2023 Annual Research Report

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CORN MARKETING PROGRAM
CMPM
OF MICHIGAN

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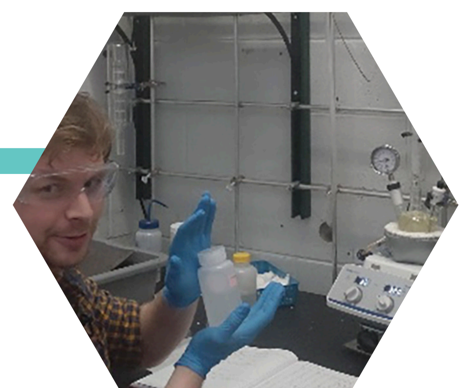

From the President

At the Corn Marketing Program of Michigan (CMPM), research is one of the most important ways that we invest your checkoff dollars. Our research is aimed at enhancing the economic viability of corn production by prioritizing topic areas that are important to Michigan's corn producers. From the development of management strategies for important diseases to finding new uses and markets for corn – our investment helps ensure a brighter future for corn farming in Michigan.

This year, we prioritized research that addressed critical needs in the following areas:

- **Innovative new uses for corn and corn by-products that are relevant to consumers.**
- **Pest management practices related to weeds and diseases that are economically feasible and environmentally sound.**
- **Evaluating precision generated data relative to input management, cost effectiveness and in-season testing across seasons to enhance the decision-making process.**
- **Cost effective production methods that may be high input or low cost, ultimately achieving profitable corn production.**

We hope you'll take the time to review results presented from our 2023 funded research projects. Thank you to all of Michigan's corn farmers for the support of CMPM and we look forward to continuing to serve you.

Sincerely,

Matt Holysz
President
Corn Marketing Program of Michigan

Michigan Genomes to Fields: A collaboration with the NCGA Genomes2Fields GxE project

PROJECT LEADERS: Addie Thompson and Maninder Singh, MSU
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Project Overview: The 2023 Michigan Genomes to Fields growing season replicated the 2022 trial, part of an international yield prediction contest. Accurate yield modeling for diverse corn varieties benefits growers through precision management, the environment with variety-specific input recommendations, and the economy by stabilizing prices. This contest serves as an excellent test bed for building and testing predictive models, especially for data scientists new to agricultural data. To address this, our project aimed to:

- Expose Detroit-area high school students to cutting-edge crop science through the Ecotek Labs program.
- Involve undergraduates in hands-on agricultural research through a specialized honors seminar.
- Integrate a Genomes to Fields module into a graduate student course bridging computational and agricultural sciences.
- Encourage involvement from other departments (e.g., engineering, computer science, mathematics) in agricultural research.

Our primary goal was to leverage genomic information, Michigan-specific phenotypic, and environmental data for predicting plant per-

Ecotek Lab students from Detroit area high schools learn techniques in the lab.

Michigan Young Farmers tour the Thompson Lab greenhouse.

Multicultural Apprenticeship Program (MAP) students Theresa and Lindsay present to a group of high school science teachers from Nourish the Future.

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formance in Michigan and diverse environments. Our secondary goal was to provide educational and outreach opportunities, inspiring new generations to pursue careers in agriculture.

RESEARCH OUTCOMES:

- **Spring and Fall 2023:** Ecotek students (Detroit-area science-minded high school students) worked in the lab and learned about corn and sorghum, lab work, field work, and data analytics.
- **Spring 2023:** CSS 844 graduate course (Frontiers in Computational and Plant Sciences) successfully conducted with nine students, coming from multiple majors and backgrounds.
- **March 2023:** Students from the lab attended the Maize Genetics Conference in St. Louis, as well as the G2F project meeting. The winner of the yield prediction contest was a breeder from Corteva, using quantitative genetic techniques learned during training at Purdue.
- **Summer 2023:** Field experiment planted on May 24, with standard operating procedures matching 2022. Germination was uneven due to late rainfall. Data was collected both by hand and by drones throughout the season.
- **Fall 2023:** Eight undergraduate students from diverse majors and backgrounds are conducting research on Michigan G2F datasets for an honors research seminar. They will present their findings in February 2024 at the North American Plant Phenotyping Network conference, funded by the Honors College.
- **Fall 2023:** PhD student Zhongjie Ji, who has been partially supported by CMPM throughout his graduate career, successfully defended his thesis.

Root samples from the field trial are collected, rinsed, and scanned.

The MSU field trials were visited by CMPM staff and by a graduate plant breeding class for a description of research projects and a demo of drone data collection.

Determination of the 2,3-Pentanedione and acrylic acid strength of association and impact on the purity of acrylic acid during the corn to acrylics process

PROJECT LEADER: Chris Nicholas, Låkril Technologies
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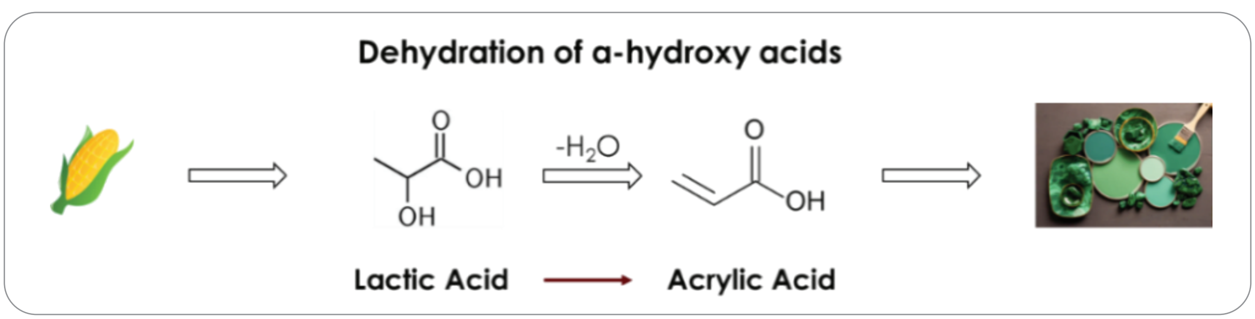
Abstract: Låkril Technologies is developing catalytic dehydration technology to convert corn-derived lactic acid and ethanol to sustainably produced bio-acrylics at cost-parity to traditional petrochemical routes. This represents a market expansion directly driving value creation of about 90 bushels of corn per metric ton of acrylic produced, or about 2.7 million bushels of corn per year for each 40kMTA typically sized plant to replace the petrochemical acrylics produced on the Texas gulf coast today to serve the North American market. Simulation of the recovery column for acrylic acid purification yields different results depending on the physical property parameters used. In 2023, we de-risked the separation process by determining the associative behavior of 2,3-pentanedione (23PD) with acrylic acid and identified the NRTL-HOC model as the appropriate parameter set for simulation and design. We utilize distillation experiments combined with additional ASPEN+ work to finalize this column design, having now moved to fully continuous distillation operation in a multi-column set up.

PROJECT RESULTS

Towards the end of the FY22 project, we discovered the physical property parameter set used in our simulation affected whether 2,3-pentanedione side product was predicted to distill up or down through the acrylic acid purification column. ASPEN is the industry standard for simulating chemical processes and integrates many chemical property databases [1]. The nonrandom two-liquid model (NRTL) forms the basis of most fluid property simulation, where regression of experimental data for a specific binary vapor liquid equilibrium (VLE) system is combined with interpolation based on group property contributions for unknown systems. [2]

Known improvements we considered to help describe the deviation from ideal gas behavior caused by interaction between two molecules in the vapor phase [3] include the Redlich-Kister (NRTL-RK) [4]and Hayden–O'Connell (NRTL-HOC [5] modifications. Overall, the NRTL-RK and NRTL-HOC methods give comparable results until we get t o >90% acrylic acid. This is the key region for the acrylic acid recovery column.

Our distillation apparatus (initially batch mode, now fully continous) allows us to capture overhead distillate fractions and recover small samples from the bottoms to compare concentrations of the mixture's components over time. In a batch mode operation, we initially simulated a feed at greater than 99.2% purity of acrylic acid containing 0.02% 2,3-pentanedione. As we started distilling, the first overhead fraction



SCHEME 1. Låkril Technologies path from corn to sustainable acrylics for paints/coatings.

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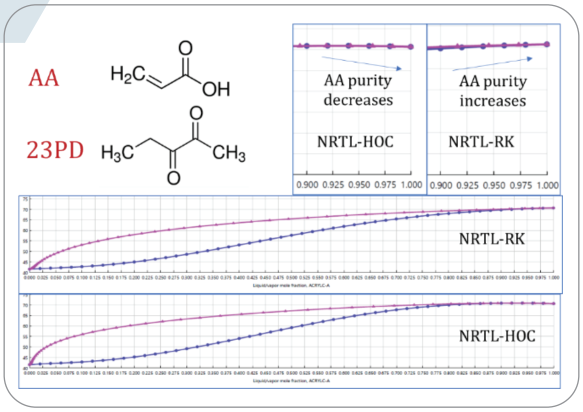
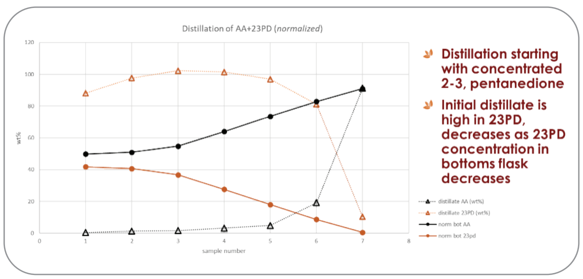


SCHEME 2. Comparison of tx,y results for binary VLE calcs of the 23PD / AA system for NRTL-RK and -HOC.

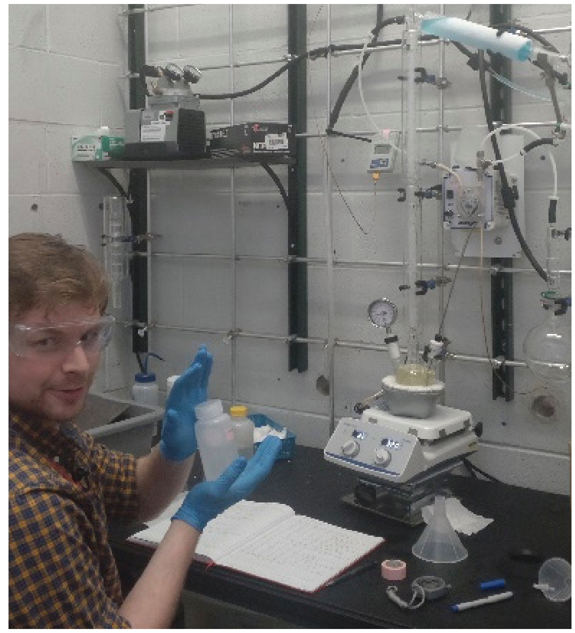


SCHEME 3. Distillation Results of 50/50 23PD/AA (wt%).

(D1) contained most of the 23PD in the system, and the second overhead fraction (D2) met the >99.6% acrylic acid purity necessary for super-absorbent polymer applications.

We then approached the projected azeotrope from the other side of the concentration gradient, beginning with a 50/50 (wt.%) composition of 23PD / Acrylic Acid. We started the distillation and then took small aliquots until we ran out of material to distill. Distillate samples are shown in open triangles, with bottoms composition shown in solid circles. 23PD is in orange, Acrylic Acid in black.

Scheme 3 shows 23PD forms an essentially pure distillate until the concentration in the distillation bottoms falls below 20wt%. At this point, 23PD continues to distill overhead until the concentration in the bottoms is zero. As illustrated in Scheme 2, the NRTL-RK model predicts the distillation will proceed with AA as the overhead distillate at high purity while the NRTL-HOC model predicts the distillation will yield 23PD as the overhead and AA must be purified as a side draw.



SCHEME 4. Distilled material meeting specifications.

Combined, our experiments show that the NRTL-HOC model provides the appropriate parameterization for ASPEN simulations and that 23PD is removed overhead. Then, distillation could continue to yield high purity AA. In our continuous system, this means we will pull our product acrylic acid as a side stream near the top of the column.

[1] ASPEN: https://www.aspentech.com/en/products/engineering/aspen-plus

[2] A) Renon, Henri; Prausnitz, John M. Local compositions in thermodynamic excess functions for liquid mixtures. AIChE J. 1968, 14, 135-144. B) Renon, Henri; Prausnitz, John M. Estimation of Parameters for the NRTL Equation for Excess Gibbs Energies of Strongly Nonideal Liquid Mixtures Ind. Eng. Chem. Process Des. Dev. 1969, 8, 413-419.

[3] Huron, M.J.; Vidal, J.; Asselineau, L. Predicting NRTL parameters for binary hydrocarbon mixtures for calculating liquid—vapor equilibriums of multicomponent systems Chem. Eng. Sci. 1976, 31, 443-452.

[4] Prausnitz, J.M., R.N. Lichtenthaler, and E.G.d. Azevedo, Molecular thermodynamics of fluid-phase equilibria. 3rd ed. 1998: Prentice-Hall.

[5] Hayden, J.G.; O'Connell, J.P. A Generalized Method for Predicting Second Virial Coefficients Ind. Eng. Chem. Process Des. Dev. 1975, 14, 209-216.

Optimizing management of tar spot

PROJECT LEADER: Martin Chilvers, MSU
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Project overview: Weather is a primary driver of disease development from season to season. The dry May and June of 2023 most likely interrupted initial transmission of the pathogen from corn residue to corn plants and preventing the disease from cycling early. In contrast, rainfall and moisture around silking for many parts of the state led to ear mold and mycotoxin issues caused by Fusarium species and white mold in soybean. Although conditions were ideal for tar spot during July and August, the lack of disease initiation earlier in the season slowed the epidemic for 2023. Over the last several years, we have noted a strong pattern between early onset of tar spot and subsequent yield loss. We see the greatest impact of tar spot when we detect tar spot by early to mid-July with continued rainfall and leaf moisture events into the season. In contrast, detections of tar spot in August don't tend to have the same impact on yield (Figure 1). Indeed, at our intensively monitored locations we did not detect tar spot until August 1, 2023, and we observed minimal yield impacts. Each year there are national efforts to monitor tar spot development by county, of note is the continued expansion of tar spot outside of the Great Lakes region. This data can be viewed at: https://corn.ipmpipe.org/tarspot/

The Chilvers lab continued efforts to develop data sets to train and test the tar spot disease forecasting app "Tarspotter" developed with our colleagues at the University of Wisconsin-Madison. The Tarspotter app is free to download and can be found on smartphone app stores. Tarspotter can be used to assess tar spot disease risk based on weather variables for multiple pinned locations within the app. When using the app keep in mind that is still important to scout fields to see if disease is present and be mindful of crop growth stage. We typically see the best fungicide timing for tar spot suppression from silking (VT/R1) through to milk (R3) or dough stage (R4).

Data from these trials will be used to update the corn foliar fungicide efficacy chart early in 2024, which can be found here or by searching the Crop Protection Network.

https://cropprotectionnetwork.org/publications/fungicide-efficacy-for-control-of-corn-diseases

Multistate fungicide trials in 2023 focused on comparing fungicide efficacy and timing, but also the value and economics of two applications. For maximum disease suppression we compared various fungicide products as a single pass at silking (VT/R1), with a second application three weeks post the VT/R1 application. When looking at data across all locations, two applications reduced tar spot development, however in general fungicide applications did not always result in significant yield protection given the low amounts of disease. Data from these trials will be used to update the corn foliar fungicide efficacy chart early in 2024, which can be found here or by searching the Crop Protection Network.

To better understand the factors driving tar spot spore release spore trap studies were established in Decatur and the MSU Plant Pathology farm (Figure 2). A network of spore traps across the state were also established to determine if they can be used to better inform fungicide application timing. In this work we developed a DNA test that is used to "count" the number of spores that are being collected in the various spore traps. The DNA test has been put into practice with colleagues around the Midwest, where spores of the tar spot fungus have been detected two weeks before disease symptomology. This tool could enable managers to provide an early warning system for disease development. Various spore traps and DNA extraction

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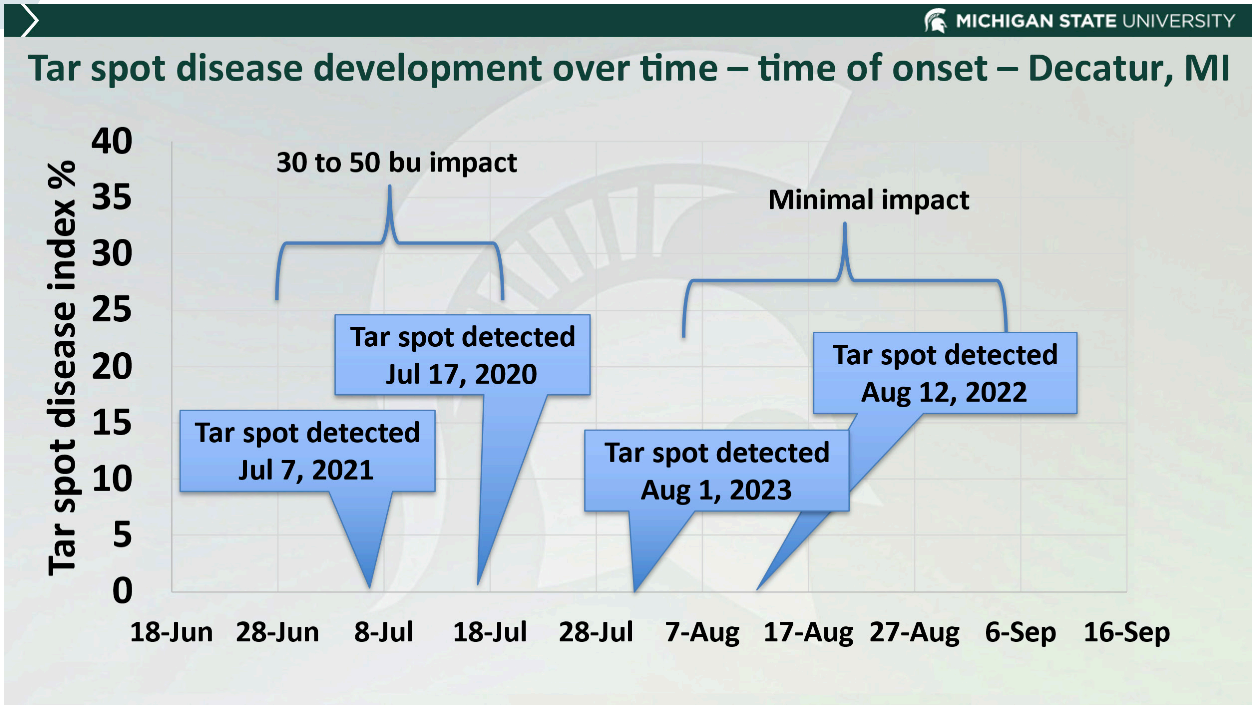

FIGURE 1: Demonstrating the date of tar spot detection between years and subsequent yield loss noted.

techniques are being compared to determine what system is best for detecting spores of the tar spot fungus.

Graduate student Jill Check continued tar spot epidemiology studies which included tracking disease development and spore release over time. Although there was little disease to track in 2022 and 2023, data will be invaluable to refining risk models and understanding weather variables related to tar spot fungus spore release and dispersal. Jill's work has been key in exploring the role of plant population and nitrogen rates in tar spot development. Jill found that although very low plant populations (~30k plants/A) did see an increase in tar spot development, however the effect of hybrid susceptibility was a much greater driver of disease development and yield impact. The studies also determined that nitrogen application rates did not affect tar spot development over the five site-years examined. Planting populations and fertility programs should continue to emphasize the best agronomic and economic practices. Although fungicide applications at the right time can be helpful in disease suppression, it needs to be remembered that hybrid resistance to tar spot is a cornerstone of disease management.

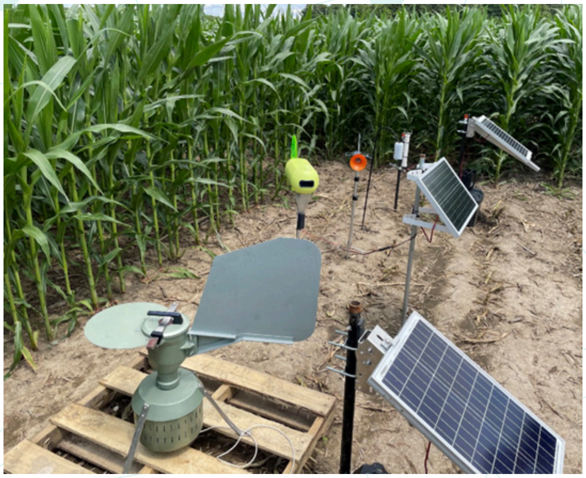

FIGURE 2: Comparison of five spore trap types at the Plant Pathology farm.

Evaluation of fungicide application methods and timing for effects on tar spot control and corn yield

PROJECT LEADERS: Tim Duckert and Quinten Sackett, North Central Research Station
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Project overview: Despite rapid spread of tar spot each year since 2016 and widespread severe infestation in 2021, tar spot was not the problem that it was expected to be in 2023. Tar spot had been observed in corn at the proposed research location for several years and had become severe in some areas in 2021. It was determined to establish this experiment in a corn-on-corn rotation which had minimum tillage so that early infestation of the disease may initiate from the previous residue and not from wind borne sources. The proposed site also benefited from overhead irrigation which could, if needed, maintain wetness periods and increase the chances of infection. Tar spot infection rates were lower in Michigan again in 2023. The first report of the disease in Clinton County was on August 4th and first detection in this experiment was found on August 30th. The proposed experiment was designed to evaluate the following factors individually and in combination to determine which would have the best outcome on disease control, yield, and economics.

RESEARCH METHODS AND QUESTIONS:

1. Fungicide. Veltyma from BASF is one of the fungicides that had shown merit in university trials and may even provide some residual control.

2. Corn Growth Stage. For best tar spot control, fungicides like Veltyma are recommended to be applied from tassel (VT) and silking (R1) to milk stage (R3). Such applications require high-clearance sprayers or aerial applications. Could application at an earlier stage, such as on five-foot-tall corn that most self-propelled sprayers could cover, be economically effective even with less tar spot control than that at later stages?

3. Hybrid selection. While all corn can become infected, there are differences in the level of susceptibility. Could hybrid selection forgo or reduce the need for fungicide?

4. Fungicide Placement. Fungicide trials have involved boom applications from high-clearance ground sprayers, or simulations of that. The canopy at that growth stage would hinder complete foliage coverage, which may be necessary for optimal control. Identified research trials have not included application equipment that can cover foliage beneath the canopy. Is there another method that may provide better disease control? 360 UNDERCOVER from 360 Yield Center enables in-the-canopy application with a multi-directional nozzle cluster. The North Central Research Station (NCRS) has used this system for several years with general corn fungicides and has had good results. Based on these factors, a research trial was developed with the following factors:

1. Check: No Fungicide
2. Veltyma (7 oz/A) – Boom only, at 5 ft tall corn (V10)
3. Veltyma (7 oz/A) – Boom only, at R3 (8-9 ft tall corn)
4. Veltyma (7 oz/A) – Boom and 360 UNDERCOVER at 5 ft tall corn (V10)
5. Veltyma (7 oz/A) – Boom and 360 UNDERCOVER at R3 (8-9 ft tall corn)

The experiment was established under irrigation as a split-plot design (6-row plots: 3 rows each for a tolerant and susceptible hybrid) with four replications of treatments. The plot length was 275 feet long. The inside two rows of each hybrid were harvested for yield by a combine utilizing a Harvest Master Grain Gage system. Numerous measurements for treatment effects on tar spot control were conducted. All applications were made with a modified Hagie STS

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10 sprayer at a spray volume of 15 gallons per acre and 70 psi. The first application was made into five-foot-tall corn (V10). The second application was at R3 where the corn was considerably higher and would be difficult for all but high-clearance sprayers. Results: The incidence of tar spot in 2023 was low and appeared late in the season, however there were noticeable differences observed in hybrid selection and fungicide placement for this experiment.

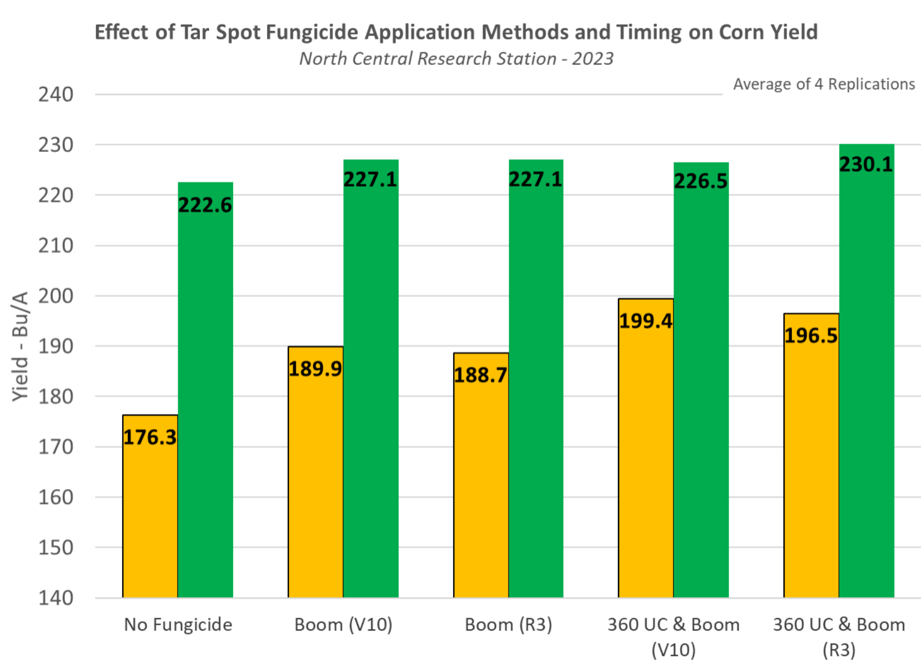
1. Fungicide applications of Veltyma can improve yields even with low tar spot or late incidence of the disease. Both hybrids, with fungicide application, responded with increased yield over the no fungicide check.

2. Corn growth stage application timing had little to no effect on yield when comparing application methods of boom vs boom.

3. Hybrid selection played a large part in the need for a fungicide application. When comparing the susceptible to the tolerant hybrid there was a significant advantage of 46.3 bu/A using the tolerant hybrid and making no fungicide applications.

4. Fungicide placement method did have an effect on yield. Application of the Veltyma at either growth stage using the boom and 360 Undercover statistically benefited the susceptible hybrid, with an average increase of 21.6 bu/A over the no fungicide check. There was no statistically significant yield difference between the no fungicide check and the applications of Veltyma on the tolerant hybrid,

A DJI P4 drone flew the plots four times from late July to early October, collecting many spectral measurements. Even with minimal tar spot disease, there were better greenness values where the fungicide applications were made. The difference of the ear leaves from tar spot and other disease infection in the no fungicide application (left side) vs the late application with the boom and 360 Undercover was striking, as seen in the pictures both taken in late-September at the NCRS (right side).



Comparison of treatment yields ranging from 222.6 (no fungicide) to 230.1 (360 UC & Boom R3) in the tolerant hybrid and 176.3 (no fungicide) to 199.4 (360 UC & Boom V10) in the susceptible hybrid.

Optimizing corn variety selection and agronomic management for specialty uses

Project leader: Maninder (Manni) Singh, MSU
Contact email: msingh@msu.edu

Project overview: The craft beverage industry in Michigan has seen continued growth over the past two decades. Corn is the most widely used cereal grain in whiskey products as most grain recipes are at least 50% corn, with some being as much as 100% corn. Most varieties are chosen based on yield and extract content, among agronomic variables that lead a producer to choose to grow and sell a specific variety. This selection process has resulted in nearly all corn produced from hybrid #2 yellow dent varieties, for which a surprisingly low amount of variation exists between varieties. We hypothesize that these unique varieties have different flavor profiles and aging potential. Thus, distillers are interested in finding unique flavors in corn as well as marketing potential that comes with utilizing varieties that are heirloom. The goal of this research is to identify open pollinated varieties of corn suited to Michigan with unique flavor qualities inherent in the spirit they produce.

OBJECTIVES AND METHODS:

1. Evaluate open pollinated varieties for yield potential and quality across Michigan environments.

Objective 1 leveraged ongoing research funded by Michigan Craft Beverage Council (MCBC). 20 varieties representing a wide range of characteristics (identity preserved heritage varieties to landraces to more recently developed varieties, including yellow dent hybrid check) were planted during May 2023 at three locations (KBS, Hickory Corners; MSU farm, Mason; UPREC, Chatham) in a randomized complete block design with 4 replications. At each location, plot size was 10' wide (4 rows) and 20' long. Corn was managed using best management practices for conventional corn (except lower seeding of 24,000 seeds/ac and fertility rates of 120 lbs. N/ac in-season) to achieve the highest yield and protect grain from disease or degradation. All varieties have been delivered to the fermented beverage analysis lab at MSU. Samples will be milled, mashed, fermented, and distilled into an unaged whiskey distillate. The unaged whiskey made from these varieties will go through multiple analyses to help differentiate the varieties.

2. Quantify optimal seeding rate in selected varieties for maximizing yield while maintaining quality characteristics.

Four varieties were selected based on 2022 results from MCBC grant and feedback from distillers. Two varieties (MN 13, Ohio Blue) were selected based on yield potential and the other two (Bloody Butcher, Wapsie Valley) based on desired quality traits. The field experiment was planted during May 2023 at the MSU farm in Mason and KBS farm in Hickory Corners. Trials were arranged in a randomized complete block design with four replications, with four varieties and four seeding rates (16,000 seeds/ac to 34,000 seeds/ac in 6,000 seeds increments). The highest seeding rate was selected based on the current recommendation for yellow dent hybrids, and the lowest rate based on observations from 2022 MCBC trials.

3. Develop a dataset for future screening of specialty corn germplasm and management strategies.

This objective focused on developing a list of germplasm and its screening for specialty uses. In 2023, 250 lines were planted at the MSU farm in East Lansing. These lines consisted of historical heirloom varieties important for the food industry (e.g., tortillas, distilling, and other specialty uses). The varieties were selected from a larger set of 1,000 heirlooms across the country based on their origin in northern latitudes.

Preliminary results: As expected, the research trials conducted for objective 1 showed variation

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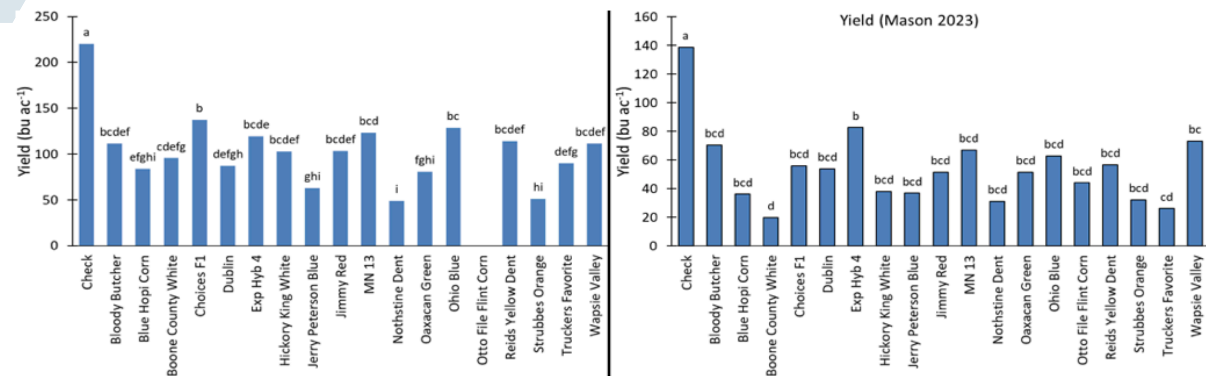

FIGURE 1: Yield across corn varieties at Hickory Corners (left) and Mason (right) in 2023.

Name	Protein %		Moisture %		Starch %		Oil %		Test wt (lbs./bu)	
EXP HYB 4	11.75	ab	8.528	ef	69.12	cd	4.01	d	60.9	a
Bloody Butcher	9.98	f-i	11.48	bcd	71.22	ab	6.72	c	56.0	efg
Boone County White	10.53	d-h	9.043	ef	70.07	bc	4.16	d	53.3	h
Dublin	11.38	bcd	9.383	def	69.51	cd	3.86	d	58.5	a-e
CHOICES F1	10.89	b-f	10.745	cde	70.33	abc	3.97	d	60.6	ab
Hickory King White	10.55	d-h	9.348	def	69.11	cd	4.57	d	54.5	fgh
Hopi Blue	11.20	b-e	13.61	ab	71.28	ab	12.14	a	54.3	gh
Jerry Peterson Blue	11.63	abc	13.773	ab	69.88	bcd	12.95	a	56.6	d-g
Jimmy Red	9.97	ghi	11.853	abc	71.83	a	6.36	c	56.6	d-g
MN 13	10.83	c-g	8.293	f	69.65	bcd	4.09	d	59.6	abc
Modern Hybrid (P0414AM)	9.45	i	7.985	f	70.38	abc	3.93	d	57.1	cde
Nothstine Dent	12.31	a	8.043	f	68.32	d	4.13	d	57.4	cde
Oaxacan Green	10.72	d-h	13.62	ab	69.88	bcd	10.22	b	58.3	b-e
Ohio Blue	9.82	hi	13.93	a	70.53	abc	9.29	b	60.2	ab
Reids Yellow Dent	10.85	b-g	9.078	def	69.54	cd	4.40	d	58.7	a-d
Strubbes Orange	11.19	b-e	10.168	c-f	69.91	bcd	4.13	d	56.9	def
Truckers Favorite	10.45	e-h	8.72	ef	69.91	bcd	4.34	d	57.5	cde
Wapsie Valley	11.02	b-e	8.935	ef	70.04	bc	4.08	d	60.2	ab

TABLE 1. Quality parameters across corn varieties at Hickory Corners in 2023.

in yield and quality traits in the planted varieties. Mason trials were negatively impacted by lack of moisture at planting leading to variable emergence, and a storm event in end-August leading to severe lodging and lower yields. Yield was estimated by collecting ears from 10 plants per plot. The highest yield was observed for the check hybrid. Among the distilling corn varieties, the greatest yield was observed for “Exp hyb 4” at Mason and choices F1 at Hickory Corners (Figure 1). In terms of quality, the greatest protein and starch content was observed for Nothstine Dent and Jimmy Red, respectively, at Hickory Corners. No interaction between variety and seeding rate was observed in objective 2, meaning response to seeding rate was similar between varieties at both locations. Response to seeding rate was also minimal, meaning lower seed rates can be used for these varieties. Yield plateaued in some varieties and declined in others with an increase in seeding rate. Regression models showed low R2 values, indicating that seeding rate was not a good predictor of yield and other factors (deer, racoons, and wind damage) might have impacted yield more. Data for objective 3 is still being evaluated.

Evaluating proposed atrazine "picklist" for feasibility in Michigan

PROJECT LEADER: Erin Burns, MSU
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Project overview: Atrazine is a vital and essential herbicide for sustainable corn production in Michigan. Loss of the effective use of atrazine, impacted by the current proposed revised EPA interim registration review decision would have the following ramifications: first, increased use of tillage to control weeds. The loss of preemergence use of atrazine would lead to more tillage, more soil disturbance, and is counteractive to current conservation practices that benefit climate-smart agriculture, ultimately reducing sustainable corn production. Second, increased selection pressure for herbicide resistant weeds. Herbicide resistance threatens sustainable crop production in Michigan and the United States. A core principle to both control herbicide resistant weeds and to reduce the selection pressure to select for new herbicide resistant weeds is to use multiple effective herbicide sites of action against the same target weed. For example, Palmer amaranth and waterhemp are highly aggressive weed species that are only controlled by three sites of action preemergence in corn production (site of action numbers: 5 (atrazine), 15, and 27), loss of atrazine would reduce this list to two and increase the selection pressure to these sites of action. In addition to the use of multiple effective sites of action for herbicide resistance management is the use of full-labeled herbicide rates. Proposed rate reduction measures in this interim registration review decision would not only threaten atrazine efficacy, but it will threaten other herbicides as well, threatening weed control in multiple production systems. Third, ultimately an overall increase in cost to control weeds. Increased costs include, but are not limited to, using more expensive herbicides and the need to add additional single active ingredients into herbicide premixes, increase in costs associated with controlling herbicide resistant weeds, and loss of effective herbicide sites of action.

Objectives: Many of the proposed "picklist" measures are not realistic to implement or monitor in Michigan. The project objectives address the proposed "picklist" mitigation in relation to weed science principles:

1) No preemergence (to the crop) applications in conventional and reduced/no-till systems.

2) Cover Crop (on-field) establishment and herbicide carryover.

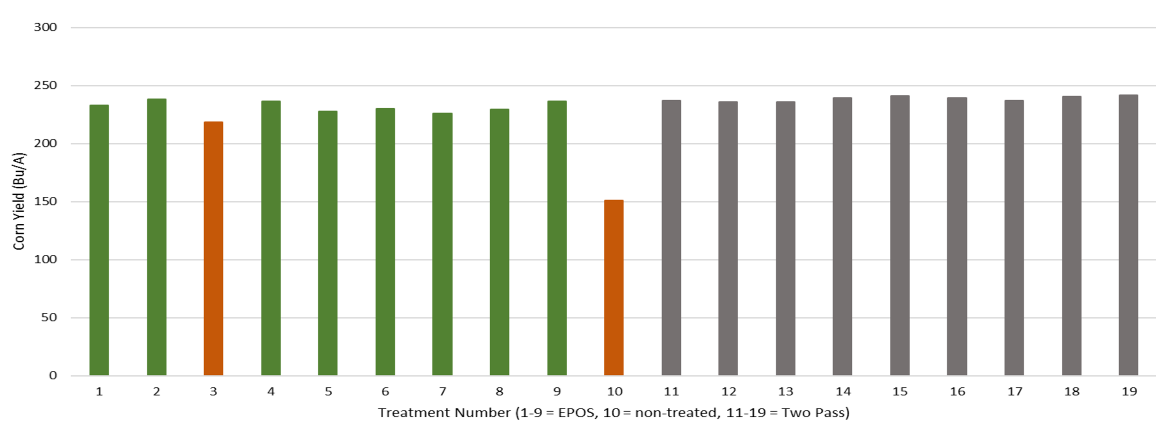

FIGURE 1. Corn yield (Bu/A). Treatments 1-9 (green bars) received atrazine application early- postemergence and treatments 11-19 (gray bars) received atrazine application preemergence, treatment 10 is the non-treated control. Red bars are statistically lowest yielding treatments.

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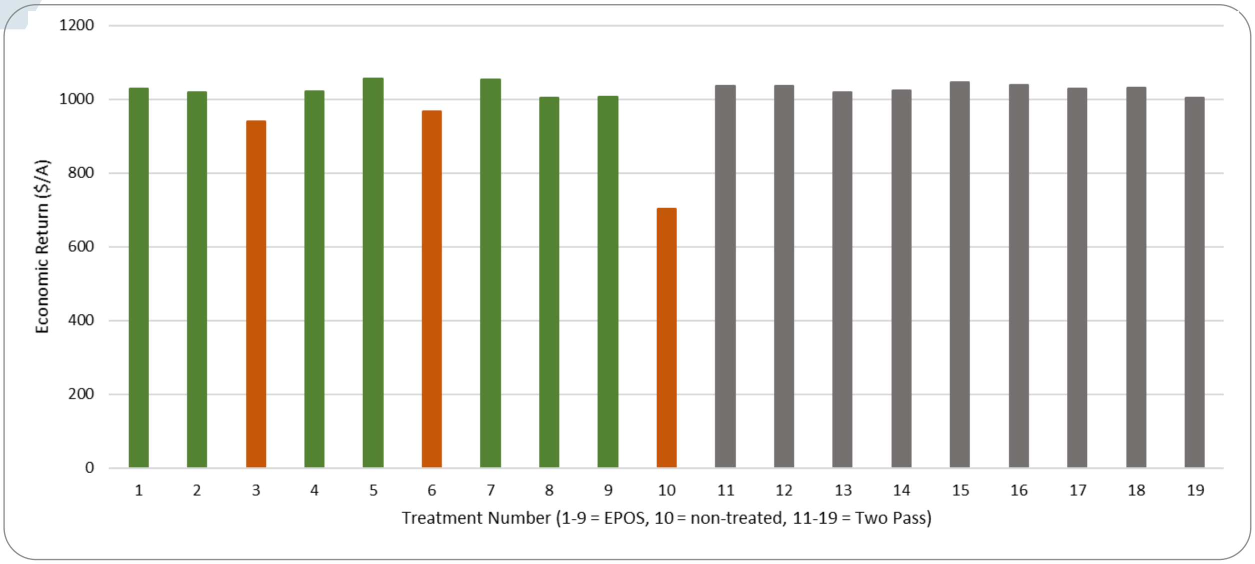

FIGURE 2. Economic return ($/A). Treatments 1-9 (green bars) received atrazine application early-postemergence and treatments 11-19 (gray bars) received atrazine application preemergence, treatment 10 is the non-treated control. Red bars are statistically lowest economic return treatments.

To address these objectives two field studies were conducted at the agronomy farm at Michigan State University. The first study uses the core structure and treatments of the Commercial Comparisons Trial (four treatments from each company recommended for use in mid-Michigan) conducted each year at MSU. Treatments that contained atrazine preemergence were paired with ones in which the atrazine active ingredient component is removed preemergence and moved to early-postemergence to evaluate the impacts of losing preemergence atrazine use. The study was planted on May 10th, preemergence, early-postemergence, and postemergence herbicide applications were made on May 11th, May 31st, and June 14th, respectively. The study was harvested on November 3rd.

Overall, there were few differences in weed control, yield, and economic return amongst treatments. Lack of treatment differences can be attributed to the extremely dry weather during and after the time of herbicide application. Residual herbicides require soil moisture for adequate weed control; without moisture during preemergence and early-postemergence applications of atrazine, few treatment differences were observed. However, 100% of treatments when atrazine was applied preemergence resulted in corn yield that was statistically similar to the highest yielding treatment, while only 88% of treatments when atrazine was applied early-postemergence resulted in corn yield that was statistically similar to the highest yielding treatment (Figure 1, red bars). Furthermore, 100% of treatments when atrazine was applied preemergence resulted in economic returns that were statistically similar to the highest economic return treatment, while only 78% of treatments when atrazine was applied early-postemergence resulted in economic returns that were statistically similar to the highest economic return treatment (Figure 2, red bars). Objective 2 treatments were planted on November 5th and biomass data will be taken spring 2024. Overall, during dry springs like 2023 there is little difference in weed control, yield, and economic returns when atrazine is applied preemergence or early- postemergence. This study will be repeated in 2024.