Final Report
Grant No. 15SCBGPWI0054
Specialty Crops Block Grant Program
Wisconsin Department of Agriculture, Trade and Consumer Protection

Report Date: November 28, 2018

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INTRODUCTION

The Wisconsin Department of Agriculture received $1,305,944.30 from the Specialty Crop Block Grant Program, Grant No. 15SCBGPWI0054. The Department was able to fund 19 projects to promote and improve specialty crop industries in the state of Wisconsin or the Midwest. WI DATCP is using 8% of the funds to cover some administrative costs for the finance department to track and disperse the funding and the Grants Manager to implement the program.

Enclosed are the reports submitted by 19 grantees.

Grant Projects:

FY15-01	*Meeting Export Demands through Innovative Crop Management*
FY15-02	*Managing alternative pollinators through understory management in Wisconsin apple orchards*
FY15-03	*Development of new cold hardy seedless table, juice and raisin grape cultivars*
FY15-04	*Understanding Spotted Wing Drosophila seasonal phenology and temporal and spatial distribution within the crop to refine management practices*
FY15-05	*Examining landscape-level hypotheses to conserve water and enhance the competitiveness of specialty crops in central Wisconsin*
FY15-06	*Tagging of resistances to pink root and Fusarium basal rot of onion and development of a resistant open-pollinated red onion for Wisconsin growers*
FY15-07	*Farm to glass: university outreach to improve the quality of Wisconsin's fermented beverages 14-08*
FY15-08	*Expanding weather-based web tools for insect, disease, and agronomic management of Wisconsin vegetable crops*
FY15-09	*Neonicotinoid concentrations in succulent snap bean, sweet corn and peas following at-plant concentrations of neonicotinoid insecticides*
FY15-10	*Food Safety Education Project*
FY15-11	*Mitigating WI Hop Diseases Through Clean Rhizomes and Stock Certification (Project #15-011)*
FY15-12	*Enhancing market acceptance and quality of Wisconsin hops to craft brewers*
FY15-13	*Instructional resources to improve the safety, efficiency, and cost of growing and harvesting hops*
FY15-14	*Scaling up the pheromone-based mating disruption program in Wisconsin cranberries*
FY15-15	*Effects of fungicide and fertilizer applications on bee fidelity to cranberries*
FY15-16	*Developing Beginning and Minority Growers for Larger Markets*
FY15-17	*Biological control of flea beetle and cranberry fruitworm using native entomopathogenic nematodes (FY15)*
FY15-18	*Optimizing nitrogen fertilizer applications for snap bean production to improve water quality*
FY15-19	*Wisconsin Specialty Mushroom Growers Education and Outreach*

1) Meeting Export Demands through Innovative Crop Management (FY15-01)

Report Date: August 30, 2018

I. Project Summary

Ginseng is a high value crop for Wisconsin, annually totaling over $100 million in value. Disease pressure from fungal pathogens can be a serious problem for growers with losses reaching >50% in some gardens. Due to the export market for ginseng, growers must also be careful in regards to pesticide residues that can sometimes accumulate in the roots. For example, exports to certain markets have dropped by more than 90% due to issues associated with changes to maximum residue limits (MRLs). The purpose of this project was to reduce pesticide costs and residues by implementing biocontrol and compost products, improving our knowledge of seed treatments and determining which products are most likely to result in detectable residues.

B. Many of the experiments conducted for the FY2015 Wisconsin SCBG proposal were continuations of work completed for the FY2014 Wisconsin SCBG. After a closer analysis of the results from 2014 seed treatment and greenhouse trials, we were able to determine which treatments should be included for further testing. Some preliminary residue tests conducted for the FY2014 grant were also used to construct the protocols for the FY2015 residue experiments. The compost products that were not helpful (or sometimes harmful as indicated in the 2014 project results) for disease control on ginseng seedlings were not included in the FY2015 experiments. Over the past decade, we have continued to build and expand our winter research meeting and field day, held annually in March and August, respectively.

II. Project Approach

The Ginseng Board of Wisconsin partnered with Michigan State University (MSU) and the laboratory of Dr. Mary Hausbeck (Plant Pathologist and Professor at MSU) to complete this project. The GBW has successfully collaborated with MSU and Dr. Hausbeck on previous projects. This perennial crop requires time and considerable expense to establish, thus working directly with commercial growers with established plantings of various maturity is crucial. Several commercial ginseng growers including Joe Heil, Kirk and Kraig Baumann, Floyd and Lloyn Baumann, and Al Hopperdeitzel provided the needed space within their gardens for the various field studies described in this report. The cooperating growers provided crop maintenance including seeding, weeding, insect/slug control, fertilization, and other field activities (e.g. restrawing, seed removal). Other growers provided project input and samples for residue testing and included Nick Sandquist of Hsu's Ginseng, Jeff Koppa, Bob Kaldunski, Randy Krautkramer, and Greg Veers. In addition to providing field space for project activities, several growers also opened their gardens up for the Growers' Field Day and welcomed nearly 100 participants to their growing operation to see the results of this project firsthand.

Greenhouse experiments were conducted to determine the effectiveness of compost and biorational products against the two most common root rot pathogens, *Cylindrocarpon* and *Phytophthora*. Due to the uneven disease pressure experienced in grower cooperator fields, trials in the greenhouse are the most effective method to gather efficacy data. These greenhouse trials, conducted on seedlings, also allows for the testing of many active ingredients and compost materials in the shortest timeframe possible. The data collected in these experiments have been used to leverage product registration through the EPA.

Prior to the seed treatment work completed for this proposal, we had not conducted a replicated study suited for publication. Three, large scale replicated seed treatment studies were initiated annually from 2014-2016. To determine the effect on germination, stand counts from each treatment were collected multiple times from June-August. The 2014-initiated trial consisted of an untreated control and eleven single active ingredient treatments of labeled and experimental fungicides. The treatments that resulted in the highest stand counts per bed were retested in the 2015-initiated experiment which consisted of thirteen treatments and an untreated control. After the data from both of these experiments were closely analyzed, the 2016-initiated trial protocol was completed, which paired two products, one for *Cylindrocarpon*/*Fusarium* and a product for *Phytophthora*/*Pythium* control. This protocol would likely mimic the type of treatment regimen a grower would use commercially. The data collected in these studies have been extremely helpful in determining which products are detrimental to seedling germination or may possibly increase the number of emerged seedlings.

Pesticide residues continue to be an important issue for ginseng growers attempting to export their crop. Although growers must account for residues when determining which products to use, efficacy of the product is the top priority when choosing a product. From 2015-2017, trials were conducted in grower cooperators' fields to test the efficacy of products against Alternaria blight. At the end of these studies, roots from the treated beds were harvested, dried, and sent to an analytical lab for testing. The results of these studies have allowed us to make recommendations to growers that not only are proven to be helpful against diseases, but are also less likely to result in residues over the maximum residue limits.

Outreach to growers was completed at the Winter Research Meeting, the Field Research Day, or via email to growers when new products were labeled or if environmental conditions were highly conducive for disease outbreaks. The research updates held in March and August continue to be well received with over 100 people in attendance at both events.

III. Goals and Outcomes Achieved

The Wisconsin Ginseng industry experienced negative publicity regarding pesticide residue (MRL) violations in Taiwan resulting in a significant market drop that is now becoming re-established because additional violations have been avoided as a result of this successful project. This negative exposure and associated loss in sales has been crippling to the Wisconsin Ginseng industry. Yet, the GBW developed a plan to overcome this obstacle and avoid these MRL violations in Taiwan by ensuring that their product is now in full compliance with standards in Taiwan and other important export destinations such as China.

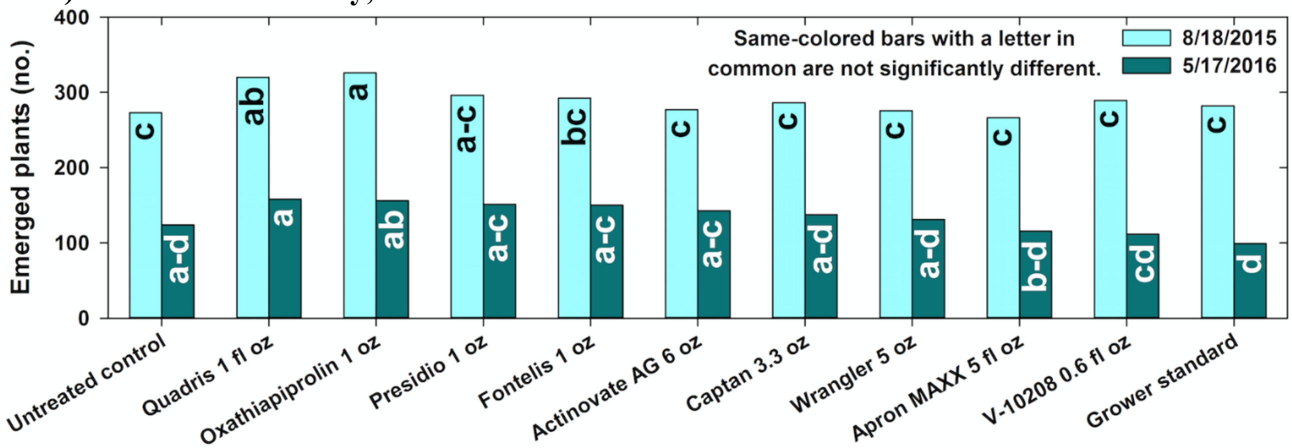
Through the completion of the activities associated with this project, we determined the pesticides most likely to result in a detectable residue, educated the growers regarding alternatives to those high-residue pesticides, and developed practices that could ease the overall use of pesticides (e.g. seed treatments, alternative products to fungicides, optimum fungicide application intervals, optimum number of fungicide applications, etc.). We identified key pesticides (examples include boscalid and bifenthrin) that consistently resulted in pesticide residues on the dried root and were removed from the growers' pesticide recommendations. The residue testing in this project served important grower educational purposes to avoid residues on the ginseng crop that would trigger MRL violations in Taiwan and China either because there is no MRL established for those pesticides or because the MRL for China and Taiwan is significantly lower than the U.S. tolerance.

The GBW subscribed to a website that lists the MRL levels for the countries including those of interest to the Ginseng growers of Wisconsin. This website is sponsored and updated by employees of Bryant Christie. This tool was used to track each of the pesticides used by Wisconsin ginseng growers to protect their crop as a means of determining which pesticide can be used without risking the triggering of a MRL violation from residue on the mature, dried root. This website is also monitored by registrants of pesticides and provided a means of communicating with those individuals within the pesticide company who are in a position of putting forward proposed MRLs to the primary countries that the GBW exports to including Taiwan and China. This updated and current MRL information is not available via other means and is supported and promoted by the Foreign Agriculture Service.

In 2014 and 2015, large-scale seed treatment trials were initiated with grower cooperators in Marathon County, WI. The 2015-initiated trial protocol was completed by choosing the best treatments from the 2014 trial results. Using a modified cement mixer, materials were applied according to manufacturers' labels to untreated stratified ginseng. A colorant was added to each treatment to ensure full coverage of the seeds. Each treatment was applied to 15 lb. of seed. After all of the treatments were applied, the seeds were immediately moved to the planting site. Each treatment was replicated three times in a randomized block design with each replicate consisting of a 50-ft length of a single raised bed. Each bed was 4-ft wide with a 2-ft buffer between treatments. Insect, disease, and weed control was managed by the grower cooperator in accordance to industry standards. The number of emerged and damped-off seedlings in two, one-square-meter sections, in the center of each bed were counted every two weeks from June through August. Data were analyzed using SAS PROC GLM and statistical differences were compared using the Fisher's Protected Least Significant Differences test (P=0.05). For the 2014-initiated trial, Quadris and oxathiapiprolin had consistently higher seedling emergence numbers throughout the season when compared to the untreated control (Figure 1). All other treatments resulted in counts statistically similar to the untreated control for all dates. It should be noted that the grower standard treatment resulted in relatively low counts in 2015, which correlated to the lowest count compared to all other treatments in 2016. No treatments significantly reduced damping off compared to the untreated control; however, Wrangler and OXTP (oxathiapiprolin) resulted in the lowest rates. Damping off does not appear to be the main factor in the differences observed in seedling germination, but rather was more often associated with drip lines in the canopy contributing increased moisture in certain plots. *Pythium* spp., *Fusarium* spp., *Phytophthora* spp. and *Rhizoctonia* spp. were found associated with damped off seedlings; however, there was no significant correlation between microorganisms isolated and treatments. A significant negative effect on emergence was not observed to be associated with any of the seed treatments when compared to the untreated control.

This large-scale seed treatment trial was a grower demonstration stop at the 2016 Ginseng Research Field Day. Growers were able to walk among the beds, which were labeled with signs containing the treatment name and rate. Although many growers believe that the seed treatments they use are helpful, the data from this trial showed that some treatments can result in reduced germination.

Figure 1. Results of the of the 2014 planted seed treatment trial over two-year period (2015-2016) in Marathon County, WI.



For the 2015-initiated trial, beds planted with the untreated seeds resulted in the highest stand counts for most of the rating dates (Table 1). Although this may discount the ability of the various fungicide treatments' abilities to protect the seed from pathogens resulting in a higher percentage of germination, the data from this trial will be helpful in determining which products are safe and do not inhibit germination. Results from the 2015 experiment confirmed some trends observed in previous years. In particular, Apron MAXX and Apron XL resulted in decreased germination when compared to the untreated control. Both products contain the active ingredient mefenoxam which has been shown to reduce germination in laboratory experiments. Although the Apron XL product is labeled for use on ginseng in Wisconsin, during the 2016 Winter Research Meeting and the 2016 Field Day, we have recommended to growers to immediately stop using the product. The commonly used fungicide Topsin 70WP (thiophanate-methyl) was included in a seed treatment trial for the first time in this experiment and resulted in the lowest stand count of any treatment in the experiment. Presidio SC (fluopicolide) and OXTP (oxathiapiprolin) treated seeds have consistently had the highest stand counts over multiple trials, and data from this trial will be used to pursue a future registration for a seed treatment on ginseng. Due to the overall low disease pressure observed in the ginseng garden that included this trial, there was no significant correlation between damping-off and the treatments.

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Table 1. Results of the large-scale seed treatment trial located in Marathon County, WI.

Treatment and rate 100 lb. seed, applied as a slurry except where indicated	Average # of emerged seedlings per 1 m^2				
	6/13	6/27	7/12	7/25	8/15

Untreated	290.2 d*	308.3 d	343.7 f	333.0 de	330.8 d
NutraPlant SD** applied as a dusting	205.3 a	231.3 ab	242.3 ab	256.8 a-c	246.3 a-c
Quadris SC 1 fl oz	214.3 a	234.8 a-c	234.7 ab	263.5 a-d	242.8 a-c
Quadris SC 1 fl oz + NutraPlant SD*	243.2 a-d	257.2 a-d	271.8 b-d	275.0 a-e	269.3 a-d
Topsin 70WP 3 oz	199.8 a	210.5 a	212.2 a	222.0 a	209.5 a
Apron XL EC 0.32 fl oz	212.5 a	215.7 a	232.7 ab	241.3 a	237.8 ab
Captan 50W 3.3 oz	220.7 a-c	259.7 a-d	266.3 a-d	271.7 a-e	262.7 a-d
Maxim SC 0.08 fl oz	241.2 a-d	277.3 a-d	279.0 b-e	286.5 a-e	279.2 a-d
Apron MAXX 0.32 fl oz	210.0 a	235.5 a-c	243.2 ab	250.3 ab	235.7 ab
Fontelis SC 2 fl oz	217.0 ab	255.8 a-d	261.0 a-c	272.8 a-e	259.0 a-d
Presidio SC 1 fl oz	272.3 cd	303.0 cd	301.0 c-f	313.7 b-e	327.2 d
OXTP OD 1 fl oz	285.0 d	305.0 d	332.3 ef	333.8 e	300.5 b-d
Inspire EC 1 fl oz	280.8 d	299.3 b-d	314.5 c-f	320.3 b-e	310.8 cd
V-10208 SC 0.6 fl oz	270.7 b-d	307.5 d	319.0 d-f	324.3 c-e	276.3 a-d

x Column means with a letter in common are not significantly different (Fisher's LSD; *P*=0.05).

Test compost and other biorational materials against root rot organisms.
Based on the results of the compost trials completed for the FY2014 trials, and that our contact person for the compost materials was no longer available, we collected compost materials from central Wisconsin that would be commercially available to growers.

Two greenhouse trials were conducted in 2016 to determine the effect of various compost materials and soil types on ginseng seedling health and development. One trial was inoculated with *Cylindrocarpon* and the second with *Phytophthora*. Two compost types were collected from Wausau-area companies. The compost materials were individually mixed at a 1:2 v/v ratio with the autoclaved soil and placed into 6-cell pack pots. The perlite soil mixture, Suremix, was included as a control. Stratified ginseng seeds were mixed in silica sand and stored at 38°F until germination. Germinated seeds were hand planted into 72-cell flats containing sterilized silica sand. Once enough seedlings emerged, they were carefully removed from the sand and observed for any disease symptoms; any seedlings showing root discoloration were discarded. The bare-rooted plants were then transplanted into the 6-cell packs containing the various soil treatments. Each soil type treatment was replicated five times in a completely randomized design. Preliminary studies have shown the difficulty in determining the effects of compost on ginseng. To combat the problems associated determining differences with ginseng soil treatments, each treatment was repeated three times in the experiment. The foliage health (1-5; 1=healthy, 2=chlorosis, 3=minor wilting, 4=moderate/severe wilting, 5=plant death) was noted on 20 and 24 June and 5 and 22 August. Data were analyzed using SAS PROC GLM and statistical differences were compared using the Fisher's Protected Least Significant Differences test (*P*=0.05).

Disease pressure did not develop in the *Phytophthora* study (data not shown). In the *Cylindrocarpon* study (Table 2), none of the compost materials statistically reduced disease severity compared to the untreated uninoculated controls, although it should be noted that overall, the untreated inoculated control compost treatments had lower disease severity compared to the Suremix inoculated control. Interestingly, the highly effective product Orondis Ultra A, was less effective than the untreated controls, possibly due to the high percentage of organic material in the soil. The biopesticide Howler was included and was not effective in limiting disease severity with any of the soil/compost types. Overall, coupled with the results of FY2014 trials, compost materials do not appear to have a fit in regards to disease control on ginseng.

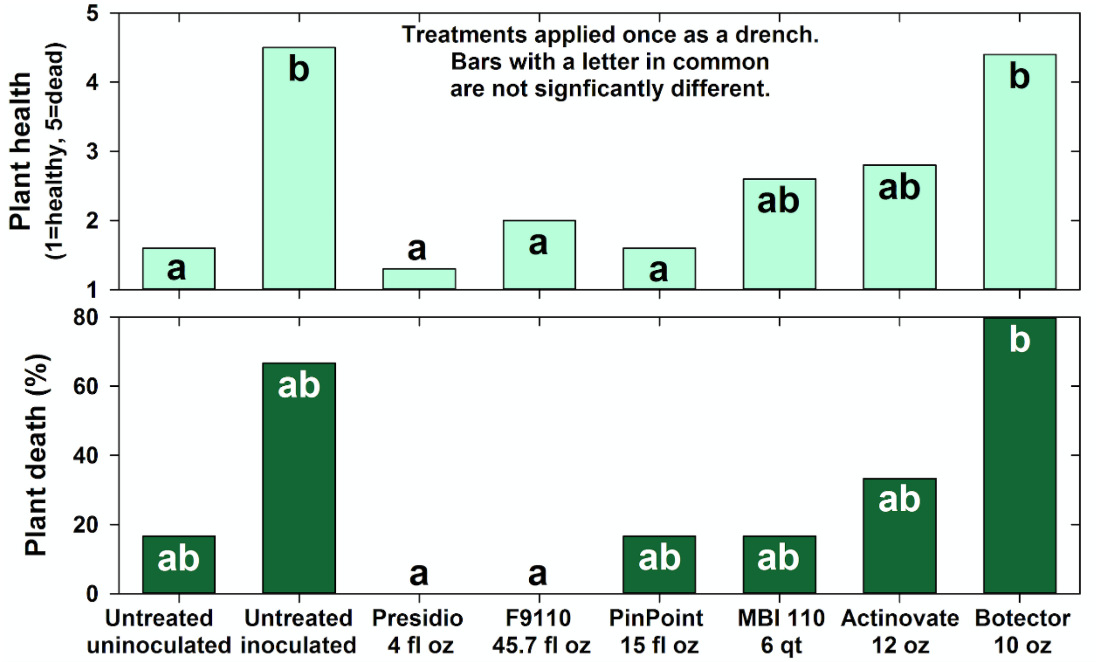
Table 2. Results of compost materials against Cylindorcarpon root rot in the greenhouse.

	Disease severity			
Treatment and Rate /100 gal	June 20	June 24	July 5	July 22
Suremix Uninoculated	1.4 ab	1.8 a	1.8 a	1.8 ab
Suremix Inoculated	1.6 ab	1.8 a	2.6 ab	2.6 abc
Suremix + Orondis Ultra A 1.6 fl oz	1.6 ab	1.8 a	1.8 a	1.8 ab
Suremix + Howler 66 oz	2.2 b	2.6 a	2.6 ab	3.4 bc
Suremix + Presidio 4 fl oz	1.0 a	1.0 a	1.0 a	1.0 a
Busy B Uninoculated	1.0 a	1.0 a	1.0 a	1.0 a
Busy B Inoculated	1.0 a	1.0 a	1.0 a	1.8 ab
Busy B + Orondis Ultra A 1.6 fl oz	1.6 ab	2.2 a	4.2 b	4.2 c
Busy B + Howler 66 oz	1.2 ab	2.0 a	2.2 a	4.0 bc
Busy B + Presidio 4 fl oz	1.0 a	1.4 a	1.8 a	2.4 abc
Tom S Uninoculated	1.0 a	1.0 a	1.0 a	1.8 ab
Tom S Inoculated	1.2 ab	1.6 a	2.2 a	2.0 abc
Tom S + Orondis Ultra A 1.6 fl oz	1.2 ab	1.6 a	2.4 a	4.2 c
Tom S + Howler 66 oz	2.2 b	2.6 a	2.6 ab	4.2 c
Tom S + Presidio 4 fl oz	1.0 a	1.0 a	1.2 a	2.6 abc

A greenhouse trial was conducted in the spring of 2017 to determine the effectiveness of biorational products against the root rot pathogen *Phytophthora cactorum*. Stratified ginseng seeds were mixed in silica sand and stored at 38°F until germination. Germinated seeds were hand planted into 72-cell flats containing sterilized silica sand. Once enough seedlings emerged, they were carefully removed from the sand and observed for any disease symptoms; any seedlings showing root discoloration were discarded. A mefenoxam-resistant isolate of *Phytophthora cactorum* was grown on V8 agar plates. Flasks filled with two parts millet and one part water were sterilized. Six 1.5-in. plugs of the infested agar were placed into the flasks. The infested millet was allowed to grow for three weeks. The healthy seedlings were transplanted into a soilless media (Suremix MI Cover Products Inc., Galesburg MI) on 13 April with six plants per treatment placed into a completely randomized design. Immediately after transplanting on 13 Apr, the treatments were applied as a drench at a volume of 3 fl oz/9 in^3. Treatments were reapplied on 20 and 27 April. On 17 April, the infested millet was added to each pot (1 oz/pot). A plant health rating (1=no disease symptoms, 2=chlorosis, 3=minor wilting, 4=severe wilting, 5=plant death) and death (%) was recorded on 24 and 27 April and 1 May.

Disease pressure was severe in the greenhouse seedling trial with 66.7% of the untreated inoculated plants dead by the final rating (Figures 2, 3). The biopesticide F9110 was the only biopesticide treatment that significantly increased plant health by the 1 May. Industry standard Presidio SC remains highly efficacious against Phytophthora root rot and resulted in a health rating of 1.3. The fungicide PinPoint (mandestrobin), although not currently registered on ginseng, was effective in this trial and will be included in future studies to determine if a registration of the product would be helpful to the industry. Phytotoxicity was not observed on any of the treated plants in this study.

Figure 2. Evaluation of biocontrol products to control *P. cactorum* on ginseng seedlings.



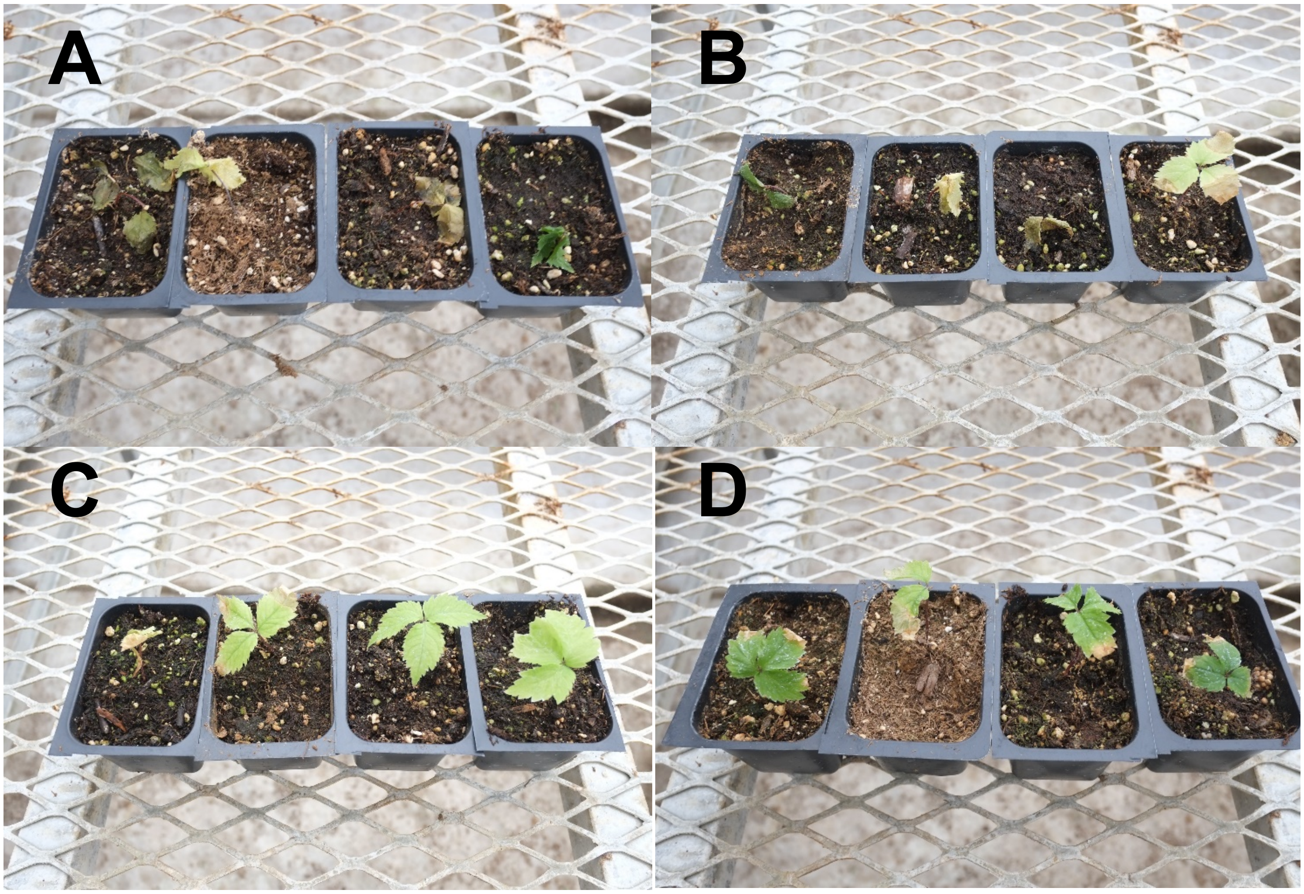


Figure 3 - Evaluation of biocontrol products for the control of *P. cactorum* in the greenhouse. Treatments are: A. Untreated control, B. Botector 10 oz, C. F9110 45.7 fl oz, D. Presidio 4 fl oz.

Develop pesticide recommendations for growers that protect the crop AND allow it to be exported with minimal or no chemical residues at harvest.

To determine how pesticide residues accumulate in ginseng roots, three trials were initiated in grower cooperators gardens in 2014 and continued through 2016. A trial was conducted on a seedling garden, a 2-year-old garden, and a 3-year-old garden. At each location, treatments were replicated four times with each replication consisting of a 20-foot bed length. Treatments were initiated in mid-June and were reapplied at 7-, 14-, or 21-day intervals through August. Insecticide treatments were applied based on grower use patterns. See tables 5-7 for the complete list of treatments. In late September, roots from a minimum of 3 replications of each treatment were harvested from the 2- and 3-year-old ginseng plots. Due to the small size of the roots, only one replication was harvested from the seedling garden. Roots were cooled for two weeks in accordance to processing standards and were then dried to 70-90% dry matter. After drying was complete, roots were transferred to the Michigan State University Analytical Testing Lab for residue testing. The samples were subsampled and ground with dichloromethane, magnesium sulfate, and sodium chloride. It was shaken and poured through a paper filter with sodium sulfate and collected in a round bottom flask. The sample was roto vapped to dryness and brought up in acetonitrile for analysis on either the GC or HPLC coupled to mass spectrometer.

The amount of residue detected in the roots appeared to be related to root age and the active ingredient in question (Tables 3-5). Of the 3-year-old roots tested, nine of the sixteen treatments tested resulted in detectable pesticide residues. Boscalid (Endura) and chlorothalonil (Bravo) were detected in all of the 3-year-old-roots regardless of the application schedule and the total number of applications. The 7-day applications of chlorothalonil to 2-year-old plants resulted in a detected residue higher than any other chlorothalonil treatment. The insecticide chlorpyrifos (Lorsban) was detected in the 3-year-old roots after just one early season application. The insecticide bifenthrin (Bifenture) was detected in all three ages of roots tested. Azoxystrobin was detected in all 2-year-old treated plants and the 7-day applications in the 3-year-old plants. Captan (Captan) and carbaryl (Sevin XLR and 7G) residues were not detected in any roots in this experiment. The detection of residue from the various products used appeared to be based more on the active ingredient itself and not on the number of applications or reapplication interval. It should be noted that all residues detected in this study were lower than the maximum residue limits set by the U.S. Environmental Protection Agency. Data from these trials will be used to help growers adjust their pest control program and implement products that are less likely to result in pesticide residues.

Table 3. Residues of various fungicides and insecticides detected on 4-year-old ginseng. Application initiated in 2014 as 2-year-old plants. The total number of applications over the three years are in parenthesis. Roots were washed and dried prior to testing.

Treatment and rate/acre	Active Ingredient	Spray Schedule	Applications applied in 2016 (2014-2016)	4-year-old garden residues (ppm)*
Untreated control	--	--	**--**	**--**
Endura WG 4.5 oz	boscalid	7-day	**5 (15)**	**0.0-0.752**
Endura WG 4.5 oz	boscalid	14-day	**5 (15)**	**0.0-0.693**
Endura WG 4.5 oz	boscalid	21-day	**5 (14)**	**0.0-1.063****
Bravo WeatherStik SC 2 pt	chlorothalonil	7-day	**8 (32)**	**0.0**
Bravo WeatherStik SC 2 pt	chlorothalonil	14-day	**8 (24)**	**0.0**
Bravo WeatherStik SC 2 pt	chlorothalonil	21-day	**5 (15)**	**0.0**
Captan 80WDG 2.5 lb.	captan	7-day	**8 (24)**	**0.0**
Captan 80WDG 2.5 lb.	captan	14-day	**8 (24)**	**0.0**
Captan 80WDG 2.5 lb.	captan	21-day	**5 (15)**	**0.0**
Quadris SC 15.5 fl oz	azoxystrobin	7-day	**8 (24)**	**0.0**
Quadris SC 15.5 fl oz	azoxystrobin	14-day	**8 (24)**	**0.0**
Quadris SC 15.5 fl oz	azoxystrobin	21-day	**5 (15)**	**0.0**
Lorsban 15G 13.5 lb.	chlorpyrifos	1 app	**1 (3)**	**0.0**
Sevin XLR 2 qt	carbaryl	14-day	**3 (9)**	**0.0**
Bifenture EC 6.4 fl oz	bifenthrin	14-day	**5 (15)**	**0.0-0.061**
Sevin G 30 lb.	carbaryl	14-day	**3 (9)**	**0.0**

*Residue levels shown as the range of the three replications tested per treatment.
**Residues numbers in red indicate residues over the EPA established maximum residue limits (MRLs).

Table 4. Residues of various fungicides and insecticides detected on 4-year-old ginseng.
Trial initiated in 2016. Roots were washed and dried prior to testing.

Treatment and rate/ 50 gal/acre	**Active Ingredient**	**Spray Schedule**	**Applications applied in 2016**	**4-year-old garden residues (ppm)***
Untreated control	--	--	**--**	**--**
Switch 62.5 WDG 14 oz	cyprodinil and fludioxonil	14-day	**4**	**0.0**
Fontelis SC 16 fl oz	penthiopyrad	14-day	**4**	**0.0-0.006**
Orondis Ultra A 9.6 fl oz	oxathiapipronil	14-day	**4**	**0.0**
Gavel DF 2 lb.	zoxamide	14-day	**4**	**0.0**
Quadris Top SC 14 fl oz	difeniconazole	14-day	**4**	**0.0**
Topsin 70WP	thiophanate-methyl	14-day	**4**	**0.0-0.009****
Coragen 5 fl oz	chlorantraniliprole	7-day	**8**	**0.0-0.002**

*Residue levels shown as the range of the three replications tested per treatment.
**No MRL has been developed by the EPA for thiophanate-methyl on ginseng.

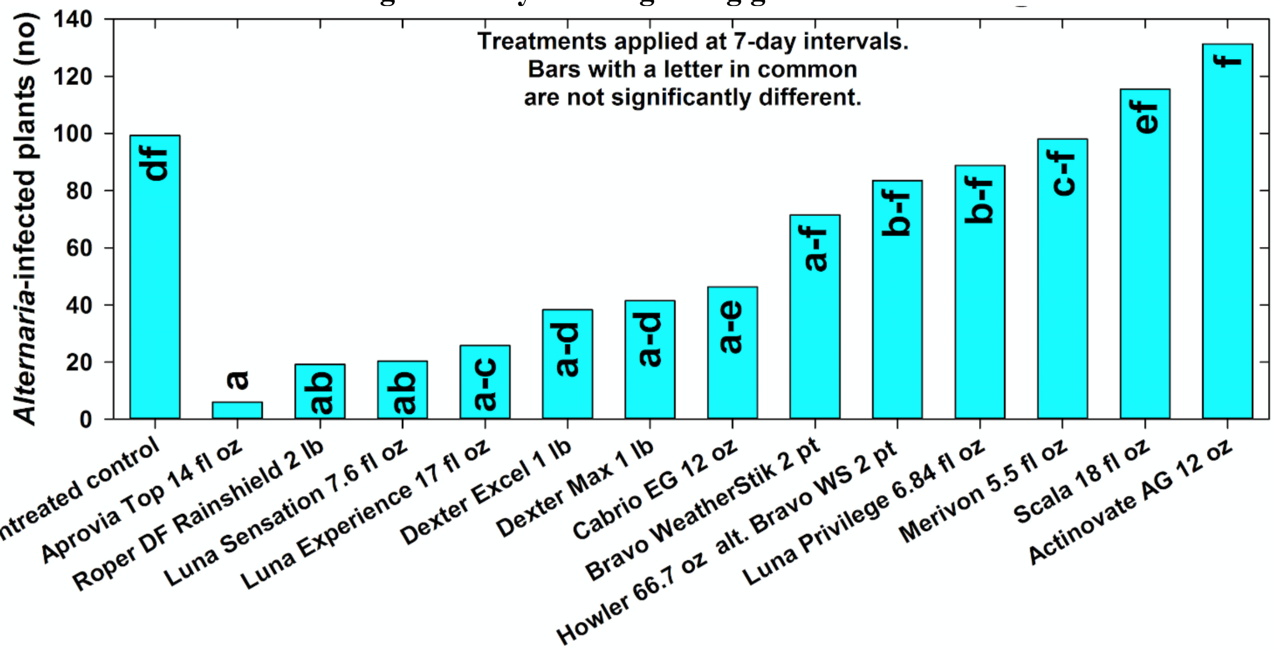
Table 5. Residues of various fungicides and insecticides detected on 3-year-old ginseng.
Trial initiated in 2016. Roots were washed and dried prior to testing.

Treatment and rate/ 50 gal/acre	**Active Ingredient**	**Spray Schedule**	**Applications applied in 2016**	**3-year-old garden residues (ppm)***
Untreated control	--	--	**--**	**--**
Scala SC 18 fl oz	pyrimethanil	7-day	**12**	**0.0**
Aprovia Top EC	difenoconazole + benzovindiflupyr	7-day	**12**	**0.0**

This study was conducted at a cooperator's farm in Marathon County, WI on three-year-old ginseng plants grown under 80% shade-cloth. Beds were 4 ft wide with 1 ft between beds. Treatment blocks consisted of a 10-ft bed with a 2-ft buffer on each end. Treatments were replicated six times in a randomized complete block design. Weed control and fertilization were made according to commercial production standards. Fungicides were applied with a CO_2 backpack boom sprayer equipped with four T-Jet 8003VS flat fan nozzles spaced 18 in. apart, operating at 40 psi, and delivering 50 gal/A. All treatments were initiated on 20 May. The number of plants in each plot with symptoms of *A. panax* infection was counted on 17 June, 1 and 13 July, and 1 and 23 August. The berries were collected and weighed from the middle 16 ft^2 of each bed on 23 August.

Disease was severe in this trial with the untreated control beds averaging almost 100 *A. panax*-infected plants per bed (Figure 4). Roper DF Rainshield and Luna Sensation were the only registered products that statistically reduced the number of *Altarnaria*-infected plants compared to the untreated control. Aprovia Top, which is currently in the process of being registered through IR-4, was highly effective and will be included in future studies. The newly registered products Dexter Max and Dexter Excel limited infection to less than half of the untreated control. The biopesticide Actinovate AG was not effective in this trial and would not be recommended to growers for foliar bight control.

Figure 4. Evaluation of biocontrol agents and experimental fungicides to control Alternaria blight in a 3-year-old ginseng garden.



To reduce the pesticide residues from commercially used fungicides, we tested biocontrol products against *A. panax* on seedlings in Marathon City, WI. The treatments were applied every 14-days using a four-nozzle boom holding 8006VS flat fan nozzles operating at 36 psi and delivering 100 gallons per acre. The treatments were initiated on 25 May 2017. The number of seedlings with *Alternaria panax* symptoms were counted for the two 1 m^2 sections of each bed on 17 August. Results from this trial were consistent with results observed in previous experiments; notably that biocontrol products, when applied alone, are not effective against *A. panax* in a field setting (Table 6). Although the results were not statistically different, due to a wide variance in infection rates between replications, the treatments that included the standard control products, such as Cannonball WP, Topsin WP, and Captan WDG resulted in lower infection rates. RootShield Plus applied alone resulted in just 2.5 infected plants per 1 m^2 and will be included in 2018 trials to determine if this product should be included in future disease management recommendations.

Table 6. Evaluation of biopesticides to control *A. panax* on ginseng seedlings.

Treatment and rate per 100 gal	*A. panax* infected plants per 1 m^2 17 August
Untreated control	32.8 a*
RootShield PLUS 3 lb.	2.5 a
Double Nickel LC 64 fl oz	37.5 a
OSO 5% 10 oz + Scanner NIS 0.13%	12.8 a
SoilGard 2 lb.	49.0 a
Actinovate AG 12 oz	50.3 a
RootShield PLUS 3 lb. alt. Captan 80WDG 2.5 lb. alt. Cannonball WP 8 oz alt. Presidio SC 4 fl oz alt. Topsin M WSB 1 lb.	4.8 a
Double Nickel LC 64 fl oz alt. Captan 80WDG 2.5 lb. alt. Cannonball WP 8 oz alt. Presidio SC 4 fl oz alt. Topsin M WSB 1 lb.	8.8 a
OSO 5% 10 oz + Scanner NIS 0.13% alt. Captan 80WDG 2.5 lb. alt. Cannonball WP 8 oz alt. Presidio SC 4 fl oz alt. Topsin M WSB 1 lb.	1.3 a

Treatment and rate per 100 gal	*A. panax* infected plants per 1 m^2 17 August
SoilGard 2 lb. alt. Captan 80WDG 2.5 lb. alt. Cannonball WP 8 oz alt. Presidio SC 4 fl oz alt. Topsin M WSB 1 lb.	8.8 a
Actinovate AG 12 oz alt. Captan 80WDG 2.5 lb. alt. Cannonball WP 8 oz alt. Presidio SC 4 fl oz alt. Topsin M WSB 1 lb.	3.3 a
Captan 80WDG 2.5 lb. alt. Cannonball WP 8 oz alt. Presidio SC 4 fl oz alt. Topsin M WSB 1 lb.	0.5 a

*Column means with a letter in common are not significantly different (Fisher's LSD; P=0.05).

To disseminate research findings to growers, including Hmong growers, so that they may be incorporated into the grower's production plan in a timely manner.

On August 5th over 100 growers, industry representatives, legislators, and researchers attended the 2016 Ginseng Research Field Day. Approximately 15 Hmong growers were among the attendees. Growers observed various research trials including the plots associated with the FY2015 Wisconsin SCBG. The 2014-15 and 2015-16 seed treatment trials were visited during the Field Day along with multiple *Alternaria* and *Phytophthora* efficacy studies (Fig. 5). Handouts with preliminary data was distributed to growers

Figure 5. Dr. Mary Hausbeck discusses results of the field trials with the attendees at the 2016 Field Research Day.

The GBW Newsletter was distributed to 175 growers during the reporting time period. Email alerts were sent to 55 growers and text alerts were sent to 63 ginseng growers.

B. All of the goals of the approved application were met. Multiple seed treatment trials were conducted and included all of the treatments listed in the application; with the exception of Kodiak HB, which is no longer manufactured. The most important accomplishment of the seed treatment trial were the stand counts, which showed that the registered product Apron XL resulted in lower germination compared to other treatments. Data collected over multiple years at a single site proved that a loss in seed germination at year one results in a significant reduction in plant stands in future years. Although the beds were counted for seedlings with symptoms of root rot, very few were observed in the trials and no differences were observed between treatments. The seed treatment data has been presented at multiple grower meetings.

Compost and biopesticide products were tested against root and foliar pathogens in greenhouse and field studies from 2016 through 2017. Data presented in the progress reports did not show a correlation between compost materials and reduction in disease symptoms caused by *Phytophthora* or *Cylindrocarpon*. Due to the loss of cooperator Jonathan Riven, compost materials were not easily collected for the 2016 trials; however, four biopesticide products were screened against Phytophthora root rot. Overall, some biopesticide products, such as F9110 and MBI-110 limited symptoms of Phytophthora root rot and will be included in future studies. Biopesticides, alone or in a program that included industry standards were also applied to seedlings to determine their effectiveness against the pathogens often observed in the field. Although the results of this trial were not conclusive in 2017, disease that overwintered at the site was severe in 2018 and growers are not likely to incorporate biocontrol products into their blight control programs.

Field studies were conducted to develop pesticide recommendations for growers that protect the crop and allow it to be exported with minimal or no chemical residues at harvest. Although new fungicides have been registered in recent years, little was known in regards to effectiveness and residues. Thirteen products were tested for efficacy in a three-year-old garden and the number of infected plants ranged greatly as levels of efficacy between products was pronounced. Eighty-four residues were collected from experiments treated based on the number of applications allowed per the label. Results were encouraging with only Endure WG treated plants resulting in limits above the MRL. The most effective treatments from the efficacy trials have been included in future recommendations presented to the growers.

Surveys were distributed to growers with close to 60 responses collected (Table 7). The average of number of years growing ginseng was 22.2 years with about 71% of growing less than 10 acres. Growers continue to be concerned with pesticide residues and the results of the survey show that the results of the residue trials have been helpful in determining which products growers apply. Some positive information was collected in regards to seed treatment, with 100% responding that they treat their seed. Growers were only moderately interested in compost materials for disease control and more grower input should be collected before continuing this project.

Table 7. Ginseng grower survey results.

Question	Yes	No
Do pesticide residues concerns influence your pest control strategy?	89.8%	10.2%
Are there products that you do not apply due to residue concerns?	26.3%	73.7%
Has the residue information presented to you at the Field Day or March Meeting resulted in you applying products less?	71.9%	28.1%
Are you aware that on the GBW website there are disease control recommendations?	91.4%	8.6%
Have you used the disease control recommendations to make decisions on your own control programs?	78.9%	21.1%
Have you received the "Disease Alert" emails that were sent from the GBW?	70.7%	29.3%
On a scale of 1-10 (1=not at all, 10=very), how interested are you in using organic matter as a soil amendment for disease control?	5.5 (moderately interested)	
When do you treat your seed? Not treated: 0.0%; Prior to stratification only: 4.7%; Prior to planting only: 31.5%; Both: 64.8%		

IV. Beneficiaries

The beneficiaries of this project were the ginseng growers, the associated industries and groups that buy or sell ginseng, and companies that supply the industry. Educating the 150 ginseng growers on the possible risk of some compost products and their association with root diseases may help growers avoid this problem. If a grower was to use a compost product that was detrimental, research results show that plant death is likely to be 50%, or about $65,000 per acre in losses. The ability of some fungicides to increase seed yield might help growers avoid purchasing seeds at ~$50/lb., or $5,000 per acre. Growers are less likely to use products such as Lorsban and Endura in the future, resulting in less products being denied sale due to residue detections of the established MRLs. The residue information is also helpful to buyers, sellers, and exporters of ginseng as they are often the ones who deal with residue problems. The testing of new products has resulted in the incorporation of many newly effective fungicides. Survey results show that growers are receiving the disease alters and that seed treatment has been widely adopted by the industry, resulting in healthier seedling gardens. Hmong grower participation at the Field Day and Winter Research Meeting has increased and the special research sessions for Hmong growers was helpful in targeting information most helpful to their needs.

V. Lessons Learned

Although Jonathan Riven needed to leave the project because he lost his job, we were able to address this objective adequately. The quality of the compost materials that were tested varied greatly and I would hesitate to recommend the products unless they were screened for pests. The results of the included compost greenhouse trial were not as conclusive as the previous experiments; however, no positive results of using compost materials have been observed over the multi-year study. The inclusion of biopesticides into the disease control program of the industry will not be easy as most of the products tested were not effective. In particular, when disease control failure occurred in a garden due to the use of these products, the pathogen became unmanageable the following year, even when the most effective products were used.

There are common misperceptions regarding the use of seed treatments for Ginseng. The labeled fungicide, mefenoxam, is labeled for use as a seed treatment and commonly used. Yet, this product performed poorly in our field trials and resulted in a decreased plant stand. Two newer fungicides performed exceptionally well and with the data developed from this study, the registrants of these fungicides have been contacted in order to explore expanding the uses of these fungicides to ginseng. Using effective seed treatments early in the growing of the ginseng crop could reduce the need for fungicides later in the crop so that the residues are likely to be reduced averting possible MRL violations.

It was also learned that a fungicide that was not registered at the time of testing, Presidio, is effective against root rot caused by Phytophthora cactorum. The data from this study was provided to the registrant of the fungicide (Valent) and the USDA IR-4 Project. Two other fungicides (PinPoint and F9110) that were experimental on ginseng were also effective including a biopesticide. This has shown ginseng growers that continued progress can be made in identifying new tools to protect the crop.

The residue testing portion of this project taught us that an immediate adjustment to the crop protection spray recommendations were warranted to ensure that residues would not trigger an MRL violation. Specifically, the fungicide Endura (boscalid), is persistent on the ginseng root regardless of the program in which it is used. As a direct result of this research, the fungicide was dropped from the crop spray recommendations. Limiting the use of fungicides that are likely to persist on the root aids the industry when exporting to Taiwan or China.

Use of the MRL website taught us how to track and monitor the dynamic nature of the MRL issues in both Taiwan and China and avoid violations and negative press. This information, along with tactics described above, have allowed the ginseng industry to regain their market share in the two key export markets of Taiwan and China. Finally, we learned that demonstrating the results of our research via the winter/spring Growers' Research Meeting and the summer Field Research Day is well attended and assists in implementing recommendations.

VI. Additional Information

none

VII. Contact Info

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2) Managing alternative pollinators through understory management in Wisconsin apple orchards (FY15-02)

Report Date: October 31, 2017

I. Project Summary

Wild bees are effective crop pollinators but are experiencing declines worldwide due to agricultural intensification, pesticide exposure, and loss of habitat among other factors (Potts et al. 2010). Previous studies demonstrate that the abundance and diversity of wild bees increases with increasing natural habitat in the surrounding landscape (Kremen et al. 2004, Morandin and Winston 2006) and that fruit set and yield increases with bee species richness (e.g., (Klein et al. 2003, Holzschuh et al. 2012, Mallinger and Gratton 2014). This is particularly true in Wisconsin apples, where recent work by our group has shown that native wild bees are sufficiently abundant and diverse to fulfill apple pollination requirements. Furthermore, mounting evidence suggests that increasing the availability of on-farm floral resources, including non-crop flowers, not only leads to an increase in the abundance and species richness of native bees (Rosa García and Miñarro 2014, Norfolk et al. 2014, Wood et al. 2015) but also results in increased fruit set in the crop (Carvalheiro et al. 2011, Blaauw and Isaacs 2014). Therefore, management practices that promote flowering resources could lead to direct economic gain for growers.

Many apple growers in Wisconsin, however, are concerned that the presence of non-crop flowering plants within the orchard during crop bloom could draw bees away from the crop, thereby reducing fruit set and yield. Management practices that reduce the abundance of non-crop flowers during bloom, for example mowing of the orchard understory, might enhance crop pollination by giving local pollinators no other option than to visit the blooming crop. On the other hand, the presence of non-crop flowering plants within an orchard may actually attract wild bees into an orchard and, through a spillover effect, enhance crop pollination. The relative importance of within-orchard flowering plants may also be dependent on the availability of flowers in the surrounding landscapes. Since bees can fly distances beyond the farm boundary, it is possible that on-farm floral availability is overwhelmed by floral resources in the surrounding landscape. If so, management recommendations regarding understory flower management may be different in different landscape types.

Therefore, the objectives of this study were to:

(1) **Test how management activities that affect floral resources on the farm (e.g., understory mowing) affect wild bee foraging and apple fruit set in the presence or absence of managed honey bees**
(2) **Evaluate how the foraging response of native, wild bees to local floral resources is influenced by aspects of the surrounding landscape**

The results of our study can inform grower practices by providing evidence for the value (or cost) of non-crop understory flowers during apple bloom.

B. This project built upon two previously funded SCBGP projects (Mallinger/Gratton FY2011 and FY2012) that found (1) wild bees are important pollinators of Wisconsin apples providing sufficient pollination for marketable yields even in the absence of honey bees and (2) apple fruit set is positively associated with wild bee species diversity. This project expanded that research to investigate how a specific management practice (i.e., understory mowing) influences the foraging behavior of the wild bees that are active in apple orchards and the resulting effect on fruit set.

II. Project Approach

Accomplishments: Over the course of two field seasons, we collaborated with 24 Wisconsin apple growers to address our two objectives, presented our findings at three grower meetings and one scientific conference, and recruited 8 apple growers to participate in a citizen science project to assess the value of short observations on assessing pollinator activity. The citizen science data will be used for a future collaboration with the IPM Institute of America in order to build a tool for growers to determine their pollinator needs. To accomplish our objectives we established a replicated on-farm experiment manipulating dandelion abundance (through mowing) and collected data on insect visitation rates to apple and dandelion, and related it to dandelion density, fruit set, seed set, and landscape diversity.

Objective 1: Test how management activities that affect floral resources on the farm (e.g., understory mowing) affect wild bee foraging and apple fruit set.

Activities and tasks performed: In 2017, we identified 14 grower collaborators who had a block of dwarf Honeycrisp trees in their orchard. All orchards either had honey bee hives present at the orchard or located nearby. At each orchard we designated half of the Honeycrisp block as the “mow” treatment and half as the “no mow” treatment. Growers were asked to mow the “mow” treatment as often as possible during apple bloom and to avoid mowing the “no mow” treatment until apple bloom was over. Each treatment block was 5 to 7 orchard rows wide by a minimum of 40 meters long. Data was collected in a central row of each block that were a minimum of 20 meters and a maximum of 100 meters apart from the data collection in the other treatment block. Within the central data collection row of each treatment block, 10 trees were labeled using Tyvek tags. The tag was attached to a lateral branch located approximately 1-2 meters above the ground and approximately 1 meter from the tip of the branch. Each orchard was visited 4 to 5 times during the spring season to collect data on fruit set, insect visitation rates, dandelion density, and seed set. At 8 of these orchards, visitation data was also collected during peak bloom by the growers.

Data was collected as follows. To assess fruit set, all flower buds on each flagged branch were counted between the flag and the tip of the branch. Then, after bloom had ended, the total number of fruitlets found on the same length of branch were counted. Since apples experience significant fruit drop in the weeks following petal fall, we visited each orchard a second time in mid- to late-June to re-count the number of fruits forming on each flagged branch. At the time of the second fruit set assessment, 10 fruits per flagged tree were also collected and the diameter and number of seeds were assessed in the lab. To assess insect visitation rates, we conducted timed observations on days that were warm (> 15 ºC), calm (wind < 2.5 m/s), and with enough sun to cast a shadow between 10 am and 4 pm. A section of each flagged tree approximately 1 m by 1 m was observed for a total of 5 minutes. During those 5 minutes, all insect visitors were recorded. At the end of the 5 minute observation period, all flowers within the observed area were counted. Insect visitation rate data to dandelions was collected over 5 minute observation periods as well, although the observer moved at a slow and steady pace down the length of one orchard lane within the treatment block. After observations, 10 - 1 x 1 m quadrats were randomly placed throughout the treatment block and the total number of dandelions were recorded.

Significant results:

1. Mowing of the orchard understory significantly decreased dandelion abundance (Fig. 1b) and thus created a strong contrast that we could use to compare the consequence to bee foraging preferences and fruit set.
2. We found that different bee communities were present visiting apple compared to dandelion flowers (ANOSIM $p = 0.001$, Fig. 2). Honey bees were the dominant visitor to apple blossoms accounting for nearly 90% of insect visitors, whereas wild bees were the dominant visitors to dandelions accounting for approximately 50-60% of insect visitors. The insect community visiting apple and dandelion flowers was not influenced by the presence of dandelions in the orchard understory (ANOSIM $p = 0.67$).
3. Visitation rates by wild bees to apple blossoms increased as the density of dandelions in the understory increased (Fig. 3a), while visitation rates to dandelions was not affected by the density of dandelions (Fig. 3b). Moreover, visitation rates by honey bees did not change on either apples (Fig. 3c) nor dandelions (Fig. 3d) as a function of dandelion flower density. Both of these results were contrary to our hypothesis that dandelions would "distract" the bees from the apple blossoms resulting in lower visitation rates to apple. Rather, wild bees increased foraging on apples as more dandelions were present in the understory.
4. There was no relationship between dandelion density in the understory and either fruit set (Fig. 4a) or seed set (Fig. 4b). This was despite the increase in visitation rate by wild bees to apple.
5. There was also no relationship between apple fruit set and visitation rates by either wild bees (Fig. 5a) or honey bees (Fig. 5b). This was unexpected and may be an artifact of the coarseness of visitation data collected just once per farm during apple bloom. Bee activity is highly variable and even when weather conditions for "good bee weather" are met, one day may not be comparable to another.

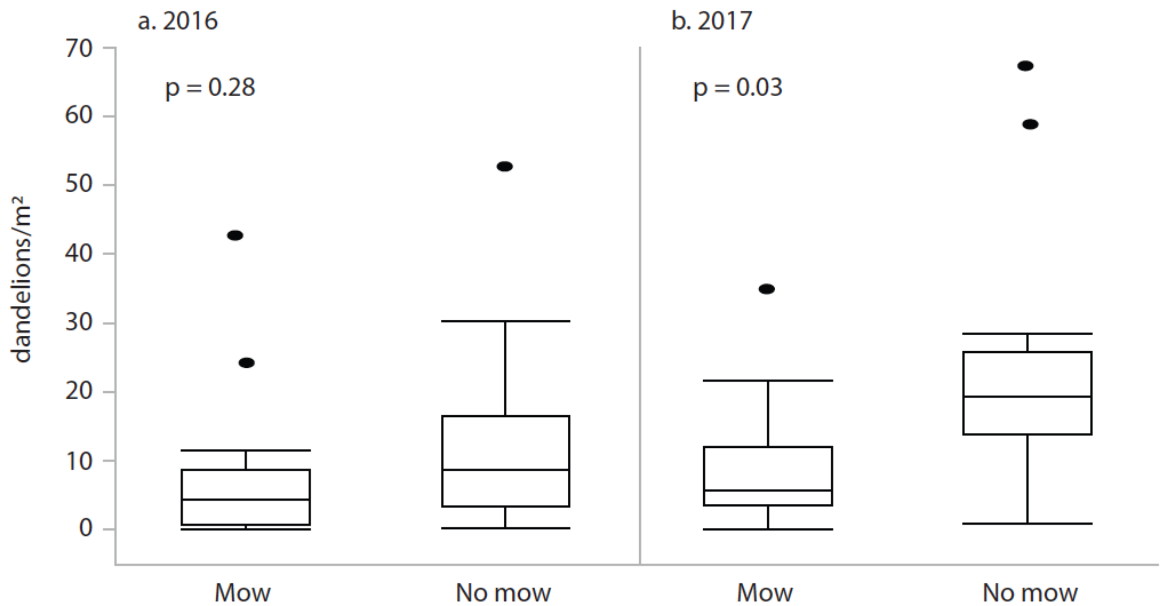

Fig. 1: The experimental mowing treatment did not effectively reduce dandelion density in 2016 (a) but did reduce dandelion density in 2017 (b).

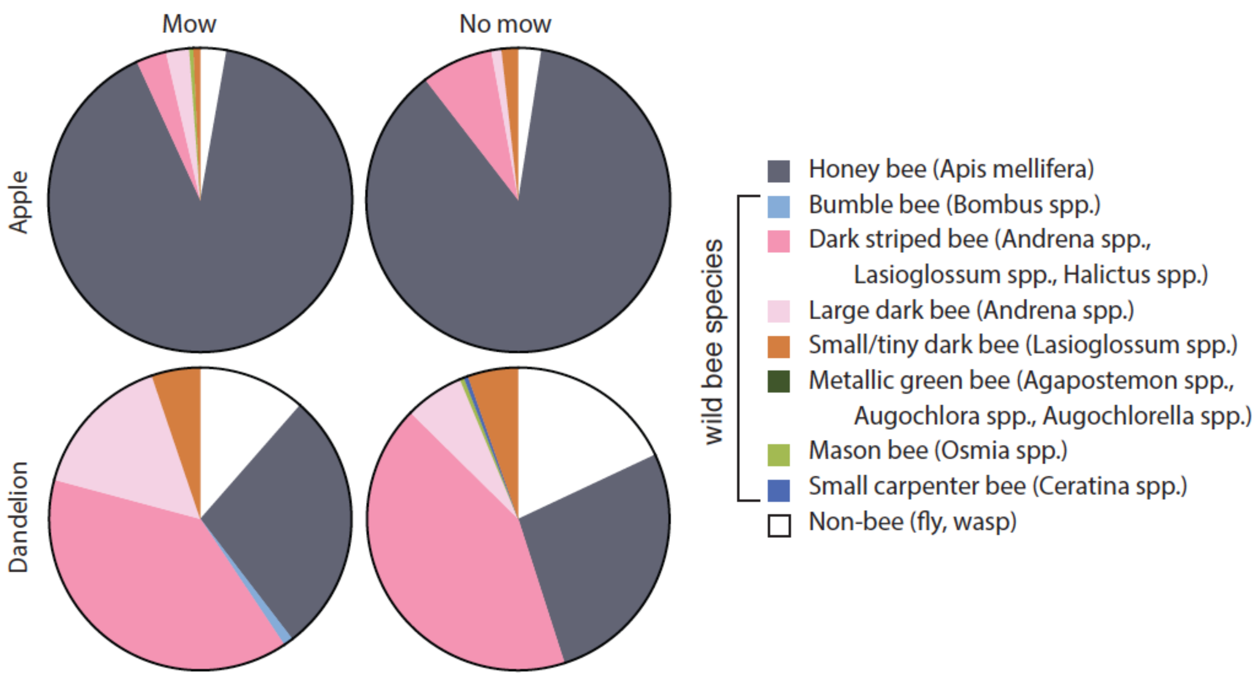

Fig. 2: Insect visitor abundance grouped by morphospecies observed on apple and dandelion flowers in the "mow" and "no mow" treatments in 2017. Insect communities were different between apple and dandelion flowers (ANOSIM $p = 0.001$) but not between mow treatments (ANOSIM $p = 0.67$). Honey bees were the dominant visitor to apple flowers (top two panels) whereas wild bees were more abundant on dandelion flowers (bottom two panels).

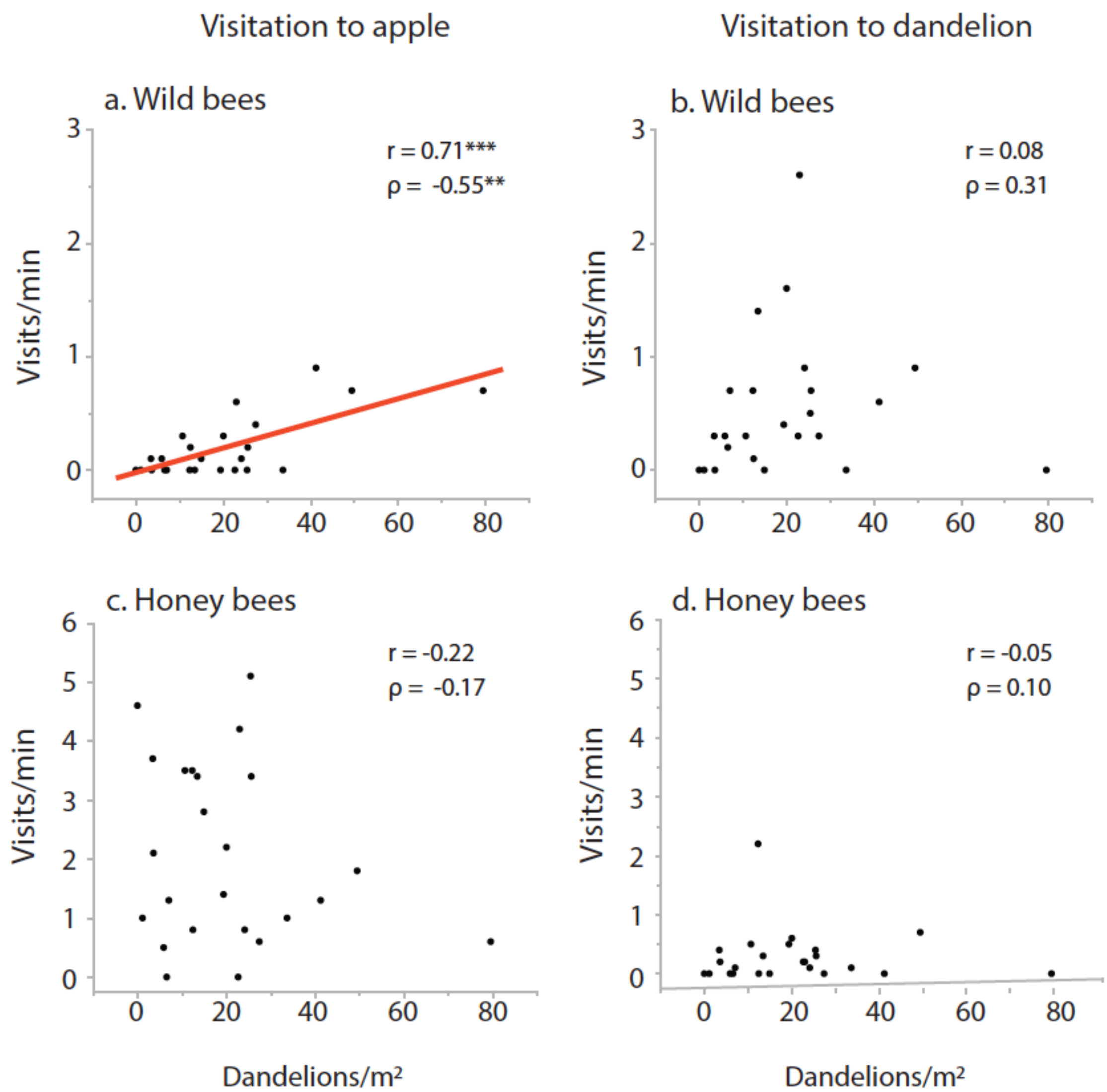

Fig. 3: Plots illustrate the relationship between bee visitation rates and dandelion density in the orchard understory. The visitation rate of wild bees to apple flowers increased as the density of dandelions in the understory increased (a). No other relationship was signifcant (b,, c, d). ** indicates $p < 0.01$, *** indicates $p < 0.001$.

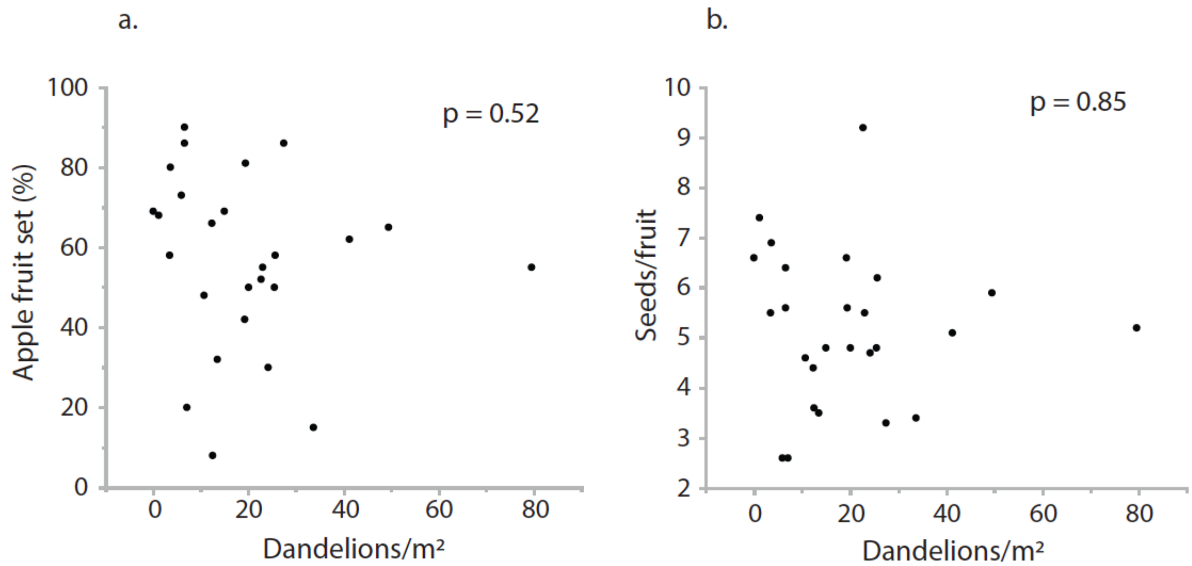

Fig. 4: Neither apple fruit set or seed set were influenced by dandelion density in the understory.

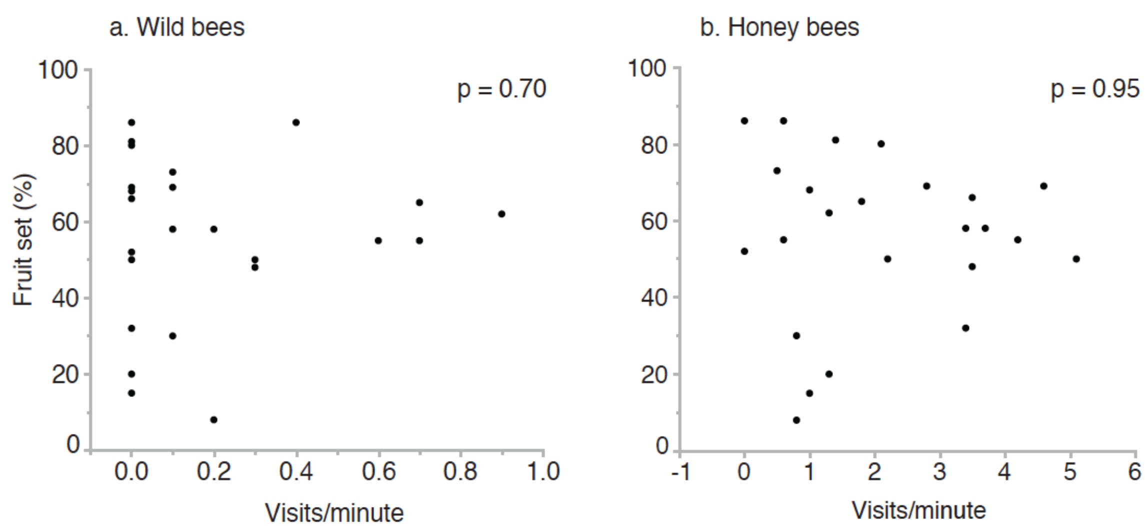

Fig. 5. Fruit set was not predicted by either wild bee or honey bee visitation rate in 2017.

Objective 2: Evaluate how the foraging response of native, wild bees to local floral resources (i.e. dandelions) is influenced by aspects of the surrounding landscape.

Activities and tasks performed: In 2016, we identified 19 apple grower collaborators whose orchards fell along a gradient of high to low landscape diversity. Landscape diversity was represented by the Shannon Wiener Diversity Index and calculated based on an analysis of the surrounding 1 km land cover types using the Cropland Data Layer (NASS CDL). Previous research in our lab demonstrated that wild bee diversity increases with landscape diversity and that apple fruit set increases with wild bee diversity (Mallinger 2015, Mallinger and Gratton 2015). At each orchard, we identified a uniform block of trees at least 9 to 11 rows wide. The blocks were composed of either a single apple variety (e.g., Honeycrisp) or several varieties so that treatment was not confounded with variety. The block was divided into two halves and designated “mow” or “no mow” as described above. The treatments were immediately adjacent to one another at some orchards and split at other orchards depending on the layout of the orchard. Data was collected in a central row of each block ensuring a minimum of a 2 orchard lane buffer on either side of the data collection row. Within the central data collection row of each treatment block, 10 trees were labeled and flagged with flagging tape. The label was attached to a lateral branch located approximately 1-2 meters above the ground and approximately 1 meter from the tip of the branch. Each orchard was visited 4 to 5 times during the spring season to collect data on fruit set, insect visitation rates, and dandelion density. Data was collected as described above for objective 1.

Significant results:

1. In 2016, mowing treatments were not effective at creating a significant difference in the density of dandelions compared to no-mow treatments with only 1.5 times as many dandelions in the “no mow” treatment than the “mow” treatment (Fig. 1a, mean dandelions/m^2 “mow” = 8, “no mow” = 12). For comparison, in 2017, the “no mow” treatment had on average 2.4 times as many dandelions as the “mow” treatment” (10 vs. 24 dandelions/ m^2). As a result, we were unable to compare treatments categorically (“mow”, “no mow”) but instead treated dandelions as a continuous variable.
2. Due to an extremely short bloom period in 2016 due to weather conditions, visitation data was only collected at 13 of the 19 orchards. We found no relationship between visitation rates by wild bees or honey bees and dandelion flower density for apple or dandelion (figure not shown). There was also no relationship between visitation rates and landscape diversity for wild bees or honey bees on dandelion or apple (figure not shown).
3. We found no variation in fruit set in response to landscape diversity (Fig. 6) or dandelion density (Fig. 7).

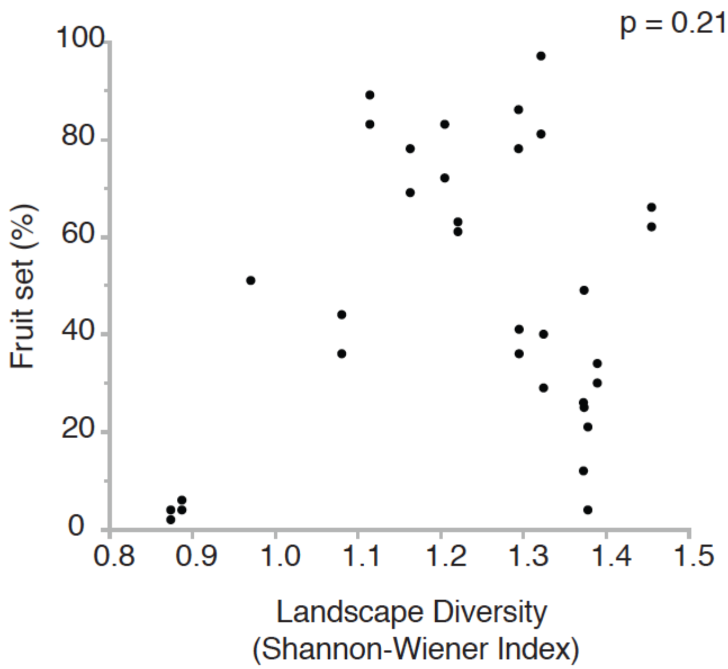

Fig. 6: Fruit set was not associated with landscape diversity.

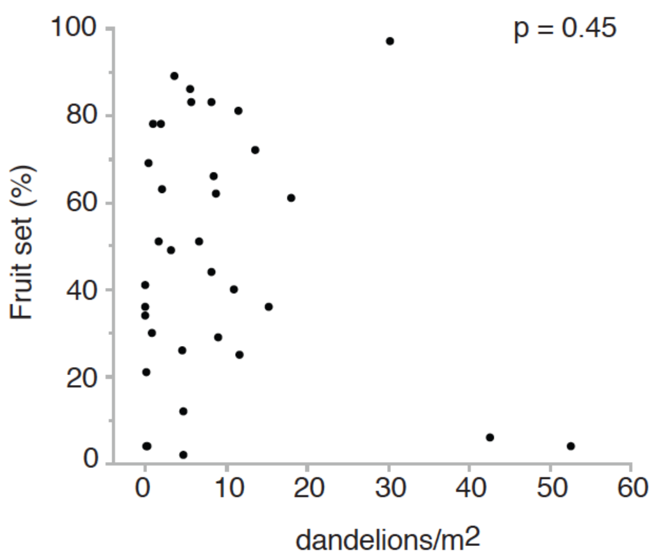

Fig. 7: Fruit set was not associated with dandelion density in the understory in 2016.

Conclusions:

Do dandelions in the understory of apple orchards affect bees and apple fruit set? We found no evidence that apple fruit set or seed set (a measure of the extent of pollination) was influenced by the density of dandelions in the understory of apple orchards. This could be due to several factors. Since honey bees were present at all orchards, and honey bees preferentially foraged on apples, these insect pollinators could have been responsible for meeting pollination requirements of apples on their own. Therefore, there may not have been any pollen limitation due to an abundance of honey bees in these orchards. Any change in visitation by wild bees to apples would have been masked by the large amount of pollen carried by honey bees. Importantly, honey bees were insensitive to variation in the density of understory dandelion. Alternatively, even if honey bees provided little pollination to apples, apples require only a few visits per flower by bees (Park 2014) so even low densities of wild bees in the orchards may have been sufficient to provide adequate pollen for successful fruit and seed set. Thus, an increase in visits by wild bees to apple blossoms as a consequence of having more dandelion resulted in no change in fruit and seed set, since the pollination threshold would have been quickly crossed. Finally, mixed flower foraging by wild bees could dilute the apple pollen being moved around, thus negating the effect of increased apple visits. Whatever the case may be, in orchards where honey bees were common, there was no measurable negative effect of the presence of dandelions in the understory on fruit set. Additional experiments in the absence of honey bees could shed light on whether the increased apple flower visitation by wild bees could influence fruit and seed set.

Recommendation. We suggest that growers not be concerned about the presence of dandelions (or likely other flowering plants) in the understory of apple orchard due to their effects on apple fruit production via potential "distraction" effects on bees. Rather, our finding that dandelions are more frequently visited by wild bees, and that wild bees increase their foraging on apple blossoms when there are more dandelions in the understory, would suggest maintaining flowering plants in the understory is a good strategy from the perspective of bees. At the very least, this will support wild bees; at best, it may improve pollination of apples if honey bees are not present, although further research is needed in the absence of managed bees.

Does the surrounding landscape context affect the influence of understory dandelions on bees and apple fruit set? Our results suggest that landscape context (by itself) was not an important determinant in bee visitation rates or fruit set in apples. This was an unexpected finding since previous research in the same area had shown that bee diversity is correlated with landscape diversity and fruit set is correlated with bee diversity.

Role of project partners: This project was awarded to the Wisconsin Apple Growers Association (WAGA) with the University of Wisconsin-Madison on a subcontract. The activities were performed by researchers at the UW-Madison. The staff at WAGA assisted in connecting the researchers to specific apple growers and coordinated presentations of results to the members of WAGA at association coordinated events.

III. Goals and Outcomes Achieved

The goal of this project was to provide information to growers to better manage their orchards in order to enhance wild bees by assessing the effect of orchard understory management on wild bee resource use and pollination services. Over the course of two field seasons, we performed an assessment on understory management as described in the sections above. Information has been provided to the growers through outreach presentations at grower meetings and field days, a research update in the apple growers magazine, and through dissemination of a brochure about wild bees in apple orchards. The final results will be further disseminated through a presentation at the 2018 Fresh Fruit and Vegetable Conference in January.

B.

Proposed goal/outcome	Explanation of outcome measure	Baseline data collected	Progress toward achieving target
Obj. 1: To test how management activities that affect floral resources on the farm (e.g., understory mowing) affect wild bee foraging and apple fruit set in the presence and absence of managed honey bees.	**-Visitation rates by wild bees to apple** **-Apple fruit set**	Visitation rate of wild bees to apple blossoms and fruit set within low and high dandelion density treatments at Wisconsin apple orchards.	The proposed metrics were measured in a replicated on-farm experiment manipulating dandelion density in the understory. Unfortunately, we were unable to locate enough farms without honey bees to address the second part of our question.
Obj. 2: To evaluate how the foraging response of native, wild bees to local floral resources is influenced by aspects of the surrounding landscape.	**-Visitation rates by wild bees to apple and dandelion** **-Apple fruit set**	Visitation rate of wild bees to apple blossoms and fruit set within low and high dandelion density treatments at Wisconsin apple orchards located along a gradient of surrounding landscape diversity.	Target addressed but further data should be collected at orchards along a landscape gradient with care taken to standardize tree size and variety.

IV. Beneficiaries

Apple grower collaborators on this project: 24
Apple growers reached directly through outreach presentations: ~200

The results of this project have direct implications for on-farm management by Wisconsin apple growers. With over 3,000 acres of apples grown in Wisconsin (USDA NASS 2015), the results could impact a large number of growers and an even greater number of bees. This research was conducted on commercial apple orchards across southern Wisconsin although the results are applicable to orchards across the state. Our results inform growers about how a farm management practice (e.g., mowing between orchard rows) impacts wild bees and apple fruit set. Our findings provide evidence to growers that understory mowing during apple bloom is likely unnecessary as it relates to pollinators and apple fruit set. Allowing dandelions to bloom in the understory resulted in higher visitation rate of wild bees to apple blossoms suggesting that the non-crop flowers attract wild bees into the orchard. This recommendation could reduce the time and money required to mow several times during the bloom season while providing valuable resources to the wild bees at a time in the season when floral resources are scarce.

Outreach efforts

Event	Date	Location	Number of attendees
Wisconsin Fresh Fruit and Vegetable Conference	January 2017	Wisconsin Dells, WI	~50
Mississippi Valley Fruit Company TruEarth Growers Meeting	March 2017	Winona, MN	~20
WAGA Summer Field Day	July 2017	Green's Pleasant Springs Orchard, Stoughton, WI	~90
Ecological Society of America Annual Meeting (poster presentation)	August 2017	Portland, OR	5000 attendees at conference
UPCOMING Entomological Society of America Meeting	November 2017	Denver, CO	~50 attendees anticipated at presentation
UPCOMING Wisconsin Fresh Fruit and Vegetable Conference	January 2018	Wisconsin Dells, WI	~50 anticipated

Publications

Wild pollinators in Wisconsin apple orchards (Appendix 2), brochure distributed at WAGA Summer Field Day to ~90 apple growers

Pollinator research: Managing alternative pollinators through understory management in Wisconsin apple orchards, Fresh Magazine, October 2016.

V. Lessons Learned

Through the many challenges encountered during this project, we learned a number of importance lessons about working in the apple system.

1. **Collect time/weather sensitive data when the opportunity arises.** The short, unpredictable bloom duration in apple means that the bloom could last 5 days or 15 days. Unfortunately, it is nearly impossible to predict. Therefore, when good weather days came around in the 2017 field season, we focused on collecting the most sensitive data (i.e. visitation data) since the next day could be poor weather.
2. **Standardize as much as possible between the orchards.** With so many different variables at play (e.g., weather, bloom timing, tree size, root stock, tree age, variety), standardizing as many variables as possible made comparison between orchards easier. For example, in the second year of the study we focused on a single variety, Honeycrisp, grown on dwarf trees. This helped reduce some of the "noise" that could affect our results such as the bloom density or display size, which could alter pollinator behavior. Differences in attractiveness between varieties could also alter pollinator behavior. Luckily, all of our growers had blocks of relatively young, dwarf-sized Honeycrisp.
3. **Most orchards have honey bees present or nearby.** Even orchards that didn't have honey managed bees on their property had managed bees in the neighborhood. Working

with more isolated orchards and asking growers not to bring in honey bees may be required if future research is attempted to parse out the contribution of wild bees to apple pollination.

4. **A single data point per farm on visitation may be too coarse to make broad conclusions.** Because of the short bloom duration, we were only able to collect visitation data on a single day at each orchard. Since bee foraging behavior is highly variable, this may be inadequate. Therefore, in 2017 we initiated a citizen science project to see if growers could collect high quality visitation data on the best good-weather days during apple bloom. In a future collaboration with the IPM Institute, we hope to create a tool for growers to assess their pollinator requirements based on short observations on multiple days during bloom. This same protocol could be used for future research as well to gain better estimates of bee activity on individual farms.

VI. Additional Information

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VII. Contact Info

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3) Development of new cold hardy seedless table, juice and raisin grape cultivars (FY15-03)

Report Date: November 1, 2018

I. Project Summary

Grapes are the most important deciduous fruit crop in the world. In the Fresh Trends 2014 Consumer Survey of 1,000 consumers in the U.S., grapes ranked as the third most-popular fresh fruit, followed by bananas and apples as 1st and 2nd, respectively. While just in its infancy, the Wisconsin winery and grape growing industries had, as of 2011, already been contributing in excess of $119.8 million in economic impact to the state annually. Much of this growth and success was attributable to relatively recently-released more winter hardy, adapted wine grape cultivars from the University of Minnesota. These facts, suggested, therefore, that fresh and wine grapes collectively, could be on the threshold of becoming a value-added fruit crop that could rival the cranberry industry for economic importance in Wisconsin. The wine grape growers in Wisconsin continue to rely quite heavily on the University of Minnesota and North Dakota State University wine grape breeding programs for future sources of ever more adapted and superior wine grape cultivars. The one under-served segment of grape production for Wisconsin and the Midwest are the dessert grape growers. The well-publicized Elmer Swenson seedless cultivars lack quality, disease resistance and hardiness. There had been no table grape breeding program in the Midwest since that private program was shut down over thirteen years ago. There is a distinct need for a table/dessert grape breeding program that can release high-quality, winter-hardy, adapted cultivars that will fill a large niche and complement the wine industries. This PI conducted an informal phone survey of Midwest growers and organizations, including members of the Wisconsin Grape Growers Association (WGGA); results indicated significant enthusiasm for a Seedless Table Grape Breeding program as evidenced by the myriad of support letters included in this proposal. Growers need a dedicated grape breeding program that focuses on the specific niche of fresh market dessert grapes that will diversify their product options, improve grower profits and yet, also satisfy general consumer and agritourism customer desires for locally-produced fruit. Added benefits of these new dessert cultivars could also open up two more segments of the industry which would include juice/jelly grapes and also locally-produced raisins. These new cultivars will complement the burgeoning Wisconsin/ Midwest wine grape industry and be at the foundation of many Wisconsin profitable, sustainable fruit operations. Although the Midwest wine grape industry primarily consists of stand-alone growers, we envision that new seedless dessert, juice and raisin cultivars will entice not only existing wine and table grape growers to expand, but also provide an option for diversification of many other small fruit, vegetable and tree fruit operations. These actions could exponentially increase the impact of grapes on the Wisconsin and other Midwestern state economies. The proposed research covered all areas of SCBG funding priorities and suggested project activities. Grant funding was used to fully initiate a commercial table (dessert) grape breeding program targeting the release of new winter-hardy, adapted, pest-tolerant cultivars with premium quality, and with the added potential to be used for juice/jelly and raisins. All research was conducted at the campus Fruit Research Facility, greenhouse complex and nursery. We used multiple techniques to achieve our goals, including conventional plant breeding methods and embryo rescue. All hybridization was conducted in the greenhouse and embryo rescue in our tissue culture facility.

Seedlings were field-planted and will be evaluated as they come into fruiting. We have an on-going replicated trial added for both comparative purposes and to allow for breeding selection performance to be documented for release purposes. Outreach efforts have included presentations at grower meetings. We requested input from both individual grape growers and grape industry organizations in order to improve our new project.

B. While this project does not directly align with other breeding projects receiving funding at UW-River Falls from SCBG, it does relate to expansion and diversification of services offered to commercial growers. 2011 Specialty Crop Block Grant Contract number 11-012, was centered on strawberry, plum/apricot and aronia cultivar development. That project enhanced the capabilities of on-going strawberry and plum/apricot breeding but added aronia as another crop to focus efforts on. Our current grape breeding project follows the trend of diversification of fruit cultivar development for Wisconsin and Upper Midwest growers.

II. Project Approach

I have decided to report based on the Work Plan Tasks and activities. I will list the Activity and then indicate the progress in that activity

Tasks	Activities Necessary	Personnel/Duties	Timeline
1	Collect 40 breeding germplasm accessions, establish compatible hybridization protocols	P1	Nov. 2015-March 2016
1,4	Establish collected and developed germplasm in field and in pots; maintain via pruning, weed control, irrigation, and winter storage	P1, P1W	Nov. 2015 to June 2018

Progress: We have made significant progress in this area as we continue to acquire new, valuable germplasm with potential for breeding. As of our latest inventory (Fall 2018), we now have 152 potted plants representing 81 genotypes as opposed to 141 and 74 and 52 and 24, for 2017 and 2016, respectively. This collection of 81 genotypes includes juice, raisin and seedless grape cultivars and many wild *riparia* selections, *riparia* hybrids and rare cultivars bearing high quality fruit originating from as far away as China, Russia and Japan. All of these plants have also been "uppotted" and are being maintained in 5-15 gal. pots instead of 1-5 gal. pots in the past. From a cultural standpoint, we have also installed tomato cages in each pot in order to more effectively manage the large amount of vining growth and fruit production. All of the genotypes listed are now of sufficient size for hybridization. One of the most serious problems in growing these plants has been the recent influx of Japanese beetles in our nursery area. While we have field sprayers for the vineyard, there is no way of adequately spraying pesticides in this area without exposing the public to undue risk. Therefore, we used approximately $1,500.00 of the budget in order to erect a wood/wire cable framework over the ¼-acre nursery area and covered it with netting designed to exclude Japanese beetles. This worked very well but we were not able to finish it before some plants were severely damaged in 2017. For 2018, we were able to completely protect our potted breeding stock with no damage incurred.

We have tested variations of techniques in order to develop the most compatible protocols regarding hybridization and have concluded that late winter/early spring hybridization on potted stock in the greenhouse is the most effective method. We can collect pollen from plants used as males and freeze the pollen over desiccant in order to retain viability for up to 3 years. In this manner, we do not have to coordinate bloom time of widely-differing parents. Another advantage of this method is that there is a much greater success rate when crosses amongst very genetically different parents are made under such ideal growing conditions, without the environmental risks of frost, rainfall and storms or vertebrate/invertebrate pests. Diseases are also far less common in the greenhouse. There is a downside in that very careful plant culture must occur in order to maintain vigor and health, with the greatest variable being careful watering techniques.

Tasks	Activities Necessary	Personnel/Duties	Timeline
1	Determine feasibility of adoption of embryo rescue; extract embryos in days 6-12 from seedless x seedless crosses	P1	March 2016

Progress: Although embryo rescue is a valuable technique for some of the largest and best-funded grape breeding programs, it is one extra level of complexity that does not appear to be widely feasible within the confines of this proposed research. We have visited with several researchers and lab techs at Cornell University, University of Minnesota, and the USDA and found that the level of training required and the cost/benefit ratio just do not add up, so we had decided not to conduct any more research along these avenues for 2016. However, after meeting a research technician from the University of Minnesota at the National Cold Climate Grape Conference, we decided to reconsider and just try the technique. Dr. David Zlesak, our in-house faculty propagation expert, got some valuable tips from the U of MN technician and was able to extract and successfully culture 15 grape seedlings via embryo extraction from seedless X seedless crosses that we had made in the greenhouse in spring 2017. Those seedlings were acclimated and grown in the greenhouse, then nursery and are now established in the vineyard as of summer 2018.

Tasks	Activities Necessary	Personnel/ Duties	Timeline
4	Conduct greenhouse hybridization on forced potted stock (target 330 hybrid crosses, 6000 seed, and 2178 seedlings)	P1, P1W	Spring 2016, 2017, 2018
4	Establish seedling field planting of 2178 seedlings; grow through summer and fall, herbicide applications, irrigation, pruning, minimal pest control	P1, P1W	Each growing season for length of project
4	Continue to add important identified germplasm into establishment and field and potted stock as appropriate	P1, P1W	Ongoing Dec. 2016 -June 2018

Progress: Our first year (spring 2016) of larger scale hybridization in the greenhouse resulted in 4,395 seed originating from 14 parental combinations. In summer 2017, we found that it was unwise to plant young seedlings in the field, due to slow establishment and potential winter mortality. Therefore, our protocol was revised so that hybridizations are made in the spring, followed by fall stratification, spring/summer germination and growth in deep plugs, overwinter in coolers and set out the next spring. Therefore, since we did not make any hybridizations the year the grant proposal was submitted (2015) we only had 295 seedlings ready to plant in summer 2016. Seed from the 2016 crosses were warm-stratified for a month and then cold-stratified for approximately 8 months before they started to germinate. By June 2017, we were able to transplant the germinating seedlings in 50-count deep plug trays. These were grown in the greenhouse all summer in order to achieve maximum growth. Our latest inventory indicated a total of 1,141 seedlings, which was fewer than our goal. We believed we could augment and fine-tune germination and stratification techniques to achieve a higher percentage on seed for our 2018 seedlings. On September 20, we moved the 1,141 seedlings to the outdoor growing nursery in order to acclimate them for winter. They were placed in winter storage in our walk-in coolers and established in the vineyard, summer 2018.

Hybridization in spring 2017 was very successful. Although we did not quite make our goal of 33 crosses (actually 31), we did achieve a much higher seed number (9,973) than the predicted goal of 6,000. Based on the total number of seed produced, 51%, 44% and 5% are targeted for the Raisin/Dessert, Juice (traditional labrusca type) and Dessert (strictly) categories, respectively. Based on the original planned % of crosses, 10%, 16% and 74% were targeted for juice, raisin, and dessert grape cultivar objectives. One raisin grape cross in particular, skewed results more towards raisin grapes since 21% of all the seeds from 2017 hybridization were produced in this particular combination of parents. Since many of the hybrid seed produced with objectives of either raisin or dessert as an end point had wild *V. riparia* as a parent, it would be unlikely any of the offspring would be so skewed towards raisins that it would make much of a difference this early in the cultivar development timetable. Seeds from all crosses were first placed in warm stratification and then cold stratification in November 2017. In June 2018, those seeds started to germinate and approximately 2,377 seedlings generated, which is above our goal of 2,178 seedlings/year.

Hybridization in spring 2018 resulted in 29 parental combinations, so again, although we did not reach our goal of 33, we did achieve 8,852 seed, well above our goal of 6,000. Since we are typically obtaining higher % of actual seedlings, we are content with the results. This year, we had a more balanced distribution of seed across the different breeding goals as opposed to 2017. Based on the total number of seed produced vs. cross type, %, %, and % are targeted for the Raisin/Dessert, Juice and Dessert(strictly categories, respectively. Seeds from all crosses are currently in warm stratification and will be switched to cold stratification in mid-November 2018.

Tasks	Activities Necessary	Personnel/Duties	Timeline
3	Evaluate field-planted 2013 seedlings and seedling selections from past years. Initial sels. through adv. eval. levels	P1	June-October, 2016-2018

Progress: We did have a few seedlings (35) fruit for the first time this year (2018). Unfortunately, none appeared to be sufficiently elite to suggest making a selection, nor were any likely to be beneficial for use in future hybridization. The majority of other remaining seedlings could be evaluated based on vigor and disease resistance. To refer back to Summer 2017, it was unusually wet and humid, so it provided an excellent opportunity to screen seedlings for foliar diseases and make decisions to eliminate some even before they have fruited. Unfortunately, there was approximately 40% mortality of the 295 seedlings planted in summer 2016. We attributed this to unusually poor establishment due to cooler and wetter than normal weather in late summer/fall 2016 which resulted in winter injury. We also suspected that some of the parents used in these crosses were not as winter-hardy as reported by some researchers.

Tasks	Activities Necessary	Personnel/Duties	Timeline
3	Order plants for replicated performance trial	P1	Nov. 2016
3	Establish replicated performance trial	P1, P1W	May 2017
3	Maintain replicated performance trial, using standard commercial Techniques of pruning, training, irrigation and weed control	P1, P1W	May 2017-June 2018

Progress: Since we had fewer seedlings to plant and manage in 2015 and 2016 (early), we decided to move the timetable forward and worked on establishing the observation/performance trial. We had hoped to obtain major plant donations as in the past but found nurseries unwilling to donate any larger quantities as needed for the trial. This is partially why we changed the budget to reflect more funds needed in order to purchase plants. We had hoped that we could even establish the trial in spring 2016 but by the time we had all our germplasm orders filled, it was July and we had one of the worst Japanese beetle infestations ever. By mid-August 2016, the beetle population was starting to subside and we moved all the potted stock to the outdoor nursery in order to acclimate them to outdoor growing conditions before transplanting them to the field vineyard in September 2016. Due to the cost of plants and availability of cultivars, we decided to decrease the size and scope of the trial and will carefully evaluate the cost/benefit involved in planting future cultivar trials on a regular basis that would correspond to each annual seedling planting. The thirteen cultivars planted in the trial ranged from 5-10 plants each, with most being replicated 3X. The trial included the following cultivars: Bluebell, Valiant, Marquis, Swenson White, Jupiter, Trollhaugen, Osceola Muscat, King of the North, Somerset, Reliance, Montreal Blues (St. Theresa) and Brianna. Total vine count was 105. Within and between-row spacings were 8 and 10 ft., respectively.

Planting the trial as late as we did in 2016, expected more winter injury than we actually observed. Inventory in late spring 2017 indicated that we had only lost 5 plants over winter. These were replaced with new plants in early summer. In June, all vines had grow tubes installed in order to accelerate growth and allow vines to grow as straight as possible in order to reach training wire height as soon as possible. In August 2017, we contracted out to have about $15,000 worth of professional trellis (2+ acres) installation for most of the remaining seedlings planted in summer 2016, the replicated performance trial vines and the future seedlings to be planted in spring 2018. As of Fall 2018, most of the vines are well-established in the performance trial and many have reached the top wire, which means that we will be able to start developing the permanent training system (single-wire, high cordon) in summer 2019, with anticipated fruiting by summer 2020 or ’21.

Tasks	Activities Necessary	Personnel/Duties	Timeline
2	Reconnect with 8 growers and 4 researchers that provide input on project; have discussions, record suggestions, reevaluate	P1	Dec 2016-Dec 2017

Progress: What was to be an annual to semi-annual reconnection with growers and researchers has turned into much more regular communication and exchanges. For instance, we see growers on a regular basis at field days and extension meetings and not just the growers we had decided on officially for this project. All of these growers have valuable input on growing techniques, cultivars to plant, and special pest controls they have developed. Basically, “the educator” is getting educated. As an example, one of the most helpful growers is Ernie Betker from Trout Brook vineyard in Hudson, WI, about 9 miles away. He has shown much interest in assisting with everything from trellis construction to pest control and has also pointed out some traits of importance for commercial growers that are unique but very worthy of consideration. We have had the opportunity to have more phone conversations with researchers on our input list and some that are not. Perhaps the most helpful has been the insight into revised embryo rescue techniques that allowed us some small-scale success in this area.

Tasks	Activities Necessary	Personnel/Duties	Timeline
1,3,4	Collect, statistically analyze and record initial data from replicated trial, hybridization results and seedling evaluation	P1	Sept. 2016, 2017, & 2018

Progress: Since the replicated trial was just getting established this year, there was no real important data to collect or analyze. We believe that the mortality we did see was not even genotype-related but a factor of plant size at planting time. Seedling data relating to poor winter survival has been reviewed and mortality in those was due to lack of winter hardiness of a parent that had been previously reported as being very winter hardy. Data regarding hybridization seed and seedling numbers and break-down of hybrid cross objective categories has been integrated elsewhere in this document.

Tasks	Activities Necessary	Personnel/Duties	Timeline
1-(5)	Annual reports to WDATCP + final report on project progress and achievements	P1	Sept. 2016, 2017, & 2018
5	Disseminate information to growers and public	P1	Dec 2016/2017 Jan. 2017/2018

Progress: In addition to writing this report, we have had multiple opportunities to educate and inform the public about this research project and grape culture in general. The following is a list of all the presentations given within the purview of this project:

Develop raisin grape evaluation techniques, including measuring traits of importance such as soft texture, little tendency to become sticky, seedlessness, a pleasing flavor, and either large or very small berry size(for bakery or fresh snack); Dried on the vine potential (DOV)	P1	Sept. 2017
Develop juice/jelly screening protocols based on input from small processors and comparison to the industry standard cultivar, 'Concord'	P1	Sept. 2017

Progress: In our efforts to establish raisin grape evaluation techniques, it became clear that there is such significant overlap in what world breeders are looking for in a quality raisin grape versus a quality table/dessert grape, that at this point in our program, it was unworthy of much further attention. To begin with, the desired traits for raisin cultivars are early ripening, seedlessness, (seed traces of 'Thompson Seedless' size or smaller), high raisin quality, suitability for drying on the vine (DOV), and tolerance to important pests and diseases. 'DOVine', one of the cultivars we are using specifically in raisin breeding, should provide most of these characteristics. The high-quality table/dessert grapes in our breeding that are also already used concurrently for commercial raisins, such as Thompson Seedless, Black Corinth, Sultana and Fiesta will provide the selections that have high potential for both uses. The trait goals originally listed in this proposal for actually evaluation the raisin product from crosses are also included: soft texture, little tendancy to become sticky, a pleasing flavor, and either large or very small berry size (for fresh snack or bakery use, respectively). A very important and interesting facet of raisin breeding goals is earliness, which by default, is a major objective of all our grape breeding due to our short growing season and lack of heat unit accumulation.

Juice/jelly screening protocols also overlap significantly with the raisin and dessert grape desired characteristics. The ultimate juice/jelly grape cultivar is 'Concord' and initial screenings of our seedlings was to select those with the pronounced fruity *labrusca* flavor of this cultivar. High yields also have to be a major factor as juice/jelly grapes will typically not command as high a price as dessert or raisin grapes and higher yields will help compensate for that. Likewise, high tolerance/resistance to diseases and insect damage will further allow for lower production inputs and contribute to greater profits. While jelly/preserves grapes typically must adhere to the more "Concord' type standards of pronounced fruity *labrusca* flavor, and dark juice, juice grapes do not necessarily have to. There are some very high quality grape juices made from cultivars of *vinifera* origins; the only problem is safe-guarding the products from microbial contamination. While we can pasteurize *labrusca* grapes and not typically ruin the flavor in the process, *vinifera* grape juices do get negatively altered. Therefore, if any of our more *vinifera*-derived seedlings with very high quality flavored juice are identified, they would have to be protected through a process known as "close filtration" which is a mechanical filtration of microbes and does not involve high temperatures that denature the flavor. Further screening of juice grapes can occur by performing titratable acidity and soluble solids content(refractometer) but more specific chemical analysis of natural compounds present can be determined using techniques such as HPLC (high-pressure liquid chromatography). 'Concord' would be the standard to compare to. This would allow analyses of color/anthocyanin content, total phenolics, and quantification and identification of biogenic amines. Although HPLC tests are possible, it is not practical given our program purview due to the cost of trained personnel, lab and supplies that would be required.

***** significant contributions and role of project partners in the project
Dr. Bruce Reisch from Cornell University was a significant contributor to the project. Several phone conversations/emails with him helped us establish a framework for a realistic program from a standpoint of limitations of our laboratory and personnel for tissue culture used for embryo rescue. He had indicated it was a valuable tool for his program but probably not as feasible without significant amounts of trained labor and a sophisticated lab. He also suggested some of the parental lines of grapes to use in breeding, seed extraction/germination techniques, seedling spacing and prioritization of procedures. John Marshall of Great River Vineyard ended up being a real mentor on his views of grape culture in the Midwest (he has produced videos and co-authored various documents on grape growing) and we integrated a significant amount of his helpful ideas. Ernie Betker from Trout Brook vineyard in Hudson, WI, about 9 miles away. assisted with everything from trellis construction to pest control and also pointed out some traits of importance for commercial growers that are unique but very worthy of consideration. The MN Grape Growers Association (MGGA) was, as a group, perhaps the most important partner in the project as we were exposed to the MN Grape Growers Google Group that shares considerable information among the members, of which this PI is a part of. Everything from weed control discussions to breeding and cultivar evaluation get discussed in this group chat/email. Since the MGGA is also the sponsor/organizer of the National Cold Climate Grape Conference, I was also asked to present at their national meeting: Smith, B. **"Dessert, Raisin and Juice Grape Breeding at UW-River Falls"** – North American Cold Climate Grape Conference. Minneapolis, MN. February 18, 2017. Attendance: 122. The Wisconsin Grape Growers Association (WGGA), Wisconsin Fresh Fruit and Vegetable Growers Association Conference Board (WFFVGA) and UW-Extension were partners that assisted with grower contacts and also provided the

opportunity to present findings to grower members and my colleagues via annual conferences, workshops and grower field days. (please see list of presentations). One final noteworthy partner is the USDA/Geneva, NY Germplasm Repository the holds grape and apple germplasm from all over the world. We obtained approximately 31% of all our breeding stock (found nowhere else in the world) as hardwood cuttings from this repository, free of charge. Our breeding program would not have been able to be nearly as effective if it were not for this very valuable entity.

Smith, B. (December 29, 2015) *Growing Grapes in Wisconsin* [Video file] Retrieved from https://www.youtube.com/playlist?list=PLrktjgTJbkvXAfS_qUD2DWlNUni5IYQbu User number: 247

Smith, B. **"Dessert, Juice, and Raisin Grape Cultivar Development at UW-River Falls" –** Annual Statewide Wisconsin Fresh Fruit and Vegetable Growers Association (WFFVGA) Conference. Wisconsin Dells, WI. January 25, 2016. Attendance: 79

Smith, B. **"Pruning & Training of Grapes, Stone Fruits & Pears"** - Presentation and demonstration. Commercial Tree Fruit Workshop, Menomonie, WI. March 4, 2016. Attendance: 27

Smith, B. **"Training, Pruning & Principles of Grape Culture" –** Rib Lake, WI. April 7, 2016. Attendance: 19

Smith, B. **"Grape Cultivars for the Wisconsin Vineyard" –** Beginning Vineyard School, sponsored by the Wisconsin Grape Growers Assn. Cambridge, WI. April 21, 2016. Attendance: 120

Smith, B. **"Fruit Breeding at the University of Wisconsin-River Falls" –** Wisconsin Horticulture Update Call-in Presentation to Extension Colleagues across WI. May 13, 2016. Attendance: 39

Smith, B. **"Table, Raisin, and Juice Grape Breeding at UW-River Falls: What Does it Mean for the Small Grower and Home Gardener?" –** Spooner Experiment Station Speaker Symposium, Spooner, WI. August 16, 2016. Attendance: 65

Smith, B. "**Growing Fruits Based on Science: Sec. 1- Foundation and History, Sec. 2- Genetics and Cultivar Development" –** Horticulture Study School, Appleton, WI, September 9, 2016. Attendance: 34

Smith, B. **"Winter Hardy & Trial Fruit Cultivars: Their Development for Northern Wisconsin 2016" –** Balsam Lake area grower monthly meeting, Balsam Lake, WI. October 10, 2016. Attendance: 33

Smith, B. **"Orchard/Vineyard Sprayer Technology & Calibration With Special Reference to PGR Application".** Regional/Statewide Wisconsin Fresh Fruit and Vegetable Growers Association (WFFVGA) Conference. Wisconsin Dells, WI. January 24, 2017. Attendance: 91

Smith, B. **"Results of the 2016 Small Fruit Growers Survey"** - Regional/Statewide Wisconsin Fresh Fruit and Vegetable Growers Association (WFFVGA) Conference. Wisconsin Dells, WI. January 25, 2017. Attendance: 54

Smith, B. **“Dessert, Raisin and Juice Grape Breeding at UW-River Falls”** – North American Cold Climate Grape Conference. Minneapolis, MN. February 18, 2017. Attendance: 122

Smith, B. **“Pruning & Grafting Concepts of Tree Fruits and Grapes”** – Area Grower Meeting Demonstration and Workshop. Spooner, WI. March 30, 2017. Attendance:24

Smith, B. **“Grafting and Budding Fruit Trees and Grapes”** – Area Grower Meeting and Workshop. Spooner, WI. March 30, 2017. Attendance: 24

Smith, B. **“Fruit Breeding Research Programs and Results at UW-River Falls” –** PowerPoint remote presentation for WHU (Wisconsin Horticulture Update) for Cooperative Extension agents and specialists. September 8, 2017. Attendance: 33

Smith, B. **“Fruit Breeding Efforts: An Explanation of Techniques and Progress” –** Walking Educational Tour of UW-River Falls Facilities for Polk County Growers. River Falls, WI. September 11, 2017. Attendance: 27

Smith, B. **“Fruit Breeding Efforts: An Explanation of Techniques and Progress” –** Walking Educational Tour of UW-River Falls Facilities. WBGA (Wisconsin Berry Grower’s Assn) Fall School. UW-River Falls campus, River Falls, WI. October 12, 2017. Attendance: 31

Smith, B. **“Progress in Dessert, Juice and Raisin Grape Cultivar Development at UW-River Falls”-** Regional/Statewide Wisconsin Fresh Fruit and Vegetable Growers Association (WFFVGA) Conference. Wisconsin Dells, WI. January 22, 2018. Attendance: 47

Smith, B. **“Small Fruit Winter Injury and Prevention”** (included grapes) - Regional/Statewide Wisconsin Fresh Fruit and Vegetable Growers Association (WFFVGA) Conference. Wisconsin Dells, WI. January 23, 2018. Attendance: 55

Smith, B. **“Small Fruit Growing Tips, Pest Control and IPM”** (included grapes) – presentation to local commercial growers and home gardeners. Red Wing, MN. March 19, 2018. Attendance: 38

Smith, B. **“Methods for Maximizing Fruit Quality for Wine Production”** (included segment on our table grape breeding program at River Falls) – Commercial Grape Grower Field Day, Elmaro Vineyard, Trempealeau, WI. June 14, 2018. Attendance: 79

Smith, B. **“Table Grape Cultivars to Grow in Northern Wisconsin”** – Commercial Grower Mini Clinic held at Erickson Orchards, Bayfield, WI. July 2, 2018. Attendance: 17
Smith, B. **“Dessert, Juice & Raisin Grape Breeding Progress at UW-River Falls”** – Commercial Grower Mini Clinic held at Erickson Orchards, Bayfield, WI. July 2, 2018. Attendance: 17

Smith, B. **“Small Fruit Research at UW-River Falls”** - WBGA Fall Field Day, Nature’s Finest Foods, Oshkosh, WI. August 21, 2018. Attendance: 37

III. Goals and Outcomes Achieved

To prevent redundancy, Sections "A" and "B" of "Goals and Outcomes Achieved" are addressed together and found under Section II.

B.

Original Work Plan Activities and Goals/Actual Outcomes

Activities Necessary	**Actual Outcomes for Project**
Collect 40 breeding germplasm accessions, establish compatible hybridization protocols,	Collected 81 genotypes for project breeding.
Determine feasibility of adoption of embryo rescue; extract embryos in days 6-12 from seedless x seedless crosses	Not feasible but did successfully extract and grow 15 seedless x seedless seedlings using technique.
Identify eight growers and four researchers that can assist with project, long-term (network at meetings, phone conversations, emails)	Identified 12 growers for testing new selections in the future. 2 growers used extensively for insight on growing techniques; identified and interacted with 3 grape researchers (1 private, 1 from Cornell University and the other from University of MN
Establish collected and developed germplasm in field and in pots; maintain via pruning, weed control, irrigation & winter storage	13 cultivars in field rep. 3X, remainder in pots for breeding (81 genotypes total.).
Conduct greenhouse hybridization on forced potted stock target of 33 hybrid crosses, 6,000 seed and 2,178 seedlings) each year	In spring 2016, made 14 hybrid combinations, resulting in 4,395 seed and 1,141 seedlings. In spring 2017, made 31 hybrid crosses, resulting in 9,973 seed and 2,377 seedlings. In spring 2018, made 29 parental combinations and 8,852 seed.
Establish seedling field planting of 2,178 seedlings row through summer and fall, herbicide applications, rrigation, pruning, minimal pest control	Planted first large seedling field in summer 2018, resulting in 1,141 seedlings established from 2017 seedlings. Seedlings are taking 1 full year before established in field due to slower development and concern over not making it through their first winter due to small size.
Evaluate field-planted 2013 seedlings and seedling selections from past years. Initial sels. through adv. eval. levels	Minimal; many died; those that did fruit were not acceptable. Those displaying high disease susceptibility were rogued out.
Order plants for replicated performance trial	Done
Establish replicated performance trial	Established replicated performance trial in September 2016 with 13 cultivars rep. 3X.
Reconnect with eight growers and four researchers that provide input on project; have discussions, record suggestions; reevaluate	Reconnected with 2 growers and 3 researchers.
Continue to add important identified germplasm in to establishment in field and potted stock as identified	Done
Collect, statistically analyze and record initial data from replicated trial, hybridization results and seedling evaluation	Hybridization results above; seedling evaluation results recorded but not sufficient to run analysis; no fruiting yet in replicated trial.
Annual reports to WDATCP + final report on project progress and achievements	Done

Disseminate information to growers and public	Done; multiple presentations given (23), with a total attendance of 1,112 people
Develop raisin grape evaluation techniques, including measuring traits of importance such as soft texture, little tendency to become sticky, seedlessness, a pleasing flavor, and either large or very small berry size (for bakery or fresh snack); Dried on the vine potential (DOV)	Done. Please see above.
Develop juice/jelly screening protocols based on input from small processors and comparison to the industry standard cultivar, 'Concord'	Done. Please see above.
Continue to collect breeding germplasm accessions, fine-tune hybridization and germination protocols + accelerated growth parameters for seedlings (this is revised from original work plan)	Collected 5 more accessions, fine-tuned germination protocols by warm and cold stratification + accelerated grape seedling growth by growing into fall & winter of the first year of growth.

IV. Beneficiaries

The primary beneficiaries are: 1. growers already raising grapes (> 260 vineyards in Wisconsin, 222 in IA, 1,012 in MN, 54 in ND and 14 in SD; in all, 2,223 total vineyards in the 13 northern states, representing 20,900 acres of vineyards); 2. growers desiring to expand their operations with table and/or juice and raisin grapes; 3. farmers contemplating starting or adding table grape growing to diversify an existing agricultural enterprise. This project will eventually create opportunities for new and underserved farmers. 4. Consumers will be the beneficiaries of an ever-increasing supply of safe, nutritious, locally-grown (and, potentially processed) grapes and grape products. 5. Wisconsin and other Midwestern state economies due to enhanced economic activity. 6. The ultimate beneficiary will be the environment; grapes, being a perennial fruit crop, will reduce soil erosion, contribute to diverse and stable microbial soil communities, require little fertility from fossil fuel sources, and reduce food miles when incorporated into a regional food supply system. Grapes with powdery mildew disease resistance will further sustain the environment by reducing the number of pesticide sprays growers need to apply.

The grape industry in general is expanding quickly across the Midwest. In Wisconsin alone, there are multiple field days held each year which encompass pruning/training, cultivars, fruit quality, weed control and potential market outlets and increasing numbers of growers in attendance. Specifically, at grower meetings and field days, dessert/table grape interest has exponentially increased as a result of the initiation of the UWRF breeding program. Growers are anticipating the first releases of new, adapted, winter-hardy table grape cultivars and many have offered to be test sites for advanced selections developed by our program. This is particularly encouraging, since the more growers that can provide input on performance of our selections over a range of environments will give us greater confidence and details when a cultivar release is being considered. The outreach extension efforts outlined in this project have had an immediate short-term impact by spurring on the new growers and more acreage. The extension outreach efforts have increased new grower confidence and increased the number of growers starting dessert grape production in the state. Wisconsin is now known as a source for grape information and research. Over the next 5 years, the outreach and research efforts of UW-River Falls are expected to reach and influence at least 100 new growers and have an economic impact (including multipliers) from new acreage planted (150) acres of approximately $10 million by 2024.

A rather unanticipated and humorous result of our breeding program will additionally help growers. The University of Minnesota has been traditionally strictly wine grape breeding but since our program initiation, they have reexamined some of their selections for potential table grape use and have been expanding their breeding program to encompass some table grape crosses. It may be just coincidence but the timing is pretty compelling evidence that they view us as competition in the world of grapes. We will claim their renewed interest as a by- product of our program and are glad Midwestern growers may have more new grape cultivars to choose from in the future because of this.

V. Lessons Learned

We have changed many facets of the project mid-stream because of things we learned along the way. For example, at the beginning of the project, there were no Japanese beetles in the River Falls area and only a year into the project, they became one of the worst pests and hurdles to overcome. We reacted to this by providing an organic solution to solve the problem of protecting all of our potted breeding material by erecting a support system for exclusion netting. Even though this worked, it took much more out of our budget than anticipated. This has also become the major pest out in the vineyard and so our program has oriented more towards purchasing sprayers that will help protect our seedlings.

While we also initially thought that a more advanced tool like embryo rescue would work for us, we found the potential payback to be much less due to the time, equipment and expertise required to be successful, so this aspect was attempted and dropped.

Another segment of the research was the timeline for grape seedling production and establishment in the field. After the first year of establishing seedlings in the vineyard the same year they had germinated, we realized much greater mortality than expected after the first winter. In response, we adjusted the timeline so that seedlings would spend their first winter in our coolers and then planted out in the vineyard the next summer.

The most important lesson learned that needs to be communicated to federal, state and university officials in charge of oversight and funding for agriculture: Plant breeding(especially fruit breeding) requires many years of consistent funding and support. Without long-term funding and acknowledgement of the importance, results will not be forthcoming. This type of research has the potential to provide solutions for improving sustainability, farm profitability and minimizing global climate change effects on commercial fruit production. The cost-effectiveness of fruit breeding has been proven over the past 120 years. Short-term grants help but there needs to be line-item funds available that can be ear-marked for fruit breeding. Only then can we revisit the profound effects that were achieved by universities in the 1900’s that resulted in the rapid growth of the fruit industry in the Midwest.

VI. Additional Information

UW-River Falls Detailed Grape Evaluation Guidelines

The following is an adapted format for UW-River Falls grape breeding extracted from The International Plant Genetic Resources Institute (IPGRI).

Based on a numerical scale for easy data entry:

Bunch: size

(Without peduncle).

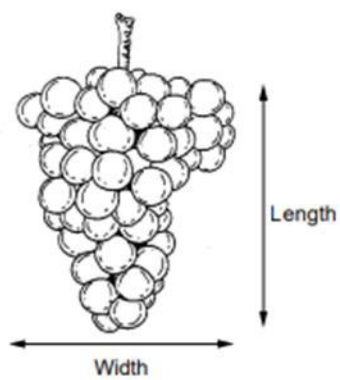
1 Very small Kober 5BB

3 Small Pinot noir – N

5 Medium Chasselas blanc – B

7 Large Müller-Thurgau

9 Very large Ugni blanc – B, Nehelescol – B



Inflorescence and Fruit

Inflorescence: sex of flower

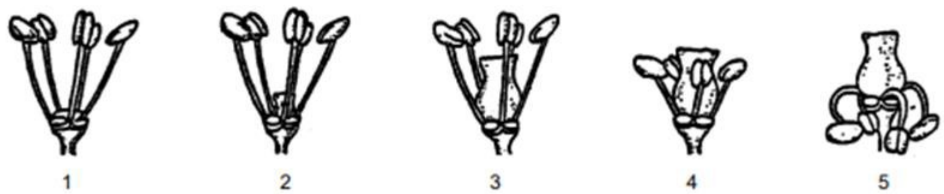
1 Only male Rupestris du Lot

2 Predominantly male 3309 Couderc

3 Male and female fully developed Chasselas blanc – B

4 Female with straight stamens Sori

5 Female with reflexed stamens Bicane – B



Bunch: density

1 Very loose (berries in grouped formation, many visible pedicels) Vitis amurensis

3 Loose (single berries with some visible pedicels) Cardinal – Rg

5 Medium (densely distributed berries, pedicels not visible) Chasselas blanc – B

7 Dense (berries not readily movable) Pinot noir – N

9 Very dense (berries pressed out of shape) Sylvaner – B

Berry: size

1 Very small Corinthe noir – N

3 Small Riesling – B

5 Medium Portuguieser – N

7 Large Muscat d’Alexandrie – B

9 Very large Alphonse Lavallée – N

Berry shape

1 Oblong [O:7] Kalili – B

2 Narrow elliptic [O:3] Olivette noir – N

3 Elliptic [O:3] Müller Thurgau – B

4 Round [O:2] Chasselas blanc – B

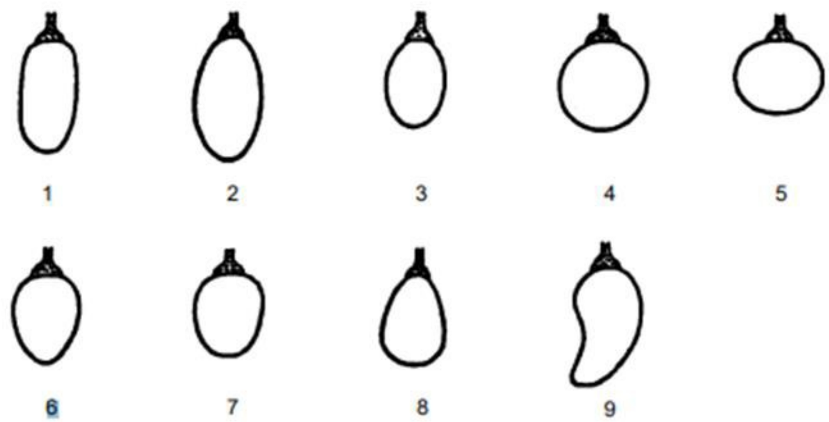
5 Oblate [O:1]

6 Ovate [O:4] Bicane – B

7 Obtuse-ovate [O:5] Ahmeur bou Ahmeur – Rg

8 Obovate [O:6] Muscat d’Alexandrie – B

9 Arched Santa Paula – B



Berry: presence of seeds

1 Seedless (absent) Corinthe noir – N

2 Rudimentary Sultana – B

3 Well developed Riesling – B

Berry: skin color (without bloom)

Light-dependent, recorded on berries which are exposed directly to sun

1 Green-yellow Chasselas blanc – B

2 Rose Chasselas rosé – Rs

3 Red Molinera gorda – Rg

4 Red-grey Pinot gris – G

5 Dark red-violet Cardinal – Rg

6 Blue-black Pinot noir – N

Berry: anthocyanin coloration of flesh

1 Very slightly coloured Pinot noir – N

3 Slightly coloured

5 Coloured

7 Strongly coloured Alicante Bouschet – N

9 Very strongly coloured

Berry: juiciness of flesh

1 Very slightly juicy Isabelle – N

2 Slightly juicy

3 Very juicy Aramon noir – N

Berry: firmness of flesh

Weight necessary for cracking the berries

1 Soft [O:3] Perle de Csaba – B
2 Medium [O:5] Razaki, Sauvignon – B

3 Firm [O:7] Flame Seedless, Olivette noire – N, Müller-Thurgau – B

Berry: particular flavor

0 None [O:1/U:1] Auxerrois – B

1 Muscat [O:2/U:2] Muscat d'Alexandrie – B

2 Foxy [O:3/U:3] Isabelle – N

99 Other special flavour [O:5/U:4]

Berry: ease of detachment from pedicel

Tensile strength necessary for separating berry from pedicel

1 Difficult [O:7] Carignan – N

2 Slightly easy

3 Very easy [O:1] Isabelle – N

Berry: seed length

3 Short Mourvèdre – N, Grenache – N

5 Medium Pinot noir – N

7 Long Cinsaut – N, Alphonse Lavallée – N

Plant descriptors

Example cultivars

Time of bud burst

1 Very early Perle de Csaba – B

3 Early Chasselas blanc – B

5 Medium Grenache noir – N

7 Late Cinsaut – N

9 Very late Mourvèdre – N

Inflorescence: number of inflorescences per shoot

1 Up to 1 Sultanine – B
2 1.1 to 2 Chasselas blanc – B
3 2.1 to 3 Riesling – B 4 More than 3 Aris – B

Time of berry ripening (véraison)

Véraison of berries corresponds with dry matter content of berries of about 3-4% and with passing over the acid maximum. About 50% of berries start getting soft and changing color, if any

1 Very early Perle de Csaba – B

3 Early Chasselas blanc – B

5 Medium Riesling – B

7 Late Carignan noir – N

9 Very late Olivette noire – N

7.1.5 Bunch length [O-202] (6.2.5)

[89] (Without peduncle)

1 Very short Pinot noir – N

3 Short Cabernet Sauvignon – N

5 Intermediate Müller-Thurgau – B

7 Long Ugni blanc – B

9 Very long Nehelescol – B

Evaluation Berry: thickness of skin

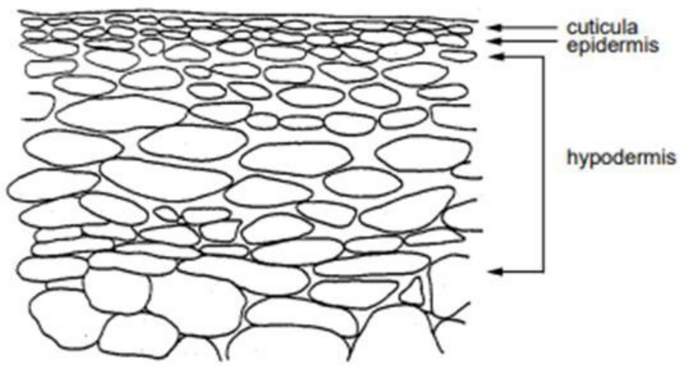
Thickness of epidermis plus hypodermis. See Fig. 21

3 Thin (about 100 µm) Chasselas blanc – B

5 Medium (about 175 µm) Carignan – N

7 Thick (about 250 µm) Servant – B

Fig. 21. Berry: thickness of skin



Single bunch weight

[89] Mean value of all bunches/shoot of 10 shoots

1 Very low (<100 g)

3 Low (150-250 g)

5 Medium (350-450 g)

7 High (650-950 g)

9 Very high (>1200 g)

Single berry weight

Mean value of each 100 berries taken from the central part of bunch of 10 bunches

1 Very low (<1 g)

3 Low (1.7-2.3 g)

5 Medium (3-5 g)

7 High (7-9 g)

9 Very high (>12 g)

Bunch weight

Yield (kg/ha). The conversion factor of 1.3 converts hl/ha into kg/ha

3 Low

5 Medium

7 High

Sugar content (refractometer)

3 Low (~ 15% sugar)

5 Medium (~ 18% sugar)

7 High (~ 21% sugar)

Total acid content

In milliequivalents: tartaric acid or sulphuric acid. Average of healthy fully turgescent berries of all bunches of 10 shoots

Milliequivalents Tartaric Sulphuric acid [g/L] acid [g/L]

1 Very low 41 £3 £2

3 Low 82 6 4

5 Medium 123 9 6

7 High 164 12 8

9 Very high 205 15 10

Abiotic stress susceptibility

Scored under artificial and/or natural conditions, which should be clearly specified. These are coded on a susceptibility scale from 1 to 9:

1 Very low or no visible sign of susceptibility

3 Low

5 Intermediate

7 High

9 Very high

Biotic stress susceptibility

In each case, it is important to state the origin of the infestation or infection, i.e. natural, field inoculation, laboratory. Record such information in descriptor 9.5 Notes. These are coded on a susceptibility scale from 1 to 9, viz:

1 Very low or no visible sign of susceptibility

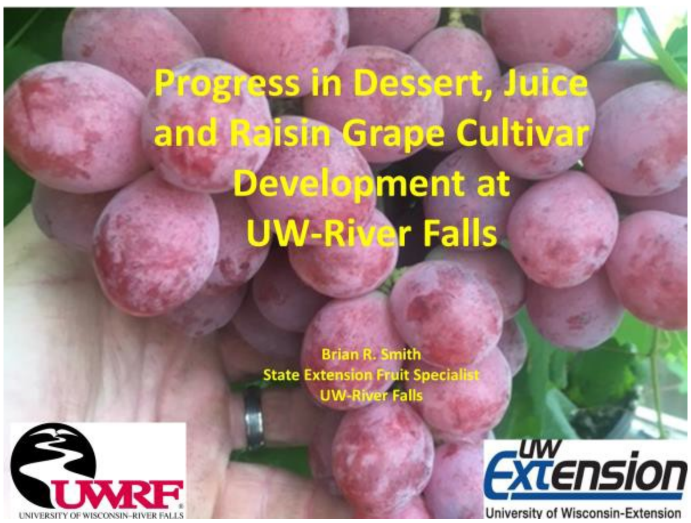
3 Low

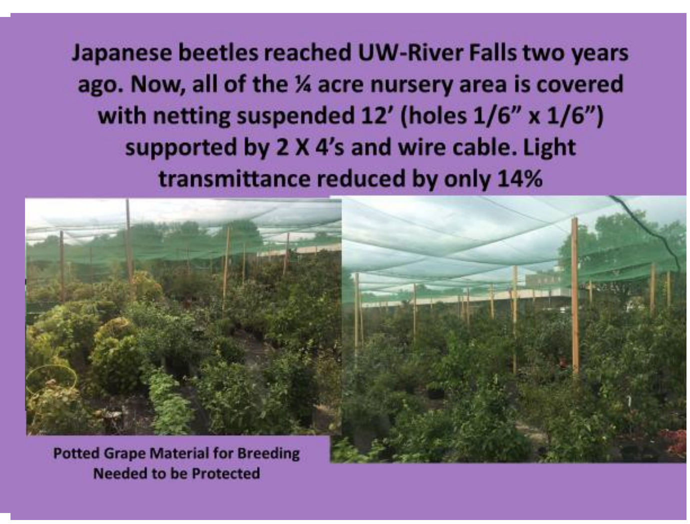
5 Intermediate

7 High

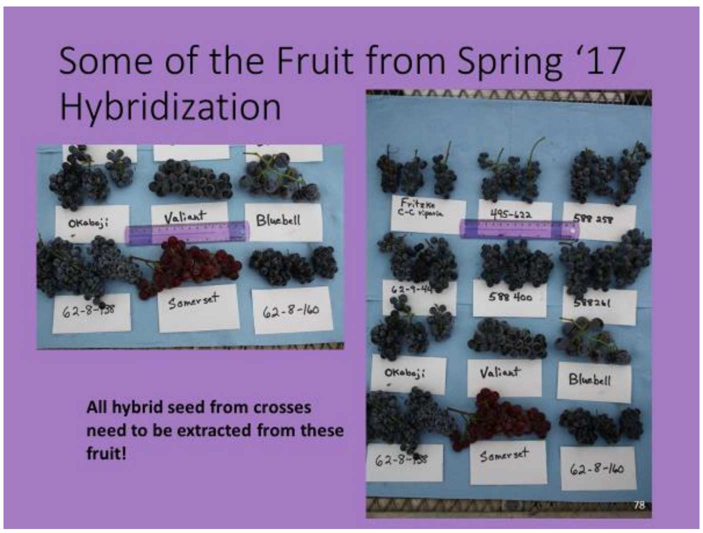
9 Very high

Pictures from the Breeding Program:



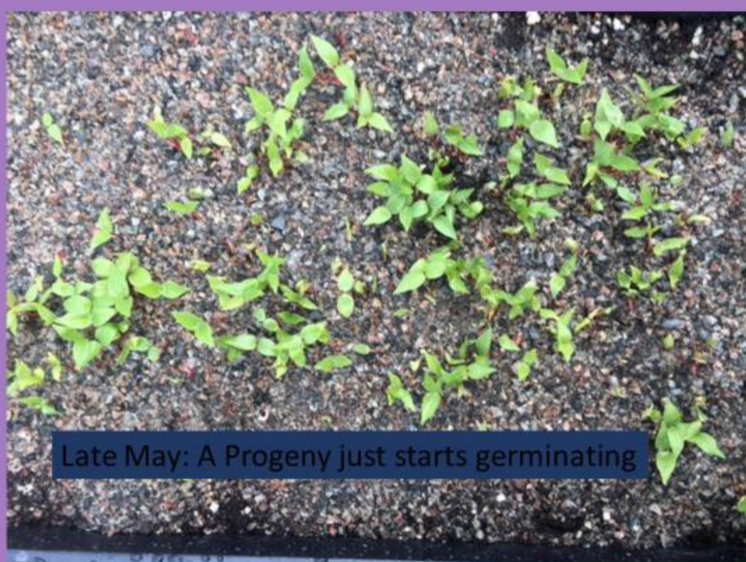



Spring/summer '17 hybridization +
Seed Germination from '16 Crosses
75


Some of the Fruit from Spring '17
Hybridization
Okoboji
Valiant
Bluebell
Somerset
62-8-160
588 400
All hybrid seed from crosses
need to be extracted from these
fruit!
78


'16 Seedlings field-planted @ 4' X 10'
will be evaluated as they come into fruiting in 3-5 yrs.

Giant grape cluster on potted grapevine growing in the UWRF greenhouse, 9/7/17. Hybrid seed inside…



Trellis Installed (9/6/17)on 1.5 acres For Grape Seedling Planting, Spring ‘18

VII. Contact Info

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4) Understanding Spotted Wing Drosophila seasonal phenology and temporal and spatial distribution within the crop to refine management practices (FY15-04)

Report Date: October 19, 2018

I. Project Summary

Spotted wing drosophila (SWD) is an invasive pest of soft-skinned fruit that has caused significant losses statewide in Wisconsin berry crops starting in 2012. Since 2014, berry growers have named SWD as their top pest concern and as a consequence, some growers have discontinued growing fall-bearing raspberry. No economic threshold has yet been established for SWD, thus once SWD is detected in a crop, fruit growers are advised nationwide to apply insecticides every 4-7 day until harvest. These intense control measures can be very costly for growers while not completely preventing crop loss as insecticides only target adult flies and not larvae inside the fruit.

Understanding the activity and distribution of pest insects can be an important component of integrated pest management (IPM). For example, pests such as Japanese beetle are most active in the middle of the day and brown Marmorated stink bug, also feed throughout the night. Similarly, the spatial distribution of pest insects, and in particular their vertical distribution within a crop, is also an important factor to consider when developing IPM strategies. For example, codling moth, a key pest of apple, is known to fly in the upper canopy of apple trees and this knowledge has been instrumental in determining the position of pheromone-baited traps for monitoring and implementation of mating disruption and attract-and-kill strategies. Our current lack of knowledge on the daily activity and location of spotted-wing drosophila (SWD) adult populations and spatial distribution within affected crops greatly impairs our ability to refine current management practices.

This project addressed four objectives: 1) we assessed the diel periodicity of SWD adult activity in the field throughout their seasonal phenology to determine when flies are most active within a 24-hour period; 2) we evaluated the vertical distribution of SWD populations by assessing the effect of trap height as a function of diel activity of flies to identify where SWD adults are present throughout this 24-hour period; 3) we also assessed the seasonal phenology of SWD populations each year to continue documenting the phenology of this new invasive pest; and 4) we delivered research findings to fruit growers in Wisconsin and the North Central Region. The goal of this research project was to provide fruit growers in Wisconsin with a better understanding of the temporal and spatial distribution of SWD and its seasonal phenology, with the ultimate goal to refine current management strategies against this emerging key pest of small and stone fruit.

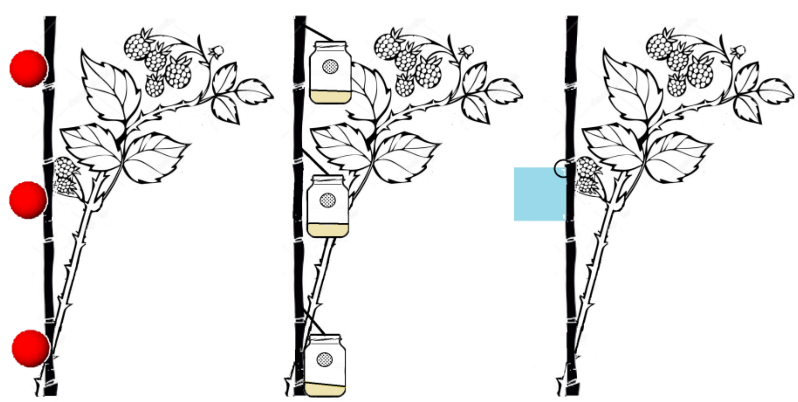
B. This is a newly funded SCBG project

II. Project Approach

Three experiments were conducted to address separately, or in combination, the spatial and temporal distribution of *D. suzukii* in raspberry crops. Three types of traps were used to assess activity: olfactory, visual, and passive (Figure 1). ***Objective 1 Determine the diel periodicity of SWD adult activity in the field throughout the growing season:*** In 2016, olfactory traps were attached to bamboo stakes and placed at least 10 m apart from another trap. In general, three relative trap heights were evaluated in our experiments: top, middle, and near the ground. Trap heights were determined at each individual location based on the top of the fruit canopy at that specific location. The traps at the top of the canopy ('top') were 90 - 120 cm above the ground, the 'ground' traps were located 6 – 10 cm off the ground, and the 'middle' traps were located halfway between those two heights. Trap heights for the diel periodicity study were set at the 'top' location. Trap locations within the crop were randomized every 7 d. Replicates of the olfactory trap (n = 5) were placed at the Mt. Horeb location for three consecutive days in early August and six consecutive days in early September. Samples were collected every 3 h from 06:00 to 18:00, after 2 h from 18:00 – 22:00, and after 8 h at 06:00 the following day. Upon return to the laboratory, we counted the number of SWD males and females.

To determine the vertical distribution of SWD, In August and September of 2016, eighteen bamboo stakes holding either olfactory (n = 9) or visual traps (n = 9), at each of the three heights on each stake, were randomly placed throughout the raspberry patch near Mt. Horeb, WI. Samples were collected for four consecutive weeks, and the number of SWD males and females at each location and with each trap were determined.

Objective 2 Evaluate vertical distribution of flies in the crop as a function of daily activity of adult SWD: In 2017, the spatial and temporal experiments detailed previously were combined into a single experiment at the Barneveld location. Using the same parameters described in Obj. 1, replicates of the passive sticky traps (n = 9) were attached at one of three different heights on a stake. Traps were replaced seven times within each 24 hr. day. Timing intervals were slightly modified from those described in Obj. 1. Passive traps were collected every 3 h from 06:00 –



A B C

Figure 1: Schematic showing trap set up for (A) visual, (B) olfactory, and (C) passive traps in various configurations.

21:00, again at 23:00 and the following morning at 06:00. The experiment was replicated for five, non-consecutive, 24-hour periods and repeated three times throughout the growing season in 2017: in late July, late August, and late September for a total of 135 replicates per treatment. In these experiments, in addition to counting the number of male and female *D. suzukii* trapped on each trap during each time period, we also identified and counted wild and managed bee pollinators trapped on the sticky cards at each height.

The applied goal of this study was to identify a height within the crop and time of maximal SWD activity and minimal pollinator activity. In respect to optimizing chemical control of SWD in raspberries, two locations and times appear to meet these criteria: 1) the bottom half of the canopy, early in the morning and 2) spraying the entire crop late in the afternoon (Figure 2).

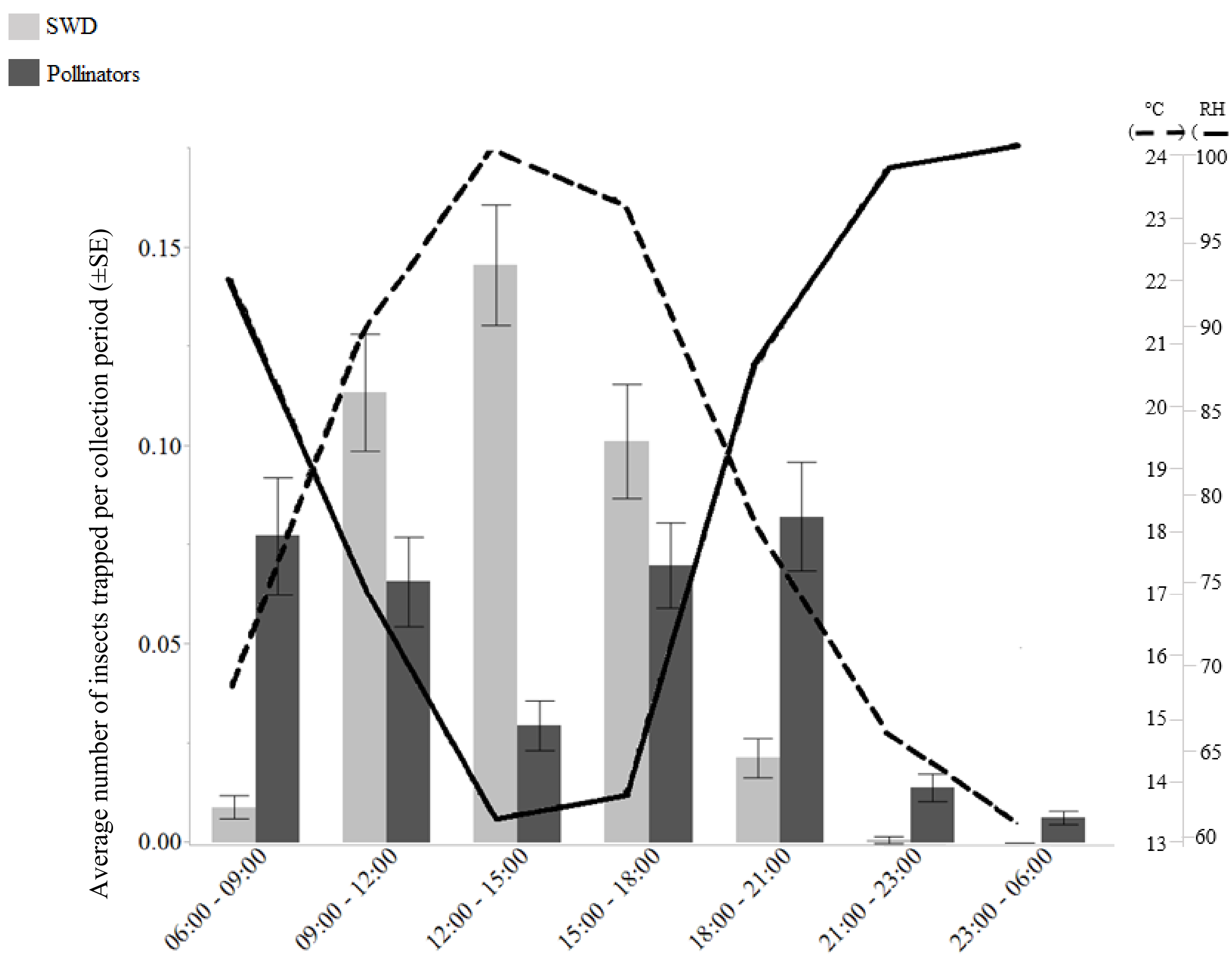


Figure 2: Average number of SWD and pollinators trapped by time period, relative to associated changes in temperature (°C) and relative humidity (RH).

In raspberries, we trapped the fewest pollinators overnight and in the bottom half of the canopy, and SWD abundance was high in the morning and in the bottom half of the canopy. This time period and location could be an effective spray period and location that also minimizes pollinator exposure. Alternatively, using chemical control across the entire crop, in the late afternoon, would also target active SWD, and maximize the latency between chemical application and peak pollinator activity. While it is clear that SWD utilized different parts of the raspberry crop at different times, more work is needed to better understand what factors are important in driving overall SWD activity, individual SWD motivations, and how to exploit these patterns to further improve chemical control efficacy.

Objective 3 Describe the seasonal phenology of SWD in Wisconsin

We explored the seasonal patterns of summer and winter morphs, their reproductive output, and the effect temperature and humidity may have on their seasonal phenology. The seasonal abundance of D. suzukii during two years (2014-2015) revealed that flies were detected in Wisconsin from early July to late December, with winter morphs being trapped from August through December (Figure 3).

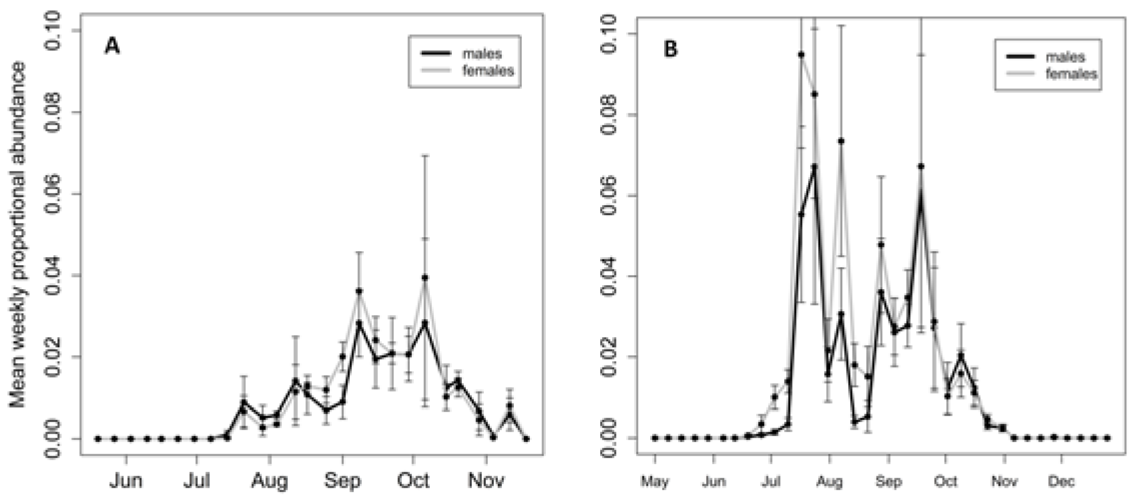


Figure 3: Mean (±SEM) weekly proportional abundance of SWD adults in 2014 (A) and 2015 (B).

The adult populations trapped spanned one month longer in 2015 than in 2014. The peak proportional abundance of D. suzukii in 2015 was recorded in August which was about two months earlier than that in 2014. The combined factor [maximum temperature and maximum humidity] explained the most amount of variation in D. suzukii abundance consistently across the two years in Wisconsin. We did not find significant differences in the fat content, number of mature eggs, proportion of females with immature eggs, or proportion of mated females between summer morph females at the beginning, summer and winter morph females during the middle, or winter morph females at the end of the collecting season in 2015. Our results build on the body of work providing a better understanding of the D. suzukii overwintering abilities and strengthen the importance of early crop risk assessment and targeted control strategies.

Our project partners were raspberry growers who allowed us to conduct research on their farms. Their involvement included access to their farms, letting us collect fruit and set up traps, avoid spraying pesticides during our experiments, and providing expertise on growing and managing raspberries.

Objective 4
We delivered research findings to fruit growers in Wisconsin and the North Central Region in person at the annual WBGA fields days and Wisconsin Fresh Fruits and Vegetable Conference in January 2016, 2017, and 2018.

III. Goals and Outcomes Achieved

Objectives 1 and 2. The research results from these objectives were submitted as a manuscript to the peer-reviewed journal *Pest Management Science*, and are currently under review.

Objective 3 The research results were accepted for publication in the peer-reviewed journal *Environmental Entomology*.

The results of this study were also presented at the UW-Madison Department of Entomology Colloquium (2018), Entomological Society North Central Branch Meeting in Middleton WI (March 2018), the WBGA berry summer field day in Oshkosh on August 23, 2018 and the Entomological Society National Meeting in Vancouver, Canada (November 2018).

Objective 4 Over the past three years, we have incorporated this research into SWD education and extension via the Wisconsin Fruit News articles, our website, and presentations at grower meetings. Over 75% of berry growers polled at the Wisconsin Fresh Fruit and Vegetable conference (WFFVC) in 2018 reported that these materials were their primary source of information on SWD. We have seen marked improvements in growers' abilities to positively identify SWD, and understand when and where they are within the crop (70% correct responses in a 2018 poll at WFFVC).

B. The benefits of increased monitoring and of a better understanding of the temporal and spatial distribution of SWD in the crop by growers may result in early detection and rapid and targeted response in managing this pest. In 2018, 83% of growers surveyed were able to at least positively ID male SWD, 84% felt they had a good understanding of SWD phenology, and 76% were able to identify when and where SWD were active. Interestingly, there was a decrease in recent years of active monitoring for SWD on their farms. In 2013, 24% of growers did not monitor for SWD, but in 2018, 66% did not monitor for SWD. Talking to growers at the WFFVC, it appears that many growers stopped monitoring because SWD are always present during harvest times and thus there is no need to monitor for them. We received positive support from the growers as 76% reported directly receiving pest management information from one of our extension sources (e.g. newsletter, website) and 88% felt that the information was 'very' or 'extremely' useful.

We provided SWD information through the UW SWD website http://labs.russell.wisc.edu/swd/ maintained by the PI and technician and through scientific and extension publications. Research results were presented to the scientific community at the Entomological Society of America Annual Conferences from 2016-2018. Results were also communicated to the farming community through on-farm presentations (Field Days, estimated attendance 40-50 per presentation) and at grower meetings, such as the annual WFFVC (estimated attendance 800).

IV. Beneficiaries

The Wisconsin fruit industry is represented by over 700 acres of grapes, 720 acres of strawberry with an economic value evaluated at $4.7M, 1,600 bearing acres of cherry with an economic value of $1.9, 249 acres of blueberry, and 181 acres of raspberry (USDA, 2012). In Wisconsin, berry growers often grow multiple berry crops on their farm, including raspberry, blueberry, blackberry, and grape. These common berry crops all provide susceptible fruit that ripens sequentially and thus could provide SWD access to suitable hosts throughout the growing season. The establishment of the seasonal phenology and spatial and temporal distribution of SWD in Wisconsin is essential for growers to learn which crops are at risk and when to protect their susceptible crops.

V. Lessons Learned

The project led us to develop a novel method for tracking the movement of SWD in crops. Until this project, odor or visual attractants were used to SWD distribution within the crop. Using attractants is not an accurate method for tracking subtle movements within a crop. The scientific manuscript submitted to the Pest Management Science emphasizes the need to passively trap SWD. The project staff also learnt a new statistical method for analyzing and modeling low levels of SWD abundances.

VI. Additional Information

See Section 3.

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5) Examining landscape-level hypotheses to conserve water and enhance the competitiveness of specialty crops in central Wisconsin (FY15-05)

Report Date: October 12, 2018

I. Project Summary

Water is a critically important resource in agro-ecosystems in the Central Sands region of Wisconsin, and water use and overall quantity levels are a concern for many lakes, streams and wetlands. To help look at options to solve quantity concerns, we developed a participatory stakeholder process involving farmers, citizens and environmental groups which was tasked with exploring mutually acceptable solutions that balance a productive agricultural economy with natural resource protection. Our overall goal was to develop a system to utilize research-based knowledge and tools to target agricultural water use that allowed farmers, local stakeholders and consumers to more effectively balance water conservation with sustainable food production for their local communities.

In 2016, University of Wisconsin and the Wisconsin Department of Natural Resources initiated the Water Stewards Program with key input from Wisconsin Potato and Vegetable Growers Association (WPVGA), local community leaders and agriculture industry representatives, Central Sands farmers and conservation stakeholders. We worked to develop a program that would allow farmers to be recognized when providing water stewardship and documenting improvements. The program was based on regionally appropriate on-farm practices that would meet research-based water steward and conservation goals. These options led to the Water Stewards tier-based program which is now being utilized by potato and vegetable growers in Central Wisconsin.

All objectives were complete during this granting cycle. Detailed results will follow, but some highlighted outcomes were:

1. Development of the tier-based approaches of on-farm adoption and farm level conservation planning for Water Stewards, including a lower-tier farm practice-based water use and conservation assessment, and higher-tier, localized water conservation planning options.
2. Inclusion of the Water Stewards tiered system into the ongoing Wisconsin, high-bar *Healthy Grown* sustainability program which is certified and validated via audit each year. This ensures that Water Stewards is being used by growers during the 2018 growing season.
3. Development of a system to maintain the Water Stewards as a self-sustaining, active program where the Wisconsin Potato and Vegetable Growers Association (WPVGA) works to help maintain grower involvement to keep the program running long-term to maintain data and document changes over time.
4. Completion of a white paper with outcomes based on stakeholder feedback describing what the Central Sands should look like in 5 to 10 years, with detailed options for expanding the Water Stewards Program.

5. Development of an informational packet which includes details on Water Stewards background, tier-based approaches, details on white paper results from stakeholders, marketing materials to entice farmer involvement, and maintenance of valuable UW-Extension based resources for growers. These packets will be distributed to additional grower groups and industries to expand participation of Water Stewards beyond just the potato and vegetable growers to multiple specialty crop industries in Wisconsin. Packets and information will be distributed during the winter of 2018/19.
6. The results and materials developed in the Water Stewards project were used as the impetus to receive a USDA:SARE Professional Development grant (Yi Wang, PI) to develop an online training course supplemented with in-field tours to encourage farmer adoption of Water Stewards and increase agro-professional training for the program.
7. Continued the expansion and work with the WPVGA to ensure farmers are properly using survey instruments and maintain well depth.
8. Started working with WPVGA to support a long-term assessment (circa 2019) of the industry which would give us 5-year comparison between the last assessment on irrigation data, water use efficiency and conservation options which will ultimately allow us to document adoption and implementation of water use practices among the industry.

Overall results supported the idea that solutions to water issues are most effective when they are developed by stakeholders who work on local issues and when practices are implemented within a small region to address specific problems. By bringing key stakeholders with differing positions on water issues together to work toward unified strategies for local implementation, while recognizing the differences identified in individual group discussions, we have developed a process to work toward comprehensive, informed, research-based options for water stewardship. Since water is a critical issue to more than just the vegetable industry, we will continue to expand the program to multiple regions and to additional growing entities across Wisconsin.

**Just to be clear, while the results from this project could be used by any agriculture industry, it was developed with specialty crop growers exclusively and no grant funds were used to support any non-specialty crop industries during this project.

B. This project was a new, independent SCBG and was not previously funded. We will keep the program active, however, since we have developed a system to ensure a self-sustaining program with WPVGA support and long-term involvement with other agricultural industries within Wisconsin.

II. Project Approach

This project was driven by an inclusive work group of stakeholders that included growers, grower associations, environmentally-oriented NGOs, public agencies and the food supply chain that met on a regular basis. The project resulted in water conservation plans that have been adopted by growers in a manner that will protect water quality and quantity.

The key to the success of this SCBG was the multi-faceted stakeholder panel which was very active and met annually to help direct objectives. Throughout the granting cycle, stakeholders refined ideas and approaches while pushing to keep the program moving forward in an effective, positive manner. The stakeholder meetings were attended by growers, industry representatives, NGOs, commodity association members, and others interested in working toward acceptable and economical solutions for water conservation goals.

During the first year of the program, Deana Knuteson (UW-Madison) and Bob Smail (Water Supply Specialist – Bureau of Drinking Water and Groundwater, DNR) worked closely with specialty crop growers, UW Specialists, industry representatives and NGO partners to encourage stakeholders to work together toward reasonable solutions for water quantity concerns. This led to the development of an assessment and place-based water and conservation management documents. These tools were vetted with individual growers and stakeholders to test the process, and refinements were made based on feedback to ensure educational value and usability for participants.

As a result of these comprehensive meetings, more detailed water conservation plans and long-term scenario options were developed to encourage practice- and place-based conservation objectives. Scenario options were developed to include conservation differences based on low to high risk areas (depending on distance from sensitive waters) and depending on land management (owned vs. leased lands). These differences were critical for growers as their landscapes and land management differed largely among Central Sands participants. The tools were finalized and different options and approaches were developed to advance water conservation within all the applicable scenarios. These documents created a framework for selecting local priorities and conservation options while looking at scenarios that could work within grower and landowner landscapes.

Ultimately, to track grower advances, Water Stewards adopted a tiered approach for growers. The base tier involves combining an irrigation technology adoption farm assessment with conservation strategies to drive continuous advancement. The top tier involves the use of groundwater models to develop local and regional conservation strategies customized to individual farms and proximity to sensitive water resources such as trout streams. This involved meeting with a water use specialist where conservation plans were developed and implemented. The plan is later revisited to ensure shared goals and subsequent implementation strategies are achievable for both economic and conservation outcomes.

During year two, local representatives (with varying perspectives on water goals) provided feedback on the Water Stewards approach and needs for local advancements in water use and conservation strategies. In early 2017, the University of Wisconsin-Environmental Resource Center (UW-ERC) developed a structured evaluation process and individually discussed options with stakeholders. The overall outcome was to evaluate, inform and suggest community solutions that address the future of agriculture and water quantity in the Central Sands. The stakeholder evaluation addressed two primary questions: (1) how can different conservation scenarios work within local production systems; and, (2) how will these options provide reasonable solutions for the Central Sands landscapes from the perspective of participating stakeholders? Overall, respondents expressed interest and optimism toward mixed land-use activities and a balanced economy of tourism, natural resources, and agriculture in the Central Sands. Many respondents advocated for the multi-faceted stakeholder groups to aid in decision-making and many were willing to look at possible funding and leadership solutions to conflicting interests for water use.

A critical step for the Water Stewards program is to link it to outcomes needed for local, regional and national sustainability programs as well as opportunities for market incentives when those outcomes are achieved. During the granting cycle, project staff evaluated value-added incentives for growers and the supply chain. Many options and programs were reviewed and discussion on how to promote the program were discussed. In general, the supply chain partners feel they can use the Water Stewards Program as a model for on-farm implementation and land-based, voluntary approaches toward water conservation, and growers can use these as local promotional efforts. Furthermore, local landowners could use this approach to work toward mutually acceptable solutions to water use concerns. Enhancing education, better messaging and increased public relations could be additional benefits of participating in the Water Stewards program.

To ensure Water Stewards is a self-sustaining, longer term program, we have linked with the WPVGA and existing Wisconsin Healthy Grown program to include Water Stewards as a component of this high-bar, certified sustainability program. Currently that program works for potatoes, carrots and onions but is looking toward expanding to include more vegetables.

Finally, we have developed an informational packet and poster display on the Water Stewards program and that will be used to promote the program to multiple specialty crop industries in Wisconsin. This educational push will occur during the winter of 2018/19.

Specific details on each objective are found below:

Objective 1: Improve irrigation efficiency and water conservation across landscapes through incentive programs that recognize achievement levels by practitioners and encourage adoption of more efficient practices.

During the first year of the program, project staff worked directly with growers and the stakeholder panel to develop options for growers to assess their water and conservation management programs. This input helped create the two-tier system for Water Stewards: a lower-tiered portion that focuses on practice-based conservation options and implementation, and a higher-tiered approach that looks at customized location-based conservation management utilizing restoration, ecological principals, stream protection and alternative strategies based on risk levels associated with farms.

A key to the higher-tiered option is to look at local priority areas within the landscape where growers can focus efforts and work with neighbors and other outlets to achieve stated goals. Scenarios were developed into 4 groupings: 1) low-risk locations (farms far from sensitive areas) where the grower owns the land, 2) low-risk locations (farm far from sensitive areas) where growers lease land, 3) high-risk locations (near sensitive sites) where growers own land, and 4) high-risk locations (near sensitive sites) where growers lease land. The differentiation of owned versus leased lands was determined to be significant, as growers had more control over lands they owned and therefore, could do more in-depth work with local conservationists to work on water conservation strategies. Leased lands were difficult to implement the advanced placed-based conservation strategies due to economics and landowner goals for the property. However, the research/outreach team involved in the Water Stewards program, developed conservation strategies and options for each of these scenarios as well. Growers pilot-tested the approaches in 2017, and overall, they expressed a desire to continue participating in Water Stewards given the research foundation and economic considerations.

Project staff and stakeholder participants discussed incentives for growers and industries to participate in the Water Stewards Program. Discussions focused on the needs for water conservation and the push from the supply chain to enhance water conservation programs. Project PI, Dr. Jed Colquhoun, worked extensively with supply chain partners during the granting cycle and promoted the Water Stewards approaches and outcomes. While no specific approaches have been developed to enhance market-based incentives for growers, there is a general feeling that intrinsic incentives (including better public relations, education, and local discussions among landowners) have resulted from Water Stewards and value-added supply chain incentives may occur in the future as more partners view the locally driven, bottom up changes that result from this program.

Objective 2: Engage communities to preserve the economic competitiveness of specialty crop production in the Central Sands by identifying water use strategies to address local concerns while conserving groundwater resources.

Work focused on Objective 2 during the winter and spring of the second year of this granting cycle. An assessment process was developed to address stakeholder's desires and options that may help answer specific water conservation plans in various locations around the state, as well as determine what the Central Sands could - and should - look like in the future to balance agriculture, conservation and water quantity concerns. Participants were asked to solicit feedback on many topics including: which options may be acceptable, improved or suggest alternatives, if focus should only be near sensitive areas or throughout the region, which criteria could be used to determine and prioritize sensitive areas, who should pay for conservation solutions, their thoughts on if agriculture and conservation programs can coexist, and finally, what their ideal landscape of Central Wisconsin would look like in five years. The assessment was delivered online to participants in March 2017, with follow up feedback conducted via individual phone conferences in May and June 2017.

The assessment questions and feedback process were developed with project staff Dr. Deana Knuteson and UW-Environmental Resource Center (UW-ERC) staff Jenna Klink and Greta Landis. The results were positive and feedback was helpful. The intended outcome was to inform and suggest community solutions that address the future of agriculture and water quantity in the Central Sands. Results were published in a white paper entitled "Wisconsin Water Stewards: 2017 Executive Results of Stakeholder Inputs, Assessment and Options to Describe Solutions for Water Use and Conservation in the Central Sands Area" written by Jenna Klink, Deana Knuteson and Greta Landis (Developed from the University of Wisconsin Environmental Resources Center).

Respondents proposed a future Central Sands with a balance of land use activities that prioritize community and stakeholder engagement and long-term vision in planning. Interviewees identified partnerships are a key part of a future Central Sands and repeatedly emphasized local and regional water management and collaboration across different stakeholder groups, working to improve water use and conservation across different organizations and values.

In addition to these similar themes, many interviewees mentioned research as a major part of next steps in achieving balanced land use in the Central Sands, to guide next steps in restoration and improved best management practices for growers. They suggested research areas such as variable rate and precision irrigation technology, drought-tolerant crop varieties, watershed function, and economic analyses on viability of different crops, risks, and potential losses for growers in the region.

In summary as one interviewee noted, contextual management decisions and collaboration are critical in the future of the Central Sands: "there's no recipe book for this stuff, it needs to be landowner and community-based… we can have it all if we plan it out right and work together."

We have finalized work to encourage longer-term adoption of the Water Stewards Program. We have worked with the Wisconsin Healthy Grown program and have included Water Stewards as required module within the program. This ensures certified adoption of Water Stewards principals and verifies program advances. Secondly, we have developed an information packet which will be used during the winter of 2018/19 to expand interest and adoption of Water Stewards by multiple agricultural industries and stakeholders. The packet provides an in-depth look at what is required to become a Water Steward, while also providing details on what are the benefits to the approaches described while also providing UW-Extension educational resources specifically designed for agricultural users.

III. Goals and Outcomes Achieved

In the grant, there were two primary desired outcomes.

1. Growers will adopt more efficient irrigation and water conservation practices. This outcome was achieved via the development of the Water Stewards tier-based approaches.
2. Diverse stakeholder communities and groups will be engaged in developing local solutions to water concerns based on research-based and modeling data. This outcome was achieved with the highly successful use of the diverse communities of stakeholders who maintained direction of the Water Stewards program, and who participated in the UW-ERC stakeholder assessment process. The outcomes of working toward solutions and attitudes of working together were the most positive outcomes.

Many specific tools were developed with support of this grant including:

1. An information piece about the program entitled "Wisconsin potato growers lead the way again with the Water Stewards program" was published in the Common 'tater magazine in June of 2016, reaching a larger audience to expand interest in the program.
2. "Wisconsin Water Steward Program Assessment" document was developed, which included 17 pages of assessment questions and practical responses to water conservation and irrigation efficiency practices. These farm level, research-based approaches could ultimately conserve water for growers and their local communities. That assessment has eight sections of practices including: 1) Irrigation Equipment, 2) Irrigation Systems Operations, 3) Measuring and Prediction Soil Water Content, 3) Water Application Records, 5) Water and Soil Management, 6) Education and Outreach, 7) Habitat Protection and Restoration Strategies, and 8) Landscape Level Water Resource Management. Within the assessment process, there are ranking scores (0-5) for all practices with higher scores for upper tiered practices (ones which would results in more conservation and/or efficiencies over time).
3. "Long-term Water Conservation Priority Planning Documentation" has been developed that helps growers prioritize locations where water quantity and/or quality concerns are the highest on their individual operations.

4. “Wisconsin Water Stewards: 2017 Executive Results of Stakeholder Inputs, Assessment and Options to Describe Solutions for Water Use and Conservation in the Central Sands Area” written by Jenna Klink, Deana Knuteson and Greta Landis; Developed from the University of Wisconsin, Environmental Resources Center (UW-ERC). Two white papers (a longer, detailed question by question version and shorter, summary version) were developed to provide look at stakeholder’s views of Water Stewards and participatory process.
5. “Conserving Water through the Community-Led Wisconsin Water Stewards Program” was presented by Dr. Jed Colquhoun at the Potato Association of America meeting in Boise, ID in August 2018. There was much interest from other potato-producing regions in adopting such a program.
6. Wisconsin Water Stewards Informational Poster and Packet. Used to promote and expand Water Stewards Participation beyond potato and vegetable producers. Includes information on: Why Water Stewards Matter, Water Stewards Background, the shortened white paper of stakeholder results, the Water Stewards Common 'tater article from July 2016, the 2-tiered documents for Water Stewards (the on-farm assessment and the farm level, location-based conservation planning document), UW-Extension publications – “Irrigation Management in Wisconsin: the Wisconsin irrigation Scheduling Program (pub A3600-01) and Methods to Monitor Soil Moisture (pub A3600-02), an NPM Publication entitled “Promoting Natural Landscapes: A Guide to Ecological Restoration and Practices on Farms”, and BioIPM Production Manuals for specific cropping systems (e.g. vine crops, cole crops, snap beans, carrots, etc.). Posters will be presented and materials distributed winter to spring 2018-19.

B. In our original proposal we proposed one outcome from each objective. A description of the original proposed outcomes and relationship to the current project outcomes for each are described below.

For Objective 1, our proposed outcome was *“Growers will adopt more efficient irrigation and water conservation practices”* while the goal from that outcome was a *“10% increase in more efficient irrigation practices each year for the project”*. In our proposal, we had originally considered using a metric of an industry-wide irrigation/conservation assessment. However, that assessment has not been warranted since more time was spent to pilot test our tier-based options with participating growers based on workgroup feedback that solutions customized to the farm (as opposed to an industry-wide prescription) would have much greater impact. By using our new tiered assessment tools, including the on-farm irrigation and conservation measurement “Water Stewards Program Assessment” document, and the localized, place-based “Long-term Water Conservation Priority Planning Documentation”, we were better able to work with participating growers on specific, detailed changes for their farms and landscapes. As a result of working with these individual pilot test farms, we were able to track and verify changes with water and landscape management in a personalized, localized manner. The use of these approaches is now being expanded to the entire industry (and additional cropping systems) so more data will be collected to ensure continued calculation of advancements in these areas.

For Objective 2, our original proposed outcome of *“Diverse stakeholder communities and groups will be engaged in developing local solutions to water concerns based on research-based and modeling data”* with the goal of *“Each stakeholder group identifies risks/rewards and reaches conclusions on best scenarios for local needs”* was achieved exactly as stated.

Stakeholders participated in group meetings and worked to improve the process to move toward large-scale adoption of water conservation scenarios. Results of the scenario development and long-term options for Central Sands landscapes, as well as priorities for water conservation were written into the "Wisconsin Water Stewards: 2017 Results of Stakeholder Inputs, Assessment and Options to Describe Solutions for Water Use and Conservation in the Central Sands Area" white paper. The executive summary of the white paper is being included in outreach materials to expand program participation. The entire white paper and the specific results are available upon request.

IV. Beneficiaries

This funding benefited a broad group with diverse interests: farmers, commodity associations, the food supply chain, conservation-oriented NGOs and local citizens. Agricultural, recreational, and the local and regional economies which are based on specialty crop production in the Central Sands region benefit from the tools developed to balance water use and conservation approaches. Results directly received from stakeholder beneficiaries emphasized repeatedly that there is no "one size fits all" solution to water management in the Central Sands, but multiple priority areas could be used to guide next activities and compile information for stakeholder groups interested in water management initiatives in the future, including:

1. Methods to assess watershed attributes and wetland restoration management strategies.
2. Decision tools for on-farm practices, management options, and equipment selection.
3. Guides for advocacy with public or private funding and policy.
4. Proposed research areas for collaboration with university funding and graduate research.
5. Techniques for facilitation, management, and evaluation of partnerships.

The direct beneficiaries were about 350 potato and vegetable farmers in the central sands region of Wisconsin.

V. Lessons Learned

The greatest lesson learned is the need to maintain the close relationships with multi-faceted stakeholders, as we have shown that reasonable solutions can be developed from all sides of the debate if stakeholders are willing to sit down, listen and work together.

VI. Additional Information

Currently, work on a correlative model between actual on-farm water withdrawals, practice-based implementation, and the place-based conservation approaches is being completed as part of Bob Smail's graduate school work where he is being advised by grant PI, Dr. Jed Colquhoun. This model will take Water Stewards to the next level by working with growers to look at previous on-farm data and local precipitation trends (including information on practices and water withdrawals) to effectively plan future agricultural needs to balance water quantity concerns.

We have also received funds to expand our educational approach by developing an on-line educational program to increase participation in the Water Stewards program. This comprehensive, on-line, self-directed course outlining the basic principles of farm water management and water conservation (enhanced with detailed on-farm training) will enable farmers and all interested stakeholders to learn about the development of practical, location-based and appropriate techniques for research-based, on-farm water management. The course will be available in early 2020 and pilot tested with agriculture professionals and growers.

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6) Tagging of resistances to pink root and Fusarium basal rot of onion and development of a resistant open-pollinated red onion for Wisconsin growers (FY15-06)

Report Date: October 3, 2018

I. Project Summary

Pink root (PR) and Fusarium basal rot (FBR) are major soil-borne diseases of onion and reduce both yield and quality of bulbs. Resistant cultivars offer the best control option for these diseases. The price received for red onion bulbs has been relatively good over many years, but seed of red cultivars for Wisconsin production has been chronically in short supply. The objectives of this study were to complete genetic analyses and mapping of PR and FBR resistances, and use marker-facilitated selection to develop a disease-resistant open-pollinated (OP) population of red onion for Wisconsin production. Growers will be able to produce their own seed of this OP onion and, if desired, select for specific bulb characteristics (such as shape, maturity, or storage ability) under their production conditions.

B. This was a new project.

II. Project Approach

Segregating families were developed from sources of PR (W446) and FBR (W440) resistances and evaluated using a seedling screen. PR resistance mapped to one position on chromosome 4 and showed codominance. Initial mapping of FBR resistance revealed regions on chromosomes 2 and 4; however family sizes must be increased to more confidently map FBR resistance. These additional families were produced in 2018 and will be evaluated for FBR resistance in 2019. A USDA inbred (B8667) of onion has deep red bulb color, early maturity, and good storage ability (Figure below), but is susceptible to both diseases. B8667 was crossed with the sources of resistance to PR and FBR used for mapping, and segregating families produced. DNA was isolated from F2 plants and is being genotyped for single nucleotide polymorphisms (SNPs) associated with PR and FBR resistance. In 2017 and 2018, F3 families were produced from red F2 plants. Seed produced in 2017 was grown in the field in 2018 and families with uniformly red bulb color selected. Seed produced in 2018 will be grown and selected in 2019. Bulbs from families with uniform red color and SNPs associated with PR and FBR resistance will be intercrossed to produce the OP population for eventual release to stakeholders.

Field space was provided by the Dean Kincaid Family Farm, Palmyra WI to produce bulbs from all segregating families developed by this research project. Selections were also grown at Jack's Pride Farms in Randolph, Wisconsin. Seed production occurred on the UW Horticulture Farm, Arlington WI. Marker genotyping for chromosome regions associated with pink root and Fusarium resistance were completed on a fee for service basis by AgBiotech.

III. Goals and Outcomes Achieved

A. Resistances to PR and FBR were confidently mapped, and SNPs closely associated with resistances identified. Segregating families from crosses of an elite red inbred with the sources of resistances have been developed, and F3 families produced. DNAs have been isolated and are presently being genotyped for SNPs associated with resistances to PR and FBR. Families that are uniformly red and possess SNPs closely associated with resistances will be used to produce a red OP cultivar for Wisconsin production. Growers will be able to produce their own seed of this onion population.

Results from genetic mapping of pink root resistance has been accepted for publication in the Journal of the American Society of Horticultural Sciences. Preliminary mapping of resistance to Fusarium basal rot was completed and published in an MS thesis.

Marzu, J.C., E. Straley, and M.J. Havey. 2019. Genetic analyses and mapping of pink-root resistance in onion. J. Amer. Soc. Hort. Sci. (submitted July 18, 2018; accepted October 23, 2018).

Straley, E. 2018. QTL analyses of Fusarium basal rot and pink root resistance in onion. Univ. of Wisc., Madison, WI. MS Thesis. 30 p.

Presentations on these results will be made at the joint NOA/NARC/IARS symposium in July 2019 to be held in Madison, Wisconsin; the Fusarium results may not be ready for formal presentation prior to submission of a manuscript.

B. All mapping goals were accomplished and red families produced. Due to the biennial (two year) generation time of onion, final seed increases of the OP population are expected to occur in 2020. We have also developed a technique to shorten the breeding time of onion into a one year calendar period via breaking the dormancy of the bulb and a shortened and precise vernalization period. These techniques are being employed to advance material more quickly.

IV. Beneficiaries

Onion growers in Wisconsin and the Great Lakes Region will be able to produce bulbs and seed of this red OP onion with resistance to PR and FBR. Onion breeders will be able to use this material to improve disease resistance. The primary beneficiaries are the close to 300 members of the Wisconsin Potato and Vegetable Growers Association and WI Muck Farmers association. However Wisconsin's more than 1500 organic and conventional fresh market growers will also benefit.

V. Lessons Learned

The project went smoothly and expected outcomes were achieved. The genetics of Fusarium resistance is more complex than previously published, however chromosome regions conditioning resistance have been preliminarily identified and family sizes increased to more confidently map resistance. This information will be used to identify families of red onion with resistances to both pink root and Fusarium. Grower collaborators, such as Kincaid's, have been outstanding supporters or our research.

VI. Additional Information

Figure 1. Bulbs of USDA inbred B8667 used in crosses with sources of PR and FBR resistances.

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7) Farm to glass: university outreach to improve the quality of Wisconsin's fermented beverages (FY15-07)

Report Date: April 3, 2018

I. Project Summary

The Wisconsin wine industry experienced rapid growth between 1999 and 2015, growing from 13 licensed wineries to more than 120 by 2015. Hard cider producers, considered wineries in regards to licensing, were the fastest growing segment in the fermented beverage category. Distilleries also became more numerous during this time period. All of these producers were seeking locally grown crops to use in their products. This rapid increase in production and potential demand for locally grown specialty crops raised concerns that continued growth of the industry would be limited without improvements in crop quality and wine making techniques. In order for wineries to be competitive in a crowded marketplace, the wines must be of high quality. This grant was developed to help improve the quality of Wisconsin grown specialty crops and the fermented beverages made from them. The University of Wisconsin-Madison developed educational programming for Wisconsin fermented beverage producers.

B. This grant follows a 2014 Specialty Crops Block Grant that allowed UW-Madison to hire a Fermentation Outreach Specialist. This position was the critical first step in the development of a comprehensive Fermentation Beverage program of outreach, research, and education. This project continued the work started with the previous grant.

II. Project Approach

WORK PLAN		
Project Activity	***Who***	***Timeline***
Work with ED of fruit and vegetable grower associations, the Fruit Crop Specialist, Entomologist and Plant Pathologist at UW-Madison to plan sessions at the Wisconsin Fresh Fruit and Vegetable Growers Winter Conference to meet fruit grower and winery educational needs. Plan seasonal educational programming for specialty crop growers, particularly of wine grapes and cider apples, to address quality concerns, such as irrigation rates/timing, optimal harvest times, and rots.	*Fermentation Outreach Specialist with Anna Maenner, ED of the fruit and veg grower associations, UW Fruit Crop Specialist, UW Plant Pathologist and other UW Horticulture specialists*	*November – December 2015* *November – December 2016*
Outreach Specialist Activities:		
Outreach specialist has worked with the ED to identify topics and speakers for the 2016 and 2017 Fresh Fruit and Vegetable Conferences. The Outreach specialist presented on several topics at both conferences.	Topics presented at 2016 and 2017 Fresh Fruit and Vegetable Conference by Outreach Specialist: -Review of Wine Quality Programs from around the US -Sensory Techniques for the Winery	January 2016 and 2017 50 to 75 attendees

	-Flavor impact of Yeast in Wine Production -Rose wine production	
Project Activity		
Schedule and implement Winery Roundtables (~5) annually throughout Wisconsin to evaluate progress and continue educational programming to address top quality challenges. (Ciders and meads will be included in the Roundtable rotation or held specifically for cider or mead as one of the five annual Roundtables.)	*Fermentation Outreach Specialist with Prof. Jim Steele*	November 2015 – April 2016 November 2016 – April 2017
Outreach Specialist Activities:		
Attendance and interest in Roundtables by WI industry members was limited. A roundtable exploring the quality of Petite Pearl Wines was held in Prairie du Chien on March 6, 2017. Wineries in the Upper Mississippi River Valley were invited to attend. Approximately 20 people attended, with wineries from 3 states (IA, IL, and MN). Many WI wineries were invited, none attended. During the Fall of 2015, Dr. Steele and the Outreach Specialist visited several wineries to discuss outreach activities. The wineries visited were owned by individuals that serve on the board of directors for either the Wisconsin Winery Association or the WI Grape Growers Association. It was suggested that the UW host a wine competition, providing comments on quality and analytical data to entrants. The Outreach Specialist has become an Ex-Officio of the Wisconsin Winery Association and participated in monthly board meetings and conference calls.	-Wineries Visited: -Fisherking Winery, Mt Horeb, Alwyn Fitzgerald, President WWA -Vines and Rushes Winery, Ripon, Ryan Prellwitz, VP WWA -Parallel 44 Vineyard and Winery, Kewaunee, Steve Johnson, WGGA President -Wollersheim Winery, Philippe Coquard	March 6, 2017 October to December 2016
Project Activity		
Participate in WI Fresh Fruit and Vegetable Growers Conference, along with Dr. J. Steele: Educate fruit growers on wine maker needs; educate wine makers on quality issues and how to address them; interact informally with growers and trade show participants to understand needs and refine educational programming and research priorities based on them. Researchable topics will be identified and shared with Dr. Steele for consideration by the Department of Food Science.	*Fermentation Outreach Specialist with Prof. Jim Steele*	January 2016, January 2017, January 2018

Outreach Specialist Activities:		
Dr. Steele and the Outreach Specialist presented at the 2016 and 2017 conferences. Topics addressed by the Outreach Specialist are mentioned under the first Project Activity.	In 2016 Dr. Steele addressed the group and discussed the goals and current projects of the UW Fermentation Sciences Program.	January 2016 January 2017
Project Activity:		
Gather annual eligible specialty crop product sales used in Wisconsin wines, meads, and ciders. *Gather annual sales data and WI wine, mead, and cider competition results from fermenters for use in assessing performance measures.*	*Fermentation Outreach Specialist*	January – March 2016; January-March 2017
Outreach Specialist Activities:		
The Outreach Specialist contacted the WI Department of Revenue and was directed to the proper resources to determine annual production volumes for WI wine, cider, and mead producers.	Information on the production volumes of WI wineries was presented by the Outreach Specialist as part of the Wine Quality Programs Review at the 2016 Conference.	October 2016
Project Activity:		
Conduct microbial and chemical analyses to address quality concerns on grapes, apples, wine, mead, and cider, in collaboration with Dr. Jim Steele and others in the Department of Food Science. Refine methods as needed.	*Fermentation Outreach Specialist with Prof. Jim Steele*	November 2015-October 2017
Outreach Specialist Activities:		
The Outreach Specialist has offered laboratory services, fee based, to the industry since 2015. The primary quality concern of wineries has been the nitrogen content of juice. Nitrogen testing is the most popular request of the analytical lab. The Outreach Specialist has worked with Dr. Atucha, the Fruit Crop Specialist on research to improve growing methods of Wisconsin grapes. The outreach specialist ferments research grapes from the West Madison Agricultural Research Station to analyze the impact of sun exposure on fruit and wine quality.	Outreach Specialist Dr. Amaya Atucha, Fruit Crop Specialist	April 2015 to December 2017 More than 100 samples were analyzed by the fermentation lab during this time.
Project Activity:		
Schedule, implement and evaluate the quality and impact of this project's educational programming held throughout the state for wine makers. *Involve Food Science faculty, Horticulture faculty, and private consultants in the*	*Fermentation Outreach Specialist with Prof. Jim Steele and others as needed in the Dept. of Food Science*	April 2016 - October 2017

educational programming to address quality issues.		
Outreach Specialist Activities:		
The Outreach Specialist has met with Dr. Steele to evaluate the educational programming. As Dr. Steele prepares to leave the UW, the Outreach Specialist will meet with the Food Science Department Chair, Dr. Scott Rankin, to evaluate and develop educational opportunities for the industry.	Fermentation Specialist Dr. Jim Steele, Food Sci Professor Dr. Scott Rankin, Chair of the Department of Food Sci	April 2016 – December 2017
Project Activity		
Use evaluations of previous year's educational programming to refine, schedule, implement and evaluate the quality and impact of this project's educational programming held throughout the state for eligible specialty crop growers, particularly grape and apple growers, who supply wine makers.	*Fermentation Outreach Specialist with Anna Maenner, ED of the fruit and veg grower associations, UW Fruit Crop Specialist, UW Plant Pathologist and other UW Horticulture specialists.*	April 2016-December 2017
Outreach Specialist Activities:		
Electronic evaluations were sent to attendees of outreach events. The events were primarily attended by wine producers, not grape and apple growers.	Outreach Specialist	April 2016 – December 2017
Project Activity		
Winemakers and fruit growers are surveyed to evaluate the benefit and impact of microbial and chemical analyses on their product qualities. Use results to refine these services provided by the UW-Madison Dept. of Food Science.	*Fermentation Outreach Specialist with Prof. Jim Steele*	January – March 2016 January – March 2017
Outreach Specialist Activities:		
This survey has not been completed at the time of this report. It is unlikely that this survey will be completed before the end of the project. Laboratory services are not likely to be offered after December 2017.	The survey was to help determine the future direction of microbial and chemical analysis services provided by UW. However, the program lacks the necessary personnel and equipment to operate a fully functional wine laboratory. After two years of attempting to operate the wine laboratory, it was determined that it could not operate in a break even or profitable manner. As a result, the survey was not administered as we already know the lab services will not continue. The only impact to the project is that wine makers will have to contract these services privately rather than through the UW.	

Project Activity:		
Disseminate project results via press releases to specialty crop grower associations (e.g., Fresh), Wisconsin Winery Association, Wisconsin Vintners Association, DATCP, CALS, and to news media for web and print dissemination. Final outcomes and results for the project are dependent on the acquisition of the additional funding needed to fully fund the project.	*Fermentation Outreach Specialist with Anna Maenner, ED of fruit and vegetable associations and WI Winery Association.*	Throughout the two-year project
Outreach Specialist Activities:		
The Outreach Specialist has provided article to Fresh magazine and presented material related to the project at the Winter Conference and WWA Membership meetings.	Presentations at the WI Fruit and Vegetable Conference and Winery Association Meetings were completed in 2016 and 2017.	Throughout the two-year project

In addition to the activities in the grant proposal, the outreach specialist held a professional wine competition for Wisconsin wineries in August of 2017. Approximately 100 wines from 20 Wisconsin wineries competed in the competition. Wineries received comments from a group of expert judges, which included enologists, wine makers, wine retailers, and restauranteurs. In addition to judge's comments, wines underwent chemical analysis and those results were provided to the wineries. The competition provided wineries with valuable assessments from professionals in the wine industry and useful analytical data on their wines. This information will be finalized and mailed to entrants in April 2018.

Project partners include members of the Wisconsin Winery Association. Association members were the primary audience for outreach activities and member wineries hosted outreach events.

III. Goals and Outcomes Achieved

The goal off the project was to increase the quality of Wisconsin's wines, meads, and ciders including the quality of the Wisconsin specialty crop ingredients used to produce them.

- Performance measures: Attendees of educational events held by the Fermentation Outreach Specialist complete an event evaluation indicating that they identified top quality issues and the steps to correct those issues.
- Benchmark: The Outreach Specialist developed educational programming as part of the 2014 SCBG project.
- Target: At least 50% of growers and fermenters that participate will make at least one change in their practices that improves quality.

Online surveys were distributed to attendees after outreach workshops.

B. Surveys were sent to attendees following educational events hosted by the outreach specialist. Responses to surveys, as described in the 2014 SCBG report, demonstrate limited response and interest by attendees to complete the surveys. The baseline data from 2014, based on those that did respond to survey requests, indicated that the majority of attendees did identify ways to improve wine quality. Whether any winery implanted any changes to improve quality remains unmeasured.

IV. Beneficiaries

The primary beneficiaries are 85 members of the Wisconsin Winery Association along with the Wisconsin Grape Grower's Association members. Growers and wine producers that are not members of the industry associations also benefited from the project. Dates, locations, and attendance at outreach events are mentioned in Section II of this report.

V. Lessons Learned

Surveys can be a useful tool for evaluating outreach effectiveness, but they can also be a challenge. Funding should be included to provide incentives for attendees to complete surveys. It may also be more useful to use physical surveys at the end of an event compared to electronic surveys following an event. Attendees appear to easily ignore survey requests following an event.

Outreach events are unlikely to fully cover the costs associated with hosting them, particularly covering the time of the outreach specialist. Currently we are exploring options that involve corporate or business sponsors that cover the costs of guest speakers and attendee meals.

Even though the industry has experienced strong growth, it does not have sufficient means to support a full time outreach position. Outreach will remain a part time endeavor that will depend on grant funding, industry support, and corporate sponsorships.

Initial projections of position funding have not proven accurate. In the original grant there was mention of various sources of income that would sustain the project and the outreach position. Those sources included funding from the University of Wisconsin, industry organizations, the development of beer and wine sold to benefit the program, and the offering of fee-based analytical services. These sources have not provided complete funding for the position. As a result, the outreach specialist began working on a second project beginning in July of 2017. This project requires half of the Outreach Specialist's time and covers half of the position's salary. The University currently covers 33% of the specialist's salary, as of July 2017. This arrangement ends in July 2019. The remaining salary is currently covered by industry donations, primarily through the sale of specific wine and beer projects coordinated with the Fermentation Sciences Program. Wisconsin Brewing Company (WBC) has generously provided two donations to the program in relation to the development of the Campus Craft Beer products the brewery markets and sells. A second product line, Campus Craft Wine, has been developed through members of the Wisconsin Winery Association, in particular Wollersheim Winery. This product is dependent upon donation of fruit from local growers and wineries. The wine project has generated funds for the program and the support of Wollersheim winery and the Wisconsin Winery Association is greatly appreciated.

Fee based analytical services were not shown to be a profitable offering for the Fermentation Sciences Program. After two years of providing analysis, it has been shown to cost the lab more funds in time and supplies than it is able to recover through fees.

To summarize, the Outreach Specialist was not able to dedicate 100% of his time to the project during the last two years. Some objectives were not able to be completed by the end of the project as a result. The Outreach Specialist has further provided instructional support to the Food Science Department.

VI. Additional Information

None

VII. Contact Info

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8) Expanding weather-based web tools for insect, disease, and agronomic management of Wisconsin vegetable crops (FY15-08)

Report Date: October 31, 2018

I. Project Summary

Potato and vegetable specialty crops grown in WI comprise significant acreage and a combined value of nearly $6.3 billion employing over 35,000 Wisconsin residents. The value of onion and carrot crops has increased significantly from 2010 to current due to an increase in acreage, yield per acre, and overall return. Potatoes were grown on over 63,000 acres with a farm gate value of roughly $275 million in recent years. Maintaining productivity and quality of vegetable crops can be challenging due to highly variable environmental conditions which affect plant growth and development, as well as disease and insect pressures. The anticipation of crop developmental status, irrigation demand, and disease and insect risk through the use of environmental data-driven models can greatly enhance vegetable crop management by optimizing the timing of inputs. We further developed and gained adoption of our current weather-based web tools for insect and disease management (previously supported through the WI SCBG Program). Additionally, we initiated an expanded offering of crop tools through the insolation, evapotranspiration, and irrigation scheduling models developed in the UW-Soil Science Department. Our UWEX Vegetable Disease and Insect Forecasting Network, established in 2014, was incorporated into a comprehensive UW Ag Weather website, currently hosted through the UW College of Agriculture and Life Sciences. The site provides information to support conventional and organic systems, and serves as a portal for agricultural eco-informatics to address vegetable and rotational crop disease, insect pest, and agronomic interests. The public information portal has the potential to greatly enhance sustainable crop production for Wisconsin and can generate data to further address key vegetable production questions. The use and benefits of the web tool, which are now accessible online through UW-Plant Pathology, Entomology, and Soil Science, have been demonstrated at grower education conferences and in the UWEX Vegetable Crop Updates newsletter.

B. This project enhanced our previously completed work by adding vegetable and potato pest and disease applications to the Wisconsin Disease and Insect Forecasting Network, expanding the agronomic tools available in one UW sponsored website, and extending the utility of the tools through multiple outreach and extension efforts.

II. Project Approach

In this project we 1) streamlined and customized computer code to automate the download of weather and insolation data, 2) maintained a weather database for further applications, 3) added additional disease, insect pest and agronomic models and presentation of the online, resulting disease and insect pest risk maps for potatoes and vegetables, 4) further validated the models with in-field weather station at the UW-Hancock Agricultural Research Station, and 5) extended updates and utility of the enhanced web-based system through the UWEX Vegetable Crop Updates Newsletter and several grower meetings including the Processing Crops Conference of the Midwest Food Producers Association Annual Meeting, the Wisconsin Fresh Market Vegetable Growers Association, and the Wisconsin Potato and Vegetable Growers Association Meeting during 2015, 2016, and 2017. We are working to summarize this multi-year project into a manuscript for peer-reviewed publication during 2018 (Journal of Extension).

The website undergoes frequent construction this time of year (growers are no longer actively using the tool, post-harvest) as we continue to refine tools and presentation of risk maps for insect phenological pests. The link is provided here: https://agweather.cals.wisc.edu/vdifn/maps The site can also be accessed through the UW-Soil Science location provided here: http://agwx.soils.wisc.edu/uwex_agwx/weather/index

III. Goals and Outcomes Achieved

Our collaboration with UW-Soil Science, which combined interests and developed a single web location for the established agricultural weather tools as well as the new vegetable tools, was very beneficial in both cost effectiveness as well as in providing tools with similar intent and producer interest in one centralized location. Our shared weather data interests allowed us to partner and share cost of contracted services for model coding and web development (adorable IO).

We were successful in gaining some commercial and UWEX utilization of the web-based vegetable disease models. For carrot, onion, and potato (and tomato as it pertains to late blight), the implementation of the weather-based models is difficult because each field requires a customized forecast that has been historically-dependent upon field-specific factors: disease severity, weather conditions, and fungicide program. Our web tools provided a set of generalized recommendations for managing foliar diseases of carrot and potato (and tomato for late blight model) and was used for many of fields in WI without need for investment and management of individual weathers stations in each field.

Again, the implementation of the weather-based models for predicting insect infestation is difficult because, not only has each field historically-required a customized forecast dependent on local weather conditions and pesticide programs, but large scale atmospheric phenomena can greatly influence insect movement in the agricultural landscape. With the development of the web tool, we achieved our goal of geographically defining insect development for the majority of fields in WI. We provided the infestation risk information for select major pests of carrot, onion, and potato.

B. In comparing our actual accomplishments with our goals, we were unable to achieve the complete set of disease models that we initially described. In particular, we were unable to include the onion DOWNCAST model. This was not completed because during the 2 years in which we ran onion disease field trials, we did not have incidence of downy mildew in the location of the trial. Because onion downy mildew can generate soilborne spores in the location of disease outbreak, we did not inoculate the commercial grower trial as it would have introduced undue risk to his operation.

Secondly, we didn't progress to the point of publication in the timeline anticipated. We have prepared a manuscript at this time for publication in the Journal of Extension (JOE). We think this approach is ideal as JOE highlights the process, impact, and outcome of applied research through extension work.

Our outcome has been, primarily, the website (link provided earlier in this report). The use of this site and application of tools within can be further measured through Google Analytics, or other web visitation quantification tool. The tool was frequently utilized within my Potato and Vegetable Disease Management Extension Program in order to provide data-supported management recommendations for high risk diseases such as late blight. The large database which has amassed since the launch of this site can provide additional material for future analytical studies on temperature, location, and disease risk. In particular, we have late blight disease incidence data from Wisconsin from 2009-2017. We can query the dataset to determine if risk forecasts were consistent with actual disease incidence during that 8 year interval.

IV. Beneficiaries

During this project our work was shared at multiple venues in education. I have listed the venues and general attendance #s, below.

Frost, K.E., Groves, R.L., Jordan, S.A**., Gevens, A.J.** 2014. The development of a web-based tool for carrot disease forecasting. Wisconsin's Annual Potato Meeting, UW-Madison College of Agriculture and Life Sciences, Research Division and UWEX, Feb. 5-7, Stevens Point, WI. 50 attendees.

Gevens, A.J., Frost, K. E. Late blight updates and a new web-based disease forecasting tool for Wisconsin. Central Wisconsin Processing Crops Conference. Hancock Agricultural Research Station. Hancock, WI. 75 attendees.

Gevens, A.J., Frost, K.E. Web-based pest and disease forecasting tool for enhanced processing vegetable crop management. Wisconsin Crop Management Conference, Madison, WI. Alliant Energy Center. 100 attendees.

Our beneficiaries were producers of onions, carrots, potatoes, tomatoes, and associated processing industries in the state of Wisconsin. Currently there are 150 members of the WI Potato and Vegetable Growers Association and this project may influence those members. This project also has potential to influence non-member commercial growers, fresh market producers (WI has more than 1600 and home gardeners. Refining pest management strategies and improving the quality of vegetables produced will increase crop competitiveness and value in the processing and fresh market sectors. WI carrot, onion, and potato growers will directly benefit from improvements made to pest and disease management practices, decreases in pesticides costs, increases in crop value due to enhanced quality, and expansions of secure market opportunities. Commercial vegetable farms in WI typically employ several people that support crop production and distribution. Statewide, hundreds of people are employed by companies with ties to vegetable production, promoting economic opportunity in rural and suburban areas.

V. Lessons Learned

Identification of knowledgeable and long-term support from a University system or private firm to conduct the model generation and associated GUI was challenging. Once we identified adorable, a Madison-based computer company, they did an outstanding job supporting our work, but required some strategic time management so that we could achieve our project goals in a reasonable timeframe. We were a bit delayed in some of our applications, but our outcome was sound and successful.

VI. Additional Information

Wisconsin Vegetable Disease and Insect Forecasting Network Website:
https://agweather.cals.wisc.edu/

2015 Oral Presentation: Gevens, A.J., Frost, K. E. Late blight updates and a new web-based disease forecasting tool for Wisconsin. Central Wisconsin Processing Crops Conference. Hancock Agricultural Research Station. Hancock, WI.

2015 Oral Presentation: Gevens, A.J., Frost, K.E. Web-based pest and disease forecasting tool for enhanced processing vegetable crop management. Wisconsin Crop Management Conference, Madison, WI. Alliant Energy Center.

2015 Trade Magazine Article: Gevens, A.J. and Groves, R.L. 2015. Advancing weather-based tools for anticipating and managing vegetable diseases and insect pests in Wisconsin. Fresh. A magazine of the Wisconsin Fresh Market Fruit and Vegetable Growers Association (August Edition).

2015-2017 UWEX Vegetable Crop Updates Newsletters: Gevens, A.J. Routine citations of website for grower and extension use. Inclusion during 2017 as primary source of weather data for Hancock and Antigo areas for multiple weeks. Representative citation included below. **Gevens, A.J.** 2016. Vegetable disease update: Late Blight Updates: DSV (Blitecast, Late Blight) and P-Day (Early Blight) updates, late blight and cucurbit downy mildew national updates. *Wisconsin Crop Manager*, Vegetable Crop Updates #27. September 10.

VII. Contact Info

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9) Neonicotinoid concentrations in succulent snap bean, sweet corn and peas following at-plant concentrations of neonicotinoid insecticides (FY15-09)

Report Date: November 6, 2018

I. Project Summary

Many Wisconsin specialty crops rely on pollinators for fruit and seed production; as well they provide resources in the form of nectar and pollen to these pollinators. By doing so, specialty crops contribute positively to pollinator health and it is our hope that our current crop culture and plant protection strategies do not interfere with this positive contribution. As previously noted, Wisconsin currently ranks 7th among US states for farmgate vegetable sales. While a portion of these sales enter fresh markets, a vast majority of Wisconsin farmgate sales go to processors for freezing, canning, drying and pickling. As a result, Wisconsin now ranks 2nd among US states for both harvested acreage and total production of processing vegetables and 3rd for production value. Moreover, the production and processing of Wisconsin specialty crops benefit the statewide economy in multiple ways. In a direct sense, each sector creates economic activity and jobs within its own industry. Additionally, both crop production and processing also benefit nearly every other Wisconsin industry based in the regional food sector.

Insecticide Use in Processing Crops. Wisconsin specialty crop producers continue to rely heavily on neonicotinoid insecticides for the control of damaging, early-season pest insects including seed maggots (Delia spp.) in snap bean, sweet corn and peas, as well as Potato leafhopper (*Empoasca fabae* Harris) and Bean leaf beetle (*Cerotoma trifurcate* Forster) in these same crops. Prior to the registration of the neonicotinoid mode-of-action (MoA) class 4A insecticides (Insecticide Resistance Action Committee: www.irac-online.org) in the late 1990's, the processing industry used combinations of both carbamate (MoA Class 1A) and organophosphate (MoA Class 1B) insecticides to limit early-season damage. The registration of Cruiser® 5FS (thiamethoxam), Poncho® 600F (clothianadin) and Gaucho® 480F and 600F (imidacloprid) as seed treatments in the early 2000's were regarded as EPA-designated, organophosphate alternatives, and highly significant in their capacity to increase the overall sustainability of the processing crops industry. Reported at-plant applications of soil-applied neonicotinoid insecticide seed treatments had the effect of collectively lowering the Environmental Impact Quotient (EIQ: Kovach et al. 1998) scores of snap beans from a high of 4.8 to 0.7 where it resides today (Nault et al. 2004) and was regarded as a very successful pest management transition. This transition has also been widely adopted in many other specialty crop systems, but the largest measurable increases in use have occurred in the field and forage crop industries where an estimated 85% of all neonicotinoid seed treatment uses are focused. A 2012 report from the Groundwater Coordinating Council (http://dnr.wi.gov/topic/groundwater/documents/GCC/Report/gccReport2012.pdf) indicates that approximately 13 million pounds of pesticides are applied to major agricultural crops in Wisconsin each year, including over 315,000 pounds of insecticides**.** Importantly, the Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP) regulates pesticide use in Wisconsin and reports and reviews monitoring data.

Pollinators and Specialty Crops. Pollinators are essential to our environment and to agriculture. This is especially true for the production of specialty crops, which rely almost exclusively upon pollinators for fruit and seed production. The ecological services provided by pollinators are critical for the establishment, reproduction, and persistence of nearly 75 percent of the world's flowering plants including crop and non-crop species. An estimated 30% of the food composing the American diet depends on insect pollination. Nevertheless, the current major reliance on a single pollinator – the domesticated European honey bee (Apis mellifera) – exposes U.S. crop production to potentially serious risks. Some of the 4,000 species of wild bees native to North America can provide, at a minimum, a complementary source of pollination services and an insurance policy against fluctuations in honey bee supply. In addition, native pollinators are keystone species in many terrestrial ecosystems. The services they provide ensure that plant communities can provide food and shelter for many other animals, prevent soil erosion and assist the wildlife community.

In 2006, the National Research Council (NRC) of the National Academy of Sciences released the report, "Status of Pollinators in North America", which called attention to the decline of pollinators resulting from habitat loss, alteration, and fragmentation, as well as pesticide use. The report urged non-profit organizations to collaborate with landowners and agencies to publicize activities that promote and sustain these important insects. The NRC report specifically cited losses in managed pollinators and reciprocal increases in applications of pesticides, as candidate explanations for these losses. It is now accepted, however, that the abundance of pollinators in the environment appears to be influenced by multiple factors, including biotic factors such as pathogens, parasites, availability of resources due to habitat fragmentation and loss; and abiotic ones like climate change and pollutants. In the most recent USDA, Report on the National Stakeholders Conference on Honey Bee Health (http://www.usda.gov/documents/ReportHoneyBeeHealth.pdf), participants continued to recognize multiple sources of potential causes of bee declines. Although the putative causes are still currently being analyzed, there was broad consensus among all stakeholders on the panel that legal pesticide uses should not affect honey bees in such a way that: (1) honey production would be reduced, or (2) pollination services provided by bees are threatened (Pesticide Risk Assessment for Pollinators Executive Summary, SETAC, 2011). However, it remains unclear, based on current research, whether pesticide exposure is a major factor associated with US honey bee health declines in general. It is clear, however, that in some isolated instances, both honey bee and wild bee colonies can be severely harmed by exposure to high doses of insecticides when these compounds are used on crops, or via drift onto flowers in areas adjacent to crops that are attractive to bees.

In the 2014 Farm Bill, pollinators and pollinator protection remained as a resource concern of many of the conservation programs. Conservationists and policy makers now have concerns about the impacts of the neonicotinoid insecticides and their interaction with diverse communities of native pollinators. Since the introduction of this important MoA Class in the early 1990s, the use of these insecticides has grown considerably. As noted previously, they are used extensively for the control of important agricultural crop pests by spraying and also as seed treatments and direct soil amendments. In the particular case of processing vegetables in Wisconsin, these systemic insecticide uses are almost exclusively used as at-plant seed treatments. And such uses typically provide 14-21 days of post-emergence control, after which time concentrations of insecticides in the vascular system are presumed to decline well below effective doses to result in acute toxicity. So potentially, foraging pollinator species would unlikely be exposed, at a large scale, to insecticide residues present in floral structures or nectary's present on snap beans, sweet corn, or peas which develop considerable later in plant development. At the current time, however, we do not know the residual concentrations of these insecticides in processing crops relative to plant development. Nor do we have sufficient, comprehensive survey data to inform us of the identity, or seasonal sequence of pollinator species that frequent processing crops, especially during the critical flowering periods of crop development. Therefore, the primary goals of this research are to, a.) characterize the temporal patterns of insecticide residues in plants treated with seed treatments, and b) determine the pollinator species present in selected processing crops (e.g. succulent snap bean, sweet corn, and peas) at different times during crop development. The impact of these chronic, low-dose exposures to the bees directly, or through the pollen and nectary's of flowering plants, is completely unknown and might be expected to negatively affect pollinators. By completion of these objectives, we will be better able to characterize the 'potential' impact of seed treatment insecticide uses on managed and domestic bees. In turn, we are meeting the stated needs of the USDA's priority areas by generating new, research-based information that ensures 'Global Food Security' through research, education and outreach that will foster and protect U.S. agricultural production. The use of the neonicotinoid class of insecticides is of significant concern in Wisconsin and the Midwest, especially as it relates to the processing crop industry. The very specific outcomes of this research have begun to aid us in understanding of how these insecticides move into and through the vascular system of plants. As well, it has provided new information to describe the seasonal sequence of native pollinators present in these crops. To determine the potential negative effects of these products on native bee species, however, additional research will be needed on this topic.

B. This project was built from a previously supported project (USDA 2014 SCBG Project 14-019) which originally focused on determining the systemic movement patterns of at-plant neonicotinoids used as seed treatments. In 2015 and 2016, we added novel objectives to include evaluations of different seed treatment rates in processing crops including succulent snap bean, sweet corn and peas, combined with surveys to document the seasonality of native and domestic pollinator fauna in each of these crop systems relative to flowering intervals.

II. Project Approach

Outcomes described below were made possible through our partnerships with the Midwest Food Products Association (MWFPA) (https://mwfpa.org/), and specifically Mr. Nicholas George, Executive Director. The Association supported this research through their own internal grants program whereby they contributed an additional $18K in direct support for LCMS/MS analysis of insecticide concentrations. Moreover, Del Monte Foods (Plover, WI), provided field research locations for the plots which contained seed treatments of sweet corn, succulent bean, and field peas. This direct support of field locations was very important for the completion of these objectives. Finally, Del Monte Foods also offered the field locations where all pollinator surveys were conducted in 2015 and 2016. Results were disseminated through the regularly scheduled Haltvick meetings, organized by the MWFPA which occur 3 times per crop season in each of 2015 and 2016. Results of these investigations were also presented at the MWFPA, Processing Crops Conference held in December of 2015 and 2016 in Green Bay, WI and Wisconsin Dells, respectively (see Beneficiaries section below).

1) Determine the in-plant neonicotinoid concentrations over the course of a growing season resulting from seed treatments.

1.1 Tissue collection

All the crop plants in this study were grown at the Del Monte Foods, Incorporated agricultural research farm in Plover, Wisconsin during the 2014 and 2015 growing seasons. Sweet corn, field peas, and snap beans were planted in a randomized complete block design, with the insecticide main effect including thiamethoxam-treated and untreated plants. Each of the three vegetable crops were planted in four replicate plots of treated seed and four replicate plots of untreated seed, for a total of 24 plots. In 2014, each plot measured 4.2 m2 with 0.9 m row spacing for a total field size of 176 m2. In 2015 the plots were larger, each measuring 7.0 m2 with 0.9 m row spacing for a total field size of 293 m2.

All treated seed was planted with a coating of Cruiser® 5FS (thiamethoxam 47.6%), at a labeled rate consistent with industry standard application. For both legumes (peas and snap beans), the application rate was 16.84 g AI/acre. For sweet corn, the application rate was 30.24 g AI/acre. In addition to thiamethoxam, both treated and untreated legumes received co-application of seed coatings of fungicide as per industry standard. Snap beans received Apron XL® (mefenoxam 33.3% AI) and Maxim® (fludioxonil 40% AI), while peas received only Apron XL® at an equivalent concentration.

In 2014, the seeding rate was 100 peas per plot, 60 beans per plot, and 25 corn kernels per plot. In 2015, the rate was the same but the plots were bigger, resulting in 165 peas per plot, 100 beans per plot, and 40 corn kernels per plot. In both 2014 and 2015, the seeds were planted in late May/early June and left to grow until either mid-August or natural senescence. According to the crops' natural phenology, peas were the first to fully flower (36-39 days after planting), then snap beans (42-45 days after planting), and finally sweet corn (59-64 days after planting).

Once plants' first set of true leaves became large enough to sample without complete defoliation, the plants were visited weekly for leaf tissue collection. In 2014, all crops were initially sampled eleven days after planting. In 2015, corn and peas were first sampled fourteen days after planting, while beans, which tend to emerge more quickly, were first sampled seven days after planting. Each sample consisted of leaf tissue pooled from five plants within a plot. In addition, when each crop was at or near full flower, floral structures were collected following the same procedure used for leaf tissue. The legume floral tissues included the petals, keel, ovary, stigma, and stamens, but care was taken not to include vascular tissues below the floral pedicel. The corn floral tissue consisted of pollen-laden anthers and spikelets and again did not include vascular tissue from the mother plant. Immediately following each weekly tissue collection, samples were weighed and stored in a freezer at -80°C until analysis could begin.

1.2 Thiamethoxam quantification

Thiamethoxan concentrations were quantified in plant tissue extracts using ultra high pressure liquid chromatography (UHPLC Waters I-Class UPLC® system, Milford, MA) with positive ionization single quadrupole mass spectrometry (ESI (+)MS: Waters Corporation, Milford, MA) detection. Approximately 200 mg of wet-weight leaf or floral tissue was combined with 700 µL of HPLC-grade acetonitrile.

Thiamethoxam was extracted from plant tissues following a modified form of an existing procedure for quantifying thiamethoxam in cereals.30 First, samples were macerated until finely ground in a FastPrep® 120 cell disruptor (Qbiogene, Carlsbad, CA) using 2 mL lysing matrix tubes filled with a matrix of garnet granules and a porcelain bead (MP Biomedicals, Santa Ana, CA). After maceration, the tubes were centrifuged at 10,000 rpm (7,826 g) for five minutes, and the supernatant was syringe-filtered through a 0.22 µm PTFE membrane. The remaining pellet was combined with an additional 700 µL of acetonitrile, then macerated, centrifuged, and filtered a second time. Finally, the two supernatants were combined and evaporated until the total volume was ≤ 100 µL. The final volume was measured with a serological pipette, and samples were refrigerated at 4ºC for <12 hr. prior to analysis.

Plant extracts were diluted by 50% with water, spiked with internal standard (to 10 mg/L 6-benzylaminopurine or to 1 mg/L caffeine), held in a refrigerated autosampler tray at 10ºC, injuected (4.0 µL) onto a Waters C18 column (CSH 1.7 µm, 2.1 x 100-mm) equipped with a 5 mm guard column, and separated at 30ºC with a gradient of 0.1% formic acid in water (A) and 0.1% formic acid in acetonitrile (B) at a rate of 0.5 mL/min. The absence of thiamethoxam carryover between injections was assured by including a needle wash with 9:1 water: acetonitrile between injections, and by analyzing solvent "blanks" after running samples with high thiamethoxam concentrations.

The thiamethoxam concentrations in plant extracts were calculated from a quadratic calibration curve fitted to UHPLC/MS response factors generated for a thiamethoxam standard (technical grade, purity, Syngenta, Greensboro, NC) injected across a range of concentrations (0.01 – 2 mg/L, 5 levels, R2 ≥ 0.99). These concentrations were converted to a percent wet tissue weight by accounting for the extraction volume and mass of wet leaf tissue extracted. For quality assurance and estimation of method recovery efficiency, three samples of untreated leaf tissue from plants grown under greenhouse conditions were spiked with different amounts of thiamethoxam. Snap bean tissue spikes were run alongside the experimental legume samples, while sweet corn tissue spikes were run alongside the experimental sweet corn samples. The percent recovery for thiamethoxam from each plant tissue type was calculated as the average percent recovery based on all samples of that tissue type spiked at concentrations within the method reporting range. The instrumental detection limit of thiamethoxam was 0.008 mg/L, based on a signal to noise ratio of 1:3. The lower quantification limit was 0.01 mg/L, based on a signal to noise ratio of 1:10. The corresponding method detection and lower quantification limits were respectively 30 ppb and 50 ppb for wet plant material.

1.3 Statistical Analysis

Comparisons of crop and phenology from each year were analyzed with a repeated measures analysis of variance (ANOVA) using a linear model in R (version 3.3.0, R Core Team 2016). Crop type, treatment, and time were analyzed as fixed variables in the models. For each sample date, the mean tissue thiamethoxam concentration plus or minus one standard error was plotted until the concentration decreased below the method detection limit. Pairwise comparisons of least squares means for each experimental treatment were performed using SAS 9.4 (SAS Institute Inc., Cary NC). Resultant probability values were adjusted using the Tukey-Kramer post-hoc test.

1.4 Thiamethoxam in floral tissue

None of the floral tissues analyzed registered concentrations of thiamethoxam above our method detection limit of 30 ppb (**Table 1**).

Table 1. Total number of snap bean, field pea, and sweet corn A) floral tissue and B) leaf tissue yielding levels of thiamethoxam above this study's detection limit of 30 ppb. Plants were grown with and without seed treatments in central Wisconsin during 2014 and 2015.

A)

Floral Tissue	Treatment	Number of samples	Number of detects	Percent of samples with detects
Pea	16.84 g AI/acre	8	0	0%
	Untreated (0 g/acre)	8	0	0%
Bean	16.84 g AI/acre	8	0	0%
	Untreated (0 g/acre)	8	0	0%
Corn	30.24 g AI/acre	8	0	0%
	Untreated (0 g/acre)	8	0	0%

B)

Leaf Tissue	Treatment	Number of samples	Number of detects	Percent of samples with detects
Pea	16.84 g AI/acre	32	18	56%
	Untreated (0 g/acre)	31	12	39%
Bean	16.84 g AI/acre	32	24	75%
	Untreated (0 g/acre)	32	9	28%
Corn	30.24 g AI/acre	32	23	72%
	Untreated (0 g/acre)	29	7	24%

1.5 Thiamethoxam in leaf tissue

Treated leaf tissue from both years had detectable thiamethoxam concentrations (Table 1). These concentrations decayed rapidly following plant emergence, and were near or below the detection limit after four weeks. Foliar thiamethoxam concentrations in all crop plants grown from treated seed were significantly higher than in plants grown from untreated seed one week after emergence in both years of the study (**Table 2**). Treated bean leaves yielded the highest thiamethoxam concentrations, which were significantly greater than corn leaves in both years ($T_{71} = 3.12$, $p_{adj} = 0.007$ in 2014; $T_{69} = 13.93$, $p_{adj} < 0.0001$ in 2015) and significantly greater than pea leaves in 2015 ($T_{69} = 15.15$, $p_{adj} < 0.0001$).

The concentrations of thiamethoxam in treated pea tissue were lower in 2015 relative to 2014 (**Table 2**). In untreated beans grown in 2015, however, the thiamethoxam concentration was significantly greater than zero (mean 1,444 ppb ± 147; T = 9.822, p = 0.0022) during the first week.

Table 2. The mean thiamethoxam concentration of treated snap bean, sweet corn, and field pea leaf tissue in 2014 and 2015. Values in bold indicate a significantly greater concentration than in untreated leaf tissue from the same date.

		2014					2015		
Crop	Week	Mean (ppb)	T_{71}	p_{adj}	Crop	Week	Mean (ppb)	T_{69}	p_{adj}
Bean	**1**	**7,001 ± 1,063**	**12.32**	**<0.0001**	Bean	**1**	**16,594 ± 1,477**	**32.72**	**<0.0001**
	2	1,972 ± 873	3.47	0.115		**2**	**1,796 ± 502**	**3.83**	**0.044**
	3	635 ± 338	1.11	1		3	75 ± 41	0.15	1
	4	16 ± 27	0	1		4	3 ± 3	0.01	1
Corn	**1**	**4,408 ± 1,194**	**7.63**	**<0.0001**	Corn	1	590 ± 30	1.16	1
	2	77 ± 25	0.14	1		2	107 ± 36	0.21	1
	3	122 ± 36	0.18	1		3	63 ± 23	0.04	1
	4	0	0	1		4	22 ± 13	-0.1	1
Pea	**1**	**4,597 ± 471**	**7.52**	**<0.0001**	Pea	1	83 ± 27	0.17	1
	2	1,881 ± 213	3.17	0.230		2	9 ± 5	0.01	1
	3	1,145 ± 221	1.57	0.996		3	4 ± 4	0.01	1
	4	201 ± 69	0.31	1		4	3 ± 3	0	1

2) Investigate the composition and species diversity of native and domestic pollinators present in flowering processing crops.

This study took place during the growing seasons of 2014 and 2015, from early June through mid-August. Fields of sweet corn (*Zea mays*), snap beans (*Phaseolus vulgaris*), and field peas (*Pisum sativum*) were selected for visitation due to their prevalence within Wisconsin's Central Sands region. In total, 53 conventionally grown, irrigated vegetable fields of sweet corn (19 fields) snap beans (18 fields) and peas (16 fields) were visited during each of their respective blooming periods (Fig. 1), all of which were located within the region's three most intensively farmed counties (Portage, Waushara, and Adams Counties). Each field was privately owned by a grower contracting their irrigated land with the Del Monte Corporation, Walnut Ridge, CA. Field sizes ranged between 10.5 and 121 ha, with the average field size being 47.8 ha.

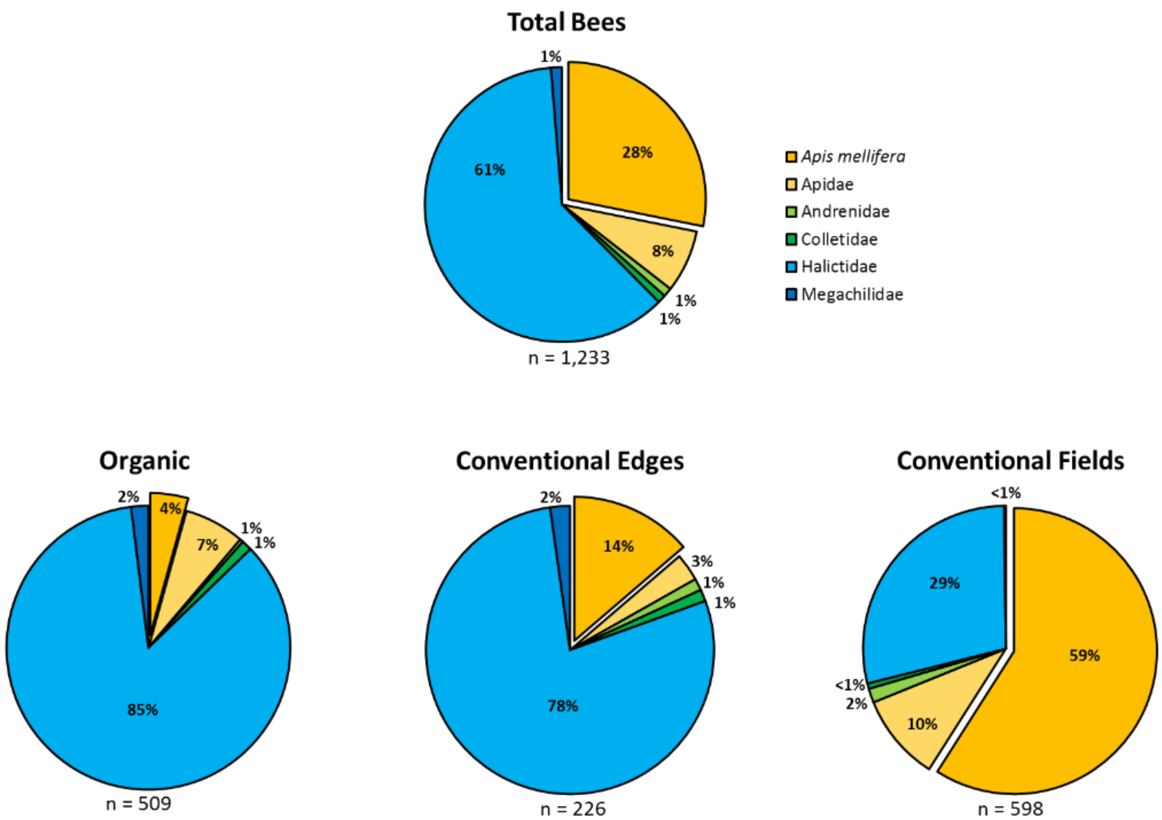
At each field site, the bee community was sampled using pan traps made with 355 ml plastic bowls (Solo Cup Co., Urbana IL). The bowls were painted white, blue, or yellow to attract foraging bees based on suggestions from Droege (2008). Each bowl was filled with a mixture of water and Dawn® dish soap (Procter & Gamble, Cincinnati OH) at a ratio of approximately 1 mL soap:1000 mL water, which served to prevent landing bees from escaping. The pan traps were arranged in 100 m2 grids of nine bowls in alternating colors. Each trap was attached to a stake and set at adjusted to floral level. The pan trap grids were placed near the center of each conventional vegetable field while the crop was at or beyond 75% bloom, then left in the field for 24-48 hours to capture the full temporal range of bee activity. At the end of each sampling period any bees caught were collected from the traps, mounted, and identified to the species level with the identification assistance of bee expert Dr. Jason Gibbs, of Michigan State University.

To confirm that bees caught in pan traps were indeed foraging at study sites rather than merely passing through, in 2015 observational data were taken collected in 2015 within all snap bean fields (n = 9) and sweet corn fields (n = 9), and arranged as two parallel 10 meter transects set up within each pan trap grid. Observation points were spaced 2 meters apart on each transect line, making a total of five observation points on each transect line and ten observation points in each trap grid. At every observation point, the observer watched all the flowers within a visual radius for one minute and recorded any bees seen visiting flowers. Bees observed during the observational sampling period were recorded in categories based on size and color.

A total of 1,233 bees representing 86 different species and 5 families were collected from all field sites in this study (Table 2). Of these, 347 individual bees (28% of all individuals captured) were domesticated honey bees, Apis mellifera (**Fig. 1**).

Within the 53 conventional vegetable fields sampled in 2014 and 2015, 498 individual bees were collected representing 28 species. Of these, 294 honey bees were captured, representing 59% of all individual bees collected from conventional vegetable fields (**Fig. 1**).

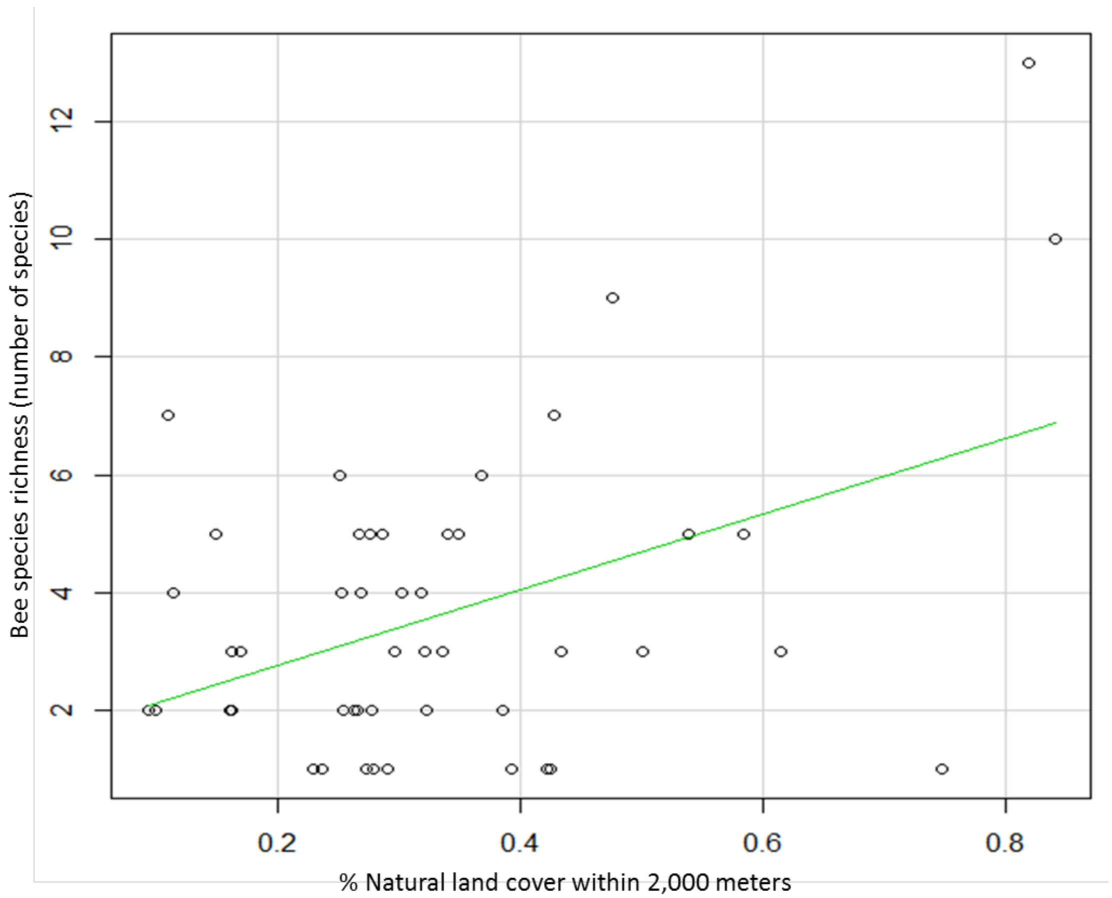
Figure 1. A comparison of individual honey bees (*Apis mellifera*) and individual wild bees representing five different families that were captured in conventional processing vegetable fields (n = 53), conventional processing vegetable field margins (n = 13), two organic farms, and all sites taken cumulatively. Bees obtained from each of the organic farms were replicated across time (n = 10). All collection sites were located within the Central Sands region of Wisconsin.



3) Evaluate how local landscape influences the abundance and diversity of both native and domestic pollinators present in flowering processing crops (e.g. green beans, field peas, and sweet corn).

The overall presence of bees within crop fields was not significantly correlated with time, surrounding land use, or field size. However, the presence of more than one species of bee in crop fields (interpreted here as the presence or absence of a diversity H-value at a sampling site) was significantly affected by field size (z = 2.014, p = 0.044, AIC = 62.08), with smaller fields tending to have more bee species. The species richness of bees was significantly affected by the proportion of natural land within a 2,000 m buffer (F1, 45 = 10.56, p = 0.0022, R2adj = 0.1720), regardless of crop type (**Fig. 2**).

Figure 2. The effect of the proportion of natural area within 2,000 meters on bee species richness within conventional vegetable fields grown in the Central Sands region of Wisconsin in 2014 and 2015 (Y = 0.227 + 0.030X, $F_{1,45}$ = 10.56, p = 0.002, R^2_{adj} = 0.172).



Crop type and time had an interactive effect on the log-transformed total abundance of bees in conventional processing vegetables. As time progressed, the total abundance of bees significantly increased in bean fields (Y = 115.855 + 6.523X, F1,13 = 10.07, p = 0.007, R2adj = 0.393), but not in pea fields (Y = 73.564 – 1.384X, F1,10 =0.62, p =0.45, R2adj = -0.036) nor corn fields (Y = 108.74 – 5.77X, F1,15 = 3.39, p = 0.085, R2adj = 0.13) (**Fig. 3**). The log-transformed abundance of wild bees within vegetable fields was best described as a function of the proportion of agricultural land (Y = -0.8666 - 2.139X, F1,38 = 10.02, p = 0.003, R2adj = 0.0.1879) and natural land (Y = 0.5326 + 0.0923X, F1,38 = 9.59, p = 0.004, R2adj = 0.1804) occurring within a 2,000 m radius (**Fig. 4**).

Figure 3. Log-transformed abundance of all bees within snap bean fields (Y = 115.855 + 6.523X, $F_{1,13}$ = 10.07, p = 0.007, R^2_{adj} = 0.393), pea fields (Y = 73.564 – 1.384X, $F_{1,10}$ =0.62, p=0.45, R^2_{adj} = -0.036), and sweet corn fields (Y = 108.74 – 5.77X, $F_{1,15}$ = 3.39, p = 0.085, R^2_{adj} = 0.13) as a function of time from April first. Fields were located within Wisconsin's Central Sands growing region in 2014 and 2015.

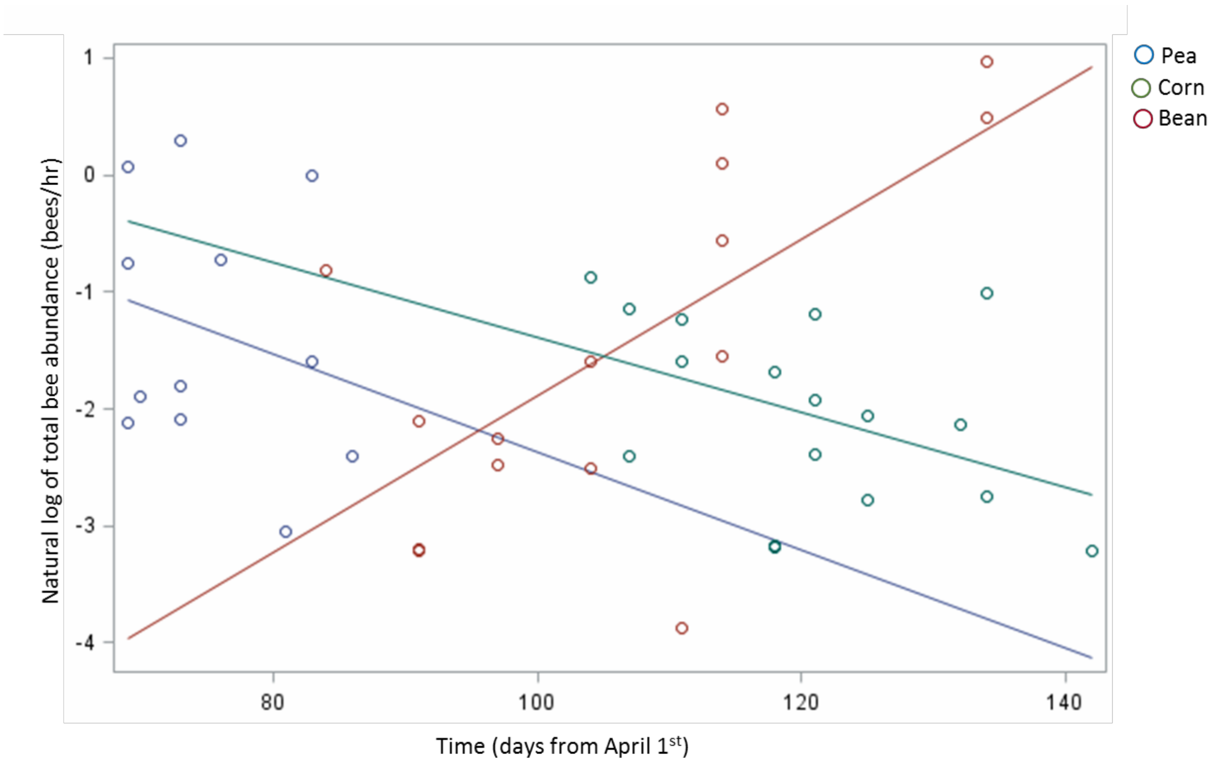
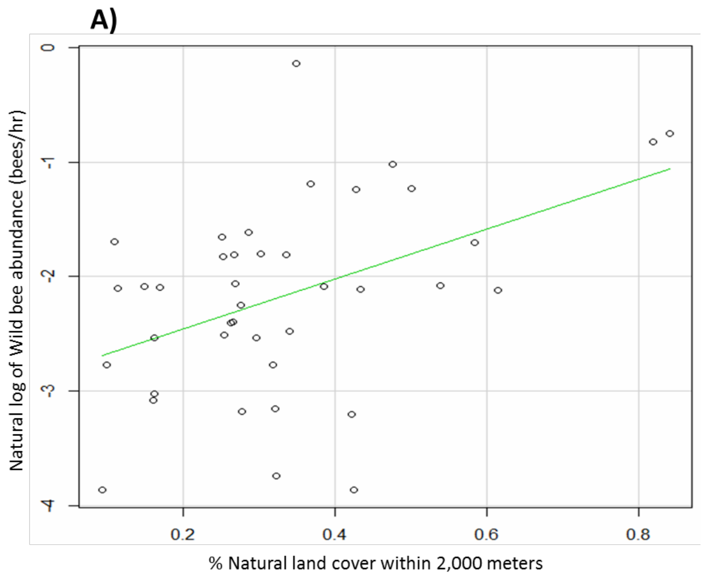
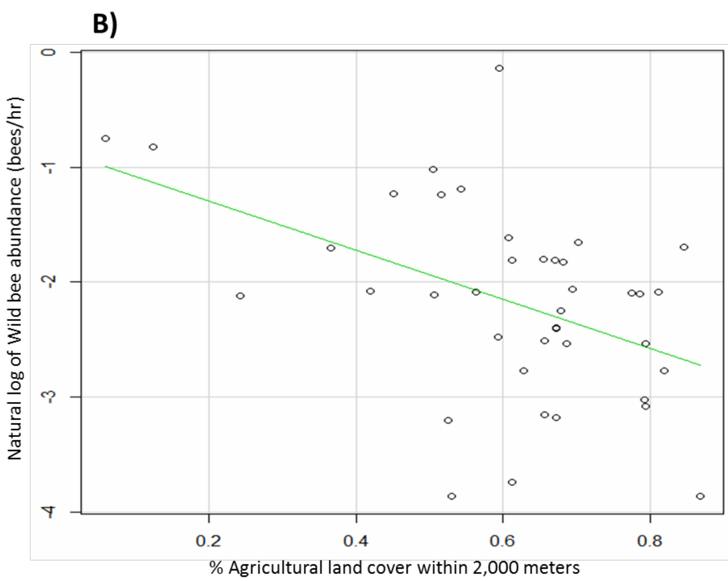


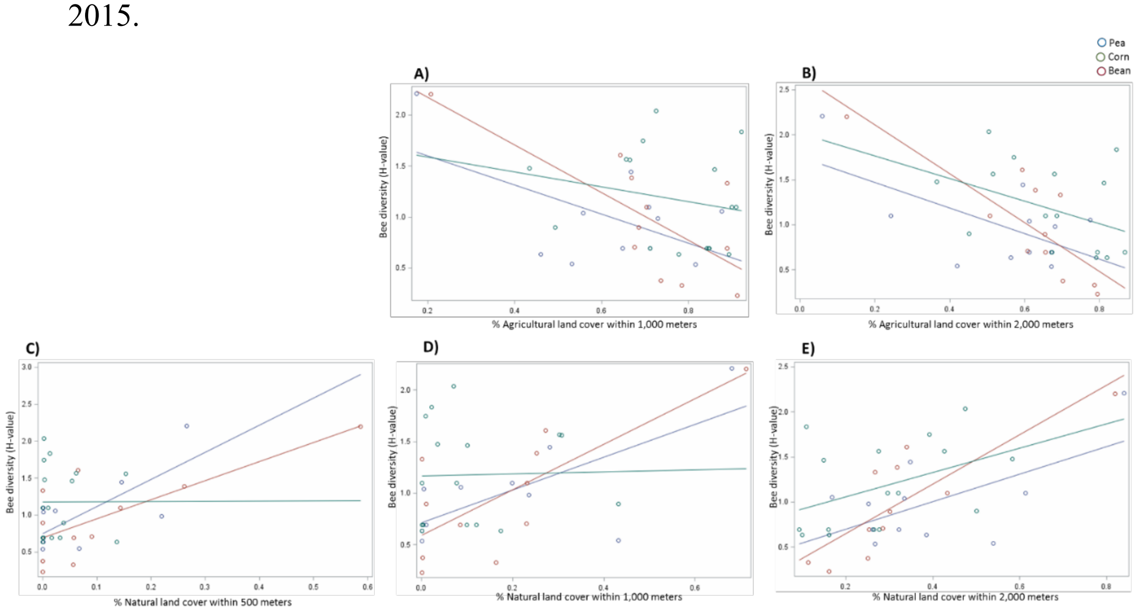
Figure 4. Log-transformed abundance of wild bee species (including *Apis mellifera*) in processing vegetable fields as a function of A) the proportion of natural land within 2,000 meters (Y = 0.533 + 0.092X, $F_{1,38} = 9.59$, $p < 0.0001$, $R^2_{adj} = 0.0.180$), and B) the proportion of agricultural land within 2,000 meters (Y = -0.867 – 2.139X, $F_{1,38} = 10.02$, $p = 0.003$, $R^2_{adj} = 0.0.188$). Crops were grownwithin Wisconsin's Central Sands growing region in 2014 and 2015.





Across conventional fields as a whole, bee diversity was positively correlated with the proportion of natural land at radii of 500 m ($F_{1,36}$ = 10.63, p = 0.002) 1,000 m ($F_{1,36}$ = 10.22, p= 0.003), and 2,000 m ($F_{1,36}$ = 15.93, p = 0.0003) and negatively correlated to the proportion of agricultural land at radii of 1,000 m ($F_{1,36}$ = 8.04, p = 0.008) and 2,000 m ($F_{1,36}$ = 13.12, p = 0.0009). There was a significant interactive effect of crop at all these buffer sizes (**Fig. 5**). The bee diversity within corn fields was not significantly affected by the amount of natural area within 500 m ($F_{1,14}$ = 0.0001, p = 0.992, R^2_{adj} = -0.071), 1,000 m ($F_{1,14}$ = 0.01, p = 0.921, R^2_{adj} = -0.071), or 2,000 m ($F_{1,14}$ = 3.09, p = 0.100, R^2_{adj} = 0.123). Bee diversity within corn fields was also not significantly affected by the amount of agricultural land within 1,000 m ($F_{1,14}$ = 0.71, p = 0.413, R^2_{adj} = -0.020) or 2,000 m ($F_{1,14}$ = 2.52, p = 0.135, R^2_{adj} = 0.092).

Figure 5. The bee diversity of conventionally grown fields of sweet corn, snap beans, and peas as a function of the proportion of agricultural land cover at A) 1,000 m (Y = 0.839 + 0.066X, $F_{1,14}$ = 0.71, p = 0.413, R^2_{adj} = -0.020 corn; Y = 0.940 – 0.234X, $F_{1,9}$ = 10.82, p = 0.009, R^2_{adj} = 0.495 bean; Y = 0.843 – 0.219X, $F_{1,9}$ = 4.07, p = 0.074, R^2_{adj} = 0.235 pea) and B) 2,000 m (Y =0.812 – 0.121X, $F_{1,14}$ = 2.52, p = 0.135, R^2_{adj} = 0.092 corn; Y = 0.855 – 0.244X, $F_{1,9}$ = 17.8, p =0.002, R^2_{adj} = 0.627 bean; Y = 0.804 – 0.269X, $F_{1,9}$ = 5.57, p = 0.043, R^2_{adj} = 0.314 pea), and asa function of the proportion of surrounding natural land cover at C) 500 m (Y = 0.0325 + 0.003X, $F_{1,14}$ = 0.0001, p = 0.992, R^2_{adj} = -0.071 corn; Y = -0.0971 + 0.214X, $F_{1,9}$ = 11.15, p =0.009, R^2_{adj} = 0.504 bean; Y = -0.0807X, $F_{1,9}$ = 10.61, p = 0.010, R^2_{adj} = 0.49 pea), D) 1,000 m (Y = 1.166 + 0.101X, $F_{1,14}$ = 0.01,, p = 0.921, $R^2{}_{dj}$ = -0.071 corn; Y = -0.0773 + 0.259X, $F_{1,9}$ = 12.01, p = 0.007, R^2_{adj} = 0.524 bean; Y = -0.144 + 0.322X, $F_{1,9}$ = 9.39, p = 0.014, R^2_{adj} = 0.456 pea), and E) 2,000 m (Y = 0.129 + 0.1341X, $F_{1,14}$ = 3.09, p = 0.001, R^2_{adj} = 0.123 corn; Y = 0.0720 + 0.254X, $F_{1,9}$ = 20.57, p = 0.001, R^2_{adj} = 0.662 bean; Y = 0.153 + 0.243X, $F_{1,9}$ = 5.34, p= 0.046, R^2_{adj} = 0.303 pea). All crops were grown within Wisconsin's Central Sands growing region in 2014 and 2015.



In bean fields, conversely, the diversity of bees was significantly positively affected by the amount of natural area within 500 m ($F_{1,9}$ = 11.15, p = 0.009, R^2_{adj} = 0.504), 1,000 m ($F_{1,9}$ = 12.01, p = 0.007, R^2_{adj} = 0.524), and 2,000 m ($F_{1,9}$ = 20.57, p = 0.001, R^2_{adj} = 0.662) and was significantly negatively affected by the amount of agricultural area within 1,000 m ($F_{1,9}$ = 10.82, p = 0.0094, R^2_{adj} = 0.495) and 2,000 m ($F_{1,9}$ = 17.8, p = 0.0022, R^2_{adj} = 0.627). The diversity of bees in pea fields was also significantly positively correlated with the amount of natural area within 500 m ($F_{1,9}$ = 10.61, p = 0.010, R^2_{adj} =0.490) 1,000 m ($F_{1,9}$ = 9.39, p = 0.014, R^2_{adj} = 0.456) and 2,000 m ($F_{1,9}$ = 5.34, p = 0.046, R^2_{adj} = 0.303) while being significantly negatively correlated with the amount of agricultural land 2,000 m ($F_{1,9}$ = 5.57, p = 0.043, R^2_{adj} = 0.314) and weakly negatively correlated with the amount of agricultural land at 1,000 m ($F_{1,9}$ = 4.07, p = 0.0743, R^2_{adj} = 0.235).

III. Goals and Outcomes Achieved

A very significant fraction of producers who are using seed treatment forms of pest management were informed of alternative forms of pest management to control early season insect pests. Pest managers learned that lower rates of active ingredients may provide a means to lower risk of exposure to foraging pollinators

We anticipate that processing crops producers will develop alternative, comprehensive pest management practices for the control of early season pests in the event that neonicotinoid insecticides exceed preventative action limits established for each active ingredient. Pest managers may also use lower overall rates of the seed treatments to accomplish similar levels of plant protection.

B. Of Wisconsin's roughly 400 bee species (Wolf & Ascher 2008), 86 were found in the Central Sands, including one new regional record, and 49 species were found within conventional processing vegetable fields. In-field bee species were most affected by the surrounding land uses at scales of 1,000 and 2,000 m, particularly the proportion of natural land, which suggests that lesser distances are within the average foraging range for the bee species found in the Central Sands area.

Since bee species tend to favor semi-natural, marginal lands, the season-long suitability of margins on a small-scale and a large-scale organic farm were compared to each other and to semi-natural conventional margins all within the Central Sands area. Conventional field margins yielded a more robust community than vegetable fields themselves, while organic margins were relatively equivalent to conventional margins, regardless of scale.

Many bees were recorded actively foraging in field margins, but few, if any, foraged within conventional fields, suggesting that most of the bees captured from within fields were merely passing through. Thus, smaller field sizes were most correlated with the presence or absence of multiple bee species in processing crops.

All of this study's conventional field sites were privately owned by growers contracting their irrigated land with the Del Monte Company Corporation to grow the aforementioned processing crops. This relegation of crop management to an outside party allows conventional farmers to successfully grow crops on many separate land parcels. Cooperation across property lines is imperative to ensure that crops and bees alike continue to thrive in this area.

IV. Beneficiaries

Research objectives outlined in this study are anticipated to benefit agricultural producers, crop consultants, University of Wisconsin Specialists and County Educators, contract producers, and other stakeholders. Immediate beneficiaries of this research would include the membership of the MWFPA (N= 2,550 members), together with the allied industries in Wisconsin, Minnesota, and Illinois to include Del Monte Foods, General Mills, Bonduelle USA, Hormel Food Corp., Pinnacle Foods, Seneca Foods, Birds Eye Foods, Lakeside Foods, GLK Foods, Bush Bros., McCain Foods, and Chippewa Valley Bean. Proposed outcomes of this research are consistent with the stated priorities of the 2014 U.S. Farm Bill and the stated priorities of the USDA SCBG request for proposals including an increase in the "environmental sustainability, pest and disease control & varietal improvement". Results of these investigations have been presented at, and published with in the following:

Prince, K.J., Bradford, B.Z. and Groves, R.L. 2016. Neonicotinoids in processing vegetables and groundwater In Proceedings of the 2016 Midwest Food Processors Association Annual Meeting, Processing Crops Conference Abstracts, November 29th and 30th, Kalahari Resort and Convention Center, Wisconsin Dells, WI. 112.

Prince, K.J. and Groves, R.L. 2016. Snap Bean Insect Pest Management. In Proceedings of the 2016 Wisconsin Crop Management Conference Abstracts, January, 14, Alliant Energy Center, Madison, WI.

North Central Branch, Entomological Society of America, Undergraduate and MS Student TMP Competition, P-IE Session. 2016. "Wild Bee Abundance and Diversity in Wisconsin Vegetable Crops.", Prince, K.J. and Groves, R.L. University of Wisconsin, NCB ESA Annual Meeting, Cleveland, OH, June 5-8, 2016.

V. Lessons Learned

Based on existing foraging records of wild Wisconsin bees and the low thiamethoxam concentrations in flowers found by this study, it is unlikely that the neonicotinoid-treated processing vegetable crops commonly grown in Wisconsin's Central Sands region pose an elevated risk to foraging pollinators. However, observed thiamethoxam contamination in untreated plant tissue observed within the first seven days of planting may imply that neonicotinoid seed coats in processing vegetables could have detrimental effects that spread to neighboring areas such as field margins where pollinators may forage and nest. Further research is needed to compare field-level tissue concentrations such as these to possible doses bees may receive, especially in regards to less-studied wild bee species

VI. Additional Information

Additional reference materials are provided at the Wisconsin Vegetable Entomology web-page (http://labs.russell.wisc.edu/vegento/current-projects/). A comprehensive summary of all of the bee taxa collected through these investigations are provided in Table 2.

Table 2. Combined list of the bee species that have been recorded within Wisconsin's Central Sands region (Wolf & Ascher 2008), as well as within the region's agricultural fields of pickling cucumbers (Lowenstein 2011), cranberry (Gaines Day 2013) and organic and conventional vegetable crops (Prince, 2016).

Species		Wolf & Ascher 2008	Lowenstein 2011	Gaines Day 2013	Prince 2016
ANDRENIDAE					
Andrena alleghaniensis	Viereck 1907			x	x
Andrena	Robertson 1897				
arabis Andrena	Robertson 1891	x		x	
asteris Andrena	(Kirby 1802)				
barbilabris	Dalla Torre 1896		x	x	
Andrena	Cockerell 1901				
canadensis	Viereck 1909				
Andrena	Viereck 1917			x	x
ceanothi Andrena	Cockerell 1899	x			
chromotricha	Smith 1879				
Andrena	Robertson 1893	x		x	x
crataegi Andrena	Robertson 1891				
cressonii Andrena	Provancher 1888			x	
distans Andrena	Cockerell 1898	x			
dunningi Andrena	Robertson 1891				
erigeniae Andrena	(Ashmead 1890)				
erythrogaster	Robertson 1891				
Andrena forbesii	Smith 1853 (Svida)	x			
Andrena	Robertson 1891	x			
geranii Andrena	Robertson 1891				
helianthi	Robertson 1895	x		x	
Andrena	Provancher 1888				
hippotes	Cresson 1872		x		
Andrena	Robertson 1901			x	
Andrena	Graenicher 1903			x	
milwaukeensis	Smith 1879				x
Andrena miranda	Cresson 1872	x			
Andrena	Robertson 1895				

Andrena	Smith185		x	x	
nivalis Andrena	3 Smith				x
perplexa Andrena	1853	x	x	x	
placata Andrena	Mitchell 1960				
platyparia	Robertson 1895				
Andrena	Cockerell 1902				

Andrena sigmundi	Cockerell 1902			x	
Andrena simplex	Smith 1853	x			
Andrena vicina	Smith 1853			x	x
Andrena violae	Robertson 1891			x	
Andrena wilkella	(Kirby 1802)			x	x
Andrena wilmattae	Cockerell 1906			x	
Andrena w-scripta	Viereck 1904			x	
Calliopsis andreniformis	Smith 1853			x	
Perdita halictoides	Smith 1853				x
Perdita maculigera	Cockerell 1896			x	
Pseudopanurgus helianthi	Mitchell 1960			x	
APIDAE					
Anthophora terminalis	Cresson 1869	x	x	x	
Apis mellifera	Linnaeus 1758	x	x	x	x
Bombus ashtoni	(Cresson 1864)	x			
Bombus auricomus	(Robertson 1903)	x	x	x	
Bombus bimaculatus	Cresson 1863	x		x	x
Bombus borealis	Kirby 1837	x	x	x	x
Bombus citrinus	(Smith 1854)	x	x		
Bombus fernaldae	(Franklin 1911)			x	
Bombus fervidus	(Fabricius 1798)	x		x	x
Bombus griseocollis	(DeGeer 1773)	x	x	x	x
Bombus impatiens	Cresson 1863	x	x	x	x
Bombus pensylvanicus	(DeGeer 1773)	x		x	
Bombus perplexus	Cresson 1863	x			x
Bombus rufocinctus	Cresson 1863	x	x	x	x
Bombus sandersoni	Franklin 1913			x	
Bombus ternarius	Say 1873	x		x	x
Bombus terricola	Kirby 1837	x		x	
Bombus vagans	Smith 1854	x	x	x	x
Bombus variabilis	(Cresson 1872)	x			
Ceratina calcarata	Robertson 1900	x		x	
Ceratina dupla	Say 1837	x	x	x	
Eucera atriventris	(Smith 1854)			x	
Eucera hamata	(Bradley 1942)		x	x	x
Melissodes agilis	Cresson 1878		x	x	x
Melissodes bimaculata	(Lepeletier 1825)			x	x
Melissodes communis	Cresson 1878		x		
Melissodes coreopsis	Robertson 1905		x		
Melissodes denticulata	Smith 1854	x			
Melissodes dentiventrus	Smith 1854	x			x
Melissodes desponsa	Smith 1854	x		x	
Melissodes druriella	(Kirby 1802)	x		x	x
Melissodes illata	Lovell & Cockerell 1906				x
Melissodes nivea	Robertson 1895		x		x

Melissodes wheeleri	Cockerell 1906		x		
Melissodes trinodis	Robertson 1901			x	x
Nomada armatella	Cockerell 1903	x			
Nomada articulata	Smith 1854	x			
Nomada (spp)					x
Nomada bella	Cresson 1863	x			
Nomada cressonii	Robertson 1893	x			
Nomada cuneata	(Robertson 1903)	x			
Nomada denticulata	Robertson 1902	x			
Nomada luteoloides	Robertson 1895	x			
Nomada maculata	Cresson 1863	x			
Nomada pygmaea	Cresson 1863	x			
Nomada superba	Cresson 1863	x			
Nomada texana	Cresson 1872	x			
Nomada vincta	Say 1837	x			
Peponapis pruinosa	(Say 1837)		x	x	
Svastra obliqua	(Say 1837)	x			
Xenoglossa kansensis	Cockerell 1905		x	x	x
COLLETIDAE					
Colletes compactus	Cresson 1868	x			x
Colletes inaequalis	Say 1837			x	
Hylaeus affinis	(Smith 1853)			x	x
Hylaeus annulatus	(Linneaeus 1758)				x
Hylaeus basalis	(Smith 1853)			x	
Hylaeus mesillae	(Cockerell 1896)			x	x
Hylaeus modestus	Say 1837		x	x	
Hylaeus rudbeckiae	(Cockerell & Casad 1895)				x
HALICTIDAE					
Agapostemon sericeus	(Förster 1771)		x	x	x
Agapostemon splendens	(Lepeletier 1841)		x	x	x
Agapostemon texanus	Cresson 1872	x	x	x	x
Agapostemon virescens	(Fabricius 1775)		x	x	x
Augochlora pura	(Say 1837)		x	x	x
Augochlorella aurata	(Smith 1853)		x	x	x
Augochloropsis metallica	(Fabricius 1793)		x	x	
Augochloropsis sumptuosa	(Smith 1853)		x	x	
Dufourea monardae	(Viereck 1924)			x	
Halictus confusus	Smith 1853	x	x	x	x
Halictus ligatus	Say 1837	x	x	x	x
Halictus parallelus	Say 1837		x	x	
Halictus rubicundus	(Christ 1791)			x	x
Lasioglossum acuminatum	McGinley 1986	x	x	x	x
Lasioglossum admirandum	(Sandhouse 1924)			x	x
Lasioglossum albipenne	(Robertson 1890)			x	x
Melissodes subillata	LaBerge 1961	x	x	x	
Melissodes wheeleri	Cockerell 1906		x		
Melissodes trinodis	Robertson 1901			x	x

Nomada armatella	Cockerell 1903	x			
Nomada articulata	Smith 1854	x			
Nomada (spp)					x
Nomada bella	Cresson 1863	x			
Nomada cressonii	Robertson 1893	x			
Nomada cuneata	(Robertson 1903)	x			
Nomada denticulata	Robertson 1902	x			
Nomada luteoloides	Robertson 1895	x			
Nomada maculata	Cresson 1863	x			
Nomada pygmaea	Cresson 1863	x			
Nomada superba	Cresson 1863	x			
Nomada texana	Cresson 1872	x			
Nomada vincta	Say 1837	x			
Peponapis pruinosa	(Say 1837)		x	x	
Svastra obliqua	(Say 1837)	x			
Xenoglossa kansensis	Cockerell 1905		x	x	x
COLLETIDAE					
Colletes compactus	Cresson 1868	x			x
Colletes inaequalis	Say 1837			x	
Hylaeus affinis	(Smith 1853)			x	x
Hylaeus annulatus	(Linneaeus 1758)				x
Hylaeus basalis	(Smith 1853)			x	
Hylaeus mesillae	(Cockerell 1896)			x	x
Hylaeus modestus	Say 1837		x	x	
Hylaeus rudbeckiae	(Cockerell & Casad				x
HALICTIDAE					
Agapostemon sericeus	(Förster 1771)		x	x	x
Agapostemon splendens	(Lepeletier 1841)		x	x	x
Agapostemon texanus	Cresson 1872	x	x	x	x
Agapostemon virescens	(Fabricius 1775)		x	x	x
Augochlora pura	(Say 1837)		x	x	x
Augochlorella aurata	(Smith 1853)		x	x	x
Augochloropsis metallica	(Fabricius 1793)		x	x	
Augochloropsis	(Smith 1853)		x	x	
Dufourea monardae	(Viereck 1924)			x	
Halictus confusus	Smith 1853	x	x	x	x
Halictus ligatus	Say 1837	x	x	x	x
Halictus parallelus	Say 1837		x	x	
Halictus rubicundus	(Christ 1791)			x	x
Lasioglossum	McGinley 1986	x	x	x	x
Lasioglossum	(Sandhouse 1924)			x	x
Lasioglossum albipenne	(Robertson 1890)			x	x

Lasioglossum anomalum	(Robertson 1892)		x	x	
Lasioglossum athabascense	(Sandhouse 1933)			x	
Lasioglossum bruneri	(Crawford 1902)	x		x	
Lasioglossum cinctipes	(Provancher 1888)		x	x	x
Lasioglossum coreopsis	(Robertson 1902)			x	
Lasioglossum coriaceum	(Smith 1853)	x	x	x	x
Lasioglossum cressonii	(Robertson 1890)	x	x	x	x
Lasioglossum ellisiae	(Sandhouse 1924)		x	x	
Lasioglossum ephialtum	Gibbs 2010		x	x	
Lasioglossum fedorense	(Crawford 1906)			x	
Lasioglossum floridanum	(Robertson 1892)			x	x
Lasioglossum forbesii	(Robertson 1890)	x		x	
Lasioglossum foxii	(Robertson 1895)			x	
Lasioglosum heterognathum	(Mitchell 1960)		x	x	
Lasioglossum hitchensi	Gibbs 2012				x
Lasioglossum laevissimum	(Smith 1853)			x	x
Lasioglossum leucocomum	(Lovell 1908)			x	x
Lasioglossum leucozonium	(Schrank 1781)	x	x	x	x
Lasioglossum lineatulum	(Crawford 1906)		x	x	x
Lasioglossum lusorium	(Cresson 1872)			x	
Lasioglossum lustrans	(Cockerell 1897)		x	x	x
Lasioglossum michiganense	(Mitchell 1960)			x	
Lasioglossum mitchelli	Gibbs, manuscript			x	
Lasioglossum nelumbonis	(Robertson 1890)	x	x	x	
Lasioglossum nigroviride	(Graenicher 1911)		x	x	
Lasioglossum novascotiae	(Mitchell 1960)			x	
Lasioglossum nymphaearum	(Robertson 1895)	x		x	
Lasioglossum oblongum	(Lovell 1905)			x	
Lasioglossum oceanicum	(Cockerell 1916)		x	x	x
Lasioglossum paradmirandum	(Knerer & Atwood 1966)				x
Lasioglossm paraforbesii	McGinley 1986	x	x	x	x
Lasioglossum pectorale	(Smith 1853)	x	x	x	x
Lasioglossum perpunctatum	(Ellis 1913)	x	x	x	x
Lasioglossum pictum	(Crawford 1902)		x	x	x
Lasioglossum pilosum	(Smith 1853)		x	x	x
Lasioglossum planatum	(Lovell 1905)				x
Lasioglossum pruinosum	(Robertson 1892)		x	x	x
Lasioglossum rohweri	(Ellis 1915)	x		x	
Lasioglossum semicaeruleum	(Cockerell 1895)				x
Lasioglossum smilacinae	(Robertson 1897)			x	x
Lasioglossum subviridatum	(Cockerell 1938)			x	x
Lasioglossum succinipenne	(Ellis 1913)		x		
Lasioglossum swenki	(Crawford 1906)		x	x	x
Lasioglossum taylorae	Gibbs 2010			x	

Lasioglossum tegulare	(Robertson 1890)		x		x
Lasioglossum timothyi	Gibbs 2010			x	x
Lasioglossum versans	(Lovell 1905)		x		
Lasioglossum versatum	(Robertson 1902)		x	x	x
Lasioglossum vierecki	(Crawford 1904)		x	x	x
Lasioglossum viridatum	(Lovell 1905)			x	x
Lasioglossum weemsi	(Mitchell 1960)			x	
Lasioglossum zonulum	(Smith 1848)	x		x	
Lasioglossum zophops	(Ellis 1914)		x		
Lasioglossum zephyrum	(Smith 1853)	x		x	x
Sphecodes atlantis	Mitchell 1956			x	
Sphecodes confertus	Say 1837			x	
Sphecodes coronus	Mitchell 1956			x	
Sphecodes davisii	Robertson 1897	x		x	x
Sphecodes dichrous	Smith 1853	x		x	x
Sphecodes levis	Lovell & Cockerell 1907			x	
Sphecodes mandibularis	Cresson 1872	x		x	x
Sphecodes ranunculi	Robertson 1897	x		x	
Sphecodes solonis	Graenicher 1911			x	
Coelioxys funeraria	Smith 1854	x			
Coelioxys immaculata	Cockerell 1912	x		x	
Coelioxys rufitarsis	Smith 1854	x			
Heriades carinatus	Cresson 1864	x			
Hoplitis pilosifrons	(Cresson 1864)	x		x	
Hoplitis producta	(Cresson 1864)	x		x	x
Hoplitis rubicundus				x	
Hoplitis spoliata	(Provancher 1888)	x		x	
Hoplitis truncata	(Cresson 1878)	x		x	
MEGACHILIDAE					
Megachile addenda	Cresson 1878	x		x	x
Megachile brevis	Say 1837			x	
Megachile gemula	Cresson 1878			x	
Megachile campanulae	(Robertson 1903)	x			x
Megachile latimanus	Say 1823	x	x	x	x
Megachile melanophaea	Smith 1853	x			
Megachile montivaga	Cresson 1878	x			
Megachile pugnata	Say 1837	x	x		x
Megachile relativa	Cresson 1878	x		x	x
Megachile rotundata	(Fabricius 1793)	x			x
Osmia albiventris	Cresson 1864	x		x	
Osmia atriventris	Cresson 1864	x	x	x	
Osmia distincta	Cresson 1864	x		x	x
Osmia georgica	Cresson 1878	x	x	x	
Osmia inspergens	Lovell & Cockerell 1907			x	

Osmia lignaria	Say 1837		x	
Osmia proxima	Cresson 1864	x		
Osmia pumila	Cresson 1864		x	x
Osmia simillima	Smith 1853		x	x
Osmia tersula	Cockerell 1912	x	x	
Osmia virga	Sandhouse 1939		x	
Stelis labiata	(Provancher 1888)		x	
MELITTIDAE				
Macropis nuda	(Provancher 1882)		x	

VII. Contact Info

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10) Food Safety Education Project (FY15-10)

Report Date: November 6, 2018

I. Project Summary

The purpose of the "Food Safety Education Project" was to provide federally mandated food safety training to fruit and vegetable growers and to assist them in coming into compliance with new food safety regulations. The Food Safety Modernization Act (FSMA), a widespread overhaul of our national produce safety regulation, was passed in 2010. The final rules are now available, and, to different degrees, affect all of our 3,000+ fresh market and commercial vegetable farmers in Wisconsin. Inspections of farms for compliance to FSMA are anticipated in 2019. A subset of the vegetable farms in the state are also required to participate in FDA approved food safety training (as stated in FSMA § 112.22(c) "at least one supervisor or responsible party from the farm to successfully complete food safety training at least equivalent to that received under the standardized curriculum recognized as adequate by the Food and Drug Administration". Farmers have already expressed frustration in the lack of resources and training opportunities available to bring their knowledge and practices up to where they need to be to maintain compliance.

B. This was a new project

II. Project Approach

The following activities were undertaken successfully through the course of this project: 1) Attend train-the-trainer food safety workshop and receive "lead trainer" certification; learn details of final regulations and implications for growers; 2) Coordinate and host 3 Grower Training Programs for farmers; 3) Coordinate and host 3 food safety focused on-farm field days, collect video and photographs highlighting food safety innovations and best practices; 4) Edit video into educational pieces, compile other helpful resources and post to UW Food Safety website.

Several significant contributions were achieved through this project. First, we were able to develop a first cohort of FSMA trainers, without which we would not have been able to being the implementation of the grower training programs required by the federal regulation. Second, we trained over 300 farmers or farming professionals in the state, contributing to not only fulfilling the requirements of the federal regulation, but a safer food supply for Wisconsin citizens. Third, we developed a more permanent, easily accessible suite of resources to continue to educate Wisconsin farmers beyond the life of this project. The quality of these materials has been recognized by other states, who have asked permission to adapt the materials for their own websites.

Project partners including UW-Extension and DATCP (who assisted with the trainings), Fairshare CSA coalition (who helped host field days), Organic Valley (who helped develop resources), and the Wisconsin Fresh Fruit and Vegetable Association (who hosted a training). Additionally, materials were reviewed by the Produce Safety Alliance.

Paid directly from grant funds, staff including Anne Pfeiffer, Chris Blanchard, and Harriet Behar assisted on various aspects of training, field days, and resource development. The staffing changed due to employee attrition and illness at various times throughout the course of the project.

III. Goals and Outcomes Achieved

An overall goal of the project was to increase on farm food safety knowledge, practices and federal regulation compliance through producer trainings and train-the-trainer events. The below mention activities of the project clearly demonstrate that this goal was achieved, as we executed 4 grower trainings (one additional than was proposed). The completion of these programs not only increased farm food safety knowledge but helped bring them to federal compliance. See below for specific details.

At the end of each Grower Training, evaluations were distributed to the attendees. These post-workshop evaluations documented that 100% of the attendees reported a better understanding of FSMA requirements after attending the trainings. The Extension personnel listed below exceeded the 20 personal contacts anticipated in the proposal, with education conducted through face-to-face meetings and phone/email conversations.

Unfortunately, due to website issues, it was impossible to track specifically those individuals who benefitted from the web-based resources.

1) Attend train-the-trainer food safety workshop and receive “lead trainer” certification; learn details of final regulations and implications for growers.

Erin Silva, PI on this project, and Kristin Krokowski, UW Extension Educator from Waukesha County, successfully attained lead trainer certification. Other UW Extension personnel receiving training included Harriet Behar, Chris Blanchard, Jerry Clark, Kaitlyn Chance, Loretta Ortiz-Ribbing, Leigh Presley, Scott Reuss, Claire Strader, and Mike Travis.

2) Coordinate and host 3 Grower Training Programs for farmers

- March 2017: FSMA Training, Rothschild, WI
- January 2018: FSMA Training, Wisconsin Fresh Fruit and Vegetable Conference, Wisconsin Dells (50 people)
- February 2018: FSMA Training, Fond du Lac, WI (50 people)
- March 2018: FSMA Training, Cashton, WI (40 people)

3) Coordinate and host 3 food safety focused on-farm field days, collect video and photographs highlighting food safety innovations and best practices

- July 2017: FSMA Training, Green Lake Co., WI (75 people)
- November 2017: FSMA Training, Soldiers Grove, WI (35 people)
- July 2018: FSMA Field Training, Verona, WI (20 people)

4) Edit video into educational pieces, compile other helpful resources and post to UW Food Safety website

Specific topics of educational materials include: 1) Identifying high-medium and low impact food safety activities, procedures and investments; 2) Practical Procedures for Meeting Harmonized Good Agricultural Practices (GAPs); 3) Identifying and Responding to

Agricultural Food Safety Emergencies; 4) UW Food Safety Plan Template; 5) FSMA guidance for produce auctions; and 6) a Qualified Exemption Checklist, which includes Instructions on How to Use Qualified Exemption Status Review and Verification Sheets Annual Summary of Farm Sales for All Food (Steps 1 and 2), Annual Review and Verification of Qualified Exemption (Steps 3 – 5), and Interactive Excel Spreadsheet Tool for Determination of Qualified Exemption.

All items can be found on the UW Food Safety Website:
http://labs.russell.wisc.edu/farmfoodsafety/

B. The actual accomplishments of this project match well with the goals and outcomes. The primary outcome measures are the number of UW Extension personnel trained as trainers, numbers of growers attending the workshops. We exceeded our goal of the number of trainers trained, reaching 11 UW-Extension-affiliated trainers. We exceeded our goal of 100 Wisconsin farmers both receiving FSMA food safety training certificates and attending on-farm food safety trainings. Additionally, we posted over six unique educational pieces on the UW Produce Food Safety Website, providing valuable on-line and printable FMSA-related resources for UW's Vegetable growers.

IV. Beneficiaries

The primary beneficiaries of this project are the over 1650 fresh market and commercial vegetable and fruit growers. It is estimated that small farms will spend up to 7% of their revenues complying with FSMA. Through closing the knowledge gap, demonstrating efficiencies, and facilitating paper work, this project could substantially reduce a growers' labor investment in FSMA in FSMA compliance up to 50%. That could be a savings of $3500 per year on a small farm with revenue of $100,000 annually.

V. Lessons Learned

One lesson learned in this project is it is challenging to solicit farms that are willing to do on-farm trainings, as they feel it opens their farm up to risk during the FSMA inspection process. Trust will need to be built between inspectors (and the inspection process) before it becomes easier to do more widespread, open education on farms. There still is substantial education required as to what FSMA regulation means with respect to practical, on-farm approaches, despite farmers being trained in the classroom and receiving their FSMA-required certificates. However, the significant body of new materials on our website should help facilitate grower learning and implementation of the FSMA regulation on their farms. In fact, the quality of these materials has already been recognized by other states, with the Oregon Department of

Agriculture requesting to adapt some of the content for their growers. One next step would be to translate these materials into Spanish and Hmong.

VI. Additional Information

None

VII. Contact Info

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11) Mitigating WI Hop Diseases Through Clean Rhizomes and Stock Certification (FY15-11)

Report Date: October 9, 2017

I. Project Summary

Hops are a labor intensive, perennial flavor crop that is typically harvested in late summer to fall of each year after yard establishment. Hops production has grown significantly in WI over the last 6 years with over 50 producers raising one half acre or more. Over a century ago, hops production in Sauk County WI comprised 20% of world production. In the late 1800's production declined in the state due, in part, to disease limitations. WI hops growers have, by economic necessity, relied upon out-of-state sources of hops rhizomes that are not verified for pathogen-free status. As the seat of the U.S. hops industry is in the Pacific Northwest, predominant available cultivars are not necessarily best suited for the unique environmental conditions of WI or its unique craft brewing industry. The availability and establishment of pathogen-free propagative plant material promotes field production with optimum yield, quality, and environmental and economic sustainability. Further, the development of a sustainable method of rhizome production in WI for WI will limit introduction of hops pathogens and create a mechanism for further advances in identifying cultivars with regionally specific traits of interest. Demand for high quality WI-grown hops has increased with the expansion of craft beer/beverage production. With collaboration from UW Extension, UW-Plant Pathology, growers, allied processing industries, and guidance from the WI Seed Potato Certification Program, building off of our previously funded hops Block Grant project, 13-003, we continued to evaluate hop varieties to identify high yielding, superior quality varieties adapted to WI; 2) further standardized and gained adoption of an economically sustainable system for production of pathogen-free planting stock for WI growers, 3) developed a disease assessment-based hop certification program for WI, and 4) continued to evaluate the disease status of existing hop yard plantings. Our research and development was complemented by a focus on grower education.

B. This research and extension team has received previous funding for hop work from the WI Specialty Crop Block Grant program FY13 and FY14). In this third year of funding we have been able to more substantially contribute to commercial production due to the fact that we completed our tissue culture and maintenance work which now supports exploration of varieties from a clean plant source, as well as supports growers' interest in adding clean propagation and plant supply to the commercial industry. During the 3 years of funding, the industry in Wisconsin has grown significantly from roughly 60 acres in 2012 to over 300 in 2017. Funds through this SCBG program have made it possible to staff and supply the work in effort to support the commercial industry.

II. Project Approach

We standardized and advanced the adoption of a tissue culture production system for pathogen-free hop plants in Wisconsin. We conducted variety trials in commercial hop yard locations to evaluate the effects of the culture process on specific hop varieties under Wisconsin conditions with respect to plant health and quality. Further, we evaluated the overall health of existing WI hop yards and propagative material. In previous years of the project, we developed a disease diagnostic package to support potential interest in a certification program for Wisconsin hops. We remain responsive to the industry's needs and interests in further pursuing a certification process for hops. At this time, there is some interest in pursuing this process with the Department of Agriculture, Trade and Consumer Protection in Wisconsin and with the Michigan Department of Agriculture. We expanded coordination of our educational opportunities with UWEX to exchange information and disseminate our findings in a greater number of locations within the state through formal educational sessions and hop yard visits.

Objective 1: We standardized a pathogen-free tissue culture collection of hop varieties. A pathogen-free tissue culture collection is the starting point for generating planting material for variety evaluation, and for providing pathogen-free planting stock for WI hop growers. Pathogen-free hop varieties are available as tissue culture plantlets or cuttings from the Clean Plant Center of the Northwest (CPCNW) at Washington State Univ., and from the National Clonal Germplasm Repository (NCGR) in Corvallis, OR. Protocols specific to hop tissue culture maintenance have been obtained from the CPCNW and NCGR. NCGR lists 185 hop cultivars and selections in its collection, including 14 of the 21 hop varieties recently planted by WI growers. Since only small amounts of plant material are available from these two sources, we established a clonal collection at UW-Madison in order to produce sufficient quantities of pathogen-free planting material for participatory hop variety trialing by WI hop growers. Varieties for on-farm evaluation were chosen in collaboration with participating hop growers and the grower advisory board. All commercially-requested varieties were placed into tissue culture with approximately 60% of varieties in potted media production in greenhouses at UW-Madison. We optimized nutrient and growth hormone inputs for the tissue culture process across varieties. We evaluated the performance of the plants resulting from tissue culture procedures in commercial hop yards and determined best culture processes for best success in field.

Objective 2: We produced pathogen-free planting material for grower-directed, on-farm variety evaluations, and advanced hop rhizome production methods to optimize productivity and economic sustainability. Our research into hop propagation methods has revealed a lack of reliable published protocols and an active and innovative grower community with keen interest in economically viable propagation methods. We consulted with WI growers to define the most commonly used propagation techniques and we collaboratively designed trials to compare and optimize these methods. Two major transitions occur in production of nuclear and propagation stock. Nuclear stock plants are derived from tissue culture plantlets, maintained in greenhouse conditions and used for further propagation. The standard method of transfer from tissue culture to sterilized potting medium in greenhouse conditions can result in plant losses due to the drop in humidity and increase in light levels. We tested 3 transfer methods, including the use of semi-opaque covers, misting chambers, and a nutrient film technology (NFT) system. The second major transition is from nuclear stock to propagation stock (plants derived as cuttings from nuclear stock which will be made available to hop growers for variety evaluation and further propagation). The standard method is to take softwood cuttings and root them in a misting chamber before transferring to sterilized potting medium. Since NFT systems allow access to parts of the plant normally covered by soil, we hypothesized that it would be possible to take both softwood cuttings and rhizome cuttings from these plants. Methods were compared for plant growth and cutting production, and inputs of time and materials were tracked to determine the most efficient production methods. In the final grant year, we had valuable communications with new and established hop growers practicing plant propagation.

Objective 3: We coordinated participatory variety trials in WI hop yards, and evaluated disease incidence in existing plantings. Field variety trials on grower cooperator farms were conducted to evaluate agronomic traits of 10 cultivars selected by industry. Grower cooperators (Albers, Buss) included 10 plants of each cultivar in standard production in their hop yards. Cooperator farms represent key hop production areas in the state of WI to best evaluate cultivars under a range of state soils and climates. In year 1 growers were provided with an evaluation form prompting them for observations of rhizome establishment, growth status, vigor, health, and pathogen/pest status. This standardization of observations enabled us to uniformly assess cultivar status as observed by growers. Unfortunately, due to challenge in harvesting individual bines at separate times, we could not include quality of hop cones and flavor profiles in this project. Such attributes require a larger number of plants to assess. Data were subjected to appropriate statistical analysis and a report will be provided to stakeholders.

During visits to growers participating in variety trials, previously existing hop plantings were assessed for Verticillium wilt and hop downy mildew, and if necessary laboratory assays were performed to confirm infection. Leaf samples were collected from participating hop yards. Samples were tested by enzyme-linked immunosorbent assays (ELISAs) for the presence of hop viruses HpMV, HpLV, AHLV, and ApMV, and by reverse transcriptase polymerase chain reaction (RT-PCR) for the presence of hop viroids.

Objective 4: We developed a disease diagnostic in preparation of an assessment-based certification for WI hops. Growers have urged us to work with industry in developing a system of uniformly testing for key diseases in propagative plant material – and providing a standardized report of disease which may serve as a certification. We will continue offering disease diagnostics with test results as the final form of documentation. However, we plan to engage industry in further discussion on the utility of and potential ramifications of a formal certification which involves state regulatory involvement.

Objective 5: We further educated and informed current and future WI hop growers about variety selection for the WI growing environment and craft brewing industry, the importance of disease-free planting stocks for healthy hop yards, and the process by which hop plants can be cleanly propagated.

III. Goals and Outcomes Achieved

We 1) standardized a pathogen-free tissue culture collection of hop varieties, 2) produced pathogen-free planting material for grower-directed, on-farm variety evaluations, and advanced hop rhizome production methods to optimize productivity and economic sustainability, 3) coordinated participatory variety trials in WI hop yards, and evaluated disease incidence in existing plantings, 4) developed a disease diagnostic in preparation of an assessment-based certification for WI hops, and 5) educated and informed current and future WI hop growers about variety selection for the WI growing environment and craft brewing industry, the importance of disease-free planting stocks for healthy hop yards, and the process by which hop plants can be cleanly propagated. We will finalize our work and summarize our findings in an accessible report to growers and others interested in propagating hops in Wisconsin and throughout the upper Midwestern region. Results will be shared through our previously stated extension fora including our grower education meetings (spring and winter of each year), online through the UWEX Potato and Vegetable Pathology website, and through our UWEX Vegetable Crop Updates newsletter and Facebook page.

B. We achieved most of the goals set out in the grant project proposal. We collected results from field evaluations of hop varieties and propagative strategies. The only objective that we practically could not achieve was the yield and quality data collection on individual hop plants that were grown at commercial sites. Because of the relatively small number of test plants, separate harvests and processing of each variety, individually, was not practical. Our focus was on collection of information on plant vigor and health during the project. Further details of studies have been included in previous section of this report.

IV. Beneficiaries

Our project benefited the 75+ current producers of hops in WI and the Midwestern region as well as future growers by making available planting stock free of disease for optimum growth, yield, and quality with potentially reduced reliance upon chemical control options for enhanced human and environmental safety. Successful and increased production of hops for WI means enhanced market placement, additional revenue in the beverage and locally grown sectors for additional benefit to brewers and consumers. Results of our efforts provided increased access and cost-effectiveness of clean stock making entry into hops production more economically sound and attractive to new hobbyists and/or commercial producers. While an economic value cannot be placed on the intrinsic significance of re-establishing WI as a key hops producing location in the world, this mission drives many hops producers who take pride in the tradition of locally grown quality craft beer in WI.

How many beneficiaries will be impacted?: Currently there are over 50 hops producers across the state of WI. Most producers have membership in one or more regional or statewide hops cooperatives or exchanges which aid in connecting market demand with production. Key organizations, such as Gorst Valley, WI Hops Exchange, and Midwest Hop and Barley Cooperative are participants in this cooperative project and are prime beneficiaries. There are 8 large and regional breweries (15,000->6 million barrels beer/year) in WI, such as Miller, Leinenkugel, New Glarus; greater than 30 microbreweries (15,000 or less barrels beer/year), such as Ale Asylum, Grumpy Troll, Hudson; and countless hobbyist brewers that would benefit from enhanced quality and quantity of WI-grown hops.

How will the beneficiaries be impacted by the project?: Beneficiaries would reap reward of high quality, locally-sourced, and sustainably produced hops for brewing established and potentially new flavors unique to WI.

What is the potential economic impact of the project if available?: In a 2013 grower survey in WI, IA, and MN, hops growers indicated an expected increase in acreage and farm gate value of crop by 5-fold. This increase is based on current production practices and expectations. With advancement in rhizome quality, expectations for yield and quality may be increased promoting further acreage expansion and expected return of greater than $2.85 million in the next 5 years.

V. Lessons Learned

We learned that on-farm trial evaluations were difficult to achieve at multiple locations that are at a distance to UW-Madison, especially with a perennial crop. The maintenance and frequency of observations was challenging at times, especially with limited equipment to achieve some of the quality measures for cone yield and quality. A UW sponsored hop research yard would be a valuable addition to the resources for further study of hop disease and other agronomic studies.

VI. Additional Information

Extension Publications

Gevens, A.J., Marks, M.E. 2014. *Hop Downy Mildew: Identification and Management*. UW-Extension Publication.

Gevens, A.J., Marks, M.E. 2014. *Hop Powdery Mildew: Identification and Management*. UW Extension Publication.

Gevens, A.J., Marks, M.E. 2014. *Hop Viruses: Identification and Management*. UW-Extension Publication.

Trade Magazine Articles

Marks, M.E., **Gevens, A.J.** 2015. What's hoppin' in Wisconsin hops?! Fresh. A magazine of the Wisconsin Fresh Market Fruit and Vegetable Growers Association (April Edition).

Extension Newsletter Articles - UWEX Vegetable Crop Updates

Gevens, A.J. 2016. Vegetable disease update: DSV (Blitecast, Late Blight) and P-Day (Early Blight) updates, late blight and cucurbit downy mildew national updates, powdery mildew on hops, diagnostic updates. *Wisconsin Crop Manager*, Vegetable Crop Updates #23. August 12.

Gevens, A.J. 2016. Vegetable disease updates: DSV (Blitecast, Late Blight) and P-Day (Early Blight) updates, early season late blight symptoms and inoculum sources; management link to potato blackleg seminar from Focus on Potato, WI hop updates. *Wisconsin Crop Manager*, Vegetable Crop Updates #9. May 27.

Gevens, A.J. 2016. Vegetable disease updates: national late blight updates, hop downy mildew updates for Wisconsin. *Wisconsin Crop Manager*, Vegetable Crop Updates #5. April 29.

Gevens, A.J. 2015. Potato fungicides for 2015: new registrations and label updates. Hop disease identification and management. *Wisconsin Crop Manager,* Vegetable Crop Update #2. Apr 3.

Professional Academic Meeting Contributions

Marks, M.E., **Gevens, A.J.** 2016. Screening for phenylamide fungicide insensitivity in Wisconsin hop downy mildew (*Pseudoperonospora humili*) populations. 296-P (Poster Presentation). Chemical Control. American Phytopathological Society Annual Meeting. Tampa, FL.

Marks, M.E., Geske, A.P., **Gevens, A.J.** 2015. Disease detection in hop rhizomes and plantlets to ensure clean yards in Wisconsin. 466-P (Poster Presentation). Diseases of Plants – Disease Detection and Diagnosis. American Phytopathological Society Annual Meeting. Pasadena, CA.

Local and State Presentations

Date	***Presentation title, e*vent, and location**
2017	
Feb 25	***Managing Disease in Wisconsin Hops & Fungicide Updates.*** University of Wisconsin Extension Hop Production Workshop. Amherst, WI.
Feb 25	***Hop Downy Mildew Research Updates.*** University of Wisconsin Extension Hop Production Workshop. Amherst, WI.
2016	
Jul 8	***Hop Disease Management Updates.*** Hop Production Meeting. University of Wisconsin Extension. Roscholt, WI.
Apr 19	***Hop diseases of Wisconsin and their diagnostics and management.*** North Central Plant Disease Diagnostic Network Meeting. Madison, WI.
Mar 12	***Updates in hop disease management.*** Hop production meeting. University of Wisconsin Extension Buffalo County. La Crosse, WI.
2015	
Aug 15	***Managing downy mildew in Wisconsin hops.*** University of Wisconsin Extension & Wisconsin Department of Agriculture, Trade, and Consumer Protection Hop Management Meeting. Albers Hop Farm. Arkansaw, WI.
Aug 14	***Managing downy mildew in Wisconsin hops.*** University of Wisconsin Extension & Wisconsin Department of Agriculture, Trade, and Consumer Protection Hop Management Meeting. Davali Ridge Farm. Waterloo, WI.
Mar 14	***Hop disease research and extension updates***. Gorst Valley Grower Education Meeting. Mazomanie Public Library. Mazomanie, WI.

National and International Invitations

Date	Event and Location
2017	
Mar 4	***Managing Disease in Wisconsin Hops & Fungicide Updates***. Minnesota Hop Growers Association Annual Meeting & Workshop. Shakopee, MN.
Mar 4	***Hop Downy Mildew Research Updates***. Minnesota Hop Growers Association Annual Meeting & Workshop. Shakopee, MN. Co-Presented with Student Michelle Marks.

VII. Contact Info

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12) Enhancing market acceptance and quality of Wisconsin hops to craft brewers (FY15-12)

Report Date: September 10, 2018

I. Project Summary

A paper entitled "ENHANCING MARKET ACCEPTANCE AND QUALITY OF WISCONSIN HOPS TO CRAFT BREWERS" is attached and was prepared by the following:

David Buss is Managing Member for Davali Ridge LLC, Waterloo, WI. Davali Ridge hop farm provided all the hop cone material, and equipment used for harvesting, drying, baling of the hops used throughout the study. David is also Managing Member of NuSolutions Agronomy LLC, an agronomy consulting company that managed and performed all of the research, and assisted with the preparation of the final paper for the studies.

Dr. Arnoldo Lopez-Hernandez, , University of Wisconsin – Madison, Department of Food Science. Dr. Lopez-Hernandez performed the statistical analyses for the studies, and assisted with the preparation of the final paper.

Please refer to the 'INTRODUCTION' section of this report that provides a background for the initial purpose of the project, which includes the specific issue, problem, or need addressed, and establishes the motivation for this project. (see below):

<u>INTRODUCTION</u>

The craft beer market is the fastest growing segment of the brewing industry in Wisconsin and nationwide. Craft brewers tend to advocate for the use of high quality locally grown ingredients and are the major potential market for hops grown by Wisconsin and other Midwest hop producers.

Hops contribute bittering, flavor and aroma during the brewing process. Although all of these hop characteristics are important in the brewing process, alpha and beta acids that contribute bittering tends to be the predominate characteristic driving purchasing decisions. Although bittering capability is an important hop characteristic in brewing, craft brewers and the beers they produce, place major emphasis on hop flavor and aroma, which are controlled by various percentages of hop essential oils unique to each hop variety. Therefore, the local hop industry (growers and processors) need to better understand how management decisions while growing, processing, packaging, and storing hops affect quality (bittering, flavor and aroma), so they can maintain and deliver top quality hop products as demanded by the craft beer market. Two major areas of study were evaluated:

The first objective of this project was focused on determining **Harvest timing for optimum quality** as measured by percent total alpha (AA) and beta acids (BA), Hop Storage Index (HSI) and total essential oils. Harvesting hops when the highest amounts of favorable hop components (bittering components – hop acids; flavor and aroma components – essential their peak is one of the periods when hop growers can have the greatest input into delivering high quality products to brewers. One method northwest U.S. hop grower's typically use to base time of harvest, is a simple grower test to determine % cone dry matter. Based on conversations with established Pacific Northwest U.S. growers and USDA researchers, harvest begins when cone dry matter reaches 20 – 25%. According to their experience, bittering components generally peak earlier (20 - 23%) compared to flavor and aroma components, which tend to peak later (24 – 25%). Also, optimum harvest timing can vary by variety. Established Pacific Northwest growers have shared general guidelines they use to determine harvest timing for specific varieties, however they caution that they are based on their local climate and may not be appropriate for our local Midwest climate.

The goal of this part of the study was to evaluate 3 varieties with different bittering and flavor profiles to learn how these profiles develop over time within the hop cone and to determine whether cone dry matter can be a useful parameter to measure to determine optimum harvest timing for hops in our local area.

A second objective was to **Identify the major post-harvest factors (period of harvest through delivery of product to brewer) that can most influence degradation of hop quality.** There were two main goals for this portion of the study:

1. Demonstrate to growers and processors the importance of proper hop processing and handling in providing top quality hop products to brewers. Due to differences in size of established northwest U.S. hop growers (100 – 1,000 acres) compared to new establishing hop growers in the Midwest (1 – 20+ acres), availability of quality small scale hop processing equipment to Midwest growers is limited. Growers have been resourceful in either acquiring used smaller-scale equipment from Europe or designing and fabricating small scale versions of proven large-scale equipment. Although innovation is welcome, an understanding of how harvesting and processing techniques affect quality components is critical for new hop growers to produce and deliver high quality hop products to brewers, and the success of the hop industry in the Midwest and other emerging hop growing areas.

2. Understanding the role that temperature control has throughout harvesting, storing, and processing of hops on quality. Maintaining proper temperature control has always been understood to be important during processing, packaging, and storage of hops. The emerging craft beer industry is constantly striving for and places a premium on unique flavor and aroma profiles in their beers. An evolving theory stresses the importance of maintaining very low temperatures during the entire hop processing period (drying, pelleting, packaging) in order to preserve the flavor and aroma properties of hops sought after by craft brewers. However, little data is available to indicate that what theoretically makes sense actually occurs in practice. It is important to verify the validity of these theories, so growers are using best management practices.

The post-harvest periods researched were:

- Period between harvest and drying
- Drying
- Storage prior to pelleting
- Pelleting

II. Project Approach

Please refer to the paper entitled "ENHANCING MARKET ACCEPTANCE AND QUALITY OF WISCONSIN HOPS TO CRAFT BREWERS". The 'MATERIALS AND METHODS' section of the paper summarizes the activities and tasks performed during the grant period. The 'RESULTS AND DISCUSSION' section describes the work accomplished in both quantitative and qualitative terms, and includes significant results. The 'CONCLUSIONS' section summarizes the conclusions and recommendations from the research. (These sections are included below)

In addition to the contributions by David Buss and Dr. Arnoldo Lopez-Hernandez, the following persons and entities provided support for the project:

Hop cone sample testing was performed by the following:

> Rick Cole, Midwest Hop and Beer Analysis LLC, Evansville, WI – Provided analyses for moisture, % alpha acids, % beta acids, HSI (Hop Storage Index), and Total Oils for the *'Harvest timing for optimal quality'* portion of the research.
>
> University of Wisconsin – Madison, Food Science Department - Provided analyses for moisture, % alpha acids, % beta acids, HSI (Hop Storage Index), and Total Oils for much of the *'Identify the major post-harvest factors (period of harvest through delivery of product to brewer) that can most influence degradation of hop quality'* portion of the study.
>
> Zach Lilla, Advanced Analytical Research (AAR), Madison, WI - Provided analyses for moisture, % alpha acids, % beta acids, HSI (Hop Storage Index), and Total Oils for some of the *'Identify the major post-harvest factors (period of harvest through delivery of product to brewer) that can most influence degradation of hop quality'* portion of the study. AAR also performed the total oil component testing for β-pinene, myrcene, linalool, caryophyllene, farnesene, humulene, and geraniol.

Cynthia Jaggi, Economic Development Partners, Verona, WI – Assisted with facilitating the development and enhancement of the Wisconsin Hop Exchange Cooperative website to better educate, promote, and market hops statewide.

Carl Duley, Buffalo County Agriculture Agent, UW-Extension, Alma, WI – Main contact in the state for hop education and outreach.

Heidi Eilenfeldt, Wisconsin Hop Exchange Cooperative, provided administrative support to the project.

MATERIALS AND METHODS

Harvest timing for optimum quality

All treatment samples were tested for Moisture content, % Alpha acid, % Beta acid, Total oil, HSI, and corrected to 10% moisture.

Three varieties were selected for this study:

- Chinook – high alpha acid variety (12-14%), a dual-purpose hop often used for bittering that also has desirable aroma characteristics. Large open cone.

- Tahoma - medium alpha acid variety (7.2-8.2%), generally considered an aroma hop, that can also be used for bittering. Very small light cone.
- Sterling – low to medium alpha acid variety (4.5 – 9%), a dual-purpose hop used for bittering and aroma. Medium compact cone.

Six sampling periods over approximately a 20-day period, 10 days prior, during, and 10 days after harvest.

Four replications:
2016 – Replicates 1 and 2
2017 – Replicates 3 and 4

Three representative plants were chosen and flagged for each variety and replication within an interior row for that variety. Approximately 10 days prior to the estimated harvest date, hop cones were harvested from 3 bines within each replication. Starting around 1:00 pm (dry weather permitting), approximately ½ gallons of cones were harvested throughout the entire bine and placed in a ½ gallon plastic bag which was left open to prevent condensation and transported immediately to the lab (Midwest Hop and Beer Analysis) in Evansville, WI for testing. The sampling and testing were repeated approximately every 3-4 days. The plants remained in the field through harvest and continued to be sampled for a total of 6 sampling and testing periods. All the samples were tested using ASBC official methods to determine %Alpha acids, %Beta acids, HSI, Total oil.

Identify the major post-harvest factors (period of harvest through delivery of product to brewer) that can most influence degradation of hop quality.

All treatment samples were tested for Moisture content, % Alpha acid, % Beta acid, Total oil, HSI, and corrected to 10% moisture. In 2017, component acid and oil testing was performed on the "Storage" and "Pelleting" treatments using gas chromatography and included the following: Co- humulone as a % of Total Acid, Co-lupulone as a % of Total Beta Acid. Oil components reported as % of Total Oil were: □-pinene, Caryophyllene, Farnesene, Geraniol, Humulene, Linalool, and Myrcene.

Period between harvest and drying hop cones (Harvest and pre-drying conditions)

Three Varieties: Chinook, Sterling, Tahoma

Three Treatments:
Place wet hops on low ambient air flow prior to applying drying treatments.
Place harvested hops in enclosure for 4-5 hours prior to applying drying treatments. Control – Freshly harvested hops

Four Replications:
2016: Day 1 = Replicate 1
Day 2 = Replicate 2

2017: Day 1 = Replicate 3
Day 2 = Replicate 4

In 2016, freshly harvested hop cones were placed in either a dryer bin (Figure 1) with a low volume of ambient air flow to keep the hops cool and dry (Treatment 1), or in a dryer bin with no ambient air flow (Figure 2) that was sealed on top with cardboard to try to force the wet hops to heat, simulating stewing of the hops if not handled properly (Treatment 2). The hops remained in these bins throughout the remainder of the harvest for the day (approximately 4 – 5 hours) until the hop drying portion of the study commenced. Treatment 2 did not heat up or stew. It was thought that there may have potentially been some incidental air flow within treatment 2 due to air leaks in the drying system.

Therefore, in 2017, wet hops for treatment 2 were placed completely in a cardboard box separate from the dryer, again to try to simulate heating and stewing of the hops. Again, the hops in treatment 2 did not heat or stew. As a result, the treatments for this portion of the study were wet hops either on low ambient air, or no ambient air flow. An attempt was made to record air flow within the hop bed during these studies. Air flow through hop beds are very low (1.0 – 1.5 ft/sec). These low air speeds are hard to detect with inexpensive vane wheel anemometers. A hot-wire or thermal flow type anemometer which can measure extremely low air speeds was purchased. However, air turbulence within and above the hop bed made it impossible to record accurate readings, so relied on sense of feel and experience to adjust air flow.

Drying
<u>Three Varieties</u>: Chinook, Sterling, Tahoma

<u>Three Treatments</u>: Forced-air drying at 140 ˚F Forced-air drying at 110 ˚F
Forced-air drying using dehumidification (no heat) at 70 ˚F

<u>Four Replications</u>:
2016: Replicates 1, 2
2017: Replicates 3, 4

The forced-air drying treatments were done on a small bin dryer system at Davali Ridge Farm (Forced-air dryer for the 110 and 140 ˚F treatments: Figure 1), (70 ˚F no heat, dehumidifying dryer treatments: Figure 2). After the "Harvest and pre-drying conditions" study treatments were created, hop samples were taken from each bin for dry matter determinations *(*Undried hop sample weights were recorded, samples dried for 9 hours in a food dehydrator, dried hop sample weights recorded, and pre-drying hop cone dry matter determinations made). Separate hop samples were taken for monitoring hop drying progress (Samples were placed in muslin mesh grain/hop bags, weighed, and wet weight without bag recorded. These samples within the muslin bags were buried within the hops in the dryer bins and allowed to dry with the hop treatments.

After sample % dry matters were determined, the final bag weights when the sample of hops within the muslin bags would reach 10% dry matter "final bag weight" was determined as follows: "Starting dry matter / 90 x cone wet weight + bag weight". As drying neared completion, the muslin bags with hops were pulled from the hop bed and weighed. If the "final bag weight" hadn't reached its calculated 10% dry matter weight, the bag was placed back into the hop bed. When the calculated final bag weight was reached, drying for that treatment was stopped and the treatment placed in the conditioning room to condition for at least 24 hours. Representative samples were taken from the center of the burlap bag of dried hops (approximately 2-3 lbs.), placed in clear plastic bags, sealed, and placed in refrigerated storage prior to delivery to the testing labs.

Since the forced-air dryer was not set up to run multiple temperature drying treatments, the 140 ˚F treatments (2 reps) along with the 70 ˚F dehumidifying treatment (2 reps) were done during one day of harvest, and the 110 ˚F treatment (2 reps) were done on the following day of harvest for each variety tested. The hop bed depth in the dryers were dependent on the volume of hops from each variety that was available for study from that day's harvest. The starting bed depth in the forced-air dryer typically ranged from 11-18". Due to size limitations of the dehumidifying dryer, bed depth was typically 8-10".

Bed depth decreased during the drying treatments, on average 22% varying by variety. Before drying commenced, temperature probes were inserted through the dryer wall into the hop bed. One probe was placed in the dryer flume beneath the hop bed to measure the temperature of the heated air before entering the bed of hops. Temperature probes where also placed in the bottom 1/3rd, middle, top 1/3rd of the bed, and just above the hop bed. Bed temperatures were recorded every 2 – 3 hours throughout the drying treatment. Because the dehumidifying treatments generally dried over a 24-hour period or more and since the bed temperature did not vary significantly, temperature readings were not taken in these treatments in the day during harvest operations. In addition to temperature readings, relative humidity was also recorded near the intake of the hop dryer fans.

Figure 1. Forced-air dryer used for the 110 and 140 ˚F treatments

Ultra-low heat burner and fan *(down to 10* ˚F *above ambient temperature)*, recycle air to achieve high temperatures, variable speed fan. Burlap bag lining to facilitate moving treatments to condition room. Air flow per bin controlled separately, access holes at 1” increments to monitor temperatures below, within, and above drying bed.

Figure 2. Dehumidifying dryer used for the 70 ˚F (no added heat) treatment

- Plastic enclosure
- Air flow enters under screened bottom
- Commercial grade dehumidifier (not shown) – removes moisture, but radiates heat
- Air conditioner to maintain room temperature
- 3 speed air flow control
- Access holes at 1-inch increments to monitor temperatures below, within, and above drying bed.

Storage (between baling and pelleting) Three Varieties: Chinook, Sterling, Tahoma

Five Treatments:

Loose (not baled), Refrigerated
Low Compression (baled at 4.45 lbs./cut.), Refrigeration
High compression (baled at 8.9 lbs./cut.), Refrigeration
Low Compression (baled at 4.45 lbs./cut.), Room temperature
Low Compression (baled at 4.45 lbs./cut.), Freezer

Four replications:

2016 – 2 replicates
2017 – 2 replicates

Either 5 lbs. or 10 lbs. of dried, conditioned hops were baled (compressed) into boxes (18" x 18" x 6") with a clear plastic bag liner to simulate hops baled at densities of 4.45 or 8.9 lbs./cu. ft. 5 lbs. of dried, conditioned hops were also placed loose in clear plastic bags to simulate hops stored without compression. Figure 3 shows the baler used and the ending containers of hops used as treatments.

Figure 3. Baler used to compress hop cones prior to storage at different temperatures and compression levels

The packaged treatments were then placed in refrigerated storage. One replication of the refrigerated treatments was in the Davali Ridge Farm walk-in cooler and the second replication in Wisconsin Hop Exchange Cooperative refrigerated trailer both years of the study. Both replications of the freezer treatment were located at Alaskan Ice freezer storage in Waterloo, WI during both years of the study. Each replication of the room temperature treatment was located in rooms maintained at 68-70 ˚F in separate buildings at Davali Ridge Farm both years of the study. The treatments were maintained from harvest in the early part of September until December when representative samples (approximately one gallon) from the center of each treatment were placed in nitrogen purged vacuum-sealed Mylar bags before delivery to the testing labs.

Pelleting

Three Varieties: Chinook, Sterling, Tahoma

Four Treatments:
Pre-pellet (milled only)
Pellet temperature – 90-100 ˚F
Pellet temperature – 110-120 ˚F
Pellet temperature – 130-140 ˚F

Four replications:
2016 – 2 replicates
2017 – 2 replicates

Hops were pelleted in February at the Wisconsin Hop Exchange Cooperative's non-heated processing facility near Deerfield, WI (Figure 4). Therefore, air temperature in the facility was typically 30 – 40 ˚F during processing. The pellet die generates heat during normal operation. In 2016, a temporary liquid nitrogen system was installed if needed to obtain the lower pelleting temperature treatments. A copper coil was wrapped around the pellet die and liquid nitrogen allowed to flow though the copper tubing to dissipate heat from the pellet die. It succeeded in keeping pellet temperatures low for obtaining the low temperature treatments, however the die temperature was hard to control and if cooled too much at times prevented the free flow of pellets through the die. Because of the cool hop temperatures entering the mill and cold ambient air temperatures, normal pellet temperatures coming out of the mill typically range from 110 – 125 ˚F. Therefore, obtaining the 110 – 120 ˚F treatment temperature was easy to obtain. However, trying to increase the pellet temperature to obtain the 130 – 140 ˚F treatment proved to be difficult for the varieties in this study. Increasing speed of the die and increasing flow of hop material into the die only increased pellet temperature marginally. Although not a recommended practice, the 130 – 140 ˚F treatment temperature was only able to be achieved by recycling fresh warm pellets back through the mill.

It was discovered through experience that when starting to pellet a new batch of hops, that pellet quality is poor (compact and have a glassy appearance) early in the batch until the pellet die increases in temperature enough to allow the pellets to move freely through the die. There is a short period of time when pellet quality is very good and the pellet temperature is low (90 – 100 degrees). It then gradually increases in temperature until it reaches its optimum temperature. Therefore in 2017, this early pelleting period was used instead of liquid nitrogen to collect our 90 – 100 ˚F pellet temperature treatment samples.

Pellet temperatures were frequently monitored while pelleting (Figure 5). When pellet temperatures were reached, an approximate 1 lb. sample of pellets was collected directly off the pellet mill into a Mylar bag. The bags were left open to cool during the sample collection period. When all samples were collected and had cooled, they were nitrogen purged and vacuum sealed and either put into freezer storage or taken directly to the lab for analyses.

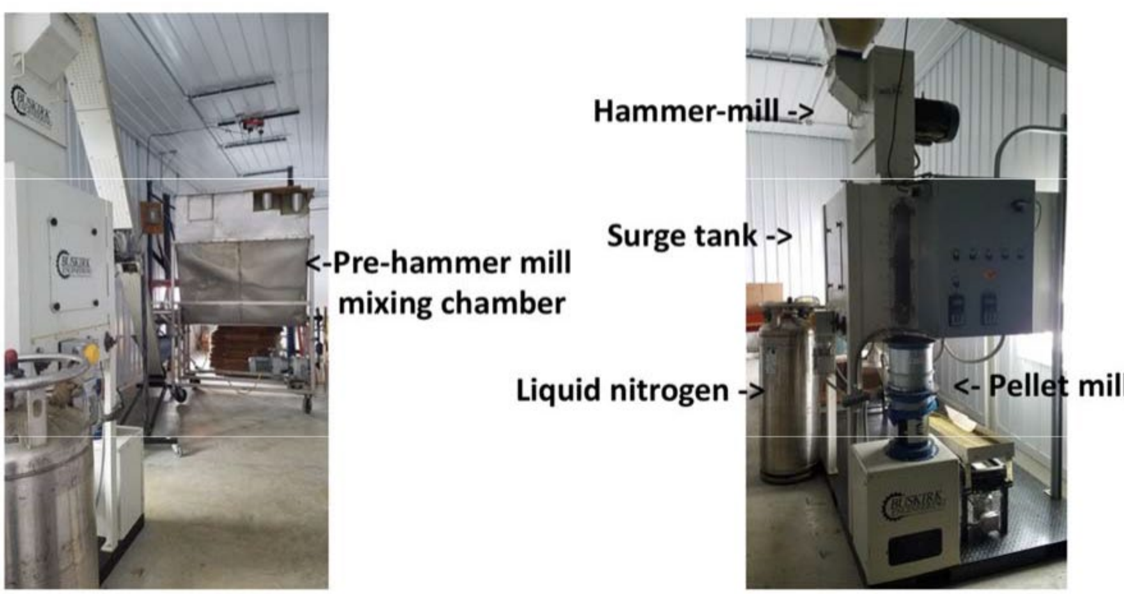

Figure 4. Pelleting system used in this project

Figure 5. Temperatures measured at the exit of the pellet extruder

RESULTS AND DISCUSSION.

In the present study, the effect of harvest timing as well as a number of post-harvest treatments (pre-drying, drying, storage and pelleting conditions) were evaluated to determine their effects on the quality of hop cones and pellets. Chinook, Tahoma and Sterling hops were the selected varieties, and the effect of such conditions were studied during two consecutive years (2016 and 2017). Representative samples were obtained in duplicate each year and official American Society of Brewing Chemist's methods were used to determine quality parameters such as the alpha and beta acid contents, total oil content, moisture, hop storage index (HSI), and specific components of the hop oils. Statistical analyses were conducted using JMP statistical software and are reported at 95% confidence. The following figures and tables summarize the results obtained in this experimental work. For simplicity, the results are presented in five separate sections corresponding to harvest timing, pre-drying, drying, storage, and pelleting steps.

Harvest timing for optimal quality.

This study focused on determining the optimal harvest times of three different hop varieties. Samples of Chinook, Tahoma, and Sterling hops were obtained on different days before, during and after harvest and analyzed to determine the percent alpha and beta acids as well as total oil content. Dry matter was monitored, and hops harvested when Davali Ridge felt that optimum hop quality could be reached using 24% dry matter as a general guideline, fine-tuned with observing lupulin gland plumpness and sensory indicators. In general, the alpha acid content was constant over the sampling period for the three varieties and the two years. A slight increase in the alpha acid concentration was observed in 2016 for Chinook hops, but that value decreased soon after harvest to the initial level. However, all the measured Chinook values were within the expected 12-14% content. The observed year to year variation for the three varieties can be explained based on the age of the bines and the weather conditions. A decrease in the alpha acid concentration prior to harvest was observed in 2016 for Tahoma. 2016 was the first harvest year for 2-year old Tahoma hops. Having no experience harvesting Tahomas, the start date for sampling this variety was likely too early for this later maturing variety. Although Tahomas have small cones, cones were observed to increase in size between the 1st and 3rd sampling periods. In 2017, it was decided to start sampling the Tahomas and Sterlings later than was done in 2016. Less variation was observed during the second year of the study for all three varieties (Figure 6).

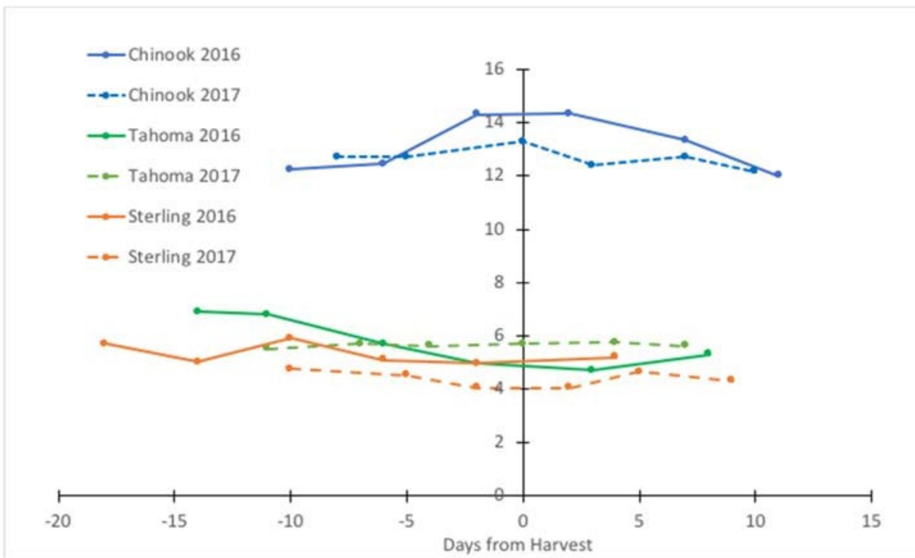

Figure 6. Alpha acid content of three different varieties of hops before, during and after harvest

Changes in beta acid concentration over the sampling period were similar to alpha acids for both years (Figure 7).

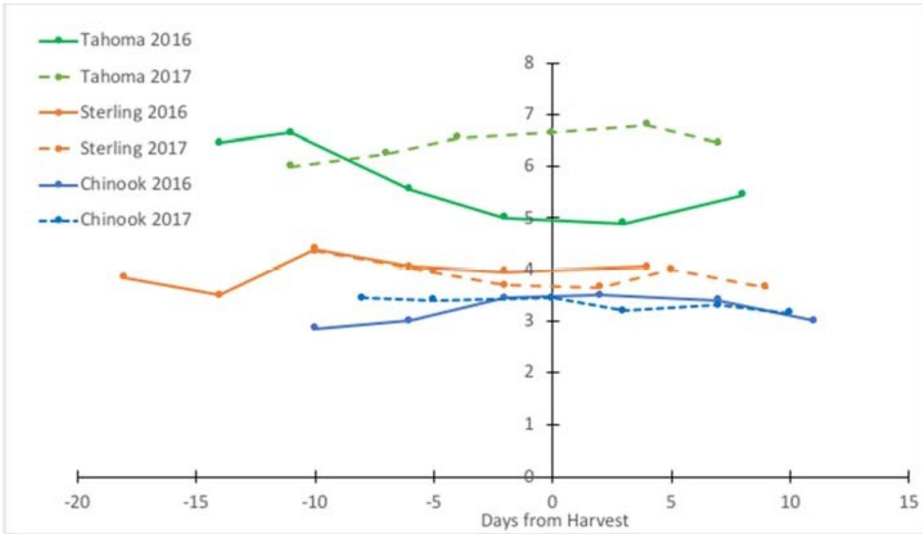

Figure 7. Beta acid content of three different varieties of hops before, during and after harvest

In general, the total oil content continuously increased for all the varieties and the two harvesting years. This trend is consistent with what is reported industry wide (Figure 8).

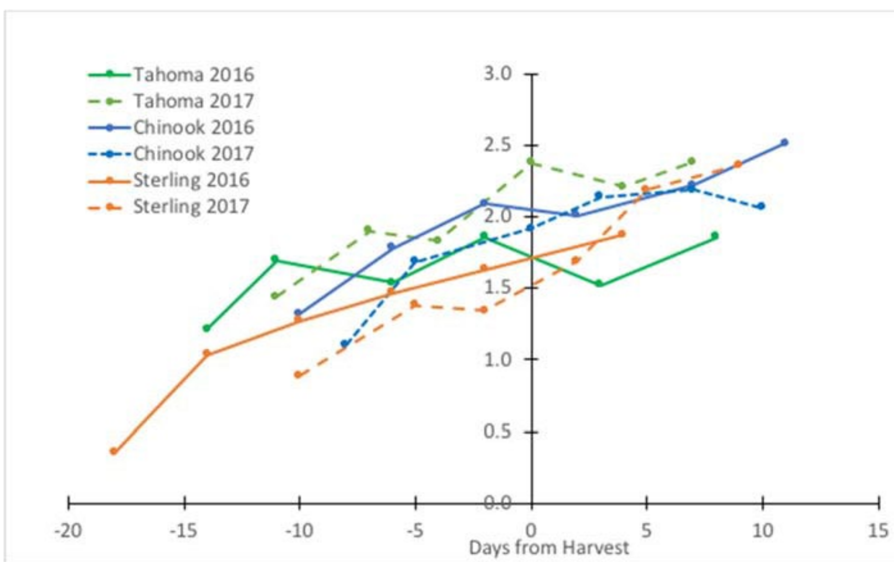

Figure 8. Total oil content of three different varieties of hops before, during and after harvest

The development of alpha and beta acids and total oils within hop cones in this study were similar to that reported by growers and researchers in the Pacific Northwest states. Although Alpha and Beta acids levels varied from year to year, they tended to peak and stay relatively constant for an extended period in the fall. Total oils, on the other hand, continuously increased over the sampling period of this study that extended slightly beyond 10 days after actual harvest.

For this study, Davali Ridge was shooting for a harvest date when alpha acids remained at their peak and total oil levels had increased into the mid to upper end of their typical range using 24% cone dry matter as a general guide. Following are the typical total oil contents for the varieties studied:

Variety	Typical Total Oil content (mL/100 g)
Chinook	1.5 – 2.7
Sterling	0.6 – 1.9
Tahoma	1.0 – 2.0

Based on the results in Figure 8, total oil at harvest ended up in the middle of the range for Chinook, middle to upper end of the range for Sterling, and upper end of the range for Tahoma. The decision of when to harvest may depend on your end user preference. Based on discussions with brewers, some feel that harvesting on the early side results in cleaner less harsh bittering and a better flavor/aroma profile, whereas others feel that for some brews they prefer the bittering of a later harvest that also maximizes the flavor and aroma from increased oil content.

Other agronomic, weather, and varietal factors may influence harvest date, such as forecasted periods of heavy rain, late fungus infections causing cone deterioration, varieties that tend to cone shatter during later harvests. As suggested by Pacific Northwest growers and USDA researchers, using dry matter as a tool to determine harvest date, and harvesting when cone dry matter is within the range of 20-25% appears to be a good place to start. The percent dry matter to harvest at however will be dependent on several factors, including varietal factors, weather, agronomic, and end user preferences for the hop characteristics they are looking for in their beers.

Identify the major post-harvest factors (period of harvest through delivery of product to brewer) that can most influence degradation of hop quality

Period between harvest and drying

This study was designed to evaluate the effect of pre-drying storage conditions on dried hop cone quality as compared to freshly harvested cones. New hop growers in Wisconsin and other Midwest states often do not have the resources initially for all the needed hop growing and processing equipment, so therefore opt to haul bines to another location for stripping and return the cones to their facility for drying. If not handled carefully, wet hop cones can quickly heat up and 'stew' during transportation, causing browning and potentially a decrease in quality. In this experiment, the amount of alpha and beta acids along with the HSI and total oil was measured in freshly harvested cones, and cones exposed to either low or no air flow prior to drying. The goal of the ‘No air’ treatment (putting hops in a closed box container) was to force the hop cones to heat up and potentially start “stewing” between harvest and drying.

However, this treatment was unsuccessful in heating the hop cones or causing stewing in either year. Therefore, there was no difference in temperature as a result of treatments. The goal of the ‘Low air’ treatment (applying a low volume of non-heated air to the hop bed) was to keep the hop bed cool while harvesting prior to drying. Figures 9 to 11 summarize the results obtained for the three varieties selected in this study (Chinook, Sterling, and Tahoma). Simple inspection of these figures suggests that contact with low amounts of air had a negative impact on the alpha and beta acid content of Chinook and Sterling cones. In both cases, the content of those acids was reduced significantly as compared to the freshly harvested cones. No significant changes were observed in terms of the HSI for these varieties. However, such differences in the amount of alpha and beta acids were not observed for the experiments conducted using Tahoma hops (Figure 11).

A very small but statistically significant reduction in the HSI index was observed but the difference in the magnitude of the change is practically negligible (Table 1). The total amount of oil in Chinook cones remained constant, whereas the amount of oils in Sterling and Tahoma hops, decreased in both treatments compared to the freshly harvested cones. It is hard to explain why hop acids or total oils would significantly decrease with exposure to ambient air without added heat. There was a fair amount of variability in the results and some error bars showed some overlap. Therefore, due to the limited replications, it cannot be concluded that some of the overlap is due to data outliers or actual differences.

The reason for applying low ambient air flow to hops is to prevent over-heating and potential stewing, which is universally accepted as being detrimental to hop brewing quality. Even though the data suggests that applying air flow to hops may marginally degrade AA and BA, it remains unclear due to the variation between samples and that more replications are needed to further substantiate the effects of air flow on hop quality.

Drying cones within a short period of time after harvest, limiting their exposure to air, and keeping the hops at relatively low temperatures is suggested to minimize undesirable effects on the quality of hop acids and oils. However, until more replications can substantiate this study’s results, applying low amounts of air to hops prior to drying, if needed to avoid hops from heating and potential stewing would still be recommended.

Table 1. Quality parameters measured in three varieties of hops before drying.

Variety	Treatment	Total Alpha Acids (%)	Total Beta Acids (%)	HSI	Total Oil (mL/100g)	
Chinook	Harvest	13.0^{A}	3.3^{A}	0.24^{A}	2.9^{A}	Low
	Air	9.0^{C}	2.4^{B}	0.25^{A}	2.9^{A}	No
	Air	11.0^{B}	3.3^{A}	0.23^{A}	2.9^{A}	
Sterling	Harvest	5.5^{A}	4.7^{A}	0.25^{A}	2.0^{A}	Low
	Air	3.2^{C}	3.1^{B}	0.23^{B}	1.0^{B}	No
	Air	4.1^{B}	3.4^{B}	0.25^{A,B}	0.9^{B}	
Tahoma	Harvest	4.5^{A}	5.8^{A}	0.20^{B}	2.9^{A}	Low
	Air	4.6^{A}	5.3^{A,B}	0.25^{A}	1.8^{B}	No
	Air	4.3^{A}	5.0^{B}	0.25^{A}	1.7^{B}	

Data corresponds to the average of four samples taken over two years. Treatments sharing letters are not statistically different (95% confidence).

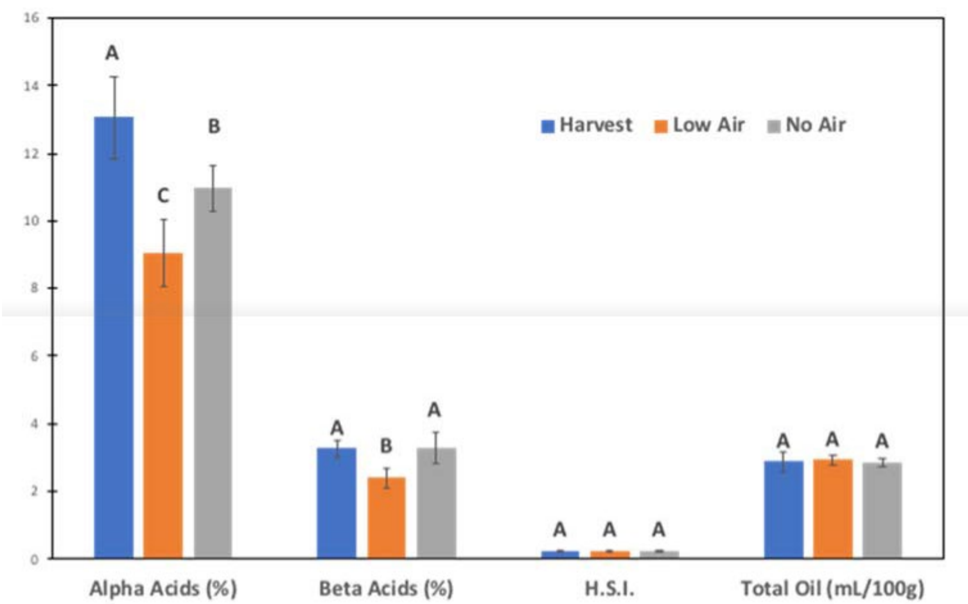

Figure 9. Effect of the pre-drying conditions on the quality of Chinook hop cones.

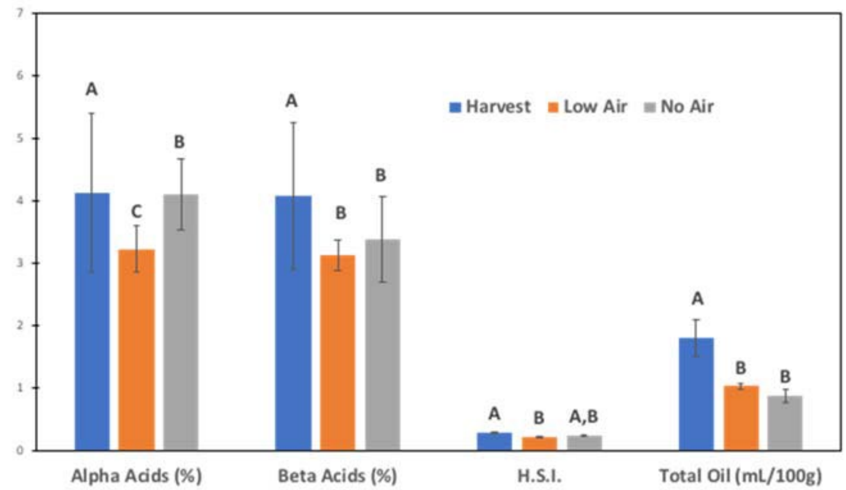

Figure 10. Effect of the pre-drying conditions on the quality of Sterling hop cones.

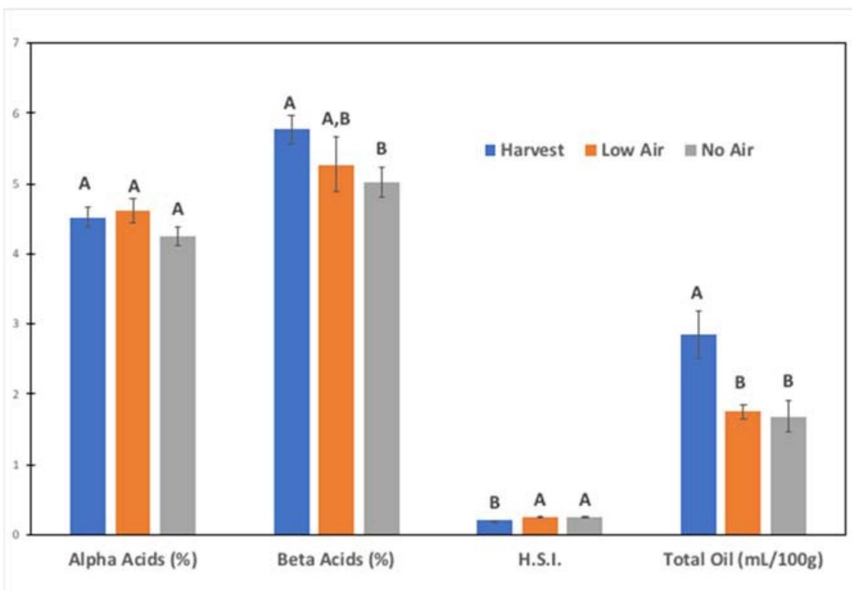

Figure 11. Effect of the pre-drying conditions on the quality of Tahoma hop cones.

Drying

It is commonly accepted that hop quality decreases when hop cones are exposed to high temperatures and oxygen. Freshly harvested hop cones have moisture contents between 75 - 80% and are typically dried to final moisture contents of 8 - 12% using forced-air heated at temperatures close to 140 ˚F. In recent years, new hypotheses stating that either lower temperature or no temperature (using dehumidification) drying maintains higher quality (higher alpha and beta acids, higher essential oils, lower HSI values) have emerged. In order to study the effect of drying temperature on these hop quality parameters, the three varieties of hops were dried at 70, 110 and 140 ˚F for the amount of time required to reduce the moisture content of the cones to approximately 10%. The drying times used in the present study increased substantially with decreasing drying temperature, with cones drying within 7 hours at 140 ˚F for Chinook and up to 37.25 hours at 70 ˚F for Tahoma.

As explained earlier in the Materials & Methods, bed temperatures were recorded every 2 – 3 hours throughout the drying treatments. Temperature probes were placed, and temperature recorded below the hop bed, bottom 1/3, middle, top 1/3, and above the hop bed. An example of the temperature profile in the drying bin is shown in Figure 12. Similar bed temperature profiles were observed for all varieties and treatments.

140 ˚F

Above hop bed (14 - 17")	79	79	87	126
Top 3rd (10 - 13")	80	81	90	127
Middle (6 -8")	79	83	111	131
Bottom 3rd (2")	104	122	132	135
Beneath the bed	138	138	140	137
Total bed depth	16"	15"	13"	13"
%RH	69	67	70	68
Hours after start	0.5	2.5	4.75	7.25

110 ˚F

Above hop bed	68	85	95	100	101	101
Top 3rd (10 - 13"	74	88	90	96	97	100
Middle (6 - 8")	74	88	88	95	98	102
Bottom 3rd (2")	85	102	98	102	104	106
Beneath the bed	110	110	110	109	109	111
Total bed depth	18"	16"	13"	13"	13"	13"
%RH	69	70	70	70	70	70
Hours after start	0.5	3	5.5	7.25	9.25	12

No heat - 70 ˚F

Above hop bed	65	62	65	62	66	67	65	62	65	67	65	66
Top 3rd (9 - 11")	65	64	64	65	65	67	65	64	65	65	62	66
Middle (5")	65	66	66	66	66	68	65	67	65	66	65	65
Bottom 3rd (2")	69	67	70	70	68	68	65	65	69	64	64	64
Beneath the bed	69	70	70	71	68	68	65	68	70	64	65	66
Total bed depth	10	9	9	9	8	8	8	8	8	8	8	8
%RH	71	83	78	71	59	49	42	40	45	39	37	37
Hours after start	0.75	3	5.25	7.5	9.5	13	23.75	27.25	29.5	31.25	33.25	36

Figure 12. Temperature variation within the drying bin observed for Tahoma hops (Rep 1, 2017) at different temperature treatments.

The drying data shows that initially, as heated air rose through the bed, evaporative cooling kept the hops 25 – 34 degrees cooler at the bottom of the bed than the heated air entering the bed, and near ambient air temperature in the top 1/3 of the bed. However, as the hops dried, the bottom of the bed gradually rose near to the treatment temperature and a temperature gradient formed throughout the bed. Over time, the bed temperature gradually rose from bottom upwards as the hops dried. At the end of the drying cycle the bottom of the bed measured close to the treatment temperature. The bed temperature gradually declined upwards, with the top of the bed 6 - 8 degrees cooler than the bottom of the bed. This data shows the power of evaporative cooling, and its ability to maintain cool hop temperatures during initial drying.

The combined effect of drying temperatures and the different drying times used to achieve a moisture content of 10% on the quality of the hops with respect to the freshly harvested cones is summarized in Table 2.

Table 2. Effect of drying temperature on the quality of three different varieties of hops

Variety	Air Temperature (F°)	Total Alpha Acids (%)	Total Beta Acids (%)	H.S.I	Total Oil (mL/100 g)
Chinook	Harvest	13.05^{A}	3.26^{A}	$0.24^{A,B}$	2.88^{A}
	140 ˚F	$13.25^{A,B}$	$3.25^{A,B}$	$0.22^{A,B}$	1.20^{B}
	110 ˚F	$9.39^{B,C}$	2.60^{B}	0.26^{B}	1.30^{B}
	70 ˚F	8.60^{C}	2.43^{B}	0.22^{B}	1.35^{B}
Sterling	Harvest	5.48^{A}	4.65^{A}	0.25^{A}	1.98^{A}
	140 ˚F	2.60^{C}	2.50^{C}	0.24^{A}	1.00^{B}
	110 ˚F	$3.15^{B,C}$	3.13^{B}	0.25^{A}	1.08^{B}
	70 ˚F	3.78^{B}	3.35^{B}	0.24^{A}	1.10^{B}
Tahoma	Harvest	4.53^{A}	5.77^{A}	0.20^{A}	2.85^{A}
	140 ˚F	4.65^{A}	4.15^{C}	0.23^{A}	1.40^{B}
	110 ˚F	4.38^{A}	5.10^{B}	0.26^{A}	1.75^{B}
	70 ˚F	4.58^{A}	$5.60^{A,B}$	0.25^{A}	1.60^{B}

Data corresponds to the average of four samples taken over two years. Treatments sharing letters are not statistically different (95% confidence).

Figures 13 to 15 summarize the results obtained for Chinook, Tahoma and Sterling cones when combining data from the two years of the experiment. Different effects were observed for each of the varieties tested. It is unclear whether the drying time or the size and geometry of the cones or the year to year variation observed, have an important role that might contribute to explain the unexpected results observed in this project. Our data shows that for Chinook hops, alpha acids did not decrease when dried at 140 ˚F compared to fresh cones at harvest. However, lowering the drying temperature to 110 and 70 ˚F resulted in decreased Alpha Acids (AA). This trend is opposite to the one observed for the other two varieties evaluated in this study. When looking at the data obtained for the 2016 and 2017 harvest years, it is evident that the AA content of the Chinook hops dried at 140 ˚F is unexpectedly higher than the results observed for the same variety at the other experimental conditions in both years.

The relatively low number of replicates combined with that high AA value can explain the trend observed when combining data from the two harvest years. Data from 2016 suggest that, for Chinook, there is no statistical difference between the AA in hops dried at 140 and 110 ˚F. A slight decrease was observed in the hops dried at 70 ˚F. The results obtained in 2017 showed that there was only a marginal difference between the AA in hops dried at 110 ˚F and the ones dried at the lowest temperature. However, the major decrease was still observed when drying at 70 ˚F. For Sterling hops the AA content decreased at all drying temperatures compared to fresh cones at harvest (Figure 14). For this variety, it was observed that %AA decreased more when higher temperatures were used. No statistical differences were observed for the treatments at 110 and 70 ˚F. For Tahoma hops, drying temperature showed no effect on the alpha acid content.

The beta acid content remained relatively constant for Chinook hops regardless of the temperature used, as only marginal statistical differences were observed for this variety. However, for Sterling and Tahoma, low drying temperatures resulted in higher beta acid contents. Hop storage index of all varieties remained relatively unchanged regardless of the selected drying temperature. Statistical differences were observed for Chinook cones, but the magnitude of the change is negligible for practical purposes. There were no differences in total oils at any of the drying temperatures for all varieties. However, drying hops at any of the temperatures significantly reduced total hop oils for all varieties when compared to the freshly harvested samples.

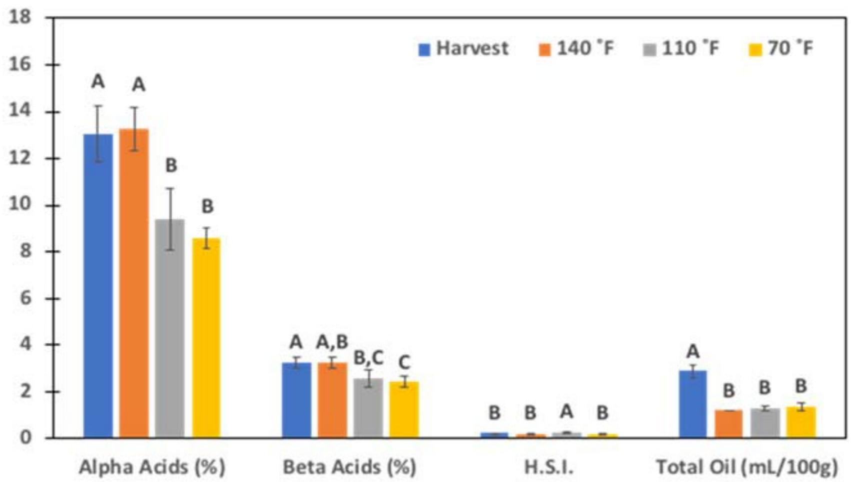

Figure 13. **Effect of drying conditions on the quality of Chinook hop cones.**

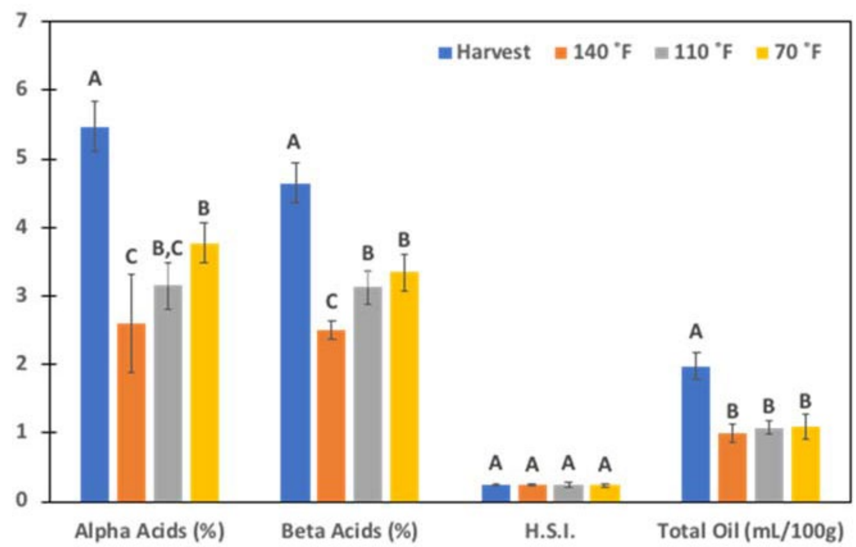

Figure 14. **Effect of drying conditions on the quality of Sterling hop cones.**

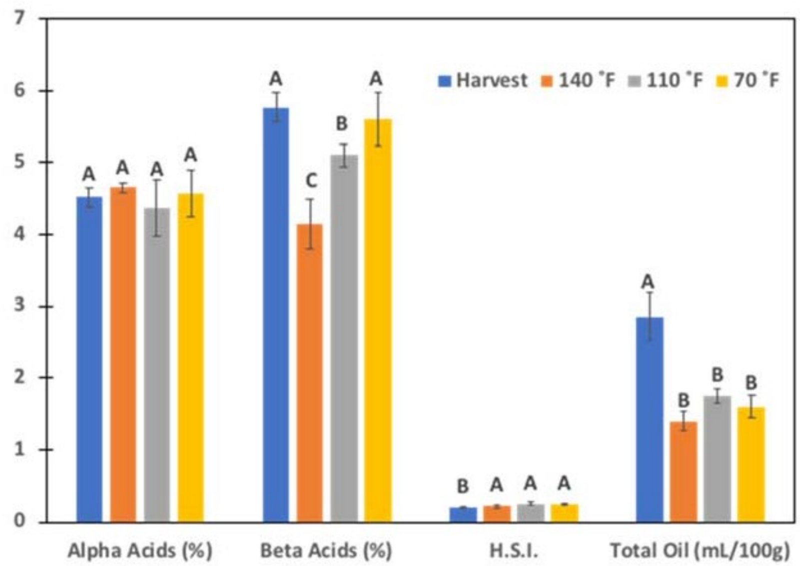

Figure 15. Effect of drying conditions on the quality of Tahoma hop cones.

In general, drying temperatures had an influence on the measured amount of alpha and beta acids. However, the effects were dependent on variety and could negatively or positively affect these quality parameters. Similar trends were observed in 2016 and 2017. It is hard to explain the reasons for these varietal differences from the data in this study. Cone characteristics were quite different between the varieties studied.

Chinook has a medium to large elongated heavy somewhat dense cone. Sterling also has a somewhat dense cone, however is medium in size. Tahoma has numerous small cones of lower density. With regards to alpha and beta, it could be hypothesized that optimum drying temperature may be dependent on a variety's cone characteristics. It may also be hypothesized that drying time may play a larger role than temperature in decreasing the amount of those acids in Chinook and other varieties. In our study, the low number of replications limited our ability to discern differences. Testing of these hypotheses may warrant future study.

Also, the length of drying period was affected greatly by drying temperature. Typical drying times at 140 ˚F averaged from 7 to 9 hours, 110 ˚F from 10 to 14.5 hours, 70 ˚F from 24.5 to 37.25 hours. With the 140 and 110 ˚F treatments, it was possible to dry the days harvest over-night, empty the hops to a conditioning room to make the hop dryer (oast) available for the next day's harvest. Using the 70 ˚F dehumidifying oast, an operation would be required to have two oasts to allow for daily harvesting. In a 2012 hop drying study presented by Dr. Val Peacock, at the University of Wisconsin – Extension winter hop workshop on March 2, 2013, it was observed that hops at the bottom of the bed, where 130 or 150 ˚F forced air treatments were applied, developed an onion/garlic off- flavor. That effect was not observed in hops located in the middle or top of the bed where cooler hop temperatures prevailed. In addition to that, the study reported loss of oils at the 150 ˚F treatment at thicker bed depth, which they attributed to inadequate air flow.

It appears that, based on the results of this and other studies that drying temperature has an important effect on the final concentration of AA, BA and total oils. In prior discussions, brewers that have done brewing trials on hops brewed at varying drying temperatures, prefer the beers brewed with hops dried at lower temperatures. They experience cleaner bittering and better flavor in batches of beer made with hops from the upper areas of the bed where temperatures were 10-15 degrees lower than the ones made with hops from lower areas of the oast where temperatures reached approximately 140 ˚F. Brewing trials were not included in our study reported here, therefore it cannot be stated whether hops dried at no temperature (70 ˚F) or low temperature (110 ˚F) were superior in that regard to those dried at higher temperatures (140 ˚F). However, this would be an interesting area for future study.

Therefore, based on the results of this and previous studies and experiences, the recommendation would be to dry hop cones at either low or no temperatures. Another factor to consider is drying time. Drying at low temperatures will allow a grower to use the oast on a daily basis. Drying using dehumidified air at ambient temperatures will tie up a grower’s dryer for at least 2 days, forcing them to harvest every other day or have more than one oast. However, there may not be as much of a difference in the moisture content of the strig (stem inside the cone) compared to the bracts and bracteoles (cone petals), reducing the time or need for a conditioning period. Therefore, the total time from start of hop drying to baling may be similar for low heat versus no heat drying.

Another potential drying technique that could result in shorter drying times with minimal effect on hop quality would be to take advantage of evaporative cooling. Start drying at 140 ˚F. Monitor the bed temperature by depth. Evaporative cooling will initially maintain bed temperatures below 110˚F. As bed temperature rises, gradually decrease dryer temperature to maintain bed temperatures below 110 ˚F. Future studies on drying temperature appear to be warranted, however more replications and better controls on variation need to be implemented to come up with conclusive results and recommendations.

Storage

Dehydrated hop comes were stored at different levels of compression and temperatures. Loose dry cones and dry cones compressed at 4.45 (low) or 8.9 (high) lb./ft^3 were stored at room temperature, refrigerated or in frozen storage units to determine optimum storage conditions. The same quality parameters used to evaluate hops before drying were measured and the results are summarized in Table 3 and Figures 16 to 18. In general, the samples stored at room temperature and compressed at 4.45 lb./ft^3 notoriously decreased in quality. Significant decreases in the amount of alpha and beta acids as well as total oil content was observed for all three varieties when stored under such conditions.

The increase in HSI is also an indicator of the quality loss caused by storing the dry cones at room temperature prior to pelleting. Interestingly, the compression level and the effect of refrigeration or freezing on the quality parameters measured was negligible. Thus, indicating that low temperature storage is more important than the level of compression in terms of preserving the quality of the dehydrated hops prior to pelleting.

Table 3. Quality parameters measured in three varieties of dehydrated hops stored at different compression levels and temperatures

Variety	Treatment Letter	Total Alpha Acids (%)	Total Beta Acids (%)	H.S.I	Total Oil (mL/100 g)
Chinook	Loose, Refrigeration	11.8^{A}	3.3^{A}	0.23^{B}	$1.9^{A,B}$
	Low Compression, Refrigeration	11.9^{A}	3.2^{A}	0.24^{B}	$1.9^{A,B}$
	High Compression, Refrigeration	11.5^{A}	3.5^{A}	0.24^{B}	$1.9^{A,B}$
	Low Compression, Refrigeration	9.5^{B}	2.6^{A}	0.30^{A}	1.7^{B}
	Low Compression, Freezer	11.5^{A}	3.5^{A}	0.24^{B}	1.9^{A}
Sterling	Loose, Refrigeration	3.6^{A}	3.6^{A}	$0.28^{A,B}$	1.4^{A}
	Low Compression, Refrigeration	3.5^{A}	3.5^{A}	0.25^{B}	1.5^{A}
	High Compression, Refrigeration	3.3^{A}	3.6^{A}	0.26^{B}	1.4^{A}
	Low Compression, Refrigeration	2.3^{B}	2.3^{B}	0.39^{A}	1.2^{B}
	Low Compression, Freezer	3.4^{A}	3.5^{A}	0.25^{B}	1.5^{A}
Tahoma	Loose, Refrigeration	4.4^{A}	5.6^{A}	0.26^{B}	1.7^{A}
	Low Compression, Refrigeration	4.8^{A}	5.8^{A}	0.28^{B}	$1.6^{A,B}$
	High Compression, Refrigeration	4.5^{A}	6.0^{A}	0.25^{B}	1.5^{B}
	Low Compression, Refrigeration	2.0^{B}	3.0^{B}	0.62^{A}	$1.6^{A,B}$
	Low Compression, Freezer	4.3^{A}	6.0^{A}	0.23^{B}	$1.7^{A,B}$

Data corresponds to the average of four samples taken over two years. Treatments sharing letters are not statistically different (95% confidence).

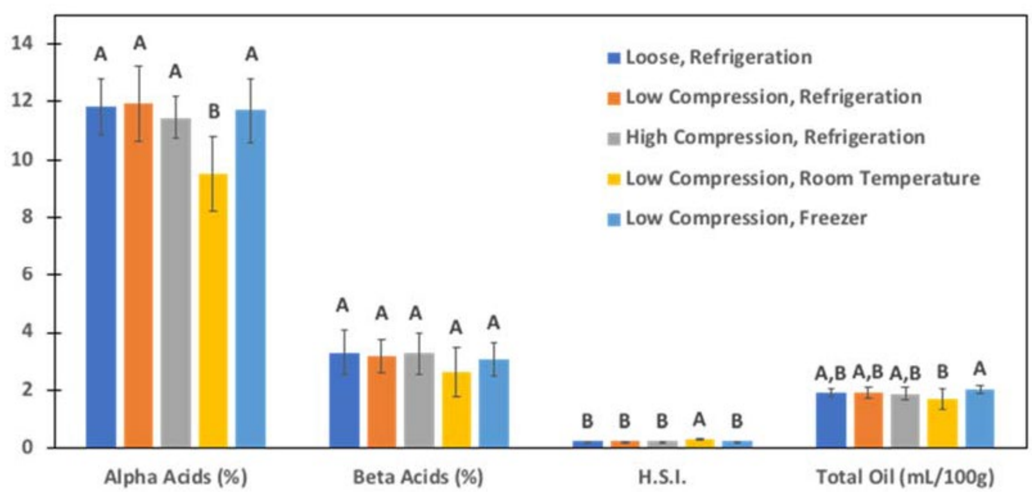

Figure 16. Effect of compression level and storage temperature on the quality of Chinook dehydrated hop cones

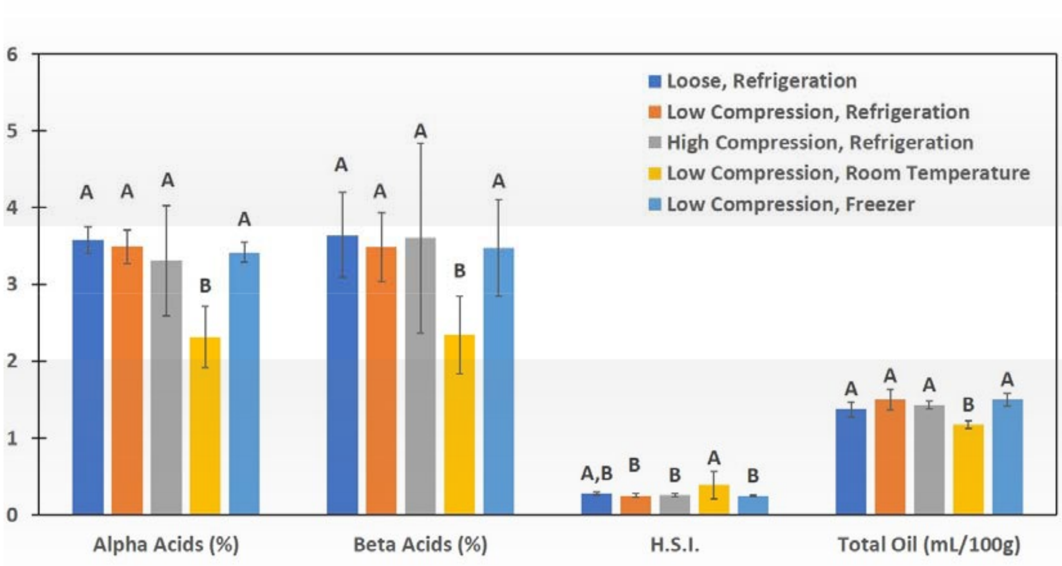

Figure 17. Effect of compression level and storage temperature on the quality of Sterling dehydrated hop cones

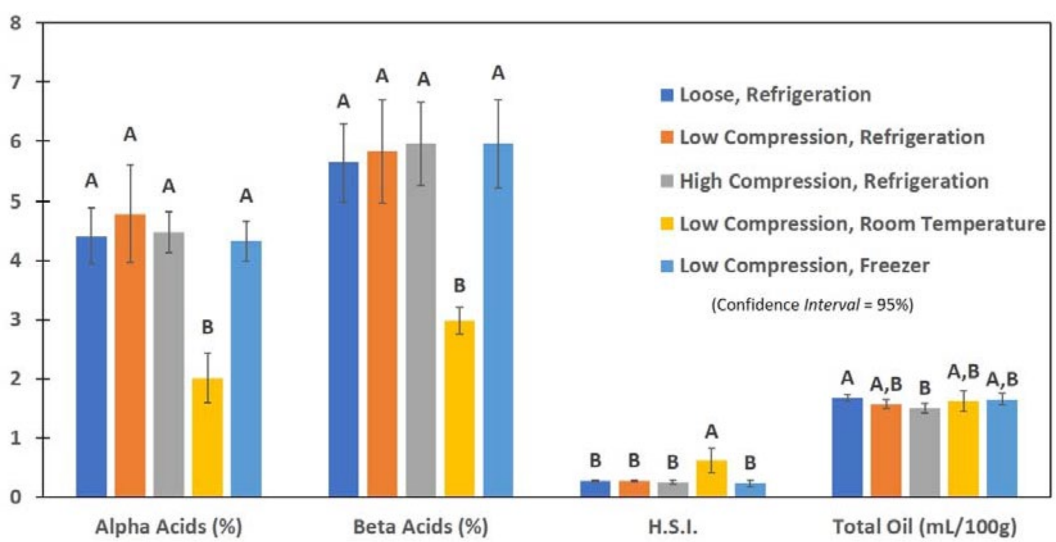

Figure18. Effect of compression level and storage temperature on the quality of Tahoma dehydrated hop cones

There were no discernible differences in hop cone color as a result of any of the treatments with the exception of the low compression, room temperature treatment, where cones resulted in a lighter green to brown color (Figure 19). Similar behavior was observed for all the varieties.

Figure 19. Color differences of dehydrated hops stored at varying temperatures

Pelleting

Hops are usually purchased by breweries in the form of pellets. In general, dried pellet cones are milled into fine particles and then extruded to create pellets of a specific size and shape. The extrusion process generates heat, that can lead to detrimental effects on the quality of the hops. It is generally recommended to pelletize hops at the lowest temperature possible. The purpose of this part of the study was to determine optimal ranges of pelleting temperatures to preserve the quality of three different varieties of hops. Three different temperature ranges were used, and the final products were analyzed and compared to the initial milled but un-pelleted material. The results of these experiments are summarized in Table 4 and Figures 20 to 22. In general, the results suggest that the quality changes observed were minimal and dependent on the variety used. The most relevant changes were observed when comparing the total amount of oil in Chinook and Tahoma after extrusion. It is important to mention that controlling temperature to create the wide variation in treatment temperatures was challenging. Variations in the temperature of the pelletizer as well as relatively short processing times might have affected the outcome of this trial. Based on the HSI and oil results from this study, the pelleting process can degrade hops somewhat. However, inherent hop cone variability and limited replication may have limited the effects of the treatments to express themselves. The current recommendation industry wide is to maintain pellets as cool as possible and not exceed 130 ˚F.

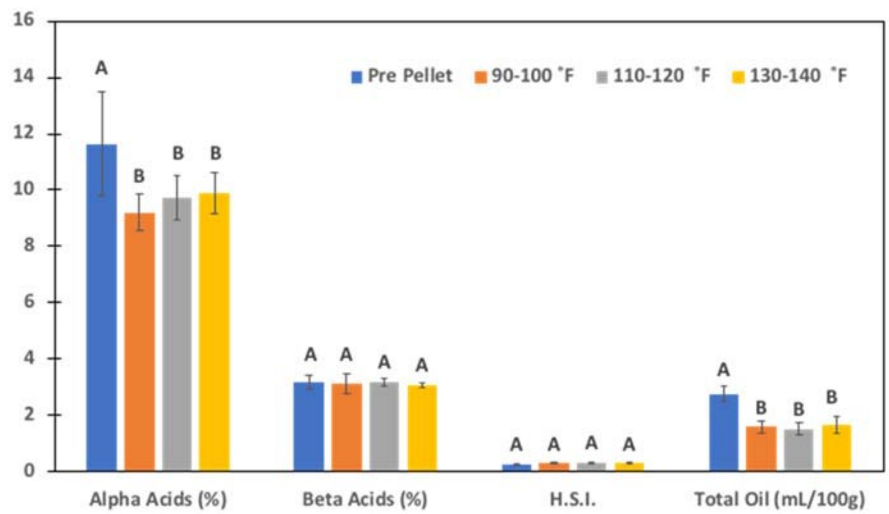

Figure 20. Effect of the pelleting temperature on the quality of Chinook hops

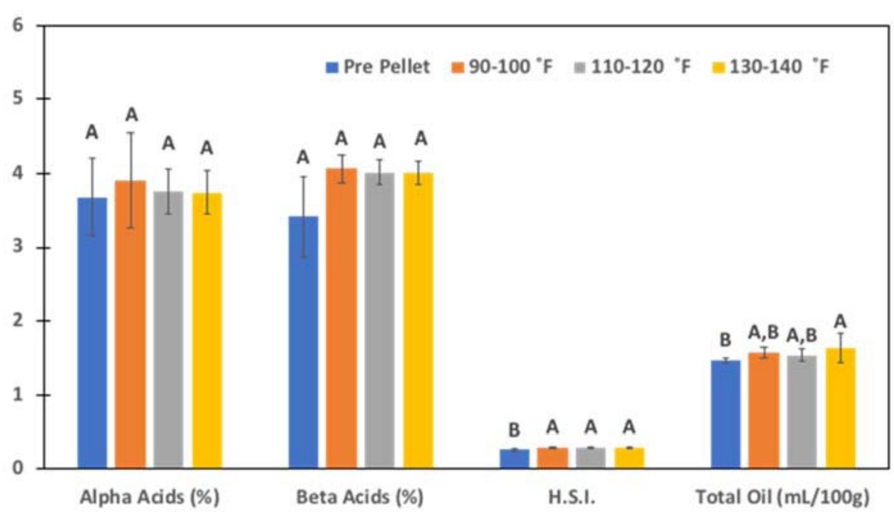

Figure 21. Effect of the pelleting temperature on the quality of Sterling hops

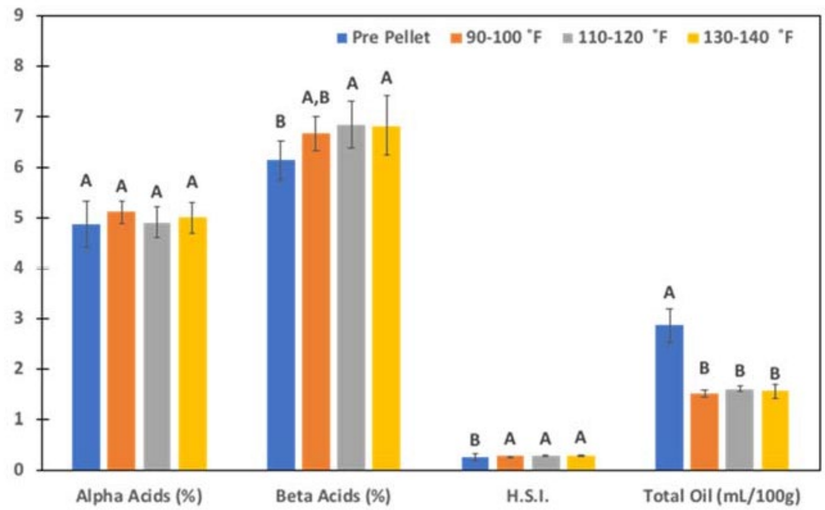

Figure 22. Effect of the pelleting temperature on the quality of Tahoma hops

Table 4. Quality parameters measured in three varieties of hops pelletized at different temperature ranges

Variety	Treatment	Total Alpha Acids (%)	Total Beta Acids (%)	H.S.I	Total Oil (mL/100 g)
Chinook	Pre-Pellet	11.64^{A}	3.19^{A}	0.28^{A}	2.76^{A}
	90-100 ˚F	9.20^{B}	3.12^{A}	0.31^{A}	1.59^{B}
	110-120 ˚F	9.72^{B}	3.19^{A}	0.33^{A}	1.53^{B}
	130-140 ˚F	9.89^{B}	3.08^{A}	0.31^{A}	1.68^{B}
Sterling	Pre-Pellet	3.68^{A}	3.42^{A}	0.27^{B}	1.47^{B}
	90-100 ˚F	3.90^{A}	4.06^{A}	0.29^{A}	1.58^{A,B}
	110-120 ˚F	3.76^{A}	4.02^{A}	0.29^{A}	1.53^{A,B}
	130-140 ˚F	3.75^{A}	4.02^{A}	0.29^{A}	1.63^{A}
Tahoma	Pre-Pellet	4.88^{A}	6.15^{B}	0.26^{B}	2.88^{A}
	90-100 ˚F	5.13^{A}	6.67^{A,B}	0.29^{A}	1.52^{B}
	110-120 ˚F	4.91^{A}	6.84^{A}	0.29^{A}	1.61
	130-140 ˚F	5.01^{A}	6.83^{A}	0.30^{A}	1.57^{B}

Data corresponds to the average of four samples taken over two years. Treatments sharing letters are not statistically different (95% confidence).

Hop oil components
The effect of storage conditions and the temperature used to pelletize the hops on the relative amount of selected essential hop oils components was also monitored in this study in 2017. The change in the concentration (percent of total oil) of -pinene, myrcene, linalool, caryophyllene, farnesene, humulene, and geraniol in dehydrated hop cones was evaluated at different compression levels and storage temperatures. Whereas, for pellets extruded at different temperatures, the levels of co-humulone, co-lupulone, B-Pinene, myrcene, linalool, caryophyllene, farnesene, humulene, and geraniol were monitored.

The amount and type of essential oils in hops is of great importance and largely affects the aroma and flavor that different varieties contribute to the final sensory characteristics of beer. -pinene is a compound that has a woody-green pine-like smell, myrcene has a green and freshly herbaceous aroma, linalool is related to the detection of floral notes, caryophyllene and humulene are herbal/spicy, farnesene contributes woody/earthy character to beers, and geraniol is generally related to the presence of floral aroma in beer. Co-humulone and co-lupulone are resins that have a great impact in the bitterness of beer and are major components of the alpha and beta acids of hops. Figures 23 and 24 show the observed effect of storage conditions on the concentration of essential oils in dehydrated Chinook cones. The most relevant difference observed is the loss of myrcene and -pinene at room temperature. While statistical differences were observed for other components, the magnitude of the change is minimal and can be regarded as not relevant for practical purposes.

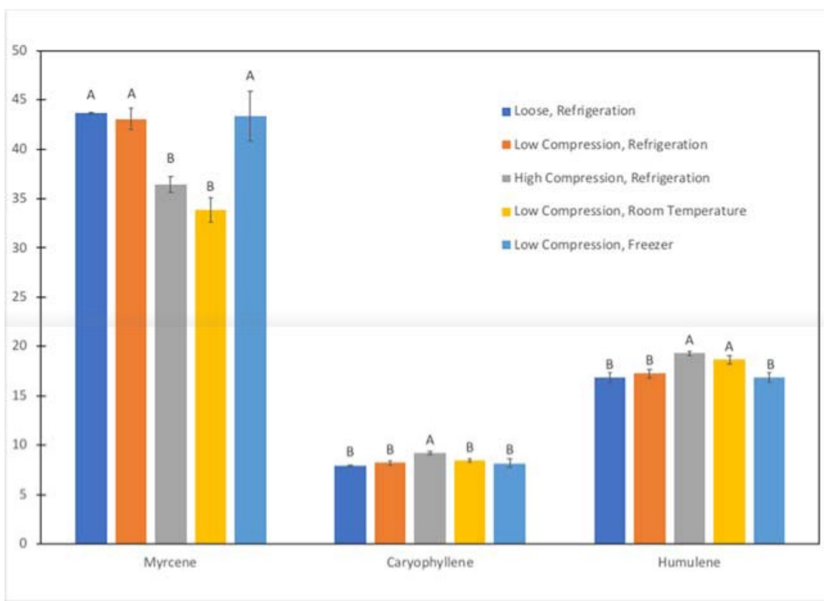

Figure 23. Concentration (percent of total oil) of myrcene, caryophyllene and humulene in dehydrated Chinook cones stored at different compression levels and temperatures.

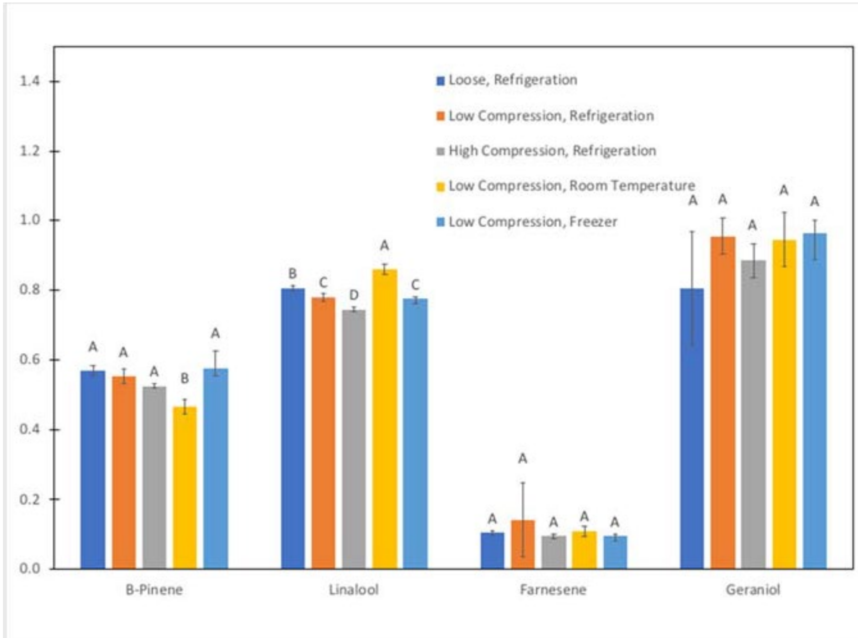

Figure 24. Concentration (percent of total oil) of β-pinene, linalool, farnesene, and geraniol in dehydrated Chinook cones stored at different compression levels and temperatures.

For Sterling cones, similar conclusions can be made (Figures 25 and 26). An unexpected increase in the amount of caryophyllene was observed when the cones were stored at room temperature. However, and due the number of experimental replicates and the relatively low concentration of such compound, it is hard to make solid conclusions or explain the observed results.

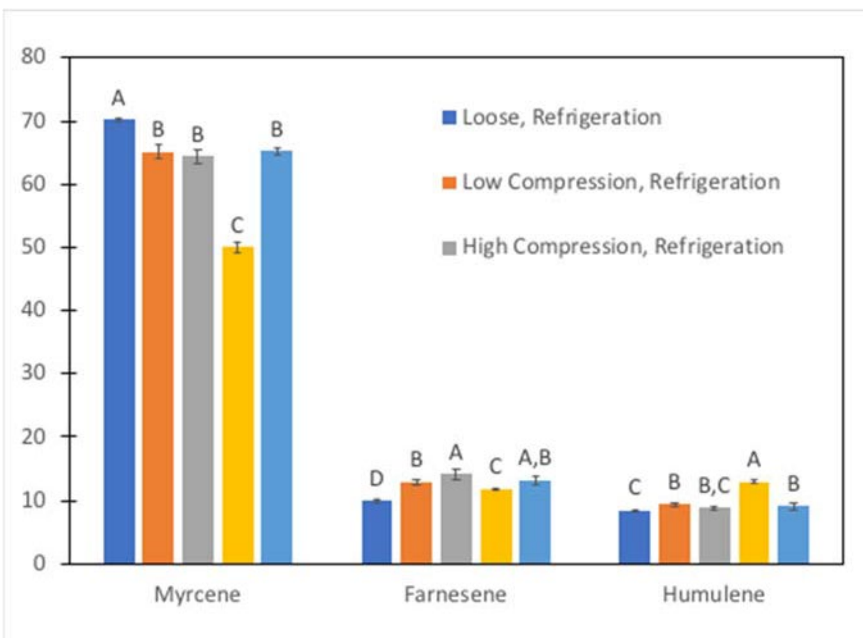

Figure 25. Concentration (percent of total oil) of myrcene, farnesene, and linalool in dehydrated Sterling cones stored at different compression levels and temperatures.

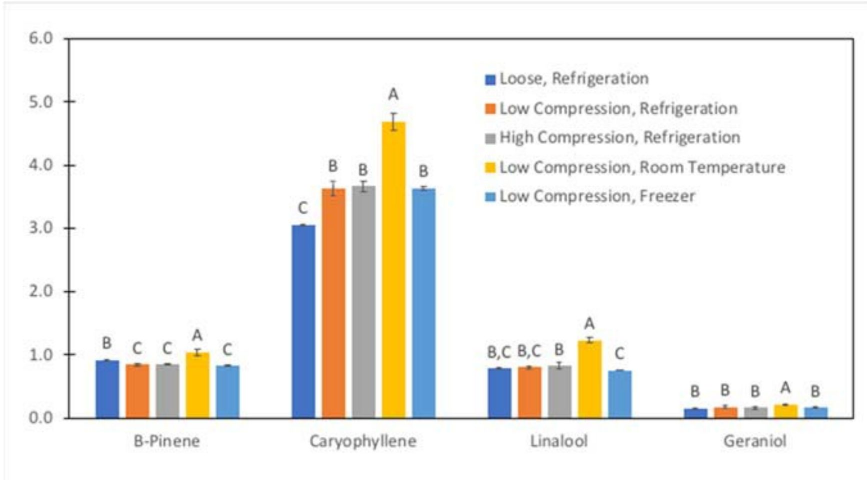

Figure 26. Concentration (percent of total oil) of β-pinene, caryophyllene, linalool, and geraniol in dehydrated Sterling cones stored at different compression levels and temperatures.

A large decrease in the concentration of myrcene was observed when dehydrated Tahoma hops were stored at low compression and room temperature (Figure 27). The relative amount of the essential oil caryophyllene, humulene, and farnesene remained largely unaffected by the storage conditions. Slight increases in the amounts of minor oil components such as β-pinene, linalool, and geraniol was also observed when the dry hop cones were stored at room temperature (Figure 28).

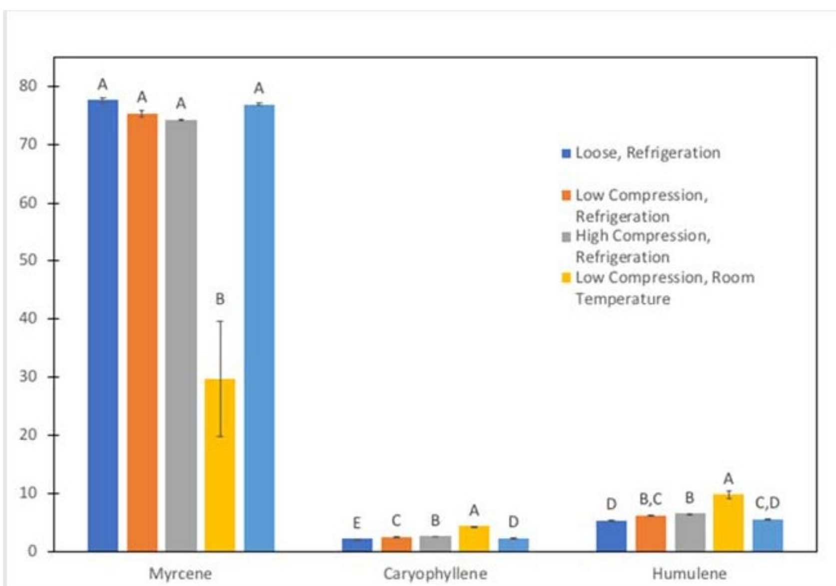

Figure 27. Concentration (percent of total oil) of myrcene, caryophyllene, and humulene in dehydrated Tahoma cones stored at different compression levels and temperatures.

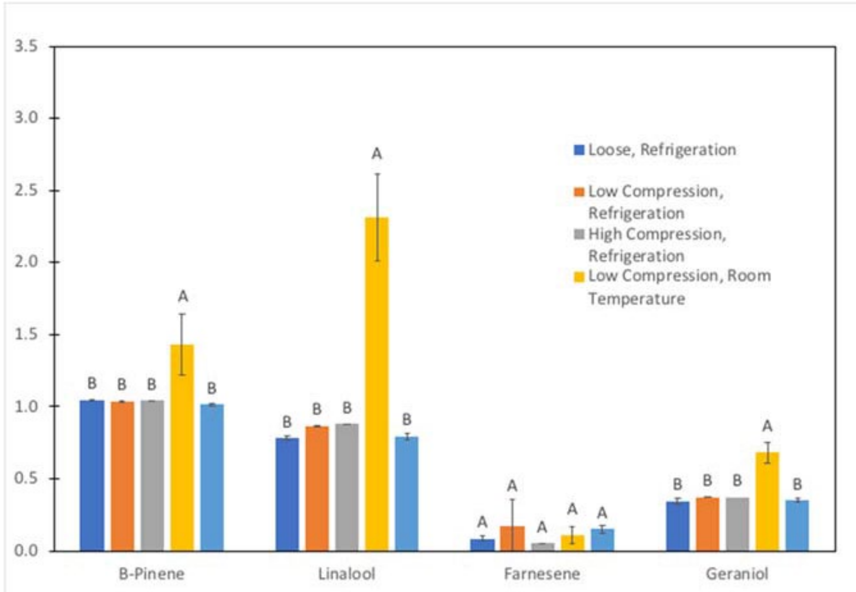

Figure 28. Concentration (percent of total oil) of β-pinene, linalool, farnesene, and geraniol in dehydrated Tahoma cones stored at different compression levels and temperatures.

A similar study was conducted with hop pellets extruded at different temperatures. As shown in Figures 29 and 30, no major changes in components of Chinook essential oil were observed in the pellets made at different temperatures. The observed statistical differences are, in most of the cases irrelevant for practical uses. As expected for this variety, the most abundant components are alpha and beta acids related to bitterness.

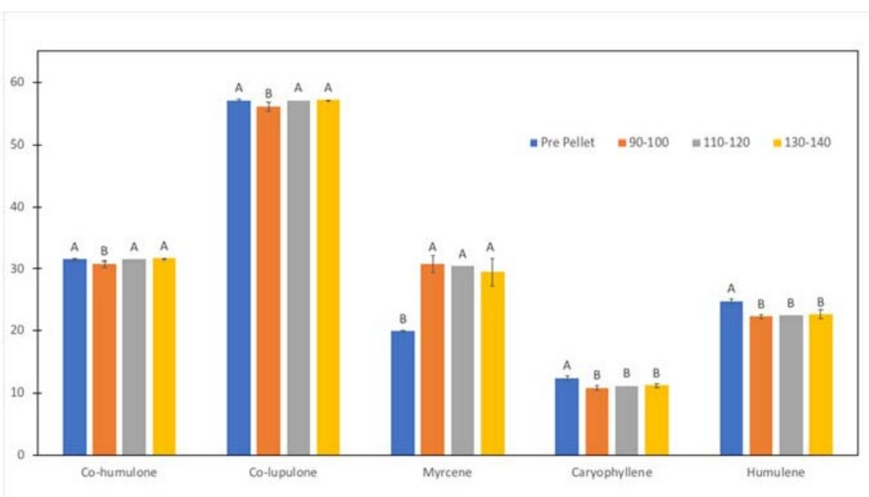

Figure 29. Concentration (percent of total oil) of co-humulone, co-lupulone, myrcene, caryophyllene, and humulene in Chinook pellets extruded at different temperatures.

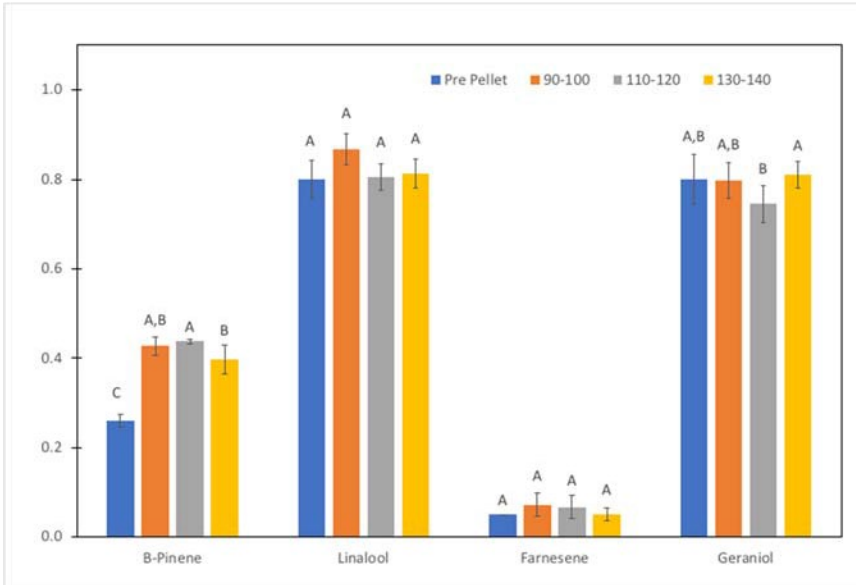

Figure 30. Concentration (percent of total oil) of β-pinene, linalool, farnesene, and geraniol in Chinook pellets extruded at different temperatures.

The results obtained for the pellets made using Sterling hops are shown in Figures 31 and 32 and revealed that the amount of bittering acids remains largely unchanged regardless of the extrusion temperature. High concentrations of the aroma compound farnesene are related to the primary use of this variety. A slight decrease in the concentration of the volatile caryophyllene was observed when extrusion temperature increased.

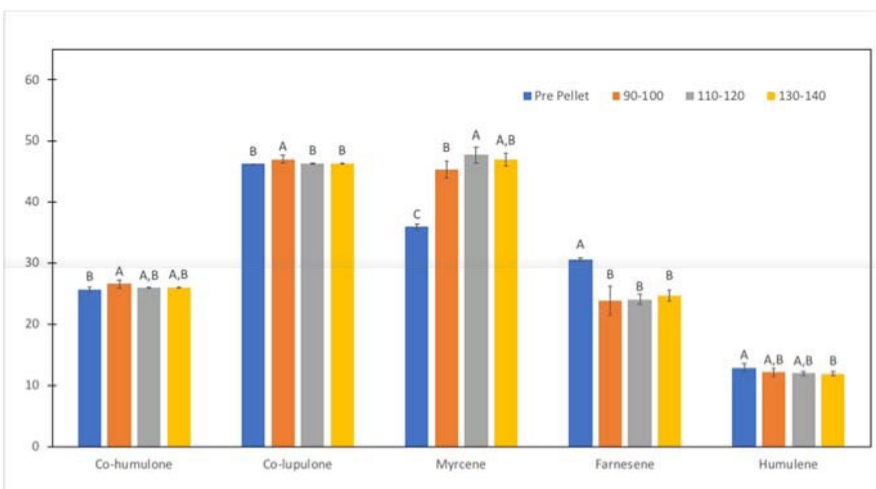

Figure 31. Concentration (percent of total oil) of co-humulone, co-lupulone, myrcene, farnesene, and humulene in Sterling pellets extruded at different temperatures.

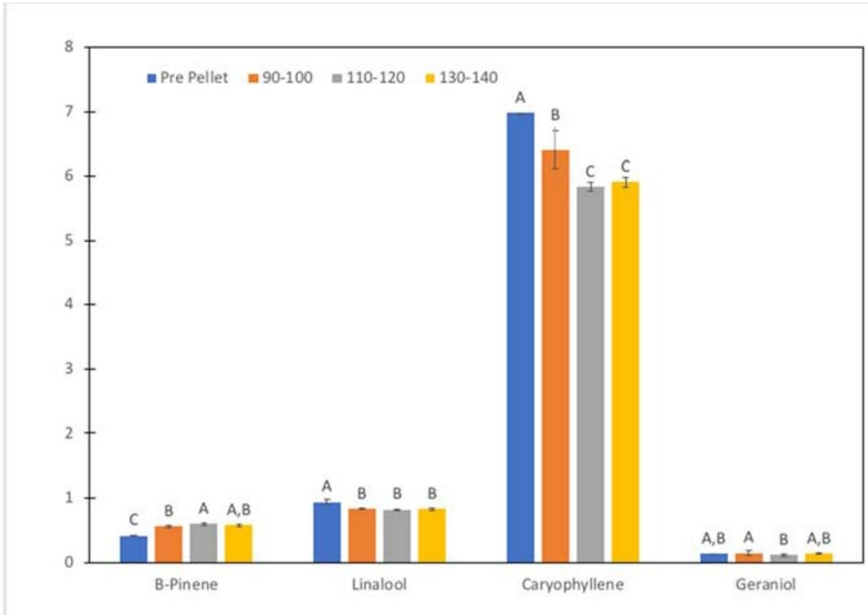

Figure 32. Concentration (percent of total oil) of β-pinene, linalool, caryophyllene, and geraniol in Sterling pellets extruded at different temperatures.

In general, the relative amount of essential oils and hop acids was not affected by the temperature used when making Tahoma hop pellets (Figures 33 and 34).

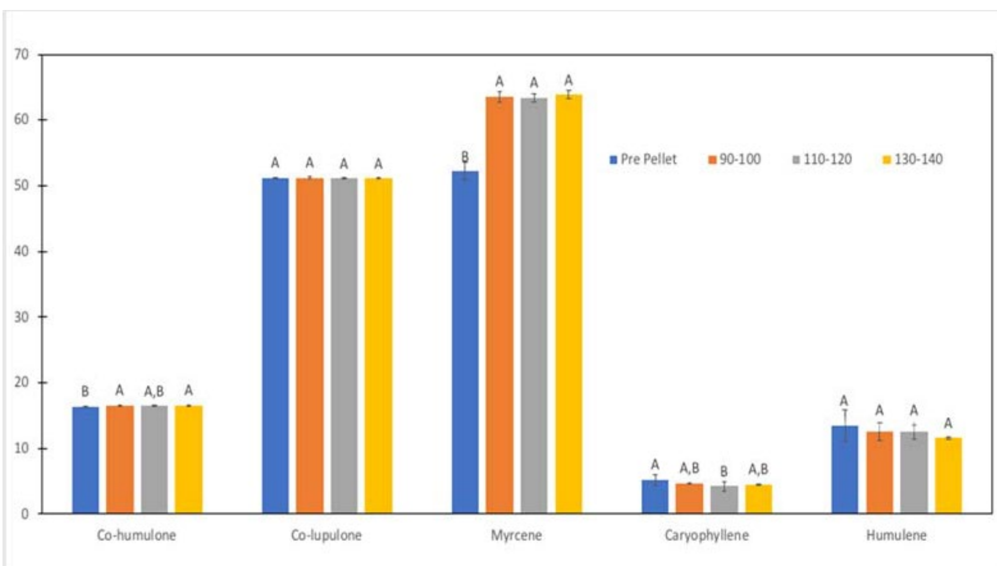

Figure 33. Concentration (percent of total oil) of co-humulone, co-lupulone, myrcene, and caryophyllene, humulene in Tahoma pellets extruded at different temperatures

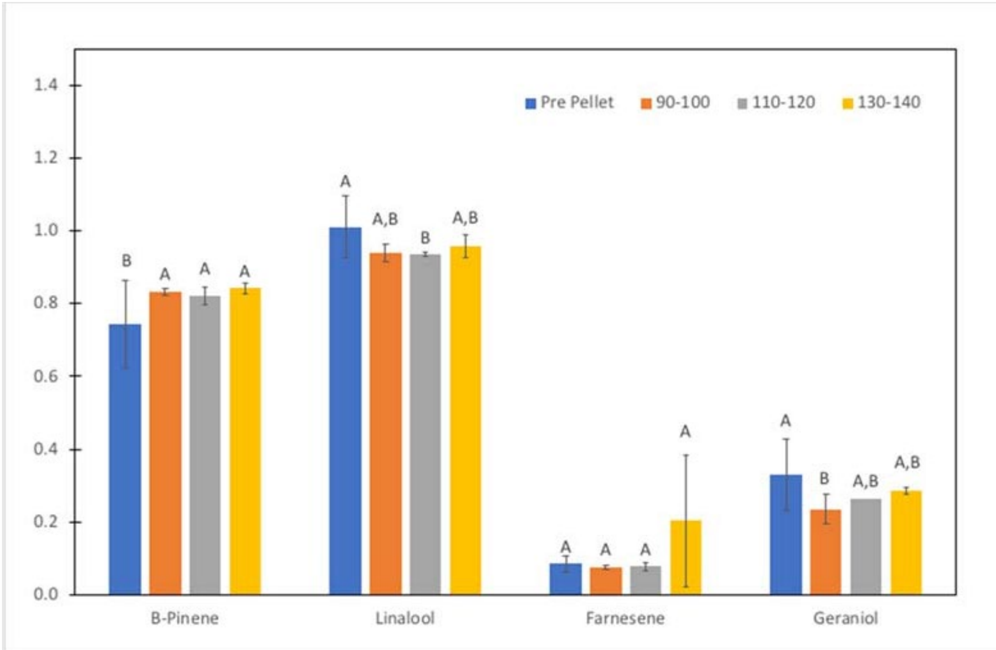

Figure 34. Concentration (percent of total oil) of β-pinene, linalool, farnesene, and geraniol in Tahoma pellets extruded at different temperatures

These results are in good agreement with the ones reported for the effect of pelletizing temperatures on the quality parameters (alpha and beta acids, HSI, total oil content) monitored in the first part of the experiment.

CONCLUSIONS

Harvest timing for optimal quality

Basing harvest date on hop cone dry matter testing in this study allowed the grower to reach their targeted hop quality goals for percent alpha acids and total oil content. As suggested by Pacific Northwest growers and USDA researchers, using dry matter as a tool to determine harvest date, and harvesting when cone dry matter is within the range of 20-25% appears to be a good place to start. In determining the percent dry matter to harvest at and the final harvest date, growers need to also consider varietal, weather, agronomic factors, as well as end user preferences for the hop characteristics they are looking for in their beers.

Identify the major post-harvest factors (period of harvest through delivery of product to brewer) that can most influence degradation of hop quality

The results of this research project suggest that, drying cones within a short period of time after harvest, and limiting their exposure to air is suggested to minimize undesirable effects on the quality of hop acids and oils. However, until more replications can substantiate this study's results, applying low amounts of air to hops prior to drying, if needed to avoid hops from heating and potential stewing would still be recommended.

Study results showed some differences in alpha and beta acids, with Chinook trending higher Alpha Acid (AA) and Beta Acid (BA) with increasing temperature, Sterling trending lower AA and BA with increasing temperature, and Tahoma also trending lower BA, but no differences in AA. However, single outlying data points may have skewed mean values, and that removing the outliers could potentially show a different trend. Since HSI is used to estimate losses of alpha and beta acids during storage and handling, and total oils volatile, these parameters would expect to change if varying drying temperature had a detrimental effect on hop cone quality. However, the drying treatments resulted in only marginal or no significant differences in HSI or total oils for all varieties. Therefore, low number of replications may have limited our ability to discern differences between treatments.

Prior research studies have shown that hops can take on undesirable flavor and aroma characteristics in areas of oasts where hops were exposed to extended periods of high temperatures. Also, in limited brewing trials, brewers preferred beers brewed with hops exposed to cooler upper sections of the hop bed in oasts compared to the lower hotter sections.

Length of drying period was affected greatly by drying temperature, with drying times ranging from 7 - 9 hours at 140 ˚F, 10 -14.5 hours at 110 ˚F, and 24.5 - 37.25 hours at 70 ˚F. Therefore, multiple oasts may be required when using a de-humifying dryer to accommodate daily harvests. However, the long drying times using a dehumidifying dryer may negate the need for lengthy conditioning periods prior to baling.

The power of evaporative cooling within the dryer bed (oast) may allow for a good compromise between the lengthy drying time of a dehumidifying dryer and the potential detrimental hop quality effects of high temperature drying. Start drying at 140 ˚F. Monitor the bed temperature by depth. Evaporative cooling will initially maintain bed temperatures below 110˚F. As bed temperature rises gradually decrease dryer temperature to maintain bed temperatures below 110˚F.

Future studies on drying temperature appear to be warranted, that potentially include either brewing trials or brewer panel sensory analyses. However, more replications and better controls on variation need to be implemented to come up with conclusive results and recommendations.

Dehydrated cones better preserved their quality when stored at low temperatures. Compression level may not be as important a factor to consider from a quality aspect. Refrigeration and frozen storage resulted in similar results. Based on the results of this study with limited replications, hop cones should be packaged and placed in at least refrigerated storage or freezer storage if available. Although differences could not be discerned between the compression treatments, baling hops are recommended to exclude oxygen, and can be important when considering handling and storage costs.

The extrusion temperatures used in this study didn’t show major differences in the quality of the hop pellets. But considering the difficulty to maintain a homogenous temperature in this process, it is recommended to use as low a temperature as possible, preferably under 130 ˚F .

III. Goals and Outcomes Achieved

1. **Ensure delivery of top quality locally grown hop products to brewers.**
   Ongoing long term.
   The brewing industry is evolving. The major growing segment in Wisconsin and nationwide has been the craft beer market. The hop industry in the Midwest and Wisconsin in particular was recently established to meet the needs of the growing craft beer market. Some local Midwest hop growers have visited the major hop producing areas of the Pacific Northwest states to increase their knowledge of hop growing. However, due to differences in size of established Northwest US hop growers (100 – 1,000 acres) compared to new establishing hop growers in Wisconsin and other Midwest states (1 – 20+ acres), availability of quality small scale hop processing equipment to Midwest growers is limited. Growers have been resourceful in either acquiring used small-scale equipment from Europe or designing and fabricating small scale versions of proven large-scale equipment. However, due to differences in climate, scale and availability of hop growing and processing equipment, and evolving local market, all of this knowledge and technology is not directly transferable to this region. Therefore, to ensure that the local hop industry delivers top quality locally grown products to brewers, local growers need to fully understand the processes necessary to produce a high-quality product. Therefore, two main areas of study were established:
   - Harvest timing for optimum quality
   - Identify the major post-harvest factors (period of harvest through delivery of product to brewers) that can most influence degradation of hop quality, that included these four time periods:
     - Period between harvest and drying
     - Drying
     - Storage prior to pelleting
     - Pelleting

   This research has been completed and summarized in the attached paper.

2. **Support the development of Wisconsin based ASBC (American Society of Brewing Chemists) certified laboratories.**
   Due to unavailability of local ASBC certified labs, the Wisconsin Hop Exchange Cooperative had historically utilized an ASBC certified testing facility (Alpha Analytics) in the state of Washington for hop chemical analyses. However, cost to ship samples was extremely high. Two new labs were establishing themselves as ASBC certified facilities in Wisconsin. Midwest Hop and Beer Analysis, LLC, was privately owned and had recently become ASBC certified and started operations in Evansville, WI. The University of Wisconsin, Food Science Department had also recently established a testing facility within its new fermentation science curriculum. The UW Lab has state-of-the-art HPLC (high performance liquid chromatography) testing equipment which would be extremely useful in multi-component chemical testing of hop acids and essential oils. The UW lab had also been collaborating with local craft brewers to quantify and determine the influence of flavor and aroma components in beer. The results of this project could complement that work. This project proposed to work with both labs in an effort to support the development of their testing services.

   As explained earlier, these two labs did much of the testing for the research portion of this project. During the first year of the project, the UW Lab became ASBC certified, and started to provide hop testing services to the local hop industry. Also, during the first year of the study, another lab in Madison (Advanced Analytical Research, AAR) was identified to be able to provide ASBC certified hop testing services to local hop growers. So, during the second year of the study, they were contracted to provide some of the post-harvest factor study testing, which included the total oil component testing using their available gas chromatography equipment.

These labs have done outstanding work, and provide an option to local growers for Wisconsin based ASBC certified hop testing.

3. **Work with the Wisconsin Brewers Guild through educational outreach to promote dialogue between brewers and hop growers in Wisconsin.**
The Wisconsin Brewers Guild wrote a letter of support for this grant project. They had defined their role in this proposal as an organization, *"…to facilitate interactions between hop growers and craft brewers by participating in co-sponsored workshops and technical seminars around the state."* To date, we have not solicited much involvement with the Wisconsin Brewers Guild as an organization, however we have discussed the project and research study with several brewers from around the state, including Octopi Brewing, MobCraft Beer, New Glarus Brewing, to name a few. However, since recently completing the research studies described earlier, we now have information that we can share with Wisconsin Brewers Guild members as a basis for discussion at future co-sponsored workshops and technical seminars. Our studies have identified future areas of research that include involvement from local brewers through brewer sensory panels or batch brews using hops from treatments within the study. Their involvement in structuring those studies will be needed and will assist in developing the dialogue between brewers and hop growers defined in this project.

4. **Assure that the latest information regarding sustainable hop production and processing practices that promote quality products for the craft brew market are disseminated to all growers and brewers**.
Ongoing long term.
Research results have been disseminated to growers throughout Wisconsin and Minnesota through either a formal presentation at conferences or grower meetings, or by dissemination of the final research report "Enhancing market acceptance and quality of WI hops to craft brewers" to hop growers in the Midwest. Details of how the information has been disseminated is summarized below. Also, results of surveys or questionares to get feedback from hop producers are included to document whether results of this research increased grower knowledge or potentially changed their production or processing practices that will result in increased quality of hops delivered to the craft brew market.

To date, preliminary results of the research studies were reported to:

- Wisconsin hop growers at the "Hop Production for the Wisconsin Craft Brew Industry - 9th annual seminar, held on February 24, 2018 at Lazy Monk Brewing, in Eau Claire, WI in a presentation by David Buss and Dr. Arnoldo Lopez-Hernandez titled *'Value Added Research Grant Report on Post Harvest Hop Handling'*

- Approximately 40 persons in attendance. Following the presentation, 29 attendees responding to a program evaluation survey. The following summarizes the number of growers responding to their level of understanding before and after the presentation.

------ Understanding before talk ------				------ Understanding after talk ------			
Very little	Some	Quite a bit	A lot	Very little	Some	Quite a bit	A lot
13	13	2	1	2	10	10	3

- Minnesota hop growers at the "Minnesota Hop Growers Association Summer 2018 Workshop", held on August 4, 2018 at the U of M Southern Research and Outreach Center, Waseca, MN in a presentation by David Buss titled *'Post Harvest Factors Affecting Hop Quality'.*
  24 persons in attendance. Program evaluations were not disseminated at the meeting. A copy of the research paper "Enhancing market acceptance and quality of WI hops to craft brewers" was emailed to all participants following the meeting. Each was asked the following question: *Did the research increase your knowledge or result in you potentially changing some production practices that will result in increased quality of hops harvested and/or processed?* 100% of those responding said 'YES'.

  Carl Duley, Univ. of Wis.-Extension, Buffalo County Agriculture Agent is the lead Extension agent in Wisconsin for hop production and a cooperator on this project. He is planning to include a copy of the research report "Enhancing market acceptance and quality of WI hops to craft brewers" on his website.

- Funds from this project were used to develop and enhance the Wisconsin Hop Exchange Cooperative website (http://wisconsinhopexchange.com/) to better educate, promote, and market hops statewide. The research paper "ENHANCING MARKET ACCEPTANCE AND QUALITY OF WISCONSIN HOPS TO CRAFT BREWERS" has been posted on the Coop's member section of the website. In addition, the research paper will be disseminated to all grower/members of the Wisconsin Hop Exchange Cooperative, Minnesota Hop Growers Association, and Wisconsin Brewer's Guild. Although dialogue with the Hop Growers of Michigan association hasn't been established, the paper is also planned to be shared with their growers.
- Will share our research findings with other groups as the opportunity arises.

IV. Beneficiaries

There are two major beneficiaries from the accomplishments of this project.

Growers

The hop growing industry in Wisconsin is still in its infancy. The Wisconsin Hop Exchange Cooperative currently has around 90 members, with approximately 15 new members each year. Most of those growers have 7 – 8 years of experience or less growing hops. As stated earlier, some local Midwest hop growers have visited the major hop producing areas of the Pacific Northwest states to increase their knowledge of hop growing. However, due to differences in climate, scale and availability of hop growing and processing equipment, and evolving local market, all of this knowledge and technology is not directly transferable to this region. Therefore, to ensure that the local hop industry delivers top quality locally grown products to brewers, local growers need to fully understand the processes necessary to produce a high-quality product.

Brewers

The major growing segment of the brewing industry in Wisconsin and nationwide has been the craft beer market. According to the Wisconsin Brewers Guild website, Craft breweries contribute $2 billion to Wisconsin's economy. Craft brewers also tend to advocate the use of high quality locally grown ingredients, and are the major potential market for hops grown by Wisconsin hop producers. At the beginning of this project, the potential market for craft beer brewed in Wisconsin was about 550,000 pounds of hops. This was based on 550,000 barrels of craft beer brewed with an average of 1 pound of dry hops per barrel (Source: Bo Belanger – president, WI Brewers Guild at the time). Quality of the hops for craft brewers is critical. The large amount of hops used means all of the flavors and aromas of the hops (good and bad) are in the beer. (Source: Dr. Val Peacock – former head of hop procurement for Anheuser–Busch).

Therefore, projects like these that promote a better understanding by local <u>growers</u> regarding how to produce and harvest hops for peak quality, and how to maintain that quality through processing and delivery to <u>brewers</u> is critically important to growing the hop industry in this state.

V. Lessons Learned

We knew going in, that this was an aggressive research project for the grant dollars we were asking for. Especially the post-harvest portion of the study where we were trying to identify the major post-harvest factors (period of harvest through delivery of product to brewers) that can most influence degradation of hop quality. We suspected that the number of replications we were proposing (2 reps per year over 2 years) may limit the statistical ability to detect significant differences. Especially working with an agronomic crop where year to year variation is expected. However, the main goal of this project was to identify the factors that may be <u>most affected</u> by grower or processor management that would warrant further study. To that end, we think we accomplished that. We could have asked for more funding to include more replication however research dollars may have been wasted on factors with small effects. It came as no surprise that controlling hop cone drying temperature is an area where hop growers could have the biggest influence on hop quality, however a few findings were surprising:

- The possibility that exposing undried hops to an extended period of ambient air-flow may cause changes in hop quality.
- That there may be varietal differences to varied air flow or hop drying temperature treatments.
- How great the power of evaporative cooling is when using heat to dry hops, and that monitoring hop bed temperatures and regulating heat levels to maintain maximum bed temperatures may prove a useful compromise between high temperature and no (de-humidified) hop cone drying.

We discovered that including some sort of brewing evaluations (sensory analyses, test batch brews, and/or acid and hop oil component testing) may be important to include in future hop studies.

Also, due to the in-season and year-to-year variability inherent in growing hops that at least 3-4 replications per year, and better control on sampling variability are needed to more often discern meaningful treatment differences.

VI. Additional Information

No other information included.

VII. Contact Info

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13) Instructional resources to improve the safety, efficiency, and cost of growing and harvesting hops (FY15-13)

Report Date: July 24, 2017

I. Project Summary

The current harvest operation at many small-to-medium sized hop yards is both injury prone and labor-intensive. It was calculated by Michigan State University study (http://hops.msu.edu/uploads/files/MI_Hops_cost_of_production_Bulletin-E3236.pdf) that each acre of hops costs $1,850 with a team of 4 laborers and 1 manager. When the net revenue per acre is estimated at $5,495, it is easy to see where a significant improvement to the net revenue could be gained. The study by Michigan State University did not address the potential costs associated with farm injuries. However, as noted in the Occupational Injury Surveillance of Production Agriculture Survey (http://www.cdc.gov/niosh/topics/aginjury/oispa/pdfs/ai-18.pdf), nearly 53% of all farm injuries are the result of either "Contact with objects and equipment" or "Falls". The typical process of running hedge trimmers nearly 18' in the air put the farmer at risk for either of those situations to occur during harvesting.

The labor costs for spraying was calculated at $750 per acre. With improved machinery, this labor cost is greatly reduced to a single-person operation typically carried out by the farm owner. Additionally, most small-to-medium sized hop farmers did not own a baler to compact the hops resulting in increased physical space required to refrigerate the hops during the post-processing phase. This increased refrigerated space results in increased cost.

Finally, a research of YouTube videos and other outreach material designated specifically to detail how these important innovations are manufactured was missing. There were plenty of videos and resources showing different products being used or how to buy one, but none that describe how to manufacture the equipment as was intended by this proposal.

This project was and is important for immediate local growers as most are expanding their yards after having established acreage for at least 3 years. Expansion of their yards only increased the need for such instructional resources. Others considering expansion of their yards, were unable to scale up without technological improvements such as these instructional resources. As a growing number of new farmers enter the hop industry, these instructional resources will continue to prove invaluable.

The objectives of the project were straightforward and simple. Provide instructional resources for small-to-medium sized hop yards so that they can build their own growing and harvesting equipment which will improve safety and net revenue. The resources are freely available on Glacial Ridge Hop and Grain's website, were posted on YouTube, distributed for posting and disseminated to any other interested partners free of charge.

B. While this project does not specifically build from a previous SCBG, in 2012-2013, Gorst Valley Hops LLC created a best practices paper discussing Good Manufacturing Practices in Hops processing. That paper discussed best practices related to the handling of the hop during the processing process. However, the best practices document did not address the equipment needed prior to processing – spraying and harvesting equipment – nor the equipment needed after the processing. This project addressed those areas through the creation of instructional resources to aid the growing number of small-to-medium sized hop farmers.

II. Project Approach

This grant focuses on four distinct and necessary pieces of equipping for growing and harvesting hops. Namely, a sprayer, a top cutter, a harvest wagon, and a baler. Each of these will be discussed individually in this report as each has their own distinct successes and challenges.

Sprayer

The sprayer – used weekly through the growing season – was greatly improved through a relatively simple redesign by moving the boom arm of a rear-towed sprayer to the front of the tractor. In previous years this was not the case and required 2 laborers to perform a spraying. The movement of the sprayer boom to be front mounted eliminated a laborer and also provided a safety advantage to the driver. Previously, the driver would have to contort his/her body while driving to maintain a visual on the spraying. Finally, the front-mounted boom arm now allows for spot spraying saving on overall costs. Overall, the sprayer is a success and will continued to be used by Glacial Ridge Hop and Grain in future growing seasons.

Figure 1: Sprayer with front mounted boom

Top Cutter

The top cutter is used during harvest season to run along the top of the hop bines and cut them from the trellis they have been growing on all season. In previous seasons this proved to be a very labor-heavy and risky activity. Cutting down hops prior to this season required 6 laborers per row with 2 of them in elevated positions running hedge trimmers. Two top-cutter designs were designed and prototyped. They had different cutting actions – a side-driven action and a center-driven action.

The center-driven top cutter eliminated many of the challenges and dangers from the previous seasons. The design of this was to guide the hops to the center of the top cutter as it cut. The fundamental flaw with this design was actually in the center design itself. Hop bines tend to be very busy on the top – right near the cutting action – which lead to some of the bigger plants weighing down the line and not going through the cutter head. The top cutter reduced laborers and eliminated laborers in the air, but needs improvements to be considered a successful and recommended for regular use.

The side-driven top cutter eliminated all of the challenges and dangers from the previous seasons. The design focused less on guiding the hops to the center and ultimately proved to be much more successful than the center-driven top cutter. The side-driven top cutter performed extremely well over the course of the harvest season. The instructional resources focuses on the side-cutting top cutter.

The real takeaway from this prototyped work was that all six acres of hops were harvested without any laborers 18' in the air cutting down hops with a hedge trimmer. Suggested improvements in the top cutter include a remote on/off switch for improved safety, possibly a hydraulic drive motor from the push vehicle and head set communication for all parties involved in the cutting operation.

Figure 2: Side-driven top cutter

Harvest Wagon

Though simple in its final design used during harvest season, the harvest wagon actually had some initial design and prototyped features removed. They were designed as time and labor saving ideas that in-fact needed to be removed for a more simplistic approach. Initial designs had diverters to move bines into the wagon and diverters to move bines away from the wagon but during harvest the bines have a tendency to be so o think and not be in a perfectly straight line (e.g., corn, beans, etc.) that it became difficult for the operators to locate visually the diverter poles and they become a hindrance rather than a help.

The wagon – a repurposed wagon – is perfect in its original design. The wagon was made for corn with 38” rows which resulted in a relatively narrow wagon. This fit perfect in the 14’ spacing between the poles in a hop hard which actually becomes narrower during harvest season with large bushy hops growing in from each side of the poles.

The goal for the wagon was to eliminate both laborers from the wagon during the cutting process. While this is very possible, we found that having one person in the wagon would result in a much better stacked load of hops. This is important as it saved time during the unloading and processing phase of the operation. By stacking the bines neatly during cutting, the bines did not have to be pulled from the pile during processing as violently which results in cones being lost from the bines before they can be processed. Overall the wagon design was a success, but the realization that all laborers in the wagon can’t be removed must be acknowledged.

Figure 3: Harvest Wagon - Side and Rear View

Baler

Two balers were prototyped.

An 18”x18”x18” horizontal baler was designed and prototyped. Overall it performed well, but could have a few additions made to it like a landing area for the baled boxes being pushed out and getting ready for sealing. Additionally, some return springs should be added to keep the push plate from rotating out of square. The size of the bale resulted in a 22-pound bale of whole cone hops. The time to bale each bale averaged just over 10 minutes which still results in a timely activity across multiple acres of hops.


Figure 4: 18x18x18 horizontal baler

The second baler was a 44-pound baler prototyped from a trash compactor. The 44-pound baler was a great success and was an ideal size for a hop yard the size of Glacial Ridge. The average time for each bale was similar to the 22-pound baler, but compacted twice the hops so it proved to be more useful than the 22-pound baler.

III. Goals and Outcomes Achieved

Final Outcomes

The following 5 measurable outcomes were defined as part of the in the grant application and have been tracked for the first year of this grant.

Measurable Outcome #1

GOAL – Reduce the number of laborers required for each spraying.
PERFORMANCE MEASUREMENT – Number of laborers.
BENCHMARK – 2 per spraying
TARGET – 1 per spraying
2016 Measurement – 1 per spraying

Measurable Outcome #2

GOAL – Reduce the number of laborers required to cut hops from trellis and drop into wagon per row of hop harvested.
PERFORMANCE MEASUREMENT – Number of laborers
BENCHMARK – 6 per row
TARGET – 2 per row
2016 Measurement – 2 could be achieved. 3 per row resulted in better stacking for later unloading and processing.

Measurable Outcome #3

GOAL – Remove any and all laborers from an elevated position required to cut down a row of

hops.
PERFORMANCE MEASUREMENT – Number of laborers
BENCHMARK – 2 per row
TARGET – No Laborers in elevated position
2016 Measurement – No laborers were in elevated positions.

Measurable Outcome #4
GOAL – Remove any and all laborers from harvest wagon required to cut down a row of hops.
PERFORMANCE MEASUREMENT – Number of laborers
BENCHMARK – 2 Laborers in Wagon
TARGET – No Laborers in Wagon
2016 Measurement – As noted, this could be achieved, but we found it was better to have 1 in the wagon to improve unloading and processing.

Measurable Outcome #5
GOAL – Reduce the time to compact a bale of dried hops.
PERFORMANCE MEASUREMENT – Time to compact a bale
BENCHMARK – 25 minutes per bale
TARGET – 10 minutes per bale
2016 Measurement – just over 10 minutes per bale

B. Noted in section III above.

IV. Beneficiaries

The project results are accessible to Wisconsin's more than 150 current hop growers. We belong to Wisconsin Hop Exchange (Co-op) and with this Grant we were able to help our Co-op members out with being able to use and build their own equipment for Spraying, harvesting and compacting the hops into bales. The following is a URL for instructional videos that we were able to produce because of the SCBG Grant. All three training videos can be found at the following link. Baler, Sprayer, Top Cutter and Wagon. They are now publicly available without passwords.

https://vimeo.com/channels/1270629

V. Lessons Learned

Most of them were listed above in the Goals and Outcomes however, our biggest lesson learned (in my eyes) is not having labors in an elevated position using hedge trimmers to cut the hops down. This was dangerous to have them up on an elevated platform while moving and cutting hops.

Another was trying to cut the number of labors down over all so we can keep Wisconsin Hops competitive in the market. Less labor = competitive hop pricing. Since we compete with large hop fields (over 250 acres) out west in Washington and Oregon this is a big win for us smaller hop farmers (7 acres for Glacial Ridge Hop and Grain)

VI. Additional Information

From participating in the SCBG Grant, we were able to produce the following videos to assist others. All three training videos can be found at the following link. Baler, Sprayer, Top Cutter and Wagon. They are now publicly available without passwords.

https://vimeo.com/channels/1270629

VII. Contact Info

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14) Scaling up the pheromone-based mating disruption program in Wisconsin cranberries (FY15-14)

Report Date: March 10, 2017

I. Project Summary

Cranberries are the top fruit crop in the State, and insects are consistently ranked as the top threats of the cranberry crop. Of the insects, the most damaging pest of all is the cranberry fruitworm, a moth that lays its eggs directly on the fruit, facilitating larval feeding within the berry. This single insect species demands much scouting effort and substantial pest management resources, and yet, year after year it often causes the most damage. Black-headed fireworm is another insect pest requiring scouting and management effort, though it is not as serious because its feeding is primarily on foliage. Together, these moths require preventative sprays pre- and post-bloom, as well as “rescue sprays” later in the season. Indeed, much of the pesticide applied to Wisconsin cranberries can be attributed to moth control. Therefore, one of the primary goals of our proposed project is to **craft a viable mating disruption system** that can reliably suppress these moth populations while reducing per-acre insecticide loads.

Mating disruption is a well-established, powerful pest control tactic that prevents egg fertilization, thereby preempting the existence of larvae. Importantly, mating disruption provides population control without introducing new pesticide residues into the cranberry fruit. This is a very timely benefit for the cranberry growers, as the industry continues to struggle with the maximum allowable residue limits in its exported fruit. Mating disruption can operate concurrently with other pest management tactics, reducing the need for pesticides while not interfering with their use, should growers opt to spray. Thus, this project addresses the major pest management needs of the Wisconsin cranberry industry, enhances the sustainability of cranberry culture, and helps to reduce environmental threats generated by cranberry production practices.

From 2012-2014, the pheromone-based mating disruption program being conducted by the USDA Cranberry Entomology Lab has successfully controlled key pest populations across over 120 acres of commercial cranberry acreage in Wisconsin (8-10 acre blocks per marsh, 5-6 marshes per year). Our team recently demonstrated in 2014 that multiple species could be simultaneously suppressed, particularly the main pest of Wisconsin cranberries, the cranberry fruitworm (see Figs. 1-2). Importantly, this mating disruption has translated into significant reductions in fruit damage (Fig. 3) within treated blocks. Results from the 2014 season showed that we virtually eliminated mating in black-headed fireworm populations (Fig. 2), and achieved a 75% reduction in cranberry fruitworm mating (Fig. 1).

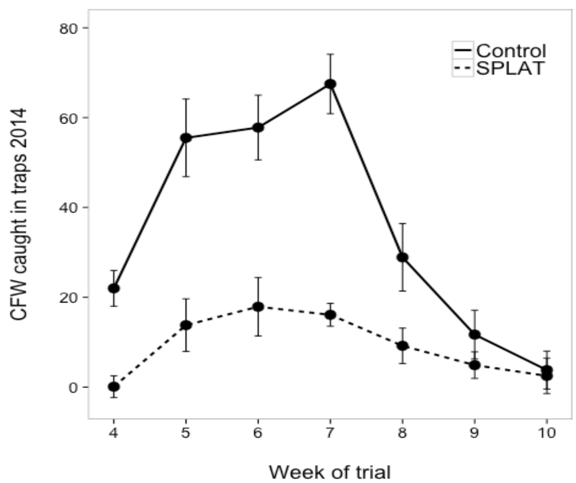

Figure 1. Adult male cranberry fireworm (*A. vaccinii)* (mean ± 1 SE) caught in pheromone traps in 2014. Trap-catch in Control (solid line) and SPLAT®-treated (broken line) beds was compared over time.

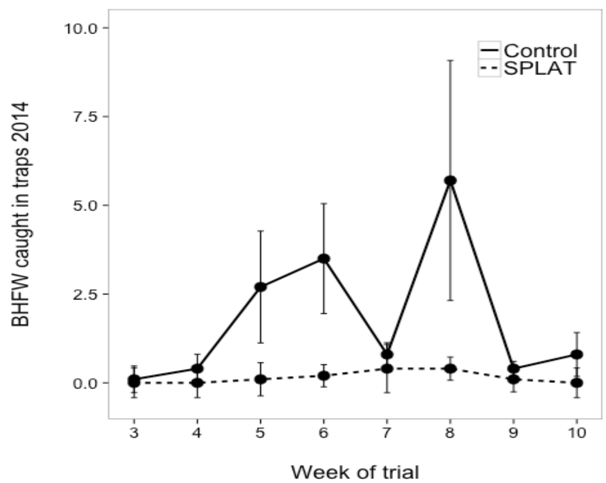

Figure 2. Adult male blackheaded fireworm (*R. naevana*) (mean ± 1 SE) caught in pheromone traps in 2014. Trap-catch in Control (solid line) and SPLAT®-treated beds (broken line) was compared over time.

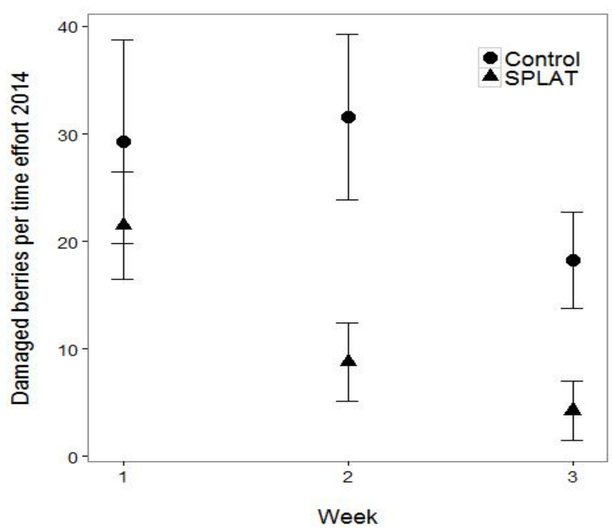

Figure 3. Damaged cranberries collected per time effort (mean ± 1 SE) for control and SPLAT®-treated beds over three different sample dates in 2014. Time steps are one week apart.

However, the program needed to be scaled up in order to efficiently provide whole-marsh pest protection for growers. Growers use pest management technologies at large, industrial scales, and the manual application of SPLAT, while very precise, is too labor-intensive. To scale up the acreage for the deployment of SPLAT, applications need to be mechanized, and one of the more promising options is the use of unmanned aerial vehicles (UAVs). Our focus was largely on the creation of a retrofitted UAV that could fly over cranberry acreage of any shape, slope, or contour, and deliver a controlled volume of SPLAT.

B. This project did not build upon past SCBGP-funded work.

II. Project Approach

The overarching goal of this project was to mechanize the deployment of mating disruption (MD) in Wisconsin cranberries, facilitating the integration of MD into current pest management programs.

Scaling up the MD system necessitated the use of unmanned aerial vehicles (UAVs) because these units can rapidly, precisely deliver SPLAT® throughout a cranberry bed.

In 2015, SPLAT-dispensing devices were designed, tested, and manufactured to suit the viscosity of SPLAT. These devices were then affixed to UAVs (octocopters). Further testing of load-bearing capacities, battery life, and flight dynamics allowed us to refine the design of the SPLAT-dispensing device.

In the early summer of 2016 (June), a fully retrofitted, field-ready UAV was brought to two commercial cranberry marshes in Wisconsin for deployment of SPLAT (Fig. 4). The UAV was automated by creating GPS-dictated flight itineraries, and oversight of the flight was maintained by a member of our research team who is a pilot licensed by the FAA for the low-altitude operation of octocopters. Our UAV maintained its data-link with multiple satellites and flew a pre-designated course, applying SPLAT from a height of 10-15 feet above the marsh. .

Figure 4. Mechanization of SPLAT-deployment on commercial cranberry acreage. In 2016, a UAV retrofitted with a SPLAT-dispensing device and GPS-link was used to apply SPLAT to two marshes in Wisconsin.

A 3-species SPLAT formulation had been manufactured by ISCA Tech, and this formulation was successfully applied via UAV on cranberry acreage. The viscosity of SPLAT was ideal, allowing it to drop deep within the cranberry canopy, yet still hold its shape within the canopy.

III. Goals and Outcomes Achieved

The outcomes of this project represent landmark advances not only for mating disruption systems in the cranberry marshes of Wisconsin, but also for pest control technologies worldwide. The use of "drones" and "UAV" systems are expanding at a rapid pace, and our team has demonstrated how 20+ lbs. of payload can be delivered and deployed with precision at prescribed locations. Further, we have designed a patentable device that can extrude materials of various viscosities from the ventral side of the UAV. Our work is receiving attention at local, state, and regional levels (see http://labs.russell.wisc.edu/steffan/media-coverage/), and at large, formal cranberry meetings in Wisconsin http://members.wiscran.org/user_image/2017WICranberrySchool.pdf .

With respect to our objectives:

Objective 1.

Goal: Develop a feasible approach to the deployment of SPLAT® via retrofitted unmanned aerial vehicles.

Performance measure: The performance metric is the field-scale deployment of SPLAT at a prescribed rate (1 kg/acre, comprised of 1,000 1 g point-sources per-acre), in a uniform, grid-like spatial distribution.

Benchmark: SPLAT applied at each commercial marsh, in a controlled fashion, at the above-described specifications.

Target: Efficient deployment of SPLAT (with 1 day of grower effort per marsh).

Outcomes: The entire year of 2015 was spent designing and refining the SPLAT-dispensing retrofit. This encompassed two elements: 1) design of the SPLAT-holding vessel type and size; 2) refining the particular circuits and hardware to allow for the simple extrusion of SPLAT at punctuated intervals; 3) establishment of the ideal range of SPLAT viscosities that would allow for extrusion across a reasonable range of field temperatures. By the end of 2015, we had designed, manufactured, and retrofitted the UAV.

In early 2016, we began the process of optimizing the battery type and UAV air speed given a specified load (15-20 lbs. payload). Both indoor and outdoor flight tests were conducted in Madison and Mt. Horeb, across a range of temperatures. Battery issues and satellite-linkage were resolved in the spring. By the summer of 2016, the UAV was ready for SPLAT deployment in the field. Two grower-collaborators in north-central Wisconsin allowed us to treat large areas of their respective marshes with the first ever 3-species pheromone blend. SPLAT was applied at each marsh at the prescribed rate of 1 kg/acre, targeting the sparganothis fruitworm, cranberry fruitworm, and the blackheaded fireworm. Across two cranberry marshes, a total of six cranberry acres were successfully treated. Applications would have been possible on 12 acres, but the combination of severe rain events and battery charging issues capped the treated acreage at six acres for 2016 growing season.

Objective 2.

Goal: Show that SPLAT effectively shuts down mating of key pests, no matter the size of a marsh, bed shape, or grower equipment.

Performance measure: Adult moth trap-catch, larval counts of black-headed fireworm and cranberry fruitworm, and berry infestation rates.

Benchmark: Growers deploy SPLAT with assistance from UW personnel. 95% reduction of black-headed fireworm trap-catch, and 75% reduction of cranberry fruitworm trap-catch in SPLAT-treated marshes. Low larval counts (below thresholds), and low berry infestation rates (1-2%).

Target: Growers self-deploy SPLAT. 100% reduction in trap-catch, indicating complete disruption of moth mating. Very low berry infestation rates (<1%)

Our latest advancements in the cranberry MD program show that the new 3-species SPLAT formulation ('SPLAT CFW BHFW SFW') effectively shut down trap-catch for all three pest species in the SPLAT-treated acreage. Some moths were caught in the SPLAT-treated blocks, but very few in comparison to the untreated blocks. Approximately 6 times as many sparganothis and 3 times as many cranberry fruitworm were caught in the baited traps of untreated areas, indicating that in the SPLAT-treated blocks, males were incapable of tracking the pheromone plumes of actual female moths. Trap shut-down translates into reduced or delayed mating, which precludes the existence of larvae.

Almost complete trap shut-down was observed with blackheaded fireworm (> 95% compared to controls). It should be noted that even when perfect trap shut-down is not achieved, mating is markedly reduced. Berry infestation rates bear this out, and our 2016 harvest samples are still being dissected. It should also be noted that the non-SPLAT blocks were still managed according to *standard grower practice*, which means they were sprayed with insecticides. This underscores the importance of MD, because it can operate "over the top" of standard pesticide spraying practices, and can significantly improve upon the established pest control system. These established IPM systems are almost completely reliant on insecticides, many of which are losing registrations (or worse, being used but then precluding access to European and Asian markets because of residues in fruit). Future cranberry IPM programs will be able to reduce spraying as MD applications provide pest suppression of the major pests, allowing growers to spot-treat the inevitable pest hotspots. We did not meet out benchmark of growers being able to self-deploy SPLAT. Our pilot and crew did all the applications. Our target of high disruption of moth mating was achieved, and we will soon have data on berry infestation rates among all harvest samples.

B. Having successfully applied our MD technology to Wisconsin cranberries using a satellite-guided UAV, we accomplished our main goal. There are several high-resolution videos of the UAV in flight that have been archived for a future Extension video documenting our progress. This video will be made available as University of Wisconsin policy on UAV research is further resolved.

A manuscript documenting our work in 2015 and 2016 is being prepared, and will provide final analyses and prognoses of the direction of UAV research in US cranberries.

IV. Beneficiaries

Wisconsin cranberry growers and the attendant industries are the major beneficiaries of this project. There are over 250 growers in the State, employing thousands of workers. By developing an innovative new means of delivering pest management technologies via UAVs, we have "opened the door" for a variety of non-surveillance applications of UAVs. Overall potential economic impacts from such UAV applications are difficult to assess, but the increase in the use of MD in cranberries will reduce insecticide spray, particularly during bloom (helping the bee-keeping industry of Wisconsin). Eliminating a single late-season insecticide spray would represent a 33-50% reduction in insecticide loading on cranberry acreage, and would allow many growers to market their crops abroad (and at higher prices) because they will not be constrained by domestic market demand.

V. Lessons Learned

We learned early in the 2016 field season that battery life for octocopters will be an issue for growers. We were able to continuously charge and replace batteries, but we learned that even when the charge in a battery was still at or near half, the charge was not adequate because there was a drop in voltage, which was accompanied by a drop in available amperage. The loss of amperage meant a loss of power to the rotors (and a few hard landings). So, future work will take us in two new directions: 1) gasoline-powered UAVs will be used, with all the same retrofitting and GPS-links; 2) retrofitting of the boom-arm of spray rigs commonly used in Wisconsin. Growers are quite enthusiastic about the retrofitting of their existing equipment (i.e., engineering the boom arm to hold and extrude SPLAT).

VI. Additional Information

Presentations and publications were made throughout 2015 and 2016, via formal cranberry meetings, online web updates (*Wisconsin Fruit News*) and printed publications (*Cranberry Crop Management Journal* and *Proceedings of the Winter Cranberry School*).

VII. Contact Info

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15) Effects of fungicide and fertilizer applications on bee fidelity to cranberries (FY15-15)

Report Date: October 19, 2018

I. Project Summary

Cranberry growers rely primarily on honey bees for their pollination needs. In Wisconsin, 89% of cranberry growers who use pollination services rely on honeybees for optimal fruit set (Gaines Day, 2013). Pollination services by honeybees represent a significant investment for cranberry growers, ranging from $140 to $210 per acre. Growers often comment that they observe honeybees flying off the marsh, presumably to forage on other flowers. Previous studies have shown that fidelity to cranberry varies from day to day and from colony to colony, ranging from 2 to 100% (Shimanuki et al 1967; Cane and Schiffauer 2003). The variability in honeybee cranberry pollination could be affected by weather conditions, varying needs of the colony, proximity to additional resources, hive placement on the marsh, and on-farm management practices.

The presence of fungicides has been shown to impair the ability of other bees to locate a food source and affecting their foraging behavior (Sprayberry et al. 2013). Fungicides may also have detrimental effects on bee health (Pettis et al. 2013). However, in cranberry, recent data suggest that honeybees do not seem repelled by certain fungicide residues (Steffan unpubl. data). Bees visiting pesticide-contaminated flowers often bring pesticide-laden pollen back to their hives, thus putting hives at risk. A recent study found fungicides in 100% samples of bee-collected pollen in agricultural settings, including cranberry (Pettis et al. 2013). Pesticides have been shown to impact bee health and this may in turn impose economic losses on the beekeeping industry, which may in turn lead to increased costs of hive rentals for cranberry growers as beekeepers contend with fewer, weaker colonies.

The proposed study was conducted on 17 cranberry marshes in the central and northern Wisconsin growing region over two years (2017-2018). We assessed foraging behavior prior to and after selected fungicide applications by collecting and counting the amount of pollen returned to the hive 24 hours and 48 hours after the application of two different types of fungicides. We found that the amount of cranberry pollen decreased while the amount of non-cranberry pollen increased following a fungicide application. However, this relationship differed depending on the type of fungicide applied.

B. The research proposed herein does not build on research previously funded by DATCP or the SCBG program.

II. Project Approach

OBJECTIVE 1: In 2016, we collected data from 12 farms but could not statistically analyze the data due the wide variety of insecticides, fertilizers, and fungicides used in an overlapping fashion across each farm. To accommodate this variation, in 2017, we collected data from 17 farms and were able to identify the two types of fungicide applications most abundantly used in

Wisconsin cranberry (Proline and Abound + Indar). Increasing the sample size and decreasing the number of active ingredient followed allowed us to focus on 9 cranberry farms, and 11 independent fungicide applications that did not overlap with any other product applied during bloom (Table 1).

Brand Name	FRAC Class Code[1]	Active ingredient	Concentration	Application Rates for Cranberry
Abound	Qoi*	azoxystrobin	22.9%	6.0 -15.5 fl oz / ac
Indar	DMI**	fenbuconazole	23.5%	6.0 - 12 fl oz / ac
Proline	DMI**	prothioconazole	41.0%	5.0 fl oz / ac

Spray	Marsh	Rate (fl oz / ac)	Active Ingredient (AI) (g ai / ac)	Spray Date	% Bloom	% Woodland[2]	Acerage[3]
Abound Indar	1	9.0 9.0	66.3 63.8	6/29/2017	54.6	32.6	180
Abound Indar	2	15.4 12.0	113.5 85.1	6/28/2017	38.0	30.0	415
Abound Indar	3	10.0 10.0	73.7 70.9	7/1/2017	42.8	70.8	25
Abound Indar	4	13.0 10.0	95.8 70.9	6/27/2017	52.1	65.6	255
Abound Indar	5a	15.0 8.0	110.6 56.7	6/28/2017	25.9	40.6	250
Abound Indar	5b	15.0 8.0	110.6 56.7	7/7/2017	51.7	40.6	250
Proline	6	5.0	70.9	7/7/2017	49.5	42.8	725
Proline	7	5.0	70.9	7/10/2017	55.3	58.2	115
Proline	8	5.0	70.9	6/27/2017	38.5	13.3	325
Proline	9a	5.0	70.9	7/7/2017	27.6	34.4	125
Proline	9b	5.0	70.9	6/27/2017	33.7	34.4	125

Table 1: Fungicides applied during cranberry pollination, and marsh specific characteristics

[1]Fungicide Resistance Action Committee classification based on mode of action to aid in resistance management.
*Quinone outside inhibitors
**Demethylation inhibitors
[2]Calculated within a 1 km radius of center of each marsh
[3]Estimated area of active fruit production

Commercial hives were rented by growers, and delivered to individual farms when beds were 15% into bloom. Data were collected when cranberry beds were 25-50% in bloom. Specific fungicide type, application rate, and time of application were determined by individual growers and applied to the cranberry beds according to label directions (Table 1). The fungicides used in our study were all considered non-toxic to bees (EPA 2018).

Three pollen collections were made from each hive: 1) a 'before' assessment was collected 24 - 48 h before any fungicide application at each marsh, 2) a '24 h after' which began 20 - 24 h after each fungicide application, and 3) a '48 h after' assessment which began 48 h after the fungicide application. Pollen samples were analyzed for the number of cranberry and non-cranberry pollen tetrads collected and we developed a novel method of systematically counting the number of pollen grains.

Fungicide applications in cranberry marshes were associated with a 43% decrease in the number of cranberry pollen tetrads returned to honey bee hives 48 h after fungicide applications (Figure 1).

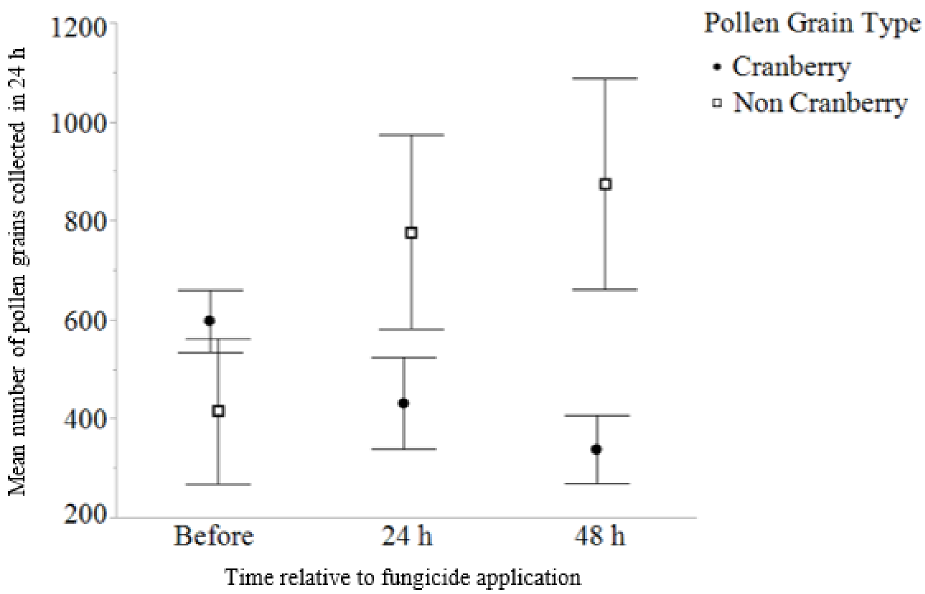
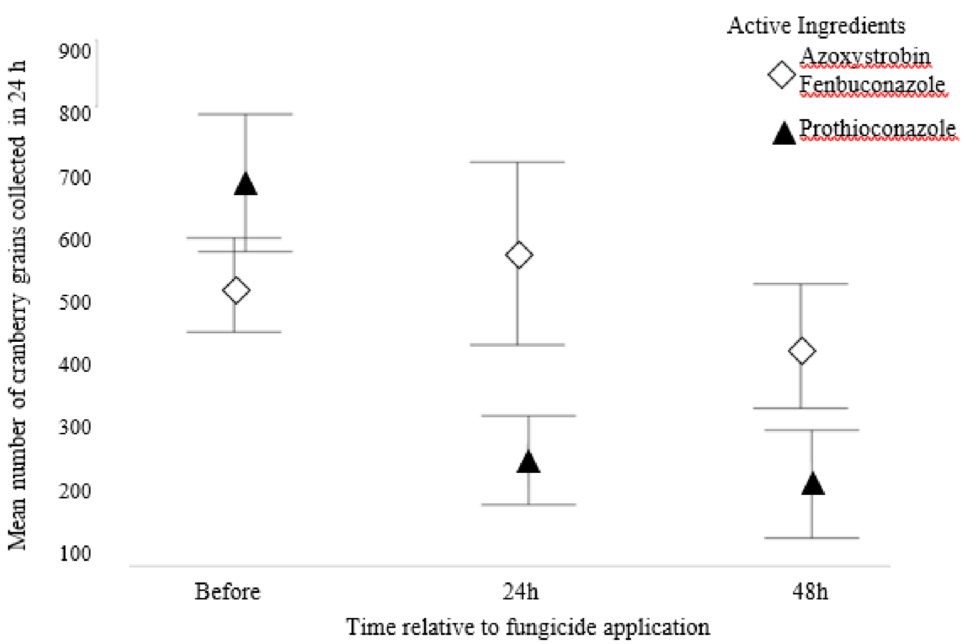


Figure 1: Mean amount of pollen grains (+SE) collected before, 24 h after, 48 h after fungicide application by type of pollen grain (cranberry or non-cranberry).

The decrease in cranberry pollen after fungicide applications was associated with a significant increase in the number of non-cranberry pollen collected, although the overall amount of pollen was not affected, suggesting that honeybees may have shifted from foraging on cranberry pollen to non-cranberry pollen. When considering the specific fungicide applied, pollen samples associated with Proline applications had significantly fewer cranberry pollen grains after the fungicide application, while pollen samples associated with the combination of Abound + Indar were not significantly affected (Figure 2).



OBJECTIVE 2
We recently finished collecting, and analyzing the data so we will present our findings at the Annual Wisconsin Cranberry School in January 2019, during the spring workshops, and in the next issue of the Cranberry Crop Management Journal (CCMJ). Results will also be presented at the Entomological Society of America Annual Meeting North Central Branch meeting in 2019.

III. Goals and Outcomes Achieved

Objective 1 was recently accepted for publication in the peer-reviewed *Journal of Economic Entomology.*

Objective 2 will be completed in 2019. We will present our findings at Cranberry School, during the spring workshops, and in the next issue of the Cranberry Crop Management Journal (CCMJ). Results will also be presented at the Entomological Society of America Annual Meeting North Central Branch meeting in 2019.

B. Objective 1: The initial goal of this project was to determine the impact of commonly used fertilizers and fungicides on pollinator foraging efficiency in conventional cranberry production. We modified the initially proposed method of looking at individual bees to measure the effects on individual hives over 24 hours. This adjustment provided a better approach to the potential impact of fungicide application on pollination at a hive level, and decreased sources of variation within the study. We were able to address the impact of two of the major fungicide application types (Proline and Abound+Indar): Proline applications were associated with decreased cranberry pollen foraging, while the Abound+Indar applications did not have an effect. While more work needs to be done to determine the specific reasons why these effects did/did not occur, this project was the first to demonstrate a potential impact of specific fungicide application method on pollination services in cranberry. We were unable to determine any effect of fertilizer on cranberry foraging as not enough growers sprayed fertilizer when honeybees were present to adequately collect and analyze the data.

Objective 2: Performance will be measured by recording attendance at Cranberry School and Spring workshops. Research results, updates and relevant research on pollination will be delivered through the CCMJ. Evaluations will be provided at Cranberry School for growers to rate the relevance of the research. Growers will also be surveyed at Cranberry School to assess the impact of the project objectives and to identify needs for future research and education. In 2014, 52% of growers said they applied fungicides during bloom. When asked in 2018, if they would consider changing their management practices to protect pollinators, 80% said they would and 22% would reduce insecticides, 0% would reduce fungicide applications, 62% would consider reducing both types of applications and 16% would not consider reducing either types of application. We will ask the same questions in 2019 to assess grower responses and impact of our research on grower management practices.

IV. Beneficiaries

The cranberry industry with its 250 members will directly benefit from the results of this research project. We expected that over 50% of growers attending our events and taking the survey would be interested in changing their management practices on their farms to protect and conserve pollinators. In a 2018 Cranberry school clicker survey, over 80% of growers would consider changing their management practices and reducing pesticide (insecticide and/or fungicide) applications during bloom to protect pollinators (Cranberry School Proceedings 2018). These results exceeded our expectations and allude to a continued interest in research to identify the impact of specific fungicides on pollinators.

V. Lessons Learned

Some of the major difficulties in trying to identify effects associated with specific fungicides are that there were a range of fungicides used by our growers, at different application rates, and with different active ingredients. The grower by grower variation made it difficult to narrow down what was driving the effects (or absence of effects) associated with certain fungicides. Moving forward, we would work more closely with the growers to standardize application rates across each fungicide. This approach would help minimize confounding variables, and further promote the collaborative nature of these studies.

We also developed a novel method for analyzing pollen data that we will be reporting in a peer-reviewed manuscript. This approach will help standardize studies that rely on pollen counts as their metric for effect.

We were not able to assess the impact of fertilizers due to the limited number of growers applying the fish fertilizer we were interested in and the fact that fertilizer applications were often overlapping too closely with fungicide or insecticide applications, not allowing us to tease apart the impact of fertilizers alone.

VI. Additional Information

None

VII. Contact Info

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16) Developing Beginning and Minority Growers for Larger Markets (FY15-16)

Report Date: December 12, 2017

I. Project Summary

A. Beginning and minority fresh produce growers cut their teeth on farmers' markets. This marketing venue worked well for small scale producers, allowing them to learn production methods, test markets, and build equity while managing risks within their means. Wisconsin has been a healthy farmers' market culture, with hundreds of markets around the state. However, vendors were reporting that the markets were becoming saturated and they were seeking other venues to move their goods. Supporting this observation was the USDA Economic Research Service, *Trends in U.S. Local Food and Regional Food Systems*, in which data showed that national local food sales at farmers' markets, farm stands, and CSAs have lost momentum.

In May, 2014, the North Central Risk Management Education Center at the University of Nebraska conducted a focus group of Hmong fresh market growers in Wisconsin to ascertain their educational needs. Their findings supported what vendors were reporting to DATCP staff. The top issue identified by the focus group was the need for help in developing new markets. Surveys conducted of beginning farmers also support the need for new markets. The second highest barrier to beginning fruit and vegetable growers' farm viability was access to markets.

So we built on the momentum we were experiencing working with the Hmong growers by continuing to reach out to these growers and provide culturally appropriate workshops and materials. This project focused on delivering workshops on safe food handling procedures specifically for underserved growers. Hmong growers had told us that their customers ask about their food safety practices and they wanted to serve their customers better in this regard. Improving producer knowledge, acceptance, and skills in this area were needed to enhance their market opportunities so they are able to respond to customer demands. The workshops included proper handling of food in the field, packing shed, and cooler, and laid the groundwork for GAP certification. A subset of Hmong fresh produce growers had an interest in growing their businesses to meet larger market demands. Preparing for the food safety standards required by these markets was important for these growers.

There are more than 255 K-12 school districts in WI actively engaged in farm to school activities, including the procurement of local foods. This presented an immense market opportunity for minority and beginning farmers in WI; however, specific knowledge and practices were necessary to successfully capture the institutional market. A survey[1] conducted in 2012 found that 63% of the producers wanted information sessions or workshops on how to sell to schools and 73% of respondents indicated a need for food safety training. Minority and beginning farmers needed to understand the food safety concerns and marketing challenges of working with institutional markets. On-farm food safety had to be addressed in order to penetrate

[1] This survey was disseminated through the Center for Integrated Agricultural Systems at UW-Madison, in partnership with the Wisconsin Department of Agriculture, Trade and Consumer Protection. This survey was responded to by 158 Wisconsin Producers

school markets in the K-12 system.

Another step in developing new markets was to understand the opportunities and challenges of breaking into institutional markets and working with these buyers. With new micro-purchasing options on the threshold, beginning and minority fresh produce growers could be poised to sell their products to schools without having to participate in a competitive bidding process. While this pending announcement presented a great opportunity for minority and new farmers; there were also challenges to selling into the institutional market. This project would provide educational workshops to help fresh market growers understand what it took to sell to institutions, including products of interest, packaging, delivery, quality and quantity, payment terms, and food safety practices.

Previous Hmong programs through our department have benefited from a non-traditional approach to both outreach and educational delivery. As a culture that traditionally transmits information orally and by doing, rather than reading, many Hmong farmers have been more likely to be receptive to new practices if recommended by a clan member within their community, especially a member of their family. Traditional approaches for promoting activities did not yield results. Hmong speaking project staff were needed to work with Hmong farm leaders in each community. These leaders then transmitted information included in the educational programs offered. Trained Hmong mentors would assist by spreading the word within their communities about the workshops. Trainings were made accessible by providing them in Hmong language and going to Hmong farmers for on-site workshops when possible.

Project Objectives included:
Help beginning and minority fresh market growers be aware of the challenges and opportunities of moving into new markets by learning more about on farm food safety, the needs of institutional buyers, and value added agriculture opportunities.

1. Increase knowledge of on-farm food safety protocols and implementation among minority and beginning fresh market growers.
2. Increase producer knowledge of the opportunities and challenges of selling to institutional markets.
3. Increase producer knowledge of value added agriculture ideas and resources.

B. While other projects focusing on Hmong farmers were funded through previous Specialty Crop Block Grants, this project does not specifically build off any of the previous projects.

II. Project Approach

We held a team meeting on 10/5/2016 to visit the Developing Beginning and Minority Growers for Larger Markets Project work plan. We also brainstormed ideas on the presenters and how the K-12 institutional buying workshop would be presented.

On February 25, 2017, we hosted the first K-12 Institutional Buying workshop in Milwaukee, WI to 29 Hmong fresh market produce growers. 22 out of the 29 participants actually completed the workshop evaluation. The evaluations from the workshop showed that all participants felt they had learned enough to feel confident about using the information they had learned. Below was the summary result after compiling all the evaluation data.

EVALUATION REPORT

K-12 Institutional Buying Workshop Evaluation

February 25, 2017
Milwaukee, WI

Please help us serve you better by completing this evaluation.

1. Please rate how much you learned from this workshop using a scale of 1 to 5.
   1= I didn't learn anything new
   2= I learned a couple of new things
   3= I learned more than a couple things to apply to my farming lifestyle
   4= I learned very well to apply the skills to my farming lifestyle
   5= I totally learned enough to use it and will pass it on to others

Knowledge/Skills	Circle number that best describes how much you learned from this workshop				
A. Demonstrations – Carrots and Lettuce & Leafy Greens	1	2(4)	3(5)	4(6)	5(7)
B. School Food Safety	1	2(5)	3(4)	4(5)	5(8)
C. Pack sizes and Packaging	1	2(1)	3(9)	4(7)	5(5)
D. Vendor Requirements (Insurance, business licenses, refrigeration, etc...)	1	2(4)	3(4)	4(7)	5(6)

2. Demographic Information - Gender: __9__ Male __13__ Female
   Age: _____ <30 __2__ 31-40 __10__ 41-55 __8__ 56-65 __2__ >65

3. How long have you been farming/gardening? __10__ 1-5 YRS __5__ 6-10 YRS __7__ 10 YRS +

4. What types of farming do you do? __22__ Vegetables __7__ Fruits _____ Dairy

5. Can you read English? __15__ Yes __7__ No

6. Do you have family member(s) who can read and write English? __21__ Yes __1__ No

7. Do you plan to do business with big buyers after this workshop? __15__ Yes __3__ No

8. Would you recommend this workshop to other people? __19__ Yes __3__ No

Please continue next page!

9. Tell us what you learned from this workshop that you will put into practice.
    1. I learn to know about clean vegetable.
    2. I learned about the opportunities available for me.
    3. Today I learned about the opportunities for me in farming and how I can expand and grow bigger to reach my goals.
    4. I learned about healthy eating and ways to grow better in my garden.
    5. Good
    6. I learned so much today.
    7. Great workshop information. The farmers to school monthly will try to attend.
    8. I gained much information from today's education.
    9. There was so much information but what I got out is that I have to pack my produce very well and accordingly to the instruction given.
    10. I learned about this new opportunity which could help my business grow and the process of handling and packing my produce.
    11. I have learn a lot new things whole a produce safety.
    12. Idea of growing larger.
    13. I learned about food safety and moving into the institution.
    14. I learn new things for this workshop.
    15. How to prepare food in school for students
    16. About clean out carrots, before severed out kids or students or my customers.
    17. I learn food, measure, I like all learn very much.

10. Tell us what you liked/didn't like about this workshop or what you would like to see differently.

    1. I would like to learn about pesticide and fertilizer.
    2. Very good.
    3. Today was a very productive and learning experience.
    4. I would like to know the name of the pesticide that is use to kill the weeds in my asparagus and the pesticide or fertilizer to improve my fruits. 262-339-4526
    5. The training today was very helpful. However, since we are old we would not be able to grow enough supply for the school or any other institute.
    6. You are very good.
    7. I believe this is very good for us.
    8. You interpret very well.
    9. Very good workshop and excellent interpreter
    10. I think more outreach needs to be done to reach out to farmers. Would like more info about herbicides and pesticides.
    11. I think this is a very good for us.
    12. Since this is my first time attending this training, I feel that I have a long way to go, therefore we will need lots of support from both of you in order to reach our goals.
    13. I think this workshop you have organize is very good and well prepared.
    14. I need to learn about a new thing. How to grow new
    15. Like most topic. Do not like that we went too slow
    16. I would like to know the names of the pesticide to kill the weeds in my raspberry and asparagus.
    17. Very good interpret!
    18. Very good this workshop.
    19. I like you talk, translate very well.

On March 25, 2017, we hosted the second K-12 Institutional Buying workshop in Wausau, WI to 30 Hmong fresh market produce growers. 26 out of the 30 participants completed the workshop evaluation. The evaluations from the workshop showed that all participants felt they had learned enough to feel confident about using the information they had learned. Below was the summary result after compiling all the evaluation data. At this time we lost our Farm to School Coordinator and Local Foods Coordinator. Neither position was refilled. We decided to keep the focus on the institutional buying and food safety workshops but decided not to host the K-12 Meet and Greet as their expertise was needed for this event and we felt our turnout was lower than hoped so we wanted to try to get more people to attend fewer events.

K-12 Institutional Buying Workshop Evaluation

March 25, 2017
Wausau, WI

Please help us serve you better by completing this evaluation. Number of Evaluations: 26

1. Please rate how much you learned from this workshop using a scale of 1 to 5.
   1= I didn't learn anything new
   2= I learned a couple of new things
   3= I learned more than a couple things to apply to my farming lifestyle
   4= I learned very well to apply the skills to my farming lifestyle
   5= I totally learned enough to use it and will pass it on to others

Knowledge/Skills	Circle number that best describes how much you learned from this workshop				
A. Demonstrations – Carrots and Lettuce & Leafy Greens	1	2 (3)	3 (7)	4 (7)	5 (9)
B. School Food Safety	1	2 (2)	3 (9)	4 (6)	5 (9)
C. Pack sizes and Packaging	1	2 (4)	3 (6)	4 (7)	5 (9)
D. Vendor Requirements (Insurance, business licenses, refrigeration, etc...)	1 (4)	2 (4)	3 (3)	4 (7)	5 (8)

2. Demographic Information - Gender: __14__ Male __8__ Female
   Age: __3__ <30 __4__ 31-40 __12__ 41-55 __2__ 56-65 __5__ >65

3. How long have you been farming/gardening? __18__ 1-5 YRS __4__ 6-10 YRS __3__ 10 YRS +

4. What types of farming do you do? __26__ Vegetables __1__ Fruits _____ Dairy

5. Can you read English? __18__ Yes __8__ No

6. Do you have family member(s) who can read and write English? __26__ Yes _____ No

7. Do you plan to do business with big buyers after this workshop? __18__ Yes __8__ No

8. Would you recommend this workshop to other people? __23__ Yes __3__ No

Please continue next page!

9. Tell us what you learned from this workshop that you will put into practice.

- I learned that schools want to buy more broccoli, carrots and cucumbers.
- I have learned a little on everything, but concern about the place to do the job.
- This workshop is very good and help me know how to get my business.
- I learned many things about growing enough crops and have them ready to ship out.
- I learned about sun flower sprouts are edible.
- I learned about new buyers for new markets.
- How to work with schools, distributors or processors.
- I learned about how to and how much to have when you pack your products.
- Programs and requirements.
- How to get a relationship with schools.
- I learn about the selling power.
- Informal, formal and micro purchase.
- Contacting school districts & larger distributers for selling produce.
- Looking into different venues besides farmers markets.

10. Tell us what you liked/didn't like about this workshop or what you would like to see differently.

- I liked everything from the workshop.
- I like to know more about shelve life of fresh produce.
- I want to connect with the buyers in the near future.
- Yes, I would like to see differently.
- I liked how there were a lot of information.
- Everything
- Like how there was a lot of information.
- Yes, I like it. It's very good idea to telling us about farm school.
- Very good. It gave us more ideas about doing business with big buyers, but we have some challenges to communicate with them.
- Everything was good. No suggestions.
- Very informative.

Respectfully translated and submitted by: Sophiaya N. Xiong

Thank you for completing this training evaluation!

This workshop is brought to you by:

USDA Specialty Crop Block Grant;

Wisconsin Farm Center

HMOOB Cultural & Community Agency

On April 1, 2017, we hosted the third K-12 Institutional Buying workshop in La Crosse, WI to 15 Hmong fresh market produce growers. 13 out of the 15 participants actually completed the workshop evaluation. The evaluations from the workshop showed that all participants felt they had learned enough to feel confident about using the information they had learned. Below was the summary result after compiling all the evaluation data.

K-12 Institutional Buying Workshop Evaluation

April 1, 2017
La Crosse, WI

Please help us serve you better by completing this evaluation. Number Evaluations: 13

Please rate how much you learned from this workshop using a scale of 1 to 5.
1 = I did not learn anything new
2 = I learned a couple new things
3 = I learned more than a couple things to apply to my farming lifestyle
4 = I learned very well to apply the skills to my farming lifestyle
5 = I totally learned enough to use it and will pass it on to others

Knowledge/Skills	Circle number that best describes how much you learned from this workshop				
A. Demonstrations – Carrots and Lettuce & Leafy Greens	1	2 (3)	3 (2)	4 (4)	5 (4)
B. School Food Safety	1 (1)	2	3 (3)	4 (5)	5 (4)
C. Pack sizes and Packaging	1	2	3 (3)	4 (5)	5 (4)
D. Vendor Requirements (Insurance, business licenses, refrigeration, etc…)	1 (1)	2 (2)	3 (1)	4 (3)	5 (6)

1. Demographic Information - Gender: __4___ Male __9___ Female
   Age: _____ <30 __2___ 31-40 __5___ 41-55 __4___ 56-65 __2___ >65
2. How long have you been farming/gardening? __6___ 1-5 YRS __5___ 6-10 YRS __2___ 10 YRS +
3. What types of farming do you do? __13___ Vegetables __5___ Fruits _____ Dairy
4. Can you read English? __9___ Yes __4___ No
5. Do you have family member(s) who can read and write English? __12___ Yes __1___ No
6. Do you plan to do business with big buyers after this workshop? __8___ Yes __4___ No
7. Would you recommend this workshop to other people? __12___ Yes __1___ No

Please continue next page!

8. Tell us what you learned from this workshop that you will put into practice.

- Food safety, pack sizes & packaging, refrigerator, show videos, pictures and recipes
- I learned 3-4 new things.
- I learned many good things for myself.
- This workshop was very good. It mentioned many good points that I will use in the future.
- USDA requirements, food safety, packaging, insurance, distributor, and farm to school food
- Good for future businesses.
- Good for future business expansion.
- I learned the regulations of food safety and the requirements of doing business with institutional buyers.
- I have learned many ways on how to sell in schools.
- I have learned how to handle food safely.
- I learned many good things from the workshop today. I thought to myself what I should do to get a contract with big buyers.
- I liked everything I heard today. I will prepare myself and move forward with the ideas presented today.
- Today I learned everything.

9. Tell us what you liked/didn't like about this workshop or what you would like to see differently.

- The workshop today was very good. I learned so many things that will help my future growth.
- I liked this workshop so much.
- This workshop will guide the farmers to the next step.
- This workshop gave useful information to us. We will use this information to the max potential.
- This workshop was very helpful to understand the rules and regulations of growing vegetables and selling to school food programs.
- I got some new ideas from the workshop.
- I liked the ideas, but sometimes the business people don't want to talk to you.
- I liked everything you brought to us for learning today.
- It's great. I heard many different ways on how to market my produce.
- I liked the ideas you presented to us today. Thank you for your time!
- It's very good. If you have other topics, please come back and educate us again.
- I liked everything.

Respectfully translated and submitted by: Sophiaya N. Xiong

Thank you for completing this training evaluation!

This workshop is brought to you by:

USDA Specialty Crop Block Grant;

Wisconsin Farm Center

HMOOB Cultural & Community Agency

On May 10, 2017, we held another team meeting to report the results from 3 K-12 Institutional Buying workshops and plan for the 4 On-Farm Food Safety Trainings. We identified the trainers and farm sites for the trainings. After the meeting, Jack Chang mentioned that he would relocate his family to different state this summer. Without Jack, this project is needed to be put on hold. We decided to put this project on hold until we come up with other plan to carry it forward.

On September 18, 2017, we held our first on-farm Food Safety Field Day. Five Hmong growers were in attendance. While all 5 farmers thought the event was worthwhile and reported that they learned a lot and would put some new safety practices in place, we were unable to get enough growers together for the additional field days.

The main project partners were the state Hmong associations (particularly the ones in Wausau, Eau Claire and La Crosse). They were extremely helpful by providing space for the workshops that was culturally appealing for the participants, and assisted with promoting the workshops which truly helped boost attendance. Other Hmong community leaders assisted by providing relevant advice and guidance on the challenges of getting growers ready for the institutional market and suggesting speakers.

III. Goals and Outcomes Achieved

A. After the 3 K-12 Institutional Buying workshops and on On-Farm food Safety Workshop, there were 74 Hmong growers and none other beginning growers attended the workshops. Based on the evaluations, 48 (79%) out of 61 Hmong growers fall under the USDA beginning farmer definition. We were short by 1 if comparing the total actual number (Hmong and Beginning farmers) 74 to the total estimate number (Hmong and Beginning farmers) which was 75. We achieved 99% of our goal for this particular activity.

Workshop ratings ranged from 3.56 to 3.80 for the four key skill areas participants were asked to rate on the “buying workshops”. The food safety field day ratings ranged from 3.3 to 4.2 on the five key topics participants were asked to rate. The topic that rated 3.3 was record keeping. We will include a more hands on approach to this topic in the future, with visuals to share with participants.

B.

Goals:	Est. Hmong	Actual	Est. Beginning	Actual
3 K-12 Institutional Buying Workshops	30	74	45	0
4 On-farm food safety	20		60	
1 K-12 Meet and Greet	2		8	
3 Value Added	45		0	
K-12 market food safety standards completed	2		0	
Kitchen Incubator Tour	6		14	
Totals	105	74	127	0

IV. Beneficiaries

This project provided numerous benefits to the 74 Hmong growers who attended workshops. Many of those in attendance are mentors for other Hmong growers and utilized their training by sharing their knowledge with others. Below are some of the feedbacks that we received from the growers who attended our workshops.

"Today I learned about the opportunities for me in farming and how I can expand and grow bigger to reach my goals."

Hmong grower

"There was so much information but what I got out is that I have to pack my produce very well and accordingly to the instruction given."

Hmong grower

"I learned many things about growing enough crops and have them ready to ship out."

Hmong grower

"I learned the regulations of food safety and the requirements of doing business with institutional buyers."

Hmong grower

"I learned many good things from the workshop today. I thought to myself what I should do to get a contract with big buyers."

Hmong grower

"I liked everything I heard today. I will prepare myself and move forward with the ideas presented today."

Hmong grower

V. Lessons Learned

We reached out to both beginning growers and Hmong growers. We also reached out to organizations/agencies that serve the beginning growers to promote our events/workshops to their beginning growers. As results, we did not have any responses from the beginning growers to attending our workshops. We did not know why, but we thought that maybe they had conflict schedule or not ready to do business with institutions and/or big buyers. We would communicate with other organizations/agencies that work with the beginning growers to come up with a better strategy to attract beginning growers for future activities.

VI. Additional Information

Below was the flyer for K-12 Institutional Buying Workshop. We released and promoted these workshops through social media, local agencies, local/regional events and mailed directly to those growers who we have their mailing address.

K-12 INSTITUTIONAL BUYING WORKSHOP

WHEN

Hmong Growers:
8:00 am – 12:00 pm (with Hmong interpreter)
Beginning Growers:
1:00 pm – 4:00 pm

Workshop Description:

This workshop will introduce you to other market avenues beyond farmers markets. It will give you some insight into wholesalers, who they are, what they want and how to do business with them. It also gives you resources to get ready and do business with big buyers. This is a good opportunity for you to grow and sustain your business!

Presenter:

Kymm Mutch is currently the Vice President of Products and Services for Food Service Management Solutions, a national consulting firm. She is also a registered dietitian (with over twenty-five years of experience) who brings a wealth of experience in child nutrition, food service management, school food procurement and systems change. She believes that sourcing food locally, eating more simply and healthfully and understanding how food is grown and prepared are significant keys to improving children's lifelong health.

This workshop is brought to you by:

USDA Specialty Crop Block Grant;

LOCATIONS:

MILWAUKEE
February 25, 2017

Hmong American Friendship Association, Inc.
3824 W. Vliet Street
Milwaukee, WI 53208

WAUSAU
March 25, 2017

Hmong American Center, Inc.
1109 N 6th Street,
Wausau, WI 54403

LA CROSSE
April 1, 2017

Hmong Cultural & Community Center, Inc.
1815 Ward Avenue
La Crosse, WI 54601

REGISTRATION:

FREE Workshop, but Pre-registration is Required!

Jack Chang:
(608) 224-5050 or
jack.chang@wisconsin.gov

Angie Sullivan:
(608) 224-5095 or
angie.sullivan@wisconsin.gov

VII. Contact Info

Kathy Schmitt
DATCP Farm Center
2811 Agriculture Drive
Madison, WI 53706
(608) 224-5048
kathy.schmitt@wisc.edu

17) Biological control of flea beetle and cranberry fruitworm using native entomopathogenic nematodes (FY15-17)

Report Date: September 30, 2016

I. Project Summary

A. The American cranberry, *Vaccinium macrocarpon*, is the top fruit crop in Wisconsin, and insects are major, consistent pests of berry production. *Vaccinium macrocarpon* also happens to be a native plant in North America, and the arthropod complex targeting it is comprised of native species, too. As natives, these arthropods have co-evolved not only with the cranberry plant but also with their natural enemies, which include nematodes. Native nematodes should be highly effective predators of cranberry pests. Such nematodes can endure Wisconsin winters and effectively forage for insect prey in the wet, acidic conditions of a cranberry marsh. We proposed to survey these native nematode populations and then isolate the more promising species for mass propagation and deployment against key pests. To these ends, we established laboratory cultures and tested for virulence against flea beetles and cranberry fruitworms. This work represents a new biological control program for Wisconsin cranberries.

B. This project builds on a previous SCBG FY14 grant that was focused on flea beetle control, both via chemical and biological means. This earlier project focused primarily on insecticide-based control and education of the grower community. It was successful in both regards, yet also initiated new efforts to create a biological control program involving native nematodes. Surveys of native nematodes were conducted as part of the earlier FY14 project, and these revealed three candidate nematodes for virulence testing.

In FY15, we conducted the virulence tests under various conditions, both in the lab and the field. These represent critical proof-of-concept studies which demonstrate that these native nematodes have tremendous potential to control not only flea beetles, but also other major cranberry pests. The current project (FY15) has also provided taxonomic resolution of our nematodes lines, and has even provided evidence that we have a species new to science. Importantly, the nematodes not only are lethal for flea beetles, but also for sparganothis and cranberry fruitworms. These bio-control agents add to the existing arsenal of insecticides that can be used against flea beetles, but the nematodes clearly provide insect control without adding chemical residues to the fruit. Ultimately, a field-ready nematode formulation (bio-insecticide) will be formulated that can be applied and irrigated into pest "hot-spots."

II. Project Approach

The objectives of our project were to: 1) culture insect-associated nematodes from wild and cultivated cranberry systems; and 2) screen for pathogenicity against flea beetles, sparganothis fruitworms, and cranberry fruitworms in greenhouse and field settings. This work is separate from previous projects funded by WDATCP in that we are focusing on creating a new biological control program for multiple cranberry pests (not just flea beetles). This project ultimately will provide the basis for a new bio-pesticide derived from native nematode species.

Collection and identification of native Wisconsin nematodes:
Using the three nematode "lines" collected during our FY14 work, we needed to use formal methods to distinguish them taxonomically. We employed genomic methods on one of the three entomopathogenic (EPN) lines we have in culture, and we have shown that is a species within the *Oscheius* genus, near *O. tipulae* (Rhabditida: Rhabditidae), a nematode named due to its association with cranefly larvae. The molecular process that yielded the result required the use of a standard Quiagen DNeasy ® kit to extract EPN DNA, a generic nematode PCR procedure to amplify the ITS region of the EPN genome, and the use of GENBANK to compare our extracted and amplified DNA, which was sequenced using Sanger Sequencing at the UW-Madison's Biotechnology Center. Until the other two species can be identified, the lines are being referred to by the colors of their cadavers, which are red and grey.

Currently, based on molecular output and anatomical morpho-metrics, we have adequate evidence of that our *Oscheius* species is likely new to science. We are in the process of formally describing it, and we plan to name this species *Oscheius wisconsini* (its shortened species name will be *O. wisconsini*).

Virulence testing of nematodes against flea beetles and sparganothis fruitworms:
After three preliminary trials using insect hosts in petri dishes, we demonstrated that these nematodes caused high (70-90%) sparganothis fruitworm mortality. We then built up nematode populations enough to conduct a larger trial outdoors using moderately sized cranberry sods (1' x 1' x 8" deep), dug up in the spring (April) of 2016 from a cranberry marsh with extraordinarily high flea beetle populations. This trial compared the efficacy of native WI nematodes to the best soil-soak insecticides currently known for cranberry flea beetles. For this trial, we tested our new nematode species (*Oscheius wisconsini*). Previously, we had shown that this nematode readily found and killed both sparganothis fruitworm and cranberry fruitworm larvae in petri dishes (Foye & Steffan 2016, Proceedings of Winter Cranberry School).

In the early summer of 2016, we investigated the nematode's ability to control flea beetle larvae within commercial cranberry sods. Flea beetle mortality achieved with the native nematode, *O. wisconsini*, was compared to mortality associated with the insecticides, Belay WSG ® and Diazinon AG 600®, along with an untreated Control. These four independent treatments were each replicated 10 times. This trial was completed using 40 one-square-foot sods donated from a Wisconsin cranberry marsh with a history of severe flea beetle infestations. Nematodes were applied at a rate of ~90,000 nematodes per sod (typical density of nematodes in marsh/bog habitats), and insecticides were applied at the top of their respective label rates. All sods (including the untreated control) received 400 ml of water to move the applications through the soil profile. The sods were stored in mesh cages, kept in greenhouses, and inspected daily for adult flea beetles until the flea beetle populations had stopped emerging.

Our results show that the nematodes significantly reduced flea beetle numbers (by 75%) below those of control sods (Fig. 1). Furthermore, there was no significant difference among the nematode or insecticide treatments. Our future work aims to determine an efficient mass production system and an economically viable nematode application rate. One interesting observation related to this trial is that very few arachnids were found in the canopies of Belay and Diazinon enclosures, but similar numbers of spiders were found between control and nematode cages. This finding suggests nematodes may pose less risk to the natural enemies, thereby helping to contribute to pest suppression down the road. Finally, in these sods, there were very few sparganothis or cranberry fruitworm larvae, so statistical analyses could not be performed on these species. Flea beetle control, however, was significant.

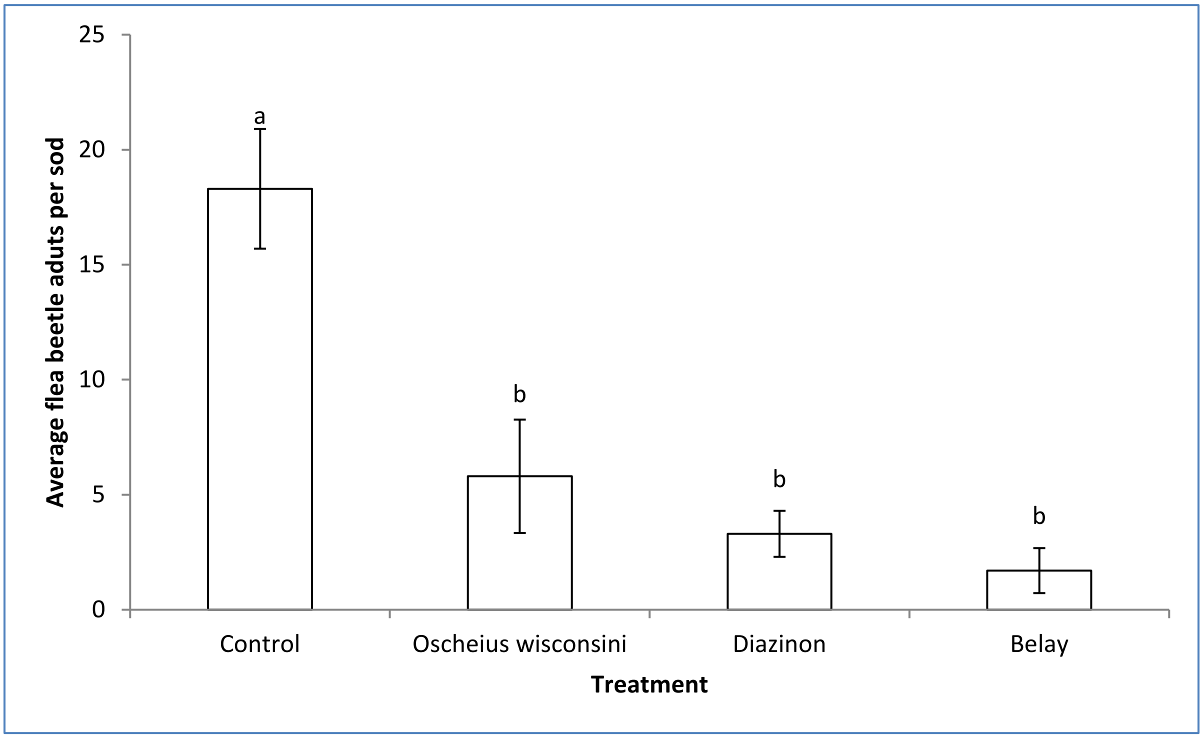
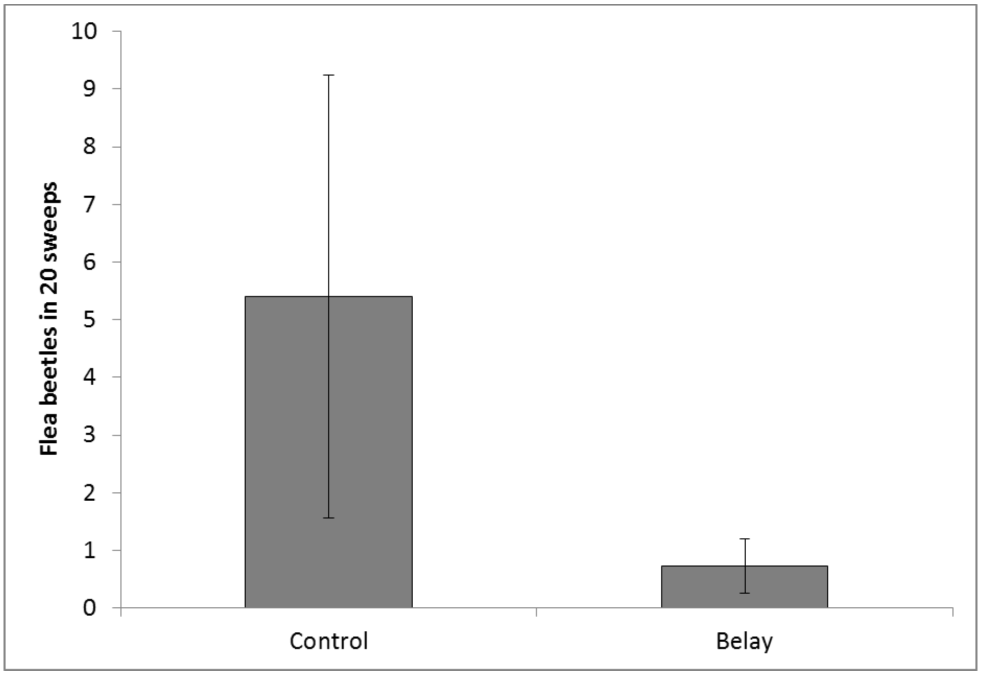


Figure 1. The average number of adult flea beetles that emerged from sods treated with 1) a water control, 2) Oscheius wisconsini nematodes, 3) Diazinon, or 4) Belay. Different letters denote significant differences in terms of mean flea beetle counts ($p < 0.05$).

We completed a second trial this past summer (FY15) that was a large farm-scale study comparing flea beetle populations in beds treated with an insecticidal soil-soak versus untreated control beds. In this study, 12 large beds with a history of flea beetle pressure were randomly assigned to either a Belay soil-soak or left as untreated controls. Belay was applied just after bees were removed from the marsh (July 25), at 12 oz/acre and irrigated for 2-3 hours following the application. This work served as further evidence that Belay can “clean up” flea beetle hot-spots in cranberry beds harboring major flea beetle populations.



Adult flea beetle populations were assessed via five sets of 20 sweeps in each bed in early August. Results (Fig. 2) show that beds treated with the Belay soil-soak had significantly fewer adult flea beetles. This suggests that we were able to effectively penetrate the soil profile with Belay, and that this was an effective insecticide for suppressing flea beetle populations in Wisconsin.

Figure 2. Adult flea beetles collected via sweep nets in cranberry beds with and without Belay.

III. Goals and Outcomes Achieved

A.

<u>*Performance goals, metrics, benchmarks, and outcomes*</u>

1) **Goal: Discover and culture native entomopathogenic nematode species that can attack and kill cranberry pests.**
   Performance measure: nematode species in culture: We have isolated and cultured 3-4 native nematode "lines" (it is often difficult to know if these are truly different species) and have successfully kept them in culture using sparganothis fruitworms. We have mass-produced millions of nematodes at this stage, and have tested them against flea beetles, cranberry fruitworm, and sparganothis fruitworm.

   Benchmark: Two or three nematode species as candidates for larger-scale virulence tests: For two of these lines, we have reached our benchmark of 90+% mortality of the targeted pest (sparganothis fruitworm). It appears to also provide robust control (75% reductions) of flea beetles under natural conditions, outdoors and within the cranberry canopy.

   Target: There is variability among nematode species, but among trials, we have evidence that a pre-bloom soil soak of the nematode, *O. wisconsini*, achieved flea beetle control that was similar to the very best insecticides: Belay and Diazinon. A third and fourth nematode species are currently under investigation for virulence.

2) **Goal: Find the best candidates for a nematode-based bio-control program (isolate 2-3 nematode lines that are highly virulent against flea beetles and fruitworms).**
Performance measure: High percent (%) mortality in host insect. The nematode, *Oscheius wisconsini*, was readily mass-produced and caused high mortality in our field trials.

Benchmark: 50-80% flea beetle mortality: Mortality rates in flea beetles were around 75%, and this benchmark was not significantly different from the best insecticides, applied at the same time via soil-soaks.

Target: a single nematode specie that can consistently cause high mortality rates: In laboratory studies, we have a nematode (*O. wisconsini*) that has achieved approximately 90% mortality. In field studies, it achieved 75% mortality.

B. This nematode bio-control program has been exceedingly fruitful—all benchmarks and targets have been reached for the current fiscal year. We continue to test other nematode lines, and will soon begin mass-propagation for large-scale field deployment.

IV. Beneficiaries

Wisconsin cranberry growers and their attendant industries (e.g., material suppliers, pest management consultant services) are the major beneficiaries of this project. There are over 250 growers in the State, employing thousands of workers. Because late-season foliar spraying remains the dominant form of flea beetle control, and this preclude most US cranberries from being exported to Asia and Europe, there is a great demand for alternative pest management tactics. Growers are enthusiastic over the successes of the nematode work, and are willing to apply it to their worst flea beetle hotspots. Eventually, a benchmark for the Steffan Lab will be to have mass-produced enough *O. wisconsini* nematodes to inoculate marshes with these native nematodes (as a free-service to growers). This will demonstrate on-site that these nematodes can provide effective pest control for flea beetles, as well as sparganothis and cranberry fruitworm.

V. Lessons Learned

Nematodes harbor symbiotic bacteria, and these bacteria can be toxic to other bacteria and fungi. Thus, in the process of doing our study, we may have uncovered bacteria of significant medical and/or agricultural value.

VI. Additional Information

Presentations and publications were made at the WSCGA winter cranberry meetings (2015 and 2016) and spring workshops (2015). Proceedings of the Winter Cranberry School can be found at the Wisconsin State Cranberry Growers Association website. Newsletters online at the Wisconsin Fruit News and Cranberry Crop Management Journal are available, as well.

VII. Contact Info

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18) Optimizing nitrogen fertilizer applications for snap bean production to improve water quality (FY15-18)

Report Date: September 10, 2018

I. Project Summary

Previous research (Wang et al., 2015; "Processing snap bean variety response to applied nitrogen and irrigation in the North Central United Stated) on snap bean response to N provided interesting results, but it was unclear if the results are applicable to a broad range of soil and climate conditions. This previous research was conducted in Plover, WI with high yielding Del Monte varieties. Results suggested that 100 lb.-N/ac was the optimal N rate (20 lb.-N/ac in starter and 80 lb.-N/ac in-season) when yields are greater than 9 ton/ac. However, typical yields for snap bean are in the 4-5 ton/ac range (personal communication with processing crop agronomists), which may not require 100 lb.-N/ac (current UW recommendations are 60 lb.-N/ac for yields up to 6.5 ton/ac). In addition, the previous research also indicated that for non-nodulating varieties (i.e. varieties that do not allow root infection of rhizobium, and thus do not directly obtain N fixed from the atmosphere), had an N utilization efficiency of 68% when 100 lb.-N/ac was applied. For nodulating varieties (in this case the high yielding Del Monte varieties) additional analysis using ^{15}N stable isotope concentrations was necessary to determine the true removal efficiency as it is unknown how the addition of N fertilizer will inhibit the amount of N that is fixed. Preliminary analyses of these results indicate that the 100 lb.-N/ac rate completely inhibits N fixation in snap beans. Now, it may seem counterintuitive, but this is actually beneficial for water quality. It means that the applied N is replacing the N fixed by the atmosphere and is actually well-utilized in the system. If applying N fertilizer did not completely inhibit N fixation, then much of the N that was applied would not be used and thus leached to groundwater. However, 100% inhibition of N fixation occurred at the 100 lb.-N/ac rate, with lower N rates inhibiting a small percentage of N fixation. Now, if more commonly used varieties require less N inputs (in the 50 to 80 lb.-N/ac range) it is important to know what the true N use efficiency is as less N on lower yielding varieties may be less efficient than more N on higher yielding varieties. With all of the issues concerning nitrate concentrations in the Central Sands, we know little about the actual fate of N (or at least the utilization of applied N) in snap bean production systems.

The other big issue in snap bean production is a lack of modern measurements on removal rates of all nutrients. There are recommendations in the A2809, but it is not clear how these recommendations were developed – it's possible that they were estimated from other similar plants or from research in other states. The goal of this project is to develop N recommendations to snap beans that are variety specific and are considerate of water quality. The objectives of this study are to: (1) determine agronomically and economically optimum N rates for nodulating and non-nodulating varieties based on linear or quadratic-plateau regression and (2) determine the N removal and N uptake efficiencies at agronomic and economic optimum N rates to assess the potential impact on groundwater nitrate. A secondary objective is to quantify the P, K, S, Ca, Mg, B, Zn, Mn, and Cu removal rates from the production system with snap bean harvest.

B. This work builds upon concurrent work with other high value, high N demand crops in the central sands (potato and sweet corn), where N use efficiency is used to evaluate the impact on water quality. Previously funded research from the Specialty Crop Block Grant (2011) evaluated NUE on sweet corn and the direct connection to groundwater nitrate concentration. Collectively, these two funded projects have provided clear recommendations for growers to maximize the efficiency of the applied N fertilizer on crops in the Central Sands.

II. Project Approach

The research was conducted at the Hancock Agricultural Experiment Station in 2016 and 2017. Our partners on this project include DelMonte, Seminis, and Syngenta (leaders in snap bean seed in the region). The other key partner is the Midwest Food Products Association, which funds similar and previous research, as well as provides a venue to distribute information. Soil analysis for pH, OM, soil test P, soil test K, S, Ca, Mg, and micronutrients were collected prior to study initiation. The experimental design was a randomized complete block, split plot study with four in-field replications. The study was also replicated twice per growing season, comparing two different planting dates (June 1 and July 1) to evaluate the effect of planting date, as well as to obtain additional site years within a two year study. The whole plot factor was snap bean variety, which included publicly available varieties of Huntington and Pismo (non-nodulating) and Caprice and Sassy (nodulating). The split plot factor was N rate and included rates of 20, 40, 60, 80, 100, and 120 lb.-N/ac. Since starter fertilizer is a common management practices (with a rate of 20 lb.-N/ac), we did not have a true zero N rate in the study. Thus, the study was an evaluation of the in-season applications of N (at rates above the 20 lb.-N/ac baseline); this made for a simpler study rather than confound the N rate treatments with different rates of starter fertilizer. In addition, this study has six N rates and thus the ability to use regression analysis to determine optimum N rates. Analysis of variance was used to determine if there was a treatment effect (i.e. if there were differences in yield based on variety or N rate, as well as if N response was different for each variety), but agronomically optimum N rates were determined using linear-plateau or quadratic-plateau regression. These regression models assume that yields plateau at higher N rates, which makes more sense biologically as compared to linear or quadratic (non-plateau models) that would suggest yields keep increasing or perhaps even decrease at the higher rates of N. The plateau models also provide a clearer indication of the optimum rate compared to other models and are more defensible to the scientific community.

The N rates were applied as follows: 20 lb.-N/ac with starter and the remaining N applied 50% at 3rd trifoliate (V3 growth state) and 50% 7 to 10 days after the first application. Each plot was four rows wide by 20 feet long and snap beans were planted at a seeding rate of 130,000 seeds/ac. Pods were harvested mechanically in the middle two rows to obtain fresh weight. A subsample of pods were collected to determine moisture, quality, and total nutrient concentration. Six whole plant samples were collected prior to harvest, separated into pods and vegetative biomass, dried, ground, and analyzed for total N and ^{15}N concentration. Total nutrient concentration was conducted by the UW Soil and Plant Analysis Lab and the ^{15}N concentration was determined by the University of California-Davis Stable Isotope Facility (http://stableisotopefacility.ucdavis.edu/). Nutrient content of the pods were calculated as the dry matter weight of the pods multiplied by the nutrient concentration. Partial factor productivity (yield/N applied) and partial nutrient balances (N removed/N applied) were determined for all N rates. The N use efficiency of in-season N applications (i.e. all treatments except the 20 lb.-N/ac rate which is applied as starter) were determined as the N uptake efficiency calculated as the N uptake in the whole plant minus the N uptake in the whole plant of the 20N treatment divided by the N applied. This is the true N use efficiency for non-nodulating varieties. However, this is only a theoretically maximum efficiency value for nodulating varieties where it is assumed that the N applied is inhibiting N fixation in a direct fashion (i.e. 50 lb.-N/ac added reduces N fixation by 50 lb.-N/ac). But we know that this is not a directly proportional relationship. We can determine the true N uptake efficiency by knowing the ^{15}N concentration of reference plants (non-nodulating varieties) and of nodulating varieties. To be clear, this is a natural abundance approach rather than an isotope tracer approach. Once ^{15}N concentrations of nodulating and non-nodulating plants were known, the calculation for the percent N in nodulating plants that is derived from the atmosphere (%Ndfa) was calculated as:

(^{15}N of reference plant – ^{15}N of N-fixing plant) / (^{15}N of reference plant)

The amount of N in the plant that came from N fixation was subtracted from the total N in the plant with no N applied to calculate the amount of N taken up from the soil. The amount of N-fixed and the amount of N taken up from the soil was subtracted from the total N in the plant when N was applied to determine the true uptake efficiency of the applied N. Any N not taken up is N that is eventually leached to groundwater.

III. Goals and Outcomes Achieved

A. Outcome:

The one measurable outcome that can be quantified during this study is the change in knowledge of growers and agronomists.

Indicator:

As a result of these efforts, 75% of presentation attendees will increase their knowledge of appropriate N application rates.

Based on the amount of presentations given and the survey responses of the audience, the short-term goal of 75% increase in knowledge was met. Continued efforts to develop additional materials and to create a change in condition (i.e. improved management practices) are underway.

B. Field trials were successfully conducted during the 2016 and 2017 growing seasons. All measurements were made.

Four varieties of snap bean were evaluated (two that nodulate – and fix N, and two that do not) and we now have eight site-years for the different types (nodulating and non-nodulating). There are three main results that are of interest: 1) the optimum N rate, 2) the fate of the applied N, and 3) the amount of nutrient removal with the pods. While each individual site years has been analyzed (see https://extension.soils.wisc.edu/wcmc/nutrient-use-in-high-yielding-snap-bean/), the data still needs to be analyzed across site years to update the nutrient recommendations (N, P, K, and S). In 2016, we had an opportunity collaborate with a visiting student from Brazil (Luiz Henrique), who was very interested in engaging with this research. He has been working with the data and is developing a draft of a research publication. Although he has returned to Brazil, we have still been in communication and expect a publication in the next year. In addition, a new graduate student has started in my lab as of Fall 2018 (Alexandra Walters). She will also be working with this dataset to develop future studies on snap bean. As you can see, this research not only will provide updated nutrient recommendations to Wisconsin farmers, but is of great scientific interest to many other researchers.

Research results were presented at the 2018 Central Wisconsin Processing Crop meeting on March 7, 2018. Survey results there was a significant change in knowledge. On scale from 1 to 5, knowledge before was 3.3 and the knowledge after was 4.3. The audience are professionals in the processing crop industry as well as crop consultants and some farmers. But all attendees grow snap bean. This lead to a potential future change in action where N fertilizer applications best match N demand based on yield potential. More efficient use of N increases productivity, but will likely have limited impact on water quality. As the update to the fertilizer recommendation is updated, we plan on survey the attendees of the Central Wisconsin Processing Crop meeting with regards to N application rate and yield. As all farmers in the Central Sands of Wisconsin are under pressure to reduce nitrate to leaching to groundwater, monitoring will continue and expand. Collaborations are underway among the commodity groups in the region to collaborate on monitoring and NUE assessment.

IV. Beneficiaries

This work has been presented at three main conferences in the past two years: the 2017 Wisconsin Agribusiness Classic, the 2018 Wisconsin Agribusiness Classic, and the 2018 Central Sands Processing Crop Workshop. The three presentations were given to a total audience of 250 attendees. But it should be noted that the total conference attendance of the Classic in each year was around 1,500 and that all attendees would have access to the presentation materials online. The audience for the Classic is a combination of processing crop company agronomists and agricultural retailers (i.e. fertilizer dealers). The audience for the Workshop is a combination of agronomists, dealer, and farmers. In all, this data has been presented to the majority of the snap bean growing population in Wisconsin. For snap bean specifically, the processing companies work directly with the farmers and are often the ones recommending the rate of N applied. So providing them with this information (even if it is only a handful of people) can influence the vast majority of acres. Surveys at the 2018 Central Sands Crop meeting showed a large increase in understanding as a results of the presentation. Other conferences were not able to provide surveys.

V. Lessons Learned

Four main lessons were learned: (1) optimal N rates for non-nodulating varieties, (2) optimal N rates for nodulating varieties (i.e. those that fix their own N), (3) calculations of nitrogen use efficiency, and (4) removal rates of P, K, and S.

The data does suggest that for high yielding snap bean (>10 ton/ac) that the N fertilizer recommendations should be increased, perhaps up to 120 lb./ac based on agronomic performance for non-nodulating varieties. The current fertilizer recommendations in Wisconsin only provide guidelines up to yields of 6.5 ton/ac yields.

Calculating optimal N rate for nodulating varieties provided much more of a challenge compared to non-nodulating varieties. For non-nodulating varieties, the response to sharp and clear. For nodulating varieties, the response was more flat – meaning yields were relatively high with low N rate. Yields did increase, but not dramatically. However, this increase was statistically significant and economically significant. So while optimum N rates are somewhere between 80 and 100 lb./ac (less than of non-nodulating), high yields can still be obtained with much lower N rates. This needs to be reflected in the recommendations in some way.

Nitrogen use efficiency was calculated using 15N stable isotope measurements. This analysis showed things four things. The first was that a small amount of N (<60 lb.-N/ac) has little impact on suppressing nodulation. The second was rates of 60 and 90 cut N fixation by 1/3 and rates of 120 cut N fixation by 2/3. Thirdly, rates at 150 or more completely cut of N fixation; all N obtained from the plant came from the fertilizer or soil. Lastly, it shows that 15N analysis is superior and essential for the true calculation of N use efficiency. Uptake of fertilizer N would be severely underestimated if based on traditional approaches.

P and K removal rates of high yielding varieties was still similar to the current recommendation application rates. This suggests that P and K may be less concentrated in the pods with greater yields. And no changes to P and K fertilizer recommendations are warranted. S removal rates were low (<5 lb./ac) but because of the sandy soil, small applications of S would still be recommended. No major differences in P, K, or S removal rates among varieties.

VI. Additional Information

Detailed information, including presentations of results can be found at:
https://extension.soils.wisc.edu/wcmc/nutrient-use-in-high-yielding-snap-bean/
https://extension.soils.wisc.edu/wcmc/nitrogen-use-efficiency-in-modern-snap-bean-production-systems/

Final steps of this project included finalizing the research publications, and developing extension publications that summarize the results for farmers, agronomists, and the general public.

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19) Wisconsin Specialty Mushroom Growers Education and Outreach (FY15-19)

Report Date: September 12, 2018

I. Project Summary

There is a growing interest in and demand for specialty mushrooms due to consumer interest in healthy eating and in the medicinal properties of some mushrooms. To meet this growing demand, local Wisconsin specialty mushroom growers need support to create, enhance and sustain a viable production economy around specialty mushrooms. There are many varieties of mushrooms used worldwide that can be grown commercially, but there are currently not enough growers to supply the growing demand for specialty mushrooms.

Traditional mushrooms make up 3.6 % of the fresh market and greenhouse-grown produce crops. The mushroom market is dominated by a small group of large scale producer cooperatives clustered in Pennsylvania and California. These producers grow primarily traditional production mushrooms (white button - Agaricus, Portabella and Bavarian browns) on manure compost as well as a fair amount of specialty mushrooms. Producers of specialty and boutique mushrooms are coming predominantly from the West Coast states, and from overseas. These mushrooms consist primarily of shiitake, oyster, reishi, maitake, straw and wine cap. A few medium scale producers in the USA also grow specialty mushrooms for, environmental restoration projects and ethnic and medicinal markets. These mushrooms are grown on a variety of substrates such as straw, wood, compost and other recycled materials. A few producers market online and ship worldwide. The challenge is there are not enough suppliers and growers in Wisconsin to meet the growing retail, restaurant, farmers market and CSA demand.

Midwest specialty mushroom production is mainly composed of very small to medium-scale production with the majority coming from small-scale basement and garage hobby operations. The majority of the specialty mushrooms available in the Midwest are coming from other states. To produce mushroom fruits, growers need consistent access to spawn and growing substrates. Last year the primary Wisconsin distributor of spawn to growers ran out of product and growers had to purchase spawn from distributors out of state.

Beginning growers and small scale individual producers have limited resources and are hampered by available production materials (substrate material, spawn). There is need for industry education and outreach in production and market practices to help farmers streamline their production practices, network, and market with local vendors allowing for industry growth and success.

This project addressed some of these issues by:

- •Assisting in connecting woodland owners and mushroom growers by developing a networking strategy to grow those business relationships.
- •Developing educational events and outreach materials to assist growers on efficient mushroom cultivation techniques and potential market opportunities.

•Participating in statewide agricultural conferences promoting a mushroom growers network.

•Developing a marketing strategy to increase awareness of specialty mushrooms and creating relationships with vendors, restaurants and other potential markets on behalf of growers.

B. This was a new project

II. Project Approach

Project goals included:
1.Increase specialty mushroom supply and demand locally by increasing local production of organic mushroom production in Wisconsin

2.Education to increase consumption of specialty crops

Project Activities focused on:
1.Marketing promotion
2.Education/training
3.Outreach to underserved farmers

WORK PLAN			
Project Activity	***Who***	***Work completed***	***Timeline***
Planning and project development	Project Lead and ShiiGAW	ShiiGAW board worked with a Web and graphic designer and for a Database and administrative Assistant to help work on the grant deliverables.	Completed
Host a producer engagement meeting, implement survey of producer needs	Project Lead, ShiiGAW advisory team and UW Extension	A survey was developed and a Round Table presentation was carried out at the 2016 Moses Conference approximately 75 individuals attended and 46 surveys were collected. Survey of farmers markets around the state was carried out.	Completed
Present findings from survey and create work groups to implement findings	Advisory team, Partners and Project Lead	Board reviewed survey results. Mindy Habecker from UW Extension helped assimilate survey data with work groups	Completed
Develop outreach plan to growers and stakeholders. Produce other outreach materials and develop a web/ social media presence for the project.	ShiiGAW and Field and Forest Products	• Website has been redesigned and was shifted to a WordPress site to accommodate more functionality. • Facebook site was created and newsletters are available in a paperless form for all interested producers and consumers.	Completed

		• Marketing/recipe information was updated and put on website for all growers to use at farmers markets. • Board members hosted numerous workshops, grower training events and gave presentations to promote mushroom growing in Wisconsin.	
Host roundtable at MOSES conference	Project Lead, ShiiGAW advisory team and SARE and UW Extension	Hosted first round table at MOSES in 2016. this information was used to help guide our strategic planning session. Discussion to do a Mushroom University in 2020.	Completed
Host grower/educator training	Partners and ShiiGAW	Board members have each hosted several hands-on how to trainings and ShiiGA hosts training workshops in conjunction with their annual meeting 2016, 2017 workshop in Peshtigo on September for 35 participants each and another is planned for 2018.	Completed
Project Completion: compile outcomes and write reports present at conferences and regional association meetings	Project Lead and ShiiGAW	New growers have joined ShiiGaw so membership has nearly doubled since the start of the project. Event coordination and participation has tripled. Interest in mushroom production has not slowed in any way since the project began.	Completed

III. Goals and Outcomes Achieved

A. See table above

B. Increase specialty mushroom supply and demand locally by increasing local production of organic mushroom production in Wisconsin

1. Outcome: increase mushroom production in Wisconsin
    a. Benchmark: Current 2015 growers selling through CSA network and local farmers markets
    b. Target: 5% increase
    c. Measure: Daily and seasonal vendors and CSA's that include cultivated mushrooms in their boxes anytime during their active season will be quantified. These markets will be surveyed in 2017
    d. These markets were surveyed in 2017. Response to the survey was disappointing however two new farmers were reported added to farmers markets. Mushrooms provided at existing markets continues to grow. Existing farmers expanded their production to meet more demand. Field and Forest Products Inc. (the only spawn

provider in Wisconsin) has seen increased demand in spawn purchases and has expanded its facility to provide for the demand to new growers.

2. Outcome: Increase # of farmers growing Shiitake mushrooms commercially
    a. Benchmark: Current ShiiGAW members that are growing mushrooms for income or are planning on growing mushrooms for income will be quantified in 2015
    b. Target: 10 additional growers starting production by end of project.
    c. Measure: Will base on increased # of mushroom producers that are actively farming in 2017
    d. Membership has grown from 10 to 18 an 80% increase as of August 2018. We expect to see continued increases as more exposure to our organization is available through face to face contact and a social media presence on Facebook, Instagram, Tweeter and our Website.

IV. Beneficiaries

Farmer's Markets

As results showed from our survey conducted in summer of 2017, there was at least a 5 % increase in the number of Mushroom growers selling at Farmer's Markets with 2 new growers participating in Dane County Farmers markets. Other markets saw an increase in sales of mushrooms from participating growers (qualitative but not quantitative – growers responded they sold more but would not report a dollar or pound increase in sales). However, this data was very hard to quantify as many farmers markets did not respond to our survey.

SHIIGA

We increased our board participation by two additional members from 5 to 7 board members both new to the organization. Membership increased 80% and new marketing materials were created to increase sales and interest in local mushroom purchases. ShiiGA were able to secure additional grants, enabling us to continue work on expanding marketing for shitake growers statewide.

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Growers and Potential Growers

SHIIGA is able to host multiple educational events around the state and provided quality information to beginning and perspective growers. Demonstration sites were set up at Silverwood Park in Dane County and Helen Brockman YMCA in Almond, Wisconsin. 20 mushroom inoculated logs were provided to each facility that held educational events. Some events include:

- Presentations to urban audiences through presentations at the Urban Ecology Center
- In Her Boots - Two presentations were given to Women farmers through the Soil Sisters events.
- MOSES conference in LaCrosse - Presentations were given to organic farmers on growing mushrooms and becoming a mushroom grower
- Wisconsin Woodland Owners Association - Presentations and Booth at the annual conference, Presentations to local chapters, Video project for woodland owners to help market logs to growers
- Foresters **-** Presentation at the tristate conference
- Mushroom Enthusiasts and Wild Mushroom Foragers - Booth at the NAMA conference in Cable Wisconsin

- Inoculation events through the Wisconsin Mycological Society
- Master Gardener and Permaculture Guild presentations

V. Lessons Learned

- Marketing and Outreach were a challenge. It is our belief that our program would serve the growers better as an "add-on" rather than a startup service. A longer timeline is needed for new log-grown producers than for other types of produce growers and in order for a mushroom business to be lucrative about 1000 logs would be needed.
- Surveying the farmers markets was very challenging and we did not get good baseline data for our project. However we were able to track a few farmers markets and met the outcomes of our grant with the increase of two additional farmer market vendors. Getting commitment ahead of time from anyone you plan to survey/include in your project is needed.
- Funding was another obstacle. Originally, we applied for a $75,000 grant. The money was scaled down considerably to $29,707. There were not sufficient funds available to make this Grant as successful as we had hoped. Bank reserves were used in order to fulfill the match funds requirements and fronting the money then waiting for reimbursement was difficult.
- Since all of our members are volunteers, the work on the grant needed to be performed around farming schedules. This limited the amount of dedicated time to complete grant work and required us to ask for an extension from our originally only two year project.

Positive Results Obtained and Future Applications

- Increased awareness of SHIIGA - throughout the state we have been giving lots of presentations and are being asked to participate in conferences and workshops. We have seen a large increase in the interest in log grown mushrooms and in growing mushrooms as a business.
- Mentoring opportunities for mushroom growers increased with this grant. Our board members have all volunteered to assist people who have questions about growing mushrooms and because of this, we applied for the buy local buy Wisconsin grant in order to provide equipment for loan to beginning growers to help lower the barriers to launching a mushroom farm. We also received two grants from the Wisconsin cooperative network to help expand the wood source connection to help provide access to high quality wood for growers. We will continue to look for ways to lower barriers and provide the best possible opportunities for success to people interested in becoming growers.
- This grant provided many opportunities for us to expand our marketing and outreach. However, there is always a need for more marketing and mentoring for all areas of Wisconsin and beyond in the Midwest.
- Implement the tools created during the grant. A Website presence was created in 2016 to facilitate these connections. The website is active and functioning. We were able to create a wonderful website that makes it easier for people to access information and to connect with other farmers, woodland owners and mentors which addressed several of the barriers identified in the beginning mushroom farmer survey.
- This project grant is continuing to improve its user-friendly interactive database that connects a woodland owner, planning on harvesting their wood and a potential grower

who will need that wood for production of Shiitake or other wood grown specialty mushrooms. Several connections have been made for the purchase of logs by growers. This site will continue to be developed and refined.
- Built on previous projects that worked to connect woodland owners and mushroom growers by developing a networking strategy to grow those business relationships. The goal here was to build on a previous mini grant where a survey was implemented and outreach was done at the WWOA regional meetings several woodland owners and growers were connected through the website wood source connection function.
- Learned there is a strong demand for our services, since all of our events were well attended many had waiting lists or were held multiple times to meet the demand.

VI. Additional Information

None

VII. Contact Info

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