2020 MCBC RESEARCH REPORT

Proposal Title: "**Building infrastructure in hops and barley to conduct plant pathology research relevant to Michigan's beer industry**"

GRANT x

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Summary of the research

Hop diseases can be difficult to diagnose and management requires a custom approach to each disease (Fig. 2). Michigan has a very different production climate than the majority of the nation's current hop production. Consequently, much of the extension and research material is not tailored to Michigan growers. DM is one of the most important diseases of hop in wet, humid production regions like Michigan. Many products are capable of controlling DM on a 10-day spray schedule (e.g. mandipropamid and flucopicolide), however, very little is known about combinations of these products to build an effective spray program for resistance management.

All of the other diseases of hops are caused by true fungi which are managed with entirely different fungicide products. Powdery Mildew (PM) caused by *Podosphaera macularis* is of critical importance among these fungal pathogens and severe infections can cause complete crop failure. A variety of products are labeled for PM, however their efficacy needs to be examined in Michigan (Table 1). Other pathogens of cones are considered of lesser importance but can still result in yield and quality loss including, *Alternaria* spp. (Fig. 2A), *Botrytis* spp. (Fig. 2B), and *Fusarium* spp.. It is important to accurately identify these diseases for correct management, for example, Alternaria cone browning is commonly a misdiagnosis of late season PM (Mahaffee et al., 2009). Currently, MI growers are likely controlling these other cone diseases primarily through the use of PM fungicides because other diseases are not specifically labeled.

Table 1. Fungicides currently labeled to control hop powdery mildew in Michigan hop yards.

Active ingredient (FRAC)	**Trade Name**
fluopyram (7)	Luna Privilege
flutriafol (3)	Rhyme
quinoxyfen (13)	Quintec
tebuconazole (3)	Monsoon, Onset 3.6L, Tebucon 3.6F and others
trifloxystrobin (11)	Flint, Flint Extra
triflumizole (3)	Procure 480 SC, Trionic 4SC
copper octanoate (M1)	Cueva
metrafenone (U8)	Vivando
sulfur (M2)	Cosavet DF Edge, Microfine Sulfur, Sulfur DF, Thiolux

Disease management in barley is a critical component, not only to protecting yield, but also quality. Fusarium head blight (FHB) caused by the pathogen *Fusarium graminearum* is a major concern with respect to the production of mycotoxins such as deoxynivalenol (DON). Deoxynivalenol quantities must be below a 1 ppm limit to be acceptable for malting. In addition, filamentous fungi such as *F.*

graminearum produce hydrophobins which are a type of protein that causes gushing or foaming of beer (Shokribousjein et al., 2011).

Barley disease management is very much understudied in Michigan and the U.S. In this project we propose to develop production guidelines to optimize barley disease management in Michigan. In addition to FHB, barley is susceptible to a number of foliar diseases such as rusts, powdery mildew and scald. Often the only way to positively identify these diseases is to conduct microscopy (Fig. 3). The foliar symptomology of the barley leaf blotch coupled with the spore morphology of *Rhyncosporium secalis* enabled accurate identification of this disease. It is essential to identify diseases correctly to ensure that correct management practices are used. For example, if this was identified to be a bacterial disease such as bacterial blight a fungicide would have no efficacy in disease management. And even between fungal diseases, there are differences in epidemiology, fungicide efficacies and management strategies.

Fig. 3. Barley leaf blotch (Scald) foliar symptomology on left caused by the fungal pathogen

By integrating disease management approaches of both hop and barley within this proposal, we will build IPM programs for both crops to support Michigan's growing beer industry. This proposal will also allow MSU Extension to optimize our communication strategies towards growers and present the best cultural, biological and chemical control strategies in hopyards and barley fields.

Use of financial support from MCBC

The MCBC funding for hop and barley has been our first research grant for these crops. The funding has enabled both the hop and barley research programs to establish capacity. Two graduate students have been recruited to work on each crop respectively. A hop yard was established for research, and a field of barley was planted and managed and harvested for the disease management trials. The MCBC funding has also facilitated funding from chemical and hop industry for private trials, there is also talk of some novel fungicides getting registered in Michigan using the hop plots, and in barley additional support has been funded through the United States Wheat and Barley Scab Initiative. As a result of MCBC funding both the hop and barley programs have initiated collaborations, such as with Dr. Dave Gent (the main hop pathologist in the Pacific Northwest), and multistate barley disease management collaborations which includes North Dakota State University, Cornell, and Ohio State University among others.

Objective 1) Establishing a hop and barley planting at MSU's Plant Pathology Farm

Hops: A Centennial' yard was planted during June of 2019 with the intent of conducting more downy mildew and powdery mildew efficacy trials in 2020 in this field.

A 0.5 acre field of ~200 plants of 30 different USDA elite varieties (e.g. Cascade, Chinook, Nugget, and Crystal) was planted. We plan on staking this field during Spring of 2020. Photos are available if requested.

Barley: A barley trial was established in the fall of 2019 and completed in the summer of 2020. The trial was successfully harvested, combine adjustments resulted in a quality grain harvest (there was some concern about how barley awns may affect harvest), grain samples are now awaiting analysis for DON and quality.

Objective 2) Fungicide efficacy and application timing in hop and barley

Hops: A downy mildew efficacy trial was conducted at MSU's Plant Pathology Farm in East Lansing MI. 'Centennial' bines were trellised in October of 2018 and the trial was conducted during the Spring and Summer of 2019 . Products were applied every 7-10 days as described above in the outline for Objective 1 and a total of 4 foliar ratings (incidence and severity) were taken during June when we had the greatest development of DM symptoms. Data is still being processed but many of the products were effective at controlling downy mildew.

Barley: The barley disease management trial consisted of 2 varieties, Calypso and Violetta (two demonstrate varietal effect on disease management). A head scab fungicide trial and a foliar disease management and timing trial were conducted as outlined in the following tables.

Objective 3) Disease surveillance and field inoculation experiments

Hops**:** Sampled over 30 yards and identified many cone pathogens present in Michigan yards. The most predominant was Alternaria spp. More work is still required here to determine the most important cone diseases for Michigan growers.

Barley: We had the chance to host two webinars relevant to Michigan growers on downy mildew management (June) and cone diseases (August) and this project was discussed.

We participated in weekly barley calls to identify diseases of primary concern.

Our barley field was scouted weekly for disease development

Objective 4) Develop extension outputs through MSU Extension for hop and barley

Hops: We have not had a chance to update the MSU Hop Management Guide because this occurs during the winter months after harvest.

Barley: A PowerPoint slide deck of current data and results has been assembled for winter meetings. Marty and Tara have also participated in weekly barley and field crop extension calls to discuss disease management. Tara and Marty also participated and presented at the GLHBC in March of 2020. A short video was filmed in the barley field for use in winter meetings.

Preliminary conclusions

Hops: Funding allowed us to do a preliminary assessment of effective materials for DM control, which was published as a plant disease management report: Hatlen, R.J., Gillett, J.M., Sysak, R.W., Smith, R.L., Miles, T.D. 2020. Evaluation of fungicides for control of downy mildew in hops, 2019. Plant Disease Management Reports. 15:OT018 – see full report below

Barley: Head scab pressure appeared to be light in the head scab trial, despite cool moist conditions during head emergence and flowering. Head scab models also predicted high risk. Our neighboring wheat trials did develop moderate head scab pressure. Mycotoxin analysis of the barley grain will determine actual levels of deoxynivalenol (DON), which needs to be below 1ppm for malting purposes. We did develop some levels of foliar disease in the foliar disease management trial, disease scores and yield data are currently being analysed.

Evaluation of fungicides for control of downy mildew in hops, 2019.

This experiment was conducted at the Michigan State University Plant Pathology Research Farm in Lansing, Michigan in a 1-year old hop yard during the spring and summer of 2019 (transplanted in June 2018). The plants were trellised up to 5.5 ft tall (using a low trellis system) with 4 ft between plants and 8 ft between rows. A total of three treatments were included in this experiment: untreated control, rotational program for downy mildew control and a straight treatment of Presidio, a new downy mildew fungicide for hop. Treatments were randomized in four complete blocks and each treatment included four plants. Treatments were applied with a hand-held Smith Contractor Sprayer equipped with a CFValve to maintain 29 psi at all times. Spray volume was 40 gpa. Spray dates and growth stages were as follows: 7 May (6-10 inches, sprout), 16 May (vegetative growth 1), 23 May (vegetative growth 2), 3 Jun (vegetative growth 3), 12 Jun (vegetative growth 4), 21 Jun (vegetative growth 5), 3 Jul (reproductive growth 1), 11 Jul (reproductive growth 2), 18 Jul (reproductive growth 3), 25 Jul. The entire plot was inoculated with 3×10^5 sporangia per plant on 14 May and 6 Jun using a hand pump 2-gal sprayer. The plot was maintained using standard management practices for fertilizer requirements and insect and weed management. Inoculum was prepared by harvesting symptomatic downy mildew spikes (initial shoots) in a neighboring, abandoned hopyard. Spikes were incubated overnight at 100% relative humidity and sporangia were harvested using handheld Preval sprayers. Sporangia were quantified using a hemocytometer and the inoculum concentration was adjusted. On 11, 17 and 24 Jun, randomly selected leaves (n = 25) from each plot were visually evaluated for downy mildew as follows: incidence (percentage of leaves with disease symptoms), severity (percentage of leaf area infected on diseased leaves), and overall severity (severity x incidence/100). An overall rating of each plot was taken on 24 Jun based on the overall plant severity (%) of the 2 interior hop plants. The number of cones in each plot was counted on 14 Aug. All plots were monitored for phytotoxicity throughout the study. Data was analyzed using the Statgraphics Centurion XVLI program (Statgraphics Technologies, Inc., The Plains, Virginia). Maximum air temperatures during this trial ranged from 52.1 during this trial (May 11) to 92.4°F (20 Jul). Total precipitation was 9.74 inches between 7 May and 25 Jul.

Incidence and severity of downy mildew was moderate to high within this trial. Disease progress was similar among all three disease ratings, so the final rating on 24 Jun is presented below. The rotational program (i.e. Ridomil/Revus/Presidio/Ranman/Zampro) and the straight program of Presidio were very effective at controlling downy mildew. Incidence in the trial ranged between 31% (rotational program) and 80% untreated control (UTC). Overall disease severity ranged between 2-3% for the two treatments compared to 19% in the UTC. The downy mildew rotational program and Presidio alone were the most effective at controlling downy mildew as compared to the UTC across all measurements of disease. Cone count means from each of the treatments separated in a similar fashion, but there was significant variability within each plant making it difficult to statistically separate the treatments. The downy mildew rotational program was statistically less than the UTC, but Presidio alone was not statistically different from the other two treatments. No evidence of phytotoxicity was observed in any of the treatments.

		Disease rating (24 Jun)				Cone count[u] (14 Aug)
		Downy mildew on leaf			Entire plant	
Treatment, rate/A[x]	Application timing[vz]	Incidence (%)	Severity (%)	Overall severity (%)	Overall plant (%)[y]	Mean number of cones
Untreated		80.0 a[x]	22.8 a	18.7 a	65.0 a	50.6 a[w]
Presidio 4SC 4 fl oz + Nufilm P 0.125%	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	39.0 b	6.9 b	3.2 b	17.5 b	81.6 ab
Ridomil Gold SL 0.5pt[w]	1					
Revus 8 fl oz	2					
Presidio 4 fl oz	3,6					
Ranman 2.75 floz	4, 7, 9					
Zampro 14 floz	5, 8, 10	31.0 b	6.0 b	2.0 b	8.8 b	115.3 b

[z]Spray dates: 1 = 7 May (6-10 inches, sprout)), 2 = 16 May (vegetative growth 1), 3 = 23 May (vegetative growth 2), 4 = 3 Jun (vegetative growth 3), 5 = 12 Jun (vegetative growth 4), 6 = 21 Jun (vegetative growth 5), 7 = 3 Jul (reproductive growth 1), 8 = 11 Jul (reproductive growth 2), 9 = 18 Jul (reproductive growth 3), 10 = 25 Jul.
[y]Overall disease rating (%) was assessed on the entire interior two plants within each plot.
[x]Column means followed by the same letter are not significantly different according to Fisher's Protected LSD test ($P \leq 0.05$).
[w]Ridomil Gold SL was applied as a drench at 0.5 pt per acre as per label specification for control of downy mildew primary infection.
[v]To control powdery mildew, cover sprays of Quintec 8.2 fl oz/A were applied on 11 Jul. and 9 Aug.
[u] On 14 Aug, cones were counted on all four plants within each plot.

Table 1: Barley head scab management trial treatments conducted on both Calypso and Violetta

Trt	Product	Rate	Timing
1	Non-treated Control	—	—
2	Caramba	13.5 oz/A	Fks 10.5 (Full Head)
3	Prosaro	6.5 oz/A	Fks 10.5 (Full Head)
4	Prosaro	8.2 oz/A	Fks 10.5 (Full Head)
5	Miravis Ace	13.7 oz/A	Fks 10.5 (Full Head)
6	Miravis Ace	13.7 oz/A	Fks 10 (In Boot)
7	Miravis Ace	13.7 oz/A	Fks 10.3 (Half Head Emergence)
8	Miravis Ace fb Prosaro	13.7 oz/A fb 6.5 oz/A	Fks 10.5 fb Fks 10.5 + 4-6 days
9	Miravis Ace fb Caramba	13.7 oz/A fb 13.5 oz/A	Fks 10.5 fb Fks 10.5 + 4-6 days
10	Miravis Ace	13.7 oz/A	4-6 days post Fks 10.5
11	Miravis Ace	13.7 oz/A	8-10 days post Fks 10.5
12	Miravis Ace fb Tebuconazole	11.5 oz/A fb 4 oz/A	Fks 10.5 fb Fks 10.5 + 4-6 days

Table 2: Barley foliar disease management trial conducted on both Calypso and Violetta.

Trt	Product	Rate	Timing
1	Non-treated Control	—	—
2	Nexicor fb Miravis Ace	7 oz/A fb 13.7 oz/A	Fks 6-7 fb Fks 10.5 (Full Head)
3	Nexicor fb Miravis Ace	7 oz/A fb 13.7 oz/A	Fks 9 fb Fks 10.5 (Full Head)
4	Miravis Ace	13.7 oz/A	Fks 10.5 (Full Head)

Figure 1: Barley disease management trial established under center pivot with misters to create a disease favorable environment.

Figure 2: Barley varieties close to maturity.