Great Lakes Fruit, Vegetable & Farm Market EXPO
Michigan Greenhouse Growers EXPO

December 5-7, 2017

DeVos Place Convention Center, Grand Rapids, MI

Grape II

Where: Grand Gallery (main level) Room C
MI Recertification credits: 2 (1C, COMM CORE, PRIV CORE)
OH Recertification credits: 0.5 (presentations as marked)
CCA Credits: PM(0.5) CM(1.5)
Moderator: Tom Todaro, Leelanau Co MSU Extension, Suttons Bay, MI

2:00 pm	Managing Pests of Ripening Grapes (OH: 2B, 0.5 hr) • Keith Mason, Entomology Dept., MSU
2:40 pm	UAS in Agriculture Training Programs and Applications for Grape Production • Brian Matchett, Program Coordinator for the MSU Institute of Agricultural Technology at Northwestern Michigan College • Alex Bloye, Aviation Director, Northwestern Michigan College
3:20 pm	Managing Grapevine Performance Through Cover Crop and Root-Zone Management • Cain Hickey, Viticulture Extension Specialist, Univ. of Georgia, Athens, GA
4:00 pm	Session Ends

Managing Pests of Ripening Grapes

Keith Mason and Rufus Isaacs
Department of Entomology, MSU

In recent years, Michigan growers have had significant challenges near harvest from yellowjackets, fruit flies, bees, ants etc. In response to this, the MSU Berry Crop Entomology lab started multiple projects in 2017 to develop strategies for monitoring and controlling harvest-time insect pests. This presentation reports on what we have learned in these studies, and we will cover these topics:

- Background and biology of the key insect pests that can affect grape harvest
- Interactions between harvest time pests
- Wasp trapping studies
- Efficacy of short pre-harvest interval (PHI) insecticides
- Border sprays for controlling late season pests

Background

Yellowjackets and other wasps. These insects have mouthparts that can cut through grape skins to feed on the sugars in ripe grapes. This damages the fruit and can raise the risk of stings. Controlling the early-season wasps with traps should reduce activity later in the season, and we are testing traps to explore this idea. Traps may also help to pull wasps away from vineyard borders to reduce cluster damage near harvest. Sprays at harvest-time tend to have only short-term benefit for reducing yellowjacket abundance.

Vinegar flies including Spotted Wing Drosophila. We already have two main species of vinegar flies that are common across Michigan, that feed on damaged or rotten fruit and get into wineries in the fall. However, these can only infest berries that are already split as they cannot pierce the skin. In contrast, Spotted Wing Drosophila (SWD) is an invasive pest that is now established in Michigan. Unlike other vinegar flies SWD can cut into ripe, undamaged grapes. Compared to many other crops, grapes are not so easily infested by SWD, but SWD can open berries to other insects including the native vinegar flies. This also has the potential to increase the levels of sour rot in grapes at harvest time, so control of SWD in susceptible varieties (thin skinned and late-harvested blocks) should be considered.

Brown marmorated stink bug. This other invasive pest has now been found in Michigan vineyards, but no damage on the fruit has been observed. In other regions and other crops it has caused both early and late-season damage and crop infestation that influenced fruit quality, and bugs in lugs may taint juice or wine. At this time we are monitoring and observing BMSB to determine whether this is a pest that requires active management in Michigan.

Bees. Bees do not chew into intact fruit, but they can be very attracted to sugary grape juice. They can fly for 2-5 miles from their colony so if vineyards are near to beehives they have a greater risk. **Consider talking to your local beekeepers to move colonies away from vineyard areas near harvest.**

Ants. These small insects have large colonies and are attracted to cracked or damaged fruit. As with other insects, they can move pathogens from cluster to cluster, such as sour rot. Ants are challenging to control because the colonies are protected in the ground. Maintaining cluster integrity is also a good way to reduce the impact of ants.

Multicolored Asian ladybeetles. This beetle can reach high density during harvest, but it has not been seen in high numbers over recent seasons. Crushing these beetles in fruit can also cause off flavors.

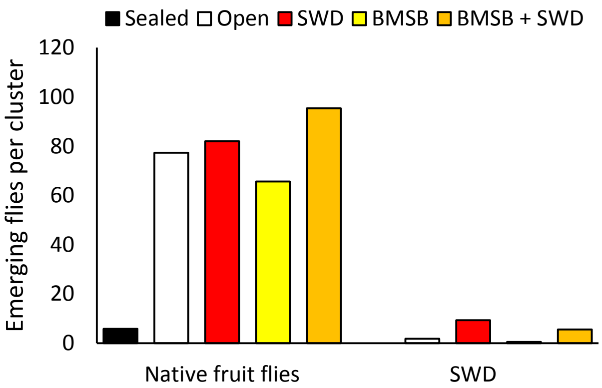
<u>Interactions between pests</u>

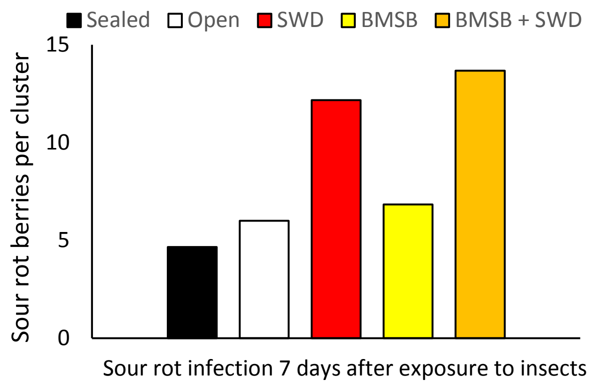
We used mesh bags to hold spotted wing drosophila (SWD), brown marmorated stink bug (BMSB) or both of these insects on ripening clusters in an Aurore vineyard at the Trevor Nichols Research Center. After one week of exposure to the treatments listed below, clusters were collected at weekly intervals and returned to the lab to determine if exposure to these pests 1) increases infestation by other *Drosophila* or 2) promotes the development of cluster rots.

<u>Bagging Treatments</u>

1. Sealed control
2. Open control
3. 3 BMSB adults
4. 10 mated SWD females
5. 3 BMSB + 10 SWD (a combination of treatments 3 and 4)

Bagged clusters in an Aurore vineyard at TNRC. Inset shows a close up of a mesh bag used to hold insects on clusters





The figure on the left shows the number native fruit flies and spotted wing drosophila (SWD) that emerged from clusters that were held in mesh bags with SWD, brown marmorated stink bug (BMSB) or both SWD and BMSB. Many more native fruit flies than SWD emerged from all treatments. The number of flies that emerged from clusters that were bagged with SWD was higher than clusters exposed to only BMSB. However the number of flies emerging from clusters bagged with these insects was generally similar to clusters that were not bagged with this insects, suggesting that exposing clusters to SWD or BMSB doesn't increase native fruit fly infestation.

The number of sour rot infected berries per cluster is shown in the figure on the right, and in general we saw the highest number of infected berries in clusters that were held in bags containing SWD. This suggests SWD exposure increases the risk of fly infestation and the incidence of sour rots. We did not find any evidence for exposure to BMSB increasing sour rot infection. This experiment will be repeated in 2018 to shed more light on this relationship.

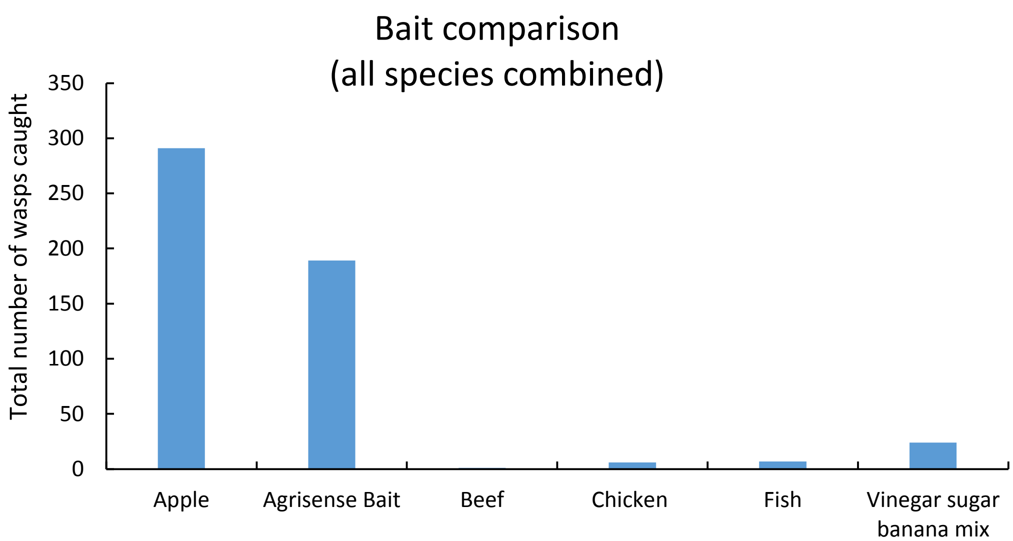
Wasp trapping

We evaluated different baits and trap types to capture wasps through the season. We did this in the spring to try to reduce the number of founding queens and reduce background populations of wasps, the traps we tested (baited with tuna) did not catch many wasps. Later in the season, we evaluated different baits and trap types for their potential to draw worker wasps and away from vineyard borders at harvest. We identified good options for traps and baits later in 2017, and will use these tools in 2018 to try to trap queens in the spring and to optimize the use of traps for controlling wasps at harvest.

We put traps out at 7 vineyards in southwest Michigan and 6 vineyards in northwest Michigan, and we caught, sorted and identified over 20,000 wasps. The most common species in both regions was the eastern yellowjacket, *Vespula maculifrons*, that made up 83% of the wasps in the northwest and 64% of the wasps in southwest Michigan. We found some slight differences between regions. The southern yellowjacket, *Vespula squamosa* was much more common in the southwest, and the ground hornet, *Vespula vidua* was more common in the northwest. We also commonly caught German yellowjackets, *Vespula germanica*, and bald faced hornets *Dolichovespula maculata* in both regions.

2-liter plastic soda bottle trap baited with apple pieces and apple juice.

At the 7 vineyards in the southwest, we used home-made 2-liter plastic soda bottle traps to test 6 bait types: 1) beef bouillon; 2) chicken bouillon; 3) anchovy paste; 4) apple pieces in apple juice; 5) a vinegar, sugar and banana mix; and 6) a commercial bait produced by AgriSense and available from Great Lakes IPM. We checked traps, replaced baits every week, and then sorted and identified wasps in the lab.



Apples and the AgriSense bait caught many more wasps than the other baits, and these baits were attractive to the same range of species.

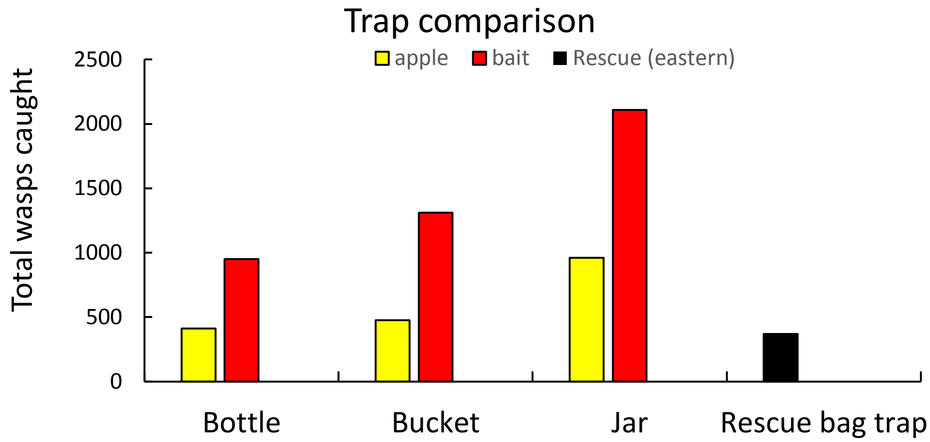
We used both the apple and AgriSense bait at 5 southwest MI vineyards to compare the 4 trap types shown below, one of which was the “eastern” version of the disposable Rescue bag trap. At an additional commercial vineyard near the MSU campus, we made a side by side comparison of the eastern and western region Rescue bags. We also compared the 2-liter soda bottle containing the AgriSense bait to both types of Rescue bag traps at 6 northwest Michigan vineyards.

2 liter soda bottle

Bucket trap

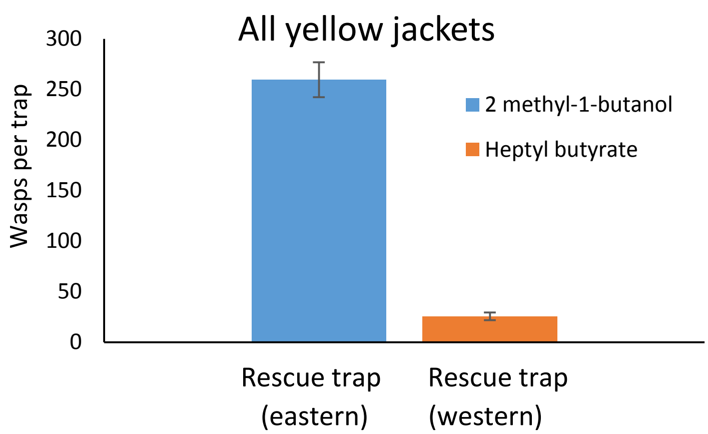
Victor © jar trap

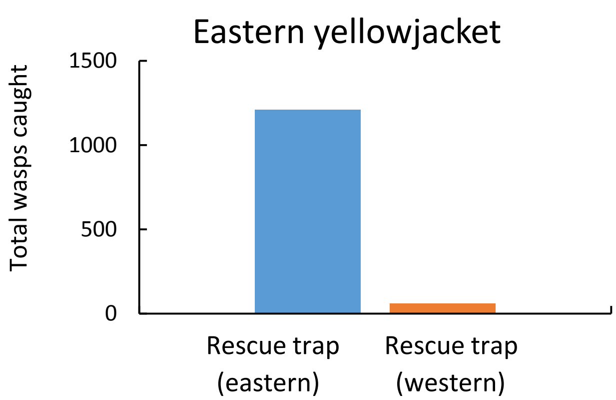
Rescue © bag traps
eastern and western

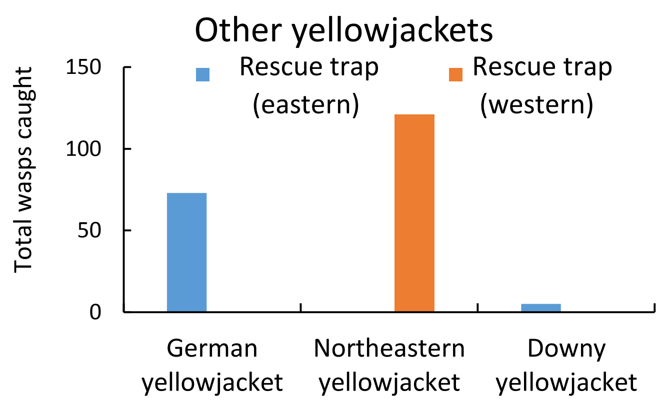


In the trap comparison study, the Victor Jar trap caught the most wasps, and this was true when using either bait. The AgriSense bait caught more wasps, and since it is a premixed bait, it is much easier to handle than the apple. The same range of species were caught in all traps and all baits. The bag trap caught the fewest wasps, but keep in mind the other traps were checked and new bait was added every week, while the bag trap was left out for the duration of the experiment (6 weeks). Further analysis will compare the material and labor costs of each trap and bait.

Comparison of Rescue bag traps in southern Michigan







The eastern version of the Rescue bag trap caught many more wasps and this included most species of yellowjackets. However the Northeastern yellowjacket was only captured in the western Rescue trap (that contains heptyl butyrate). This species was not common in our samples, so it appears the eastern trap (containing 2-methyl-1-butanol) is a much better fit for trapping wasps in our area. Both types of the rescue trap were found in retail stores in Michigan, so if you are going to use these traps, be sure to get the eastern version, or a trap that contains the correct active ingredient.

Efficacy of short pre-harvest interval (PHI) insecticides

There are various insecticides that can be used in the period immediately before harvest because they have short pre-harvest intervals (PHI) and re-entry intervals (REI) – see table below. Some of these are broad-spectrum contact insecticides (the organophosphate and pyrethroid insecticides) while others are more selective and systemic (neonicotinoids). Venom has provided good control of yellowjackets and ladybeetles in our MSU grape trials. The Azadirect and Pyganic can be used in organic production and they provide very fast but short lived control. Evergreen is the same active ingredient as Pyganic, but with a (non-organic) chemical added to make it more effective.

With all applications close to harvest, be aware of the restrictions on use at this time and also consider the expectations of your buyer or winery.

Trade name	Active ingredient	Chemical class	PHI (days)
Malathion	malathion	organophos.	3
Baythroid XL	cyfluthrin	pyrethroid	3
Mustang Max 0.8 EC	zeta-cypermethrin	pyrethroid	1
Scorpion 35 SL	dinotefuran	neonicotinoid	1
Venom 70 SG	dinotefuran	neonicotinoid	1
Belay 2.13 SC	clothianidin	neonicotinoid	0
Leverage	cyfluthrin+imidaclo.	pyreth+neonic	3
Aza-direct	azadiractin	biological	0
Pyganic	pyrethrum	pyrethrum	0.5
Evergreen	pyrethrum+PBO	pyrethrum	0.5

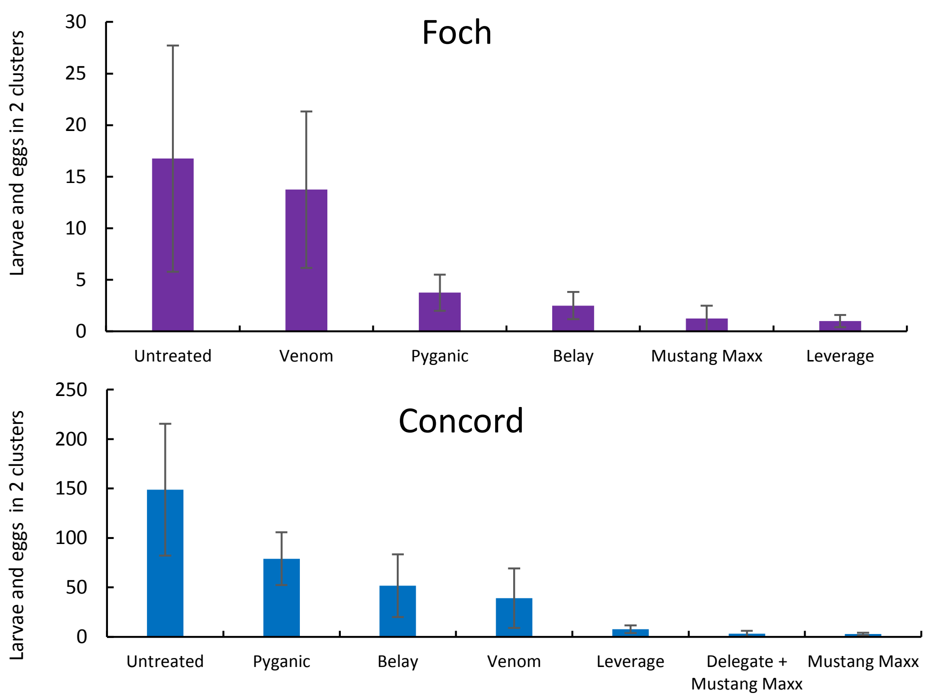
Remember the label is the law!

We tested the efficacy of short PHI insecticides for control of harvest time pests in trials that were run in Concord and Foch. In both experiments, 7 vine plots received one of the following insecticides to be applied every 7 to 10 days beginning at Veraison (4 applications and 4 replicates)

1) **Untreated**
2) **Mustang Maxx (4 oz/ac)**
3) **Leverage (3.2 oz/ac)**
4) **Venom (3 oz/ac)**
5) **Belay (4 oz/ac)**
6) **Pyganic (32 oz/ac)**
7) **Delegate (5 oz/ac) + Mustang Maxx (4 oz/ac)**

We made weekly timed samples (5 min per plot) in each vineyard, and recorded the # of wasps, bees, lady beetles and brown marmorated stink bugs (BMSB). We also recorded the presence of ants, fruit flies or other insects on the clusters.

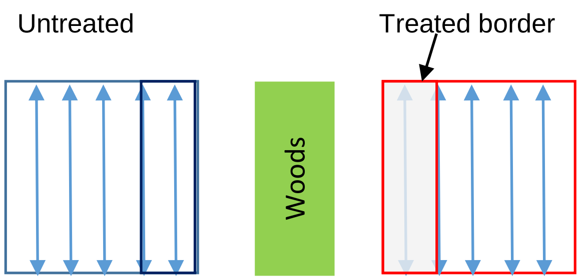
We sampled fruit at harvest from each plot to determine insect infestation, damage and symptoms of bunch rots and other diseases. Clusters were then either tested by soaking them in a salt solution to see the larvae in the fruit, or clusters were held in a plastic rearing chamber containing a yellow sticky card to trap the SWD and other fruit flies that emerge, so they can be counted.



The graphs above show the number of larvae and eggs of vinegar flies (SWD and native species). Infestation was lowest in treatments containing pyrethroid insecticides with good contact activity. The neonicotinoid insecticides and Pyganic reduced vinegar flies, but were generally not as effective at controlling fruit fly infestation.

Border spray approach to controlling late season pests

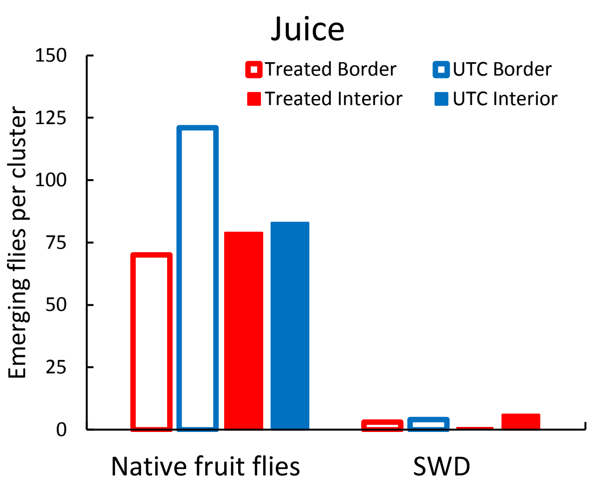
In on-farm trials, we investigated the efficacy of border applications of insecticides to reduce harvest time pests and the incidence and severity of cluster rots. We used a rotation of short PHI insecticides applied every 7-10 days from veraison until harvest to 5 rows of one vineyard (or vineyard section) adjacent to a wooded border. A similar area was left untreated and used as a comparison. We did this at 2 juice grape vineyard pairs and in 2 paired wine grape blocks.

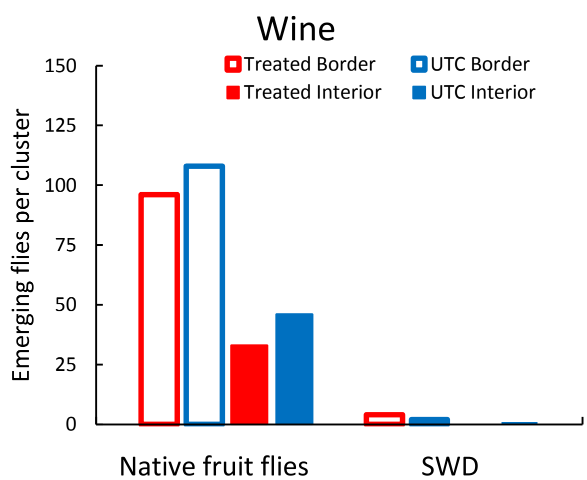


Insecticide rotation:
Sevin XLR (64 fl oz/ac) or Delegate (5 oz/ac) *7 day PHI*
Malathion (30 fl oz/ac) *3 day PHI*
Venom (3 oz/ac) *1 day PHI*
Mustang Maxx (4 fl oz/ac) *1 day PHI*

We monitored SWD populations each week in both vineyards with standard monitoring trap, and performed weekly timed samples on the border and interior (10 min at each location). At each assessment, we recorded the number of wasps, bees, lady beetles and BMSB, and we recorded the presence of ants, fruit flies or other insects on the clusters. Standard insecticide and fungicide programs were applied to each vineyard through the third grape berry moth generation.

We sampled fruit at harvest from the border and interior of each vineyard to determine insect infestation, damage and symptoms of bunch rots and other diseases. Clusters were either tested by soaking them in a salt solution to see the larvae in the fruit, or held in a plastic rearing chamber containing a yellow sticky card to trap emerging SWD and other fruit flies, so they could be counted.





These figures show the native fruit flies and SWD that emerged from clusters collected in each vineyard area. In general, border sprays reduced fruit fly infestation, but there was not a very significant reduction. We found that treating the border did not reduce fruit fly infestation in the vineyard interior. The vast majority of flies that emerged from all vineyards were native fruit flies and not SWD. We plan to repeat this experiment in 2018 after reviewing our treatment list and using separate vineyards.

Thanks to the Michigan Grape and Wine Industry Council and Project GREEEN for their support of our current projects investigating control of late-season insect pests. Any questions – contact masonk@msu.edu or isaacsr@msu.edu

UAS in Agriculture Training Programs and Applications for Grape Production

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UNMANNED AIRCRAFT SYSTEMS IN AGRICULTURE

Northwestern Michigan College's (NMC) Aviation program in partnership with the MSU Institute of Agricultural Technology (IAT) have developed an Unmanned Aircraft Systems (UAS) training program for students studying in one of MSU IAT's Certificate programs. The structure and scheduling of the UAS in agriculture training program will allow for MSU IAT students to complete the UAS in Agriculture Training during their Certificate program of study and will not interfere with their regularly scheduled courses or required internship. The intended training will include three major components.

Program Focus

- UAS agricultural applications
- Sensor/Payload integration in UAS platforms
- Operation of senseFly eBee agricultural flyer
- Training on DJI's Agras MG-1 Octo-Copter (agricultural sprayer)
- Flight and simulator training tailored to agricultural applications
- Flight time over multiple agricultural commodities
- UAS Regulation, Law, & FAA compliance
- FAA Remote Pilot Certificate exam preparation

For More Information Contact:

Brian Matchett
Program Coordinator
matchet4@msu.edu
231.995.1719

<u>Part 1 – UAS Build and Flight Training</u>
<u>(January 2 – 6, 2018 – Traverse City, MI)</u>

NMC's UAS instructors will teach a 5-day in-person training at Northwestern Michigan College. Students will build a multi-rotor UAS system, adjust the UAS for proper flights and will be provided flight training. Flight training will include time on a flight simulator as well as flight time on the multi-rotor UAS.

<u>Part 2 – FAA Remote Pilot Certificate Training</u>
<u>(spring 2018 semester - online)</u>

IAT students will enroll in an online test preparation course toward preparation for their *FAA Remote Pilot Certification* exam. Upon completion of the test preparation course, students will be required to take the *FAA Remote Pilot Certification* test at an approved testing center ($150-not included in course fees). Successful completion of the *FAA Remote Pilot Certification* will be required for students prior to attending the 1-week UAS Applications in Agriculture training program in Traverse City (May or August 2018).

<u>Part 3 – UAS Applications in Agriculture (summer 2018)</u>
<u>(May 7-11, May 14-18, Aug. 13-17, or Aug. 20-24 – Traverse City, MI)</u>

IAT students will participate in an intensive, **<u>1-week</u>** training for UAS applications in agriculture at NMC. Students will be provided with sensor training including Lidar, Multispectral, Radar, Thermal camera sensors as well as the use of RGB color cameras in UAS. Students will incorporate sensor integration, conduct flights, and collect aerial imagery with fixed wing and rotor aircraft. Training will include operation of the senseFly eBee and the DJI Agras MG-1 Octo-Copter (agricultural sprayer). Following daily flights and missions, students will process and analyze data collected to determine potential agricultural applications for UAS. Flights will be conducted over multiple agricultural commodities (apple, cherry, grape, hops, corn, soybean, wheat, etc.) in NW Michigan.

<u>Requirements & Eligibility:</u>

- must be a current MSU IAT student or be enrolled as an MSU Lifelong Education student
- ***<u>must</u>*** submit completed *UAS in Agriculture Training – APPLICATION FORM*
 *****applications due by October 27, 2017***
- students ***<u>must</u>*** complete all parts (1 – 3) of the training program
- requires enrollment in ***3 MSU credits***
 MSU AT 291 – 3 credits (spring 2018)
 (an additional $576 course fee assessed with MSU tuition)

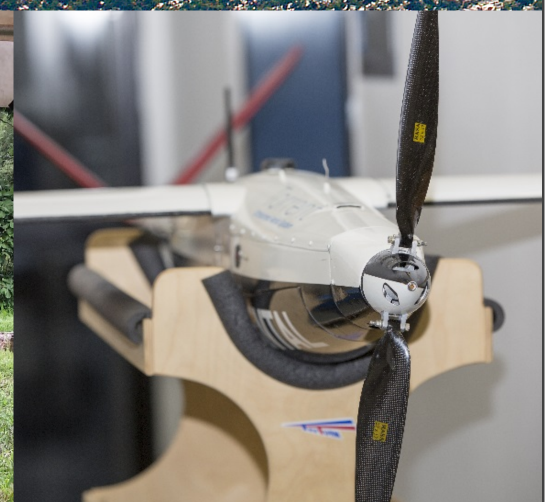
Institute of Agricultural Technology
MICHIGAN STATE UNIVERSITY

Northwestern Michigan College

UNMANNED AIRCRAFT SYSTEMS IN AGRICULTURE

Training Details

- **10 days of intensive build, flight and sensor application training for agriculture**
- **3 credits of MSU Tuition (*required*)**
- **Receive your *FAA Remote Pilot Certification***
- **Sensor training will include Lidar, Multispectral, Radar, Thermal sensors, and RGB cameras**
- **Flight training with unmanned aircraft designed specifically for agricultural applications**
- **Data processing and analysis involving multiple agricultural commodities**
- **Identification of new applications for UAS in agriculture**
- **Training with Agras Octo-Copter agricultural sprayer for precision spray applications**
- **Housing is included in $576 course fee**



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Root-Zone and Vineyard Floor Effect on Cabernet Sauvignon Vine Performance

Cain Hickey, Horticulture Department, University of Georgia, vitis@uga.edu

Introduction and background:

Grapevines are inherently vigorous plants. Grapevine vigor can be exacerbated or attenuated by local climate, amongst other factors. The variable seasonal rainfall and humidity in the midwestern and eastern US results in strong vegetative vigor in regional vineyards. Unmanaged vegetative growth results in canopy and fruit zone shading, and these responses have been documented to limit crop yield and quality. Thus, remedial canopy management strategies, such as fruit zone leaf and lateral removal and canopy hedging, have become standard vineyard practices. However, those practices account for a high percentage of the manual labor inputs in the vineyard between fruit set and veraison. We evaluated if using under-trellis cover crop and root zone management (rootstocks, root restriction) could be used as tools to *proactively* manage vine vigor and, therefore, alleviate the need for intensive *remedial* canopy management. It was also of interest to see if these growth management tools would change crop quantity or quality. This work was conducted in a cordon trained/spur pruned, vertically shoot positioned (VSP) Cabernet Sauvignon vineyard located in northern Virginia.

Results:

Cover crop and rootstock effects on vine size, crop yield, and fruit chemistry over a six-year period.

Findings published in:

Hickey CC, Hatch TA, Stallings J and Wolf TK. Under-trellis cover crop and rootstock affect growth, yield components, and fruit composition of Cabernet Sauvignon. Am J Enol Vitic. 67:281-295.

The use of under-trellis cover crops (CC) tended to reduce plant tissue nitrogen concentration when compared to HERB, while the use of 420-A rootstock reduced plant tissue potassium concentration (data not shown). There was less foliar shading of grapes in CC compared to HERB vines, but differences in fruit zone porosity were not observed between rootstocks (data not shown). Under-trellis cover crops reduced pruning weight when compared to HERB, and this was particularly true in early compared to later years of the six-year study (Fig 1). Rootstock had lesser effect on pruning weight compared to cover crop, but *Riparia* rootstock tended to produce lower pruning weight than 101-14 and 420-A rootstocks. Crop yield was reduced by CC when compared to HERB, and increased by *Riparia* when compared to 420-A and 101-14 (Table 1). Treatment had minimal and inconsistent effect on fruit chemistry, although 420-A tended to reduce pH, phenolics, and anthocyanins compared to the other two rootstocks (data not shown).

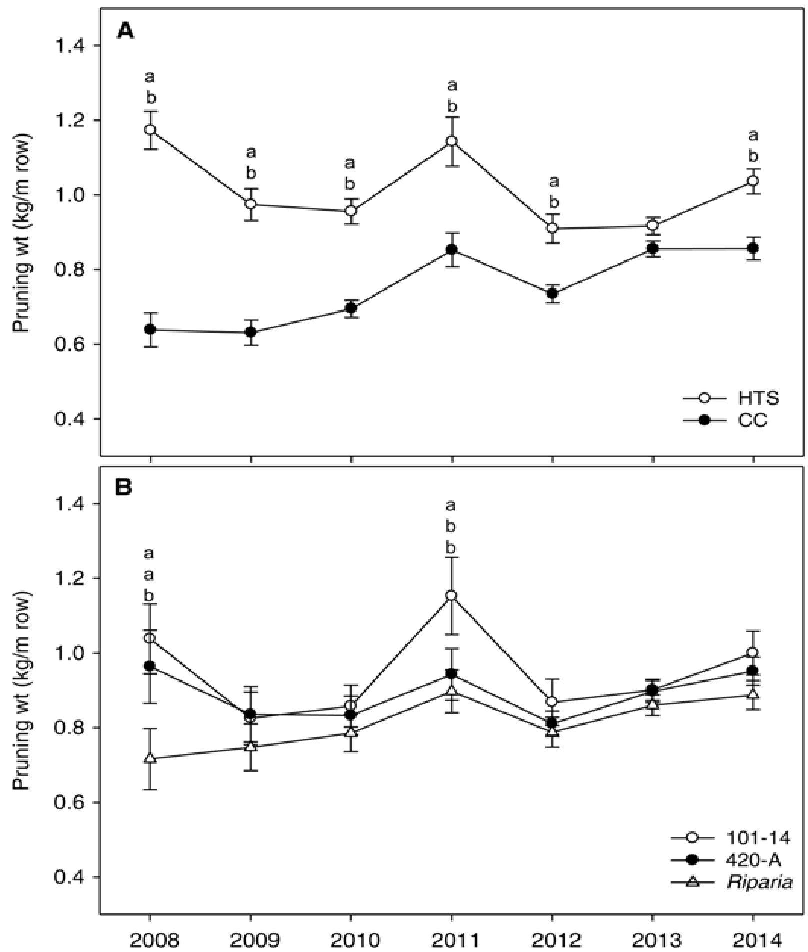

Figure 1. Effects of under-trellis groundcover (**A**; HTS = herbicide-treated strip; CC = cover crop) and rootstock (**B**) on mean dormant cane pruning weight from 2008 to 2014. Different letters within years indicate significant differences between treatment means.
Adapted from: © 2016 American Society for Enology and Viticulture. AJEV 67:281-295.

Table 1. Effects of UTGC and rootstock on mean values of yield components and crop yield from 2008 to 2013.
Adapted from: © 2016 American Society for Enology and Viticulture. AJEV 67:281-295.

Treatment	Crop yield (t/acre)	Cluster weight (g)	Berry weight (g)
UTGC[a]			
CC	3.73 b	139 b	1.35 b
HTS	4.29 a	172 a	1.40 a
Rootstock			
101-14	3.80 b	141 b	1.33 b
420-A	3.71 b	155 ab	1.35 b
Riparia	4.53 a	170 a	1.44 a

[a]UTGC = under-trellis groundcover; HTS = herbicide-treated strip; CC = cover crop.

Root growth restriction effects on vine size, crop yield, and fruit chemistry over two-year periods.

Small "companion trials" to the above cover crop/rootstock trial revealed that root restriction bags can be used as tools to effectively regulate vine size - perhaps to extents that can result in fiscally remiss crop yield if the volume of root restriction is extreme. In a trial evaluating *only* 0.015 m^3 volume root bag restriction, pruning weight was reduced by 65% compared to NRM. Grape clusters in the 0.015 m^3 root bags were produced in less-shaded fruit zones when compared to NRM (data not shown). Root restriction with 0.015 m^3 volume root bags reduced crop yield by % compared to no root manipulation (NRM), and this was mainly due to a reduction in cluster weight (Table 2) due to reduced berry weight and number per cluster (data not shown). Root restriction to 0.015 m^3 increased skin anthocyanins (Table 2) and inconsistently increased soluble solids (data not shown) when compared to NRM.

Table 2. Effects of 0.015 m^3 root restriction on crop yield components of Cabernet Sauvignon, averaged over 2010-2011.

Treatment	Pruning weight (kg/m row)	Crop yield (t/acre)	Cluster weight (g)	Anthocyanins (au)
Root restriction[a]				
0.015 m^3	0.31 b	2.56 b	116 b	40.9 a
NRM	0.89 a	3.98 a	165 a	38.0 b

[a]0.015 m^3 indicates root bag volume; NRM = no root manipulation.

The second companion trial evaluated root restriction with three different volume of root bags, all greater than the 0.015 m^3 root bags mentioned above. There was a linear-type reduction in pruning weight with root restriction – pruning weights decreased as roots were restricted and the volume of bags were decreased (Table 3). However, fruit zone architecture was less consistently affected by the root bag volumes used in this trial compared to the above-mentioned trial (data not shown). This second companion trial revealed that root restriction volume plays an important role in this tool's effect on crop yield - root restriction to 0.026, 0.035, and 0.058 m^3 volumes did not affect crop yield compared to NRM (Table 3). Root restriction to 0.026 m^3 increased total grape anthocyanins compared to NRM (Table 3), and soluble solids were inconsistently increased with root restriction when compared to NRM (data not shown).

Table 3. Effects of variable root restriction volumes on crop yield components of Cabernet Sauvignon, averaged over 2015-2016.

Treatment	Pruning weight[b] (kg/m row)	Crop yield (t/acre)	Cluster weight (g)	Anthocyanins (mg/g berry)
Root restriction[a]				
0.026 m^3	0.49 c	5.23	154	1.28 a
0.035 m^3	0.58 c	5.96	168	1.07 ab
0.058 m^3	0.77 b	5.18	154	1.05 ab
NRM	1.08 a	5.50	165	0.90 b

[a]0.026, 0.038, and 0.058 m^3 indicates root bag volume; NRM = no root manipulation.
[b]Pruning weight only collected in 2015.

The reduction in vine size (i.e. pruning weight) afforded with root restriction resulted in reduced labor time spent on annual canopy management practices when compared to NRM (Fig. 2). Considering both of these practices, root restriction could save approximately 4.8 to 8.7 labor hours per acre when compared to NRM.

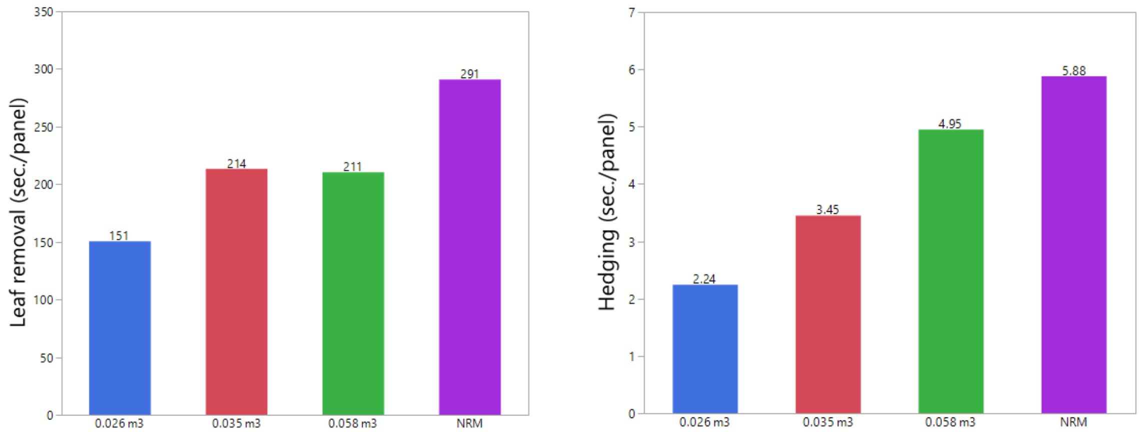

Fig. 2 Root volume restriction effect on labor time spent on annual canopy management practices in 2015.

Overall take home:

Our observations show that vine growth can be proactively regulated in a humid climate, but that fruit composition was not necessarily responsive to vine size regulation until root restriction was employed. This was likely because vine size was not regulated enough with cover crop and rootstock treatments to have a physiological impact on factors that affect fruit ripening. It remains difficult to isolate the underlying cause of a "vigor-fruit metabolite relationship" in a field setting. Thus, what remains unknown to us is whether vine vigor itself or the contrasting traits of high/low vigor vines (i.e. shaded/exposed fruit zones, larger/smaller berries, high/low water status) has a greater effect on fruit composition. Nonetheless, excessive vine growth is laborious to manage and can make it difficult to produce economical amounts of quality crop, particularly in the confines of a VSP system.

The use of cover crops and root zone management can be used as tools to regulate grapevine growth. However, these tools should be used judiciously, as our results show that some of these tools can reduce crop yield without documented benefit to fruit composition. We suggest that growers consider their site and management goals if/when deciding to employ the use of cover crops rootstocks, and root restriction in their vineyards. If the site is generally well-sloped and has rocky soil, then it is possible excessive vine vigor is not an issue, and the use of cover crops will help limit soil erosion. If the site is generally flat and has a clay-loam soil with high organic matter content, then the use of more extreme measures (root restriction of $\geq 0.026\ m^3$) may help attenuate apparent vine vigor and labor inputs for canopy management while maintaining economical crop yield. It is advised, however, that nutritional status be closely monitored in fully cover-cropped and root-restricted vineyards as nitrogen and potassium deficiencies can manifest in these situations.