

Final Technical Report

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Grant 22-1562 – Evaluating Terroir of Rye Whiskey in Michigan – Genotype x Environment

Abstract

What factors influence the flavor and quality of rye whiskey, particularly focusing on the contributions from rye grain? Our research over the past several years has identified that many factors are involved, including 1) variety, 2) weather (rainfall, temperature), 3) location (as influenced by climate, weather, soil, management, history and fertility), 4) management, particularly crop inputs such as fertilizer, fungicides and growth regulators, 5) storage and post-harvest management, and 6) processing, including fermentation, yeast, distillation and aging interactions. New sensory data generated from this project add critical components to the story, but also have revealed some challenges in distinctly connecting aged rye whiskey sensory characteristics to varieties and other quality characteristics measured in the laboratory.

Introduction

Rye is commonly used as a cover crop by Michigan's farmers, and variety selection has been based on performance as a cover crop more so than grain quality. Thus, we started our work on rye distilling characteristics knowing little about the grain quality of common or improved rye varieties as it relates to distilling, brewing, or food purposes. Agronomic survey data on rye is limited; the USDA has not collected data on rye planted or harvested on Michigan farms since 1999. Realizing information on grain quality, spirit yield, and flavor of named rye varieties would be of great value to distillers and farmers, Michigan State University (MSU) began the evaluation of cereal rye varieties in 2019 with the support of the Michigan Craft Beverage Council.

Rye is typically used as a raw, un-malted ingredient in spirits and beer, making it a very accessible grain to source locally; the distillery or brewery can purchase it directly from a farm if it's been appropriately dried and cleaned. Thus, craft beverage artists and farmers alike are interested in what varieties are best suited to produce high yields of quality grain for local and regional use. Our work at MSU over the past two years has produced, and continues to produce data on yield, quality, and flavor from over 20 rye varieties grown in multiple locations of the state of Michigan. This body of work is the first of its kind in Michigan, but similar studies are being conducted in other states (e.g. [Far North Spirits in Minnesota](#)).

Stakeholders in the distilling industry have begun asking questions about what varieties or factors would help set Michigan produced spirits apart from other regions of North America and the world. **To that end, we believe it's worth investigating the degree to which location influences key quality and flavor characteristics of the rye grain and distillate produced from the rye.** In the "Terroir of Whiskey," Rob Arnold (2020) highlights that a few historic whiskey regions of the world continue to generate unique flavors, but most of the whiskey produced now uses grain from the commodity marketplace and thus loses any sense of local flavor. Can we re-invigorate this sense of local flavor in Michigan rye whiskeys, and how much of a difference is there between identical rye varieties grown in different regions of Michigan and other parts of the Midwest?

In 2019, the project team began working with cereal rye as a grain crop. This work was informed by many years of working with rye as a cover crop and forage crop. Data from two years across three sites in Michigan show up to a threefold difference in grain yield between the lowest and highest yielding varieties at any given site, with the hybrid rye varieties standing out with top yields. Grain quality

(protein, spirit yield, 4-VG) also exhibited a wide range between varieties. The ensuing [rye report](#) detailed that highest yielding varieties tended to have lower grain protein, higher spirit yield, and lower 4-VG, suggesting that the best varieties for yield in the field and distillery may unfortunately impart the least amount of flavor. The above-mentioned trials were conducted in small plots, with benchtop scale laboratory analyses. To complement that work, we also grew larger quantities of six different rye varieties to have enough quantity of grain to conduct commercial scale distilling, aging and flavor analyses. These six varieties were fermented by Michigrain, and low wines were delivered to MSU for further distillation and aging, as well as laboratory and flavor analyses.

In 2022-23, our team received support from the Michigan Craft Beverage Council to continue investigating rye varieties for the Michigan Craft Distilling Industry. This project received a no-cost extension into 2024 and continues the multi-year effort started in 2019 and continuing to present. **Our goal for this next step in the research program (and the focus of this funded proposal) was to specifically investigate the effect that growing environment has on quality and flavor of the rye whiskey (terroir).** Climate diversity in Michigan results in dramatically different growing environments between different parts of the state. These factors justify a multi-year / multi-site variety trial in Michigan to evaluate how variety and key management practices influence yield, disease, and grain quality / taste.

Objectives

We've confirmed over the past two years that rye varieties differ in qualities important to the craft beverage industry. And we've also confirmed in small plot trials and laboratory analyses that varieties perform similarly in different locations, but also that growing environment can result in some differences in the way each variety expresses its characteristics. The specific objective of this proposal was to fully evaluate genetic x environment interactions for rye varieties, focusing on flavor and key quality characteristics when grown in different environments.

1. Complete sensory analysis for six varieties harvested in 2021 and aged in Dr. Shriner's laboratory.
2. Choose six varieties of rye that performed well, but expressed varying characteristics, to grow at commercial scales in two different environments.
3. Produce raw and aged spirits from each variety/location and evaluate important quality and flavor characteristics from each variety/location.

Methods

Six rye varieties (AC Hazlett, Aroostook, KWS Bono, KWS Brasetto, Danko, Maton) were grown in large plots across two locations in 2020/2021 and aged in small barrels for over one year in Dr. Nicole Shriner's laboratory. AC Hazlett, KWS Bono and Danko were grown at the Upper Peninsula Research and Extension Center (UPREC) and Aroostook, KWS Brasetto and Maton were grown at the Kellogg Biological Station (KBS). Due to this long aging process, the sensory evaluation was completed after the end of the previous grant cycle that funded the operations of that work. Blind samples were sent to dozens of experts across the U.S. for evaluation of taste and aroma characteristics, and each evaluator rated each sample based on a rubric established by our project team. All six aged rye whiskey samples were also sent to Roy Desrochers at the University of Vermont for a descriptive sensory analysis (DSA) conducted by the University of Vermont Extension trained panel on rye whiskey samples. Each of these efforts produced sensory data for the six aged rye whiskey samples.

Subsequently, we selected six varieties that have performed well at multiple locations in Michigan in the 2020 and 2021 trials, but also considering a wide range of quality characteristics. The six varieties of rye chosen included AC Hazlet, Danko, KWS Serafino, ND Gardner, Rosen and Wheeler. Locations chosen for 2022 planting / 2023 harvest included KBS in Hickory Corners and UPREC in Chatham. Each variety was planted in replicated plots that were large enough to produce 20-pound composite samples per variety x location for laboratory scale fermentation, distillation and aging. All replicates were managed conventionally to achieve optimal yields, which includes the use of fertilizers and herbicides based on

MSU recommendations. Grain samples were collected from each variety and location and composited for quality analysis. Rosen rye grain was also sourced from two additional locations: South Manitou Island and Empire, MI.

Quality analysis for each 2023 grain sample was completed by the Hartwick College Center for Craft Food and Beverage. In addition, bulk samples of each harvested variety were taken to Dr. Shriner’s lab for fermentation and HPLC analysis of sugars, acids and alcohols before and after fermentation. Distillation of each sample followed fermentation which resulted in data on spirit yield including fraction of alcohol in the heads, hearts and tails fractions. Evaluation of sensory characteristics of these raw rye distillate samples was still in process when this report was completed.

Results

1. Complete sensory analysis for six varieties harvested in 2021 and aged in Dr. Shriner’s laboratory.

Roy Desrochers at the University of Vermont completed a descriptive sensory analysis (DSA) of the six rye whiskey samples from different varieties, in partnership with a University of Vermont Extension trained panel on rye whiskey samples. Three of these varieties (Aroostook, KWS Brasetto, Maton) were grown near KBS (Hickory Corners) and three (AC Hazlet, Danko, KWS Bono) at UPREC (Chatham). Several criteria were evaluated, but the most informative metric was a general level of “Liking” that was compared against a commercial check rye whiskey (Figure 1). All three of the varieties grown at UPREC scored higher than the three varieties grown near KBS, with the top performer being Danko (879) followed by KWS Bono (510). We hypothesize that this difference in location was in part due to grain moisture at harvest, assuming that the varieties grown near KBS were slightly wet during storage which led to some off flavors that can be connected to musty grain. All of the rye whiskey samples scored lower than the commercial check whiskey.

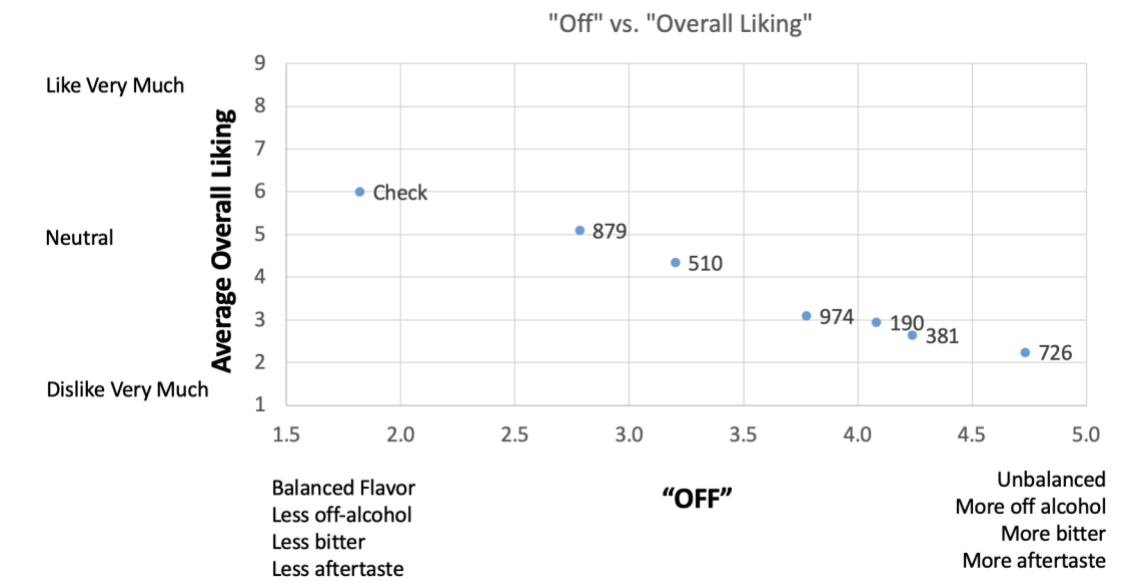


Figure 1. Evaluation of overall “liking” compared against “off” flavors for the six rye whiskey samples evaluated at the University of Vermont. Key includes 190-Aroostook (KBS), 726-KWS Brasetto (KBS), 381-Maton (KBS), 974-AC Hazlett (UPREC), 879-Danko (UPREC), 510-KWS Bono (UPREC).

A tasting panel assembled by Dr. Nicole Shriner at MSU also evaluated these six rye whiskey samples, and provided feedback on flavor and aroma notes they could detect in the samples. These results are

shown in the spider plot in Figure 2 below. Sweet, spicy, and woody notes stood out as more present than others, with certain samples trending towards more intense notes than others. AC Hazlet was higher than all other samples in the “woody” category, while Danko, KWS Brasetto and Aroostook were rated as spicier. The level of sweetness was quite variable across all samples.

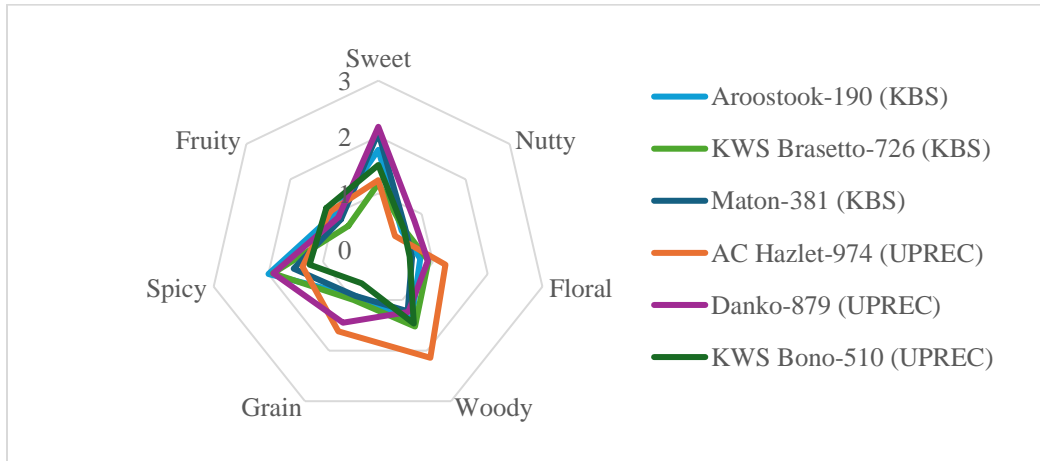


Figure 2. Flavor profiles for the six rye whiskey samples, as noted by a tasting panel organized by Dr. Nicole Shriner.

In summary, the six varieties of rye that were harvested in 2021 at two locations in Michigan produced interesting results, but these results were confounded by the fact that different varieties were grown and handled in different parts of the state. While differences existed in sensory characteristics across these varieties and locations, we are not confident in being able to attribute these differences to location. Comparing varieties within each location does indicate that varieties lead to differences in sensory characteristics in aged whiskey made from them, but more research is needed to fully characterize these varieties including how they respond to different growing locations and handling conditions.

2. Choose six varieties of rye that performed well, but expressed varying characteristics, to grow at commercial scales in two different environments.

Six varieties of rye that were grown in 2022/2023 at two locations in Michigan were collected for comparing the same varieties of rye at multiple locations within the same year. The 2023 spring was drier than usual at KBS (Hickory Corners) resulting in moderate yields, and visibly stressed plants. Nonetheless, the yield trend across varieties was similar to previous years, with the hybrid rye (KWS Serafino) out-yielding open pollinated varieties. Within open pollinated varieties, Danko, AC Hazlet and Gardner were higher yielding than Rosen and Wheeler (Figure 3). Yield data was not collected at the UPREC site where priority was placed on collecting a large sample for quality evaluation.

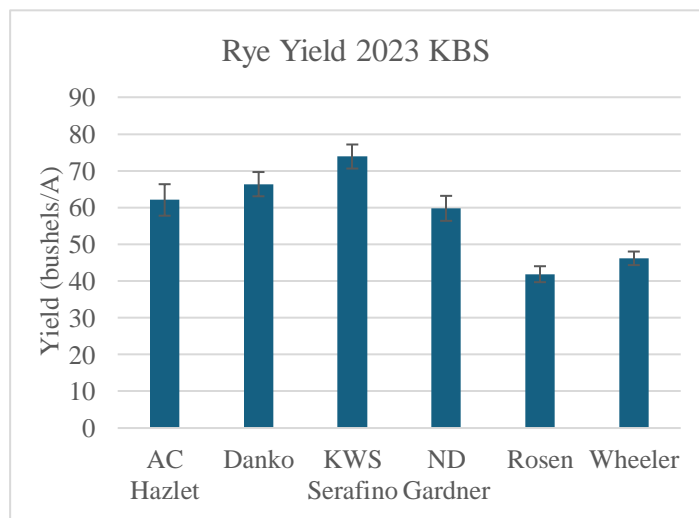


Figure 3. Rye grain yield from six varieties grown at KBS (Hickory Corners) in 2023

3. Produce raw and aged spirits from each variety/location and evaluate important quality and flavor characteristics from each variety/location.

The six varieties of rye from each location, plus Rosen rye from two additional locations, were evaluated for quality characteristics at Hartwick College Center for Craft Food and Beverage. Several trends were observed in the data (Table 1), including: 1) Some variation existed within varieties across sites, but overall varieties exhibited similar characteristics for Predicted Spirit Yield, Ferulic Acid and 4VG across locations, except for Rosen rye grown on Manitou Island and Empire, 2) Rosen rye samples from Manitou Island and Empire had the lowest predicted spirit yield and ferulic acid values for all the samples, diverging from Rosen rye grown at UPREC and KBS, 3) Variety characteristics were similar to previous years; AC Hazlet had the highest predicted spirit yield and Wheeler had the highest ferulic acid and 4VG values, 4) 4VG values were more than two times higher than previous years of 2020 and 2021, possibly due to the stressful drought during grain fill, 5) Ferulic acid and 4VG values were highly correlated, as expected ($R^2 = 0.778$).

Table 1. Average quality values for rye varieties across all locations in 2023.

Variety	Predicted Spirit Yield (LAA/tonne)	Ferulic Acid (mg/L)	4VG (mg/L)
AC Hazlet	357.0	6.0	20.8
Danko	345.5	5.5	17.6
KWS Serafino	347.5	5.8	18.3
ND Gardener	338.0	6.3	19.1
Rosen	333.8	5.7	20.6
Wheeler	342.5	7.7	24.4
Average	342.6	6.1	20.2

Fermentation and distillation of larger samples of rye varieties from the two primary locations was completed in Dr. Nicole Shriner's lab. Due to the high beta glucan content in rye, there were some sticky mash issues that resulted in some scorching of grain during mashing and/or stripping. This challenge helped to inform an improvement to the method to avoid this same issue in the future. Results from this process indicated some interesting trends for actual ethanol and hearts yield indicated in Figure 4 and Figure 5. Two varieties exhibited substantial differences in ethanol yield across location, including KWS Serafino and Wheeler. For both varieties, ethanol yield was substantially lower for the rye grown at KBS. Total ethanol yield was not a good predictor of hearts yield. In some cases, hearts yield followed a similar trend to total ethanol yield, but for other varieties, the trend reversed, and hearts yield was not correlated with total ethanol yield.

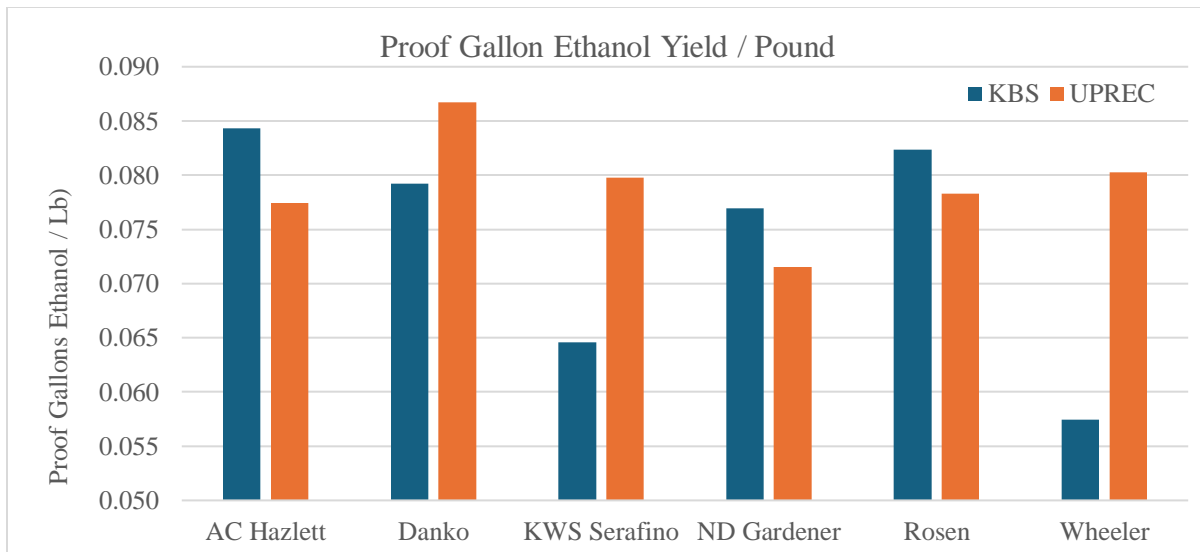


Figure 4. Proof gallon ethanol yield per pound for each of the six varieties grown at two locations, KBS (Hickory Corners) and UPREC (Chatham).

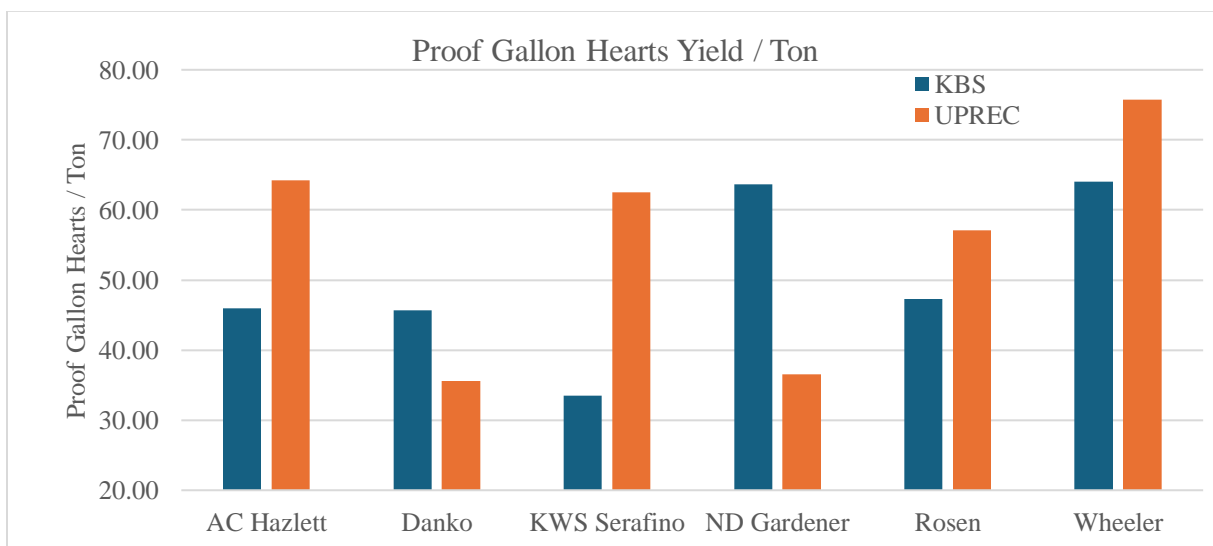


Figure 5. Proof gallon hearts yield per ton for each of the six varieties grown at two locations, KBS (Hickory Corners) and UPREC (Chatham).

Communication Activities

The process of forming a tasting panel to evaluate rye distillate and whiskey samples was a valuable tool in engaging stakeholders in this research project. Many conversations with individual distilling and agricultural professionals ensued during this tasting panel, including with Mammoth Distilling who provided the additional Rosen rye samples. Results were shared at the March 2024 Craft Beverage Summit, and through individual activities. Once finalized, results will be shared on the MSU Malting Barley website and through digital communications.

Budget Narrative

The project was conducted consistent with the budget proposed by the principal investigator and approved by the State of Michigan.