2022 MI Craft Beverage Council Final Report
Proposal Title: Variety Selection and Agronomy Practices for Soft Winter Wheat Malting
(grant# 200000001794)

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**Abstract:** Craft brewing is a large and growing economic sector in Michigan, but the malting industry is held back by lack of a local supply of quality raw grains. Wheat beers already comprise an appreciable segment of craft beer production in Michigan and the U.S. Demand for wheat beer products is growing. Often grains with the best malting characteristics have the lowest yield potential for farmers, creating a dichotomy between maltsters and farmers. The goal of the project is to identify wheat varieties and agronomic production practices that provide acceptable quality to maltsters and high yield potential for farmers. Four wheat varieties were selected based on previous grain quality responses and planted in a split plot design with six fertility treatments (3 nitrogen plus 2 potassium). Yield, moisture and test weight data was collected at harvest. In year 1, subsamples were sent to the Center for Craft Food and Beverage Center at Hartwick College for pilot malting and full malt analysis. In year 2, subsamples were sent to the MSU Malting Barley Quality Lab for partial malting quality analysis.

**Materials and Methods:** Fertility treatments were designed with the goal of producing the highest grain yield, while keeping protein content low. Twelve varieties from the 2019 MSU Wheat Performance Trials were pilot malted by Vince Coonce. Data from the pilot malt was used to select four varieties to include in the trial (6771 EXP, Kokosing, W 304 and Dyna-Gro 9362W). Small plots (5 foot x 12 foot) were planted at the Saginaw Valley Research and Extension Center near Frankenmuth, MI. Plots were planted with an Almaco HD grain drill equipped with a packet planter. Plots were arranged in a split plot design with fertilizer rate as the main factor and variety as the sub factor. Main factor treatments include 3 nitrogen rates (0, 40, 80 lbs. per acre) plus 2 potassium rates (0, 60 lbs. per acre). Sub factor treatments include the 4 varieties selected from the preliminary screen.
Treatments (rates are pounds of actual nutrient per acre):

1. 0 nitrogen, 0 potassium (control)
2. 40 lbs. nitrogen, 0 potassium
3. 80 lbs. nitrogen, 0 potassium
4. 40 lbs. nitrogen, 60 potassium
5. 80 lbs. nitrogen, 60 lbs. potassium
6. 0 lbs. nitrogen, 60 lbs. potassium

Plots were seeded at 2 million seeds per acre. Affinity broadspec (0.8 oz/a) was applied for weed control. Prosaro fungicide (8 oz/a) was applied at Feekes 10.5.1 (flowering) to control fusarium head blight. Plots were harvested by a Wintersteiger Quantum research combine equipped with an H2 HarvestMaster system to obtain yield, moisture and test weight. All plots were bagged and subsampled. In year 1, subsamples from each replication was submitted to Hartwick College Center for Craft Food & Beverage lab for full malt analysis including moisture, assortment, friability, fine extract, coarse extract, f/c difference, β-glucan, fan, soluble protein, s/t, dp, α-amylase, color, pH, filtration time, clarity, DON and protein. In year 2, subsamples were submitted to the MSU Malting Barley Quality Lab for analysis including protein, moisture, plump, thin, germination energy 4ml, germination energy 8ml, germination capacity and RVU. Statistical analysis of the data was conducted by the PI using SAS 9.4 Proc Mixed.

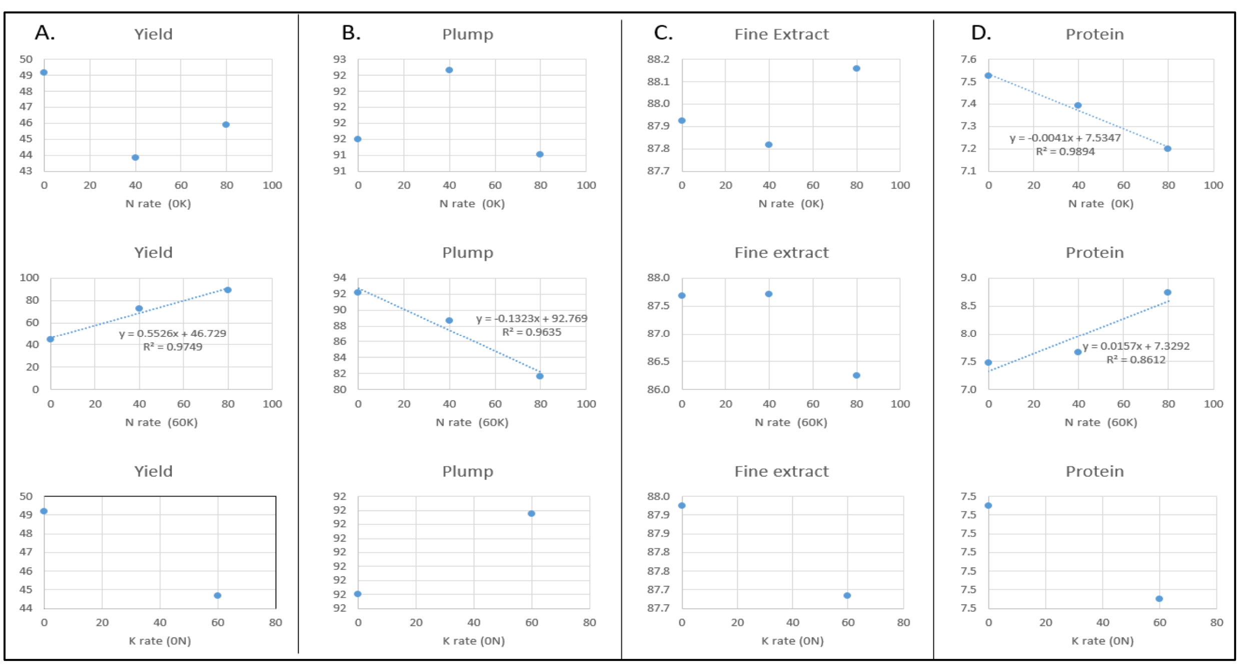
**Results and Discussion:** Farmers will be most interested in the yield response to treatment while maltsters will be more interested in malt quality parameters. Yield, plump, fine extract, grain protein and germination energy are reported here. Germination capacity, color, ßeta glucan, soluble protein, Kolbach index, FAN, diastatic power, alpha amylase, filtration time and clarity data is available, but not reported here. Results are organized by response: variety and agronomy. Key traits showing a variety response include yield, total plump, fine extract, protein and germination energy. Key traits showing agronomy response include yield, total plump and protein. Other parameters tested showed either small or inconsistent response. These parameters need to be test further to determine how the variety and agronomy treatments used in this study these parameters.

**Agronomy response**

Data from Figure 1 shows that there was no significant yield response to nitrogen when no potassium fertilizer was added (panel A, top chart). However, the highest yields (reported in bushels per acre) were achieved when potassium was applied at a rate of 60 pounds per acre and the yield response to nitrogen (panel A, middle chart) showed a strong positive linear relationship ($r^2$=0.9749). In the absence of nitrogen, yield response to potassium was not significant (panel A, bottom chart).

Plump is a measure of kernel size and is the proportion of seed that will not pass through a 6/64 screen. In barley, larger kernel size is strongly correlated with higher extract yield meaning more beer can be made from the same number of kernels. It is desirable to maximize the plump. Here we tested the effect of fertility treatments on plump. In the absence of potassium, plump was not significantly impacted by nitrogen rate (panel B, top chart). In the presence of 60 pounds of potassium per acre (panel B, middle chart), there was a strong negative relationship between plump and nitrogen rate (r2=0.9635). In the absence of nitrogen, plump was not significantly effected by potassium rate (panel B, bottom chart).

*Figure 1. Data from year 1 of malting wheat project. Each panel contains a chart showing the response of yield (A), plump (B), fine extract (C) and protein (D) for three different fertility treatments. The top chart is the response to nitrogen in absence of potassium (0K), middle chart is the nitrogen response in the presence of potassium (60 pounds K/a) and the bottom chart is the response to potassium in the absence of nitrogen. Trend lines are displayed where the response was significant at α=0.05.*



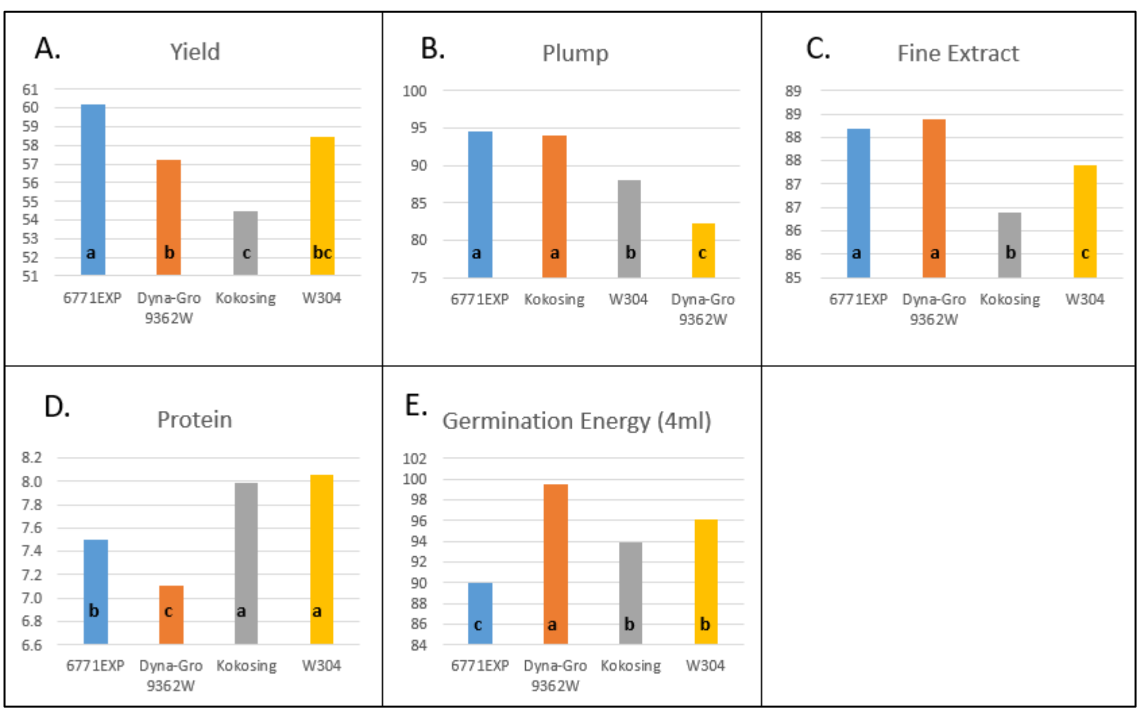
Surprisingly, fine extract was not significantly effected by nitrogen or potassium in any of the comparisons (panel C). This suggests that fine extract is related to some other aspect of production, such as variety. This can be seen in Figure 2, chart C where two varieties (6771EXP and Dyna-Gro 9362W) has significantly higher fine extract compared to Kokosing and W304 varieties.

Total protein Figure 1, panel D showed an interesting and unexpected response to nitrogen and potassium. In setting up this trial, it was discussed with collaborators that in order to grow high yielding wheat with low protein, we need to manage nitrogen very carefully. It is well known that wheat yields increase with nitrogen fertilizer, but so does total grain protein content. In the plant, potassium is involved in protein synthesis. Higher potassium levels generally relate to higher protein synthesis. In this trial, protein response to nitrogen and potassium was mixed. In the presence of potassium (panel D, middle chart) protein increased with nitrogen as expected ($r^2$=0.8612). However, in the absence of potassium (panel D, top chart) protein level was inversely proportional to nitrogen rate (r2=0.9894). While it makes sense that in the absence of potassium, there would be lower protein production, it was not expected that increasing nitrogen rates would decrease protein.

**Variety response**

As expected, there was a significant variety response to yield, plump, fine extract, germination energy and protein (see Figure 2). Yield responses to variety and agronomy in both years. Differences in malt quality characteristics also occurred. There is not a single variety that has all of the traits needed by farmers and maltsters. For example, variety 6771EXP has higher grain yield, plump fine extract and lower protein – all desirable traits. However, it also had lower germination energy (Figure 2, panel E). Other quality traits showed high variability in responses to treatments. In this trial, only 4 varieties have been evaluated. It is recommended that future research evaluates a wider range of varieties. About 115 varieties are tested each year in the MSU Wheat Performance Trial program. There could be additional varieties available that meet farmer and maltster needs.

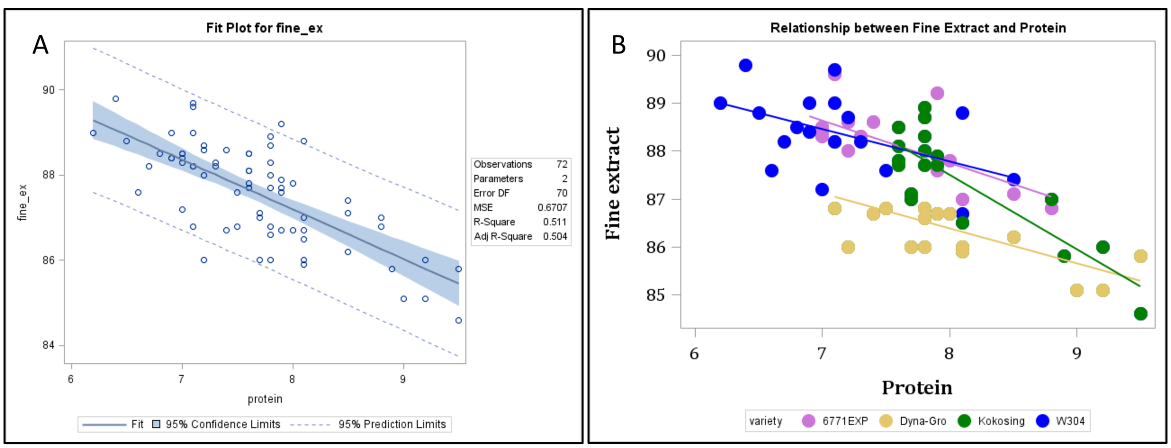
*Figure 2. Variety response to yield (A), plump (B), fine extract (C), protein (D) and germination energy (4ml).*



One of the objectives of this work is to find out what malting characteristics are most important and which ones can be used as predictors for malt quality. Conducting the full malting and lab analysis is prohibitively expensive if we want to expand testing to include additional fertility and variety evaluations for malting quality. For barley, there have been many associations quantified and verified for grain yield and malting quality. This work is lacking for wheat and other small grains that are being increasingly considered to make unique, craft beverages. In this study, protein was evaluated to determine if its relationship with fine extract could be used to reliably predict malt quality. Assessing grain protein is relatively cheap compared to malting. This would allow many more comparisons to be made at lower cost.

There appears to be a weak relationship ($r^2$=0.511) between protein and fine extract across all treatments and varieties (Figure 3A). When looking at the same relationship for each variety, there are slight differences in the magnitude of the relationship (slope of each line) in Figure 3B. Variety 'W304' has the largest amount of variation and lowest relationship. Data from this study suggest that there is a relationship between fine extract and protein, but factors such as agronomy and variety add enough variability to the equation that using protein to predict fine extract will have low to moderate value.

*Figure 3. Relationship between kernel protein and fine extract in soft winter wheat.*




Finally, the last objective of this study was to look at the profitability of different fertilizer treatments in terms of income potential for farmers, while delivering a product that meets the needs of maltsters. Partial budget analysis is a tool that looks at the income and expense items only for the variables included in the trial. It assumes all other expense items are the same across treatments. Results from this analysis across both crop years are listed in Figure 4. Data for Yield, Plump, Fine extract and Protein are reported in columns along with the calculated Income and Expense. Income is calculated as yield x $7.76/bushel (MAC Brown City, 10/13/22). Expense is calculated as (N rate x $1.31)+(K rate x $0.91). The Partial Budget column is calculated as Income – Expense. Commodity and fertilizer prices are very high at the time of publishing this report. While this impacts the magnitude of the partial budget, the relative differences between treatments remain similar.

*Figure 4. Partial budget analysis showing the income potential of each treatment.*

| Trt | N rate | K rate | Yield | Plump | Fine extract | Protein | Income | Expense | Partial Budget | Diff from Max ($) | Diff from Max ($/bu) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 67.8 | 91.6 | 87.9 | 7.5 | $525.88 | $0.00 | $525.88 | -$88.19 | -$1.30 |
| 2 | 40 | 0 | 78.0 | 92.5 | 87.8 | 7.4 | $605.03 | $52.40 | $552.63 | -$61.44 | -$0.79 |
| 3 | 80 | 0 | 79.6 | 91.4 | 88.2 | 7.2 | $617.76 | $104.80 | $512.96 | -$101.11 | -$1.27 |
| 6 | 0 | 60 | 68.0 | 92.2 | 87.7 | 7.5 | $527.31 | $54.60 | $472.71 | -$141.36 | -$2.08 |
| 4 | 40 | 60 | 91.3 | 88.7 | 87.7 | 7.7 | $708.64 | $107.00 | $601.64 | -$12.42 | -$0.14 |
| 5 | 80 | 60 | 99.7 | 81.6 | 86.3 | 8.7 | $773.47 | $159.40 | $614.07 | $0.00 | $0.00 |

Farmers would select the treatment that has the highest partial budget number, in this case - treatment 5 at $614.07. This treatment also produces the lowest plump, fine extract and highest protein – all of which are opposite of what a maltster is looking for. If a malt company wanted to contract with a farmer to grow wheat and specify a lower fertility program, that could be done with a contract that provides market price plus a premium to offset the lower income potential. The difference from the max (last column) would be the amount of premium needed by the farmer to offset the lower income potential. Discussion of this data with maltsters is needed to help determine what is fair and equitable to both parties.

**Bottom line**

Wheat grain can be a viable option for craft beverage manufacturers. Lowering nitrogen applications to moderate levels still maintains viable crop yields while providing high quality grain for malting. However, there needs to be a middle ground that is negotiated between farmers and maltsters. Lowering nitrogen application leads to the quality parameters needed to malt wheat. A contract between farmers and maltsters would be a useful tool to spell out how much nitrogen should be used and how much of a premium should be paid to the farmer to offset lower yield potential. Ideally, we could engage wheat breeders to develop wheat varieties that have high yield, yet lower protein and proper malting quality. This should be a long-term goal of the malting industry. In the near term, farmers working cooperatively with malsters using existing wheat varieties can be a viable alternative.