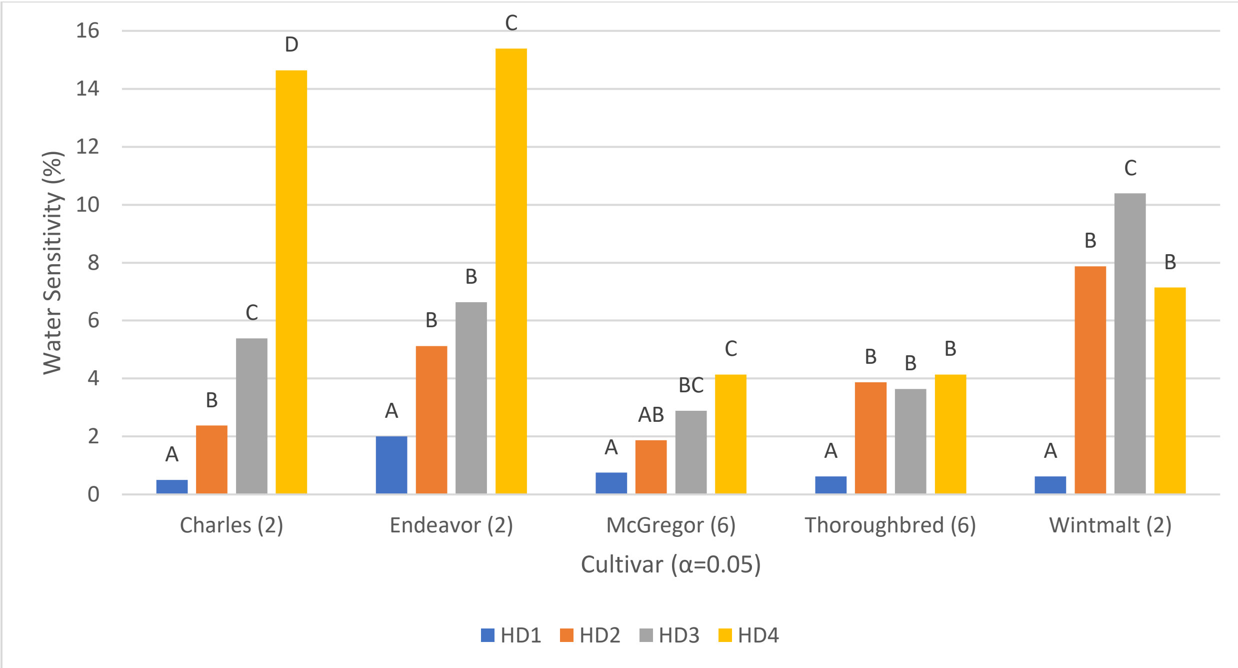

Figure 4. Effect of cultivar by harvest date interaction on water sensitivity.

Table 1. Analysis of Variance (P-values) for Malting Traits in Five Barley Cultivars

	Water sensitivity	Germination energy	Germination capacity	Protein
Cultivar	<0.0001	<0.0001	<0.0001	0.0567
Harvest date (HD)	<0.0001	<0.0001	<0.0001	0.2512
Cultivar x HD	<0.0001	<0.0001	<0.0001	0.8503
Replication	0.0585	0.5801	0.696	0.0188