A Review of Vine Mealybug Controls Tested and Those That Work Well

Sustainable Ag Expo

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Current Research on Vine Mealybug

1. Mealybug Controls
   a) damage - a review
   b) insecticides - current studies
   c) biological controls - a review
   d) mating disruption - final comments

2. GLRaV Control Programs
   a) mealybug-leafroll epidemiology
   b) areawide controls

3. Red Blotch
   a) are mealybugs or any insects vectors
Which mealybug species do you have?

Grape mealybug (native)

Long-tailed mealybug (Australia)

Obscure mealybug (South America)

Gill’s mealybug (native – southeastern US)
Vine MB is 1 of 4 important invasive mealybug species (sets us apart)
Vine MB causes more damage
1) more eggs (higher fecundity)
2) feeds on leaves
Vine MB causes more damage
1) more eggs (higher fecundity)
2) feeds on leaves
3) more honeydew excretion
Vine MB causes more damage
- more eggs (higher fecundity)
- feeds on leaves
- more honeydew
- more generations

Daane, Walton, Daugherty, submitted J Econ Entomol, based on temperature cabinet studies, field validation in some areas.
photo courtesy of Deborah Golino
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Previous studies with insecticides

- Movento is typically the best product.
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<table>
<thead>
<tr>
<th>Fruit damage (% category)</th>
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</thead>
<tbody>
<tr>
<td>Control</td>
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</table>

Spray Volume: 150 GPA, Air-blast Sprayer, June, (Gill’s MB), label rate, Placerville, CA
Previous studies with insecticides

- Movento is typically the best product

2011 Lodi-Woodbridge wine grape trial

Fruit damage (% category)

Spirotetramat Buprofezin Control
Clothianidin Acetamiprid

Buprofezin (Applaud) Clothianidin (Belay/Clutch) Acetamiprid (Assail)
Previous studies with insecticides

- we are working to find out how Movento moves

Spray Volume: 100 GPA; Air-blast Sprayer; label rate.

Vine mealybug (*P. ficus*) was the target pest; Lodi, CA.
Movento and Belay applied May 29, 2012
Applaud and Assail applied June 20, 2012
Belay additionally applied to all plots July 20, 2012
Why are VMB sometimes hard to kill?

- population on the leaves can be controlled
- fruit generally remain clean
- population on the trunks and roots harder to kill

some failures are not failures – but a delay in kill
Our Goals: better VMB on the trunk

- test applications in the spring and early fall
- different vineyards, regions & cultural practices
Our Goals: better VMB on the trunk

- test applications in the spring and early fall
- different vineyards, regions & cultural practices
Understanding the systemic movement of pesticides

- Example from the early work with Admire

Several factors might affect the pesticide uptake rate

Efficiency to kill the pest
For most materials – timing and coverage is critical

Courtesy of Haviland & Rill (Kern County):
Timing of Movento may impact levels of control

In most trials the earlier application (April) had better control in Kern County table grapes trials.
For most materials – timing and coverage is critical.

Courtesy of Haviland & Rill (Kern County):
Timing of Movento may impact levels of control

Work by Bentley (2010) & Daane (2012) in Fresno Co. showed applications from April - May were equally effective.
Understanding the systematic uptake of pesticide

- Timing of application
- Location of pest population
- Vine factors (e.g., vine age)
- Pest population stage
Understanding the systematic uptake of pesticide
Understanding the systematic uptake of pesticide

Spirotetramat (SPTA)

Spirotetramat metabolite (SPTA Enol)

Modified after: http://www.uic.edu/classes/bios/bios100/lectf03am/translocation.jpg
Factors

• Age of vineyards: 6 to 25 years old vines
• Irrigation type: drip vs. flood
• Type of vines:
  • Table grapes (Crimson, Thompson)
  • Raisin grapes (Selma Pete, Thompson)
  • Wine grapes (9 varieties)
• Grafted vs. non-grafted
• Different rootstocks
• Presence of girdle
• Different pesticide application rates
• Geographical area
• Level of VMB infestation and location on the vine
Area and level of infestation

Lodi, heavy infestation
Napa, moderate infestation
Fresno, light infestation
Leaf & petiole
Cane
Arm/Cordon
Trunk
(above & below girdle)
Roots
Tissue sampling: following the pesticide

To obtain the concentration of the active ingredient of the Movento pesticide and its metabolite: use of two standards, one for SPAT and one for SPAT Enol

HPLC – QuEChERS extraction
(Quick Easy Cheap Effective Rugged Safe)
Testing the extraction QuEChERS method for leaves

![Graph showing a peak at 6.14 minutes with an elution of spirotetramat-enol at 9 mg/l.]

spirotetramat-enol eluted at 6.14 min

9 mg/l
Testing the extraction QuEChERS method for leaves

mg of SPTA and SPTA-Enol in Entire Sample

<table>
<thead>
<tr>
<th>Compound (mg)</th>
<th>3946</th>
<th>3951</th>
<th>3956</th>
<th>3961</th>
<th>3966</th>
<th>3971</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPTA-Enol</td>
<td>0.066740083</td>
<td>0.111901386</td>
<td>0.199860602</td>
<td>0.3882639</td>
<td>0.35723156</td>
<td>0.402701131</td>
</tr>
<tr>
<td>SPTA</td>
<td>0.004867563</td>
<td>0.011216558</td>
<td>0.012274724</td>
<td>0.0</td>
<td>0.006419539</td>
<td>0.008888593</td>
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   a) are mealybugs or any insects vectors
Anagyrus pseudococci - female
Anagyrus pseudococci - male
Problem I: Mealybug Location

Parasitized mealybugs (%)

- Exposed Mealybug
- Hidden Mealybug

May 1 Jun 1 Jul 1 Aug 1 Sept 1 Oct 1 Nov 1

Daane et al, unpublished data
Problem II. Parasitoid Overwintering Biology

Anagyrus pseudococci oviposition and adult emergence dates

Daane et al. 2005. Biol. Control
Mating disruption - synthesized sex pheromone
Mating disruption - raisin block in Del Rey

Number of clusters rated as “lost”

- Control: ~8.8%
- Pheromone: ~2.8%

Severe damage
Moderate damage
An areawide program was tested: 1) monitoring the vector, 2) VMB mating disruption and applying insecticides as needed, and 3) roguing diseased vines.

Results for 1 of 3 sites, shows that further spread can be prevented, and that farmers must work together.
Insecticides for ‘high density’
Mating disruption to prevent spread
Results from male trap captures shows a plume is formed, but there was limited range or impact.
Could “meso” dispensers reduce costs?
Lower labor costs ... but fewer ‘point’ sources

‘meso dispensors’ may reduce costs, requires placement of 50 / ha, but they did not perform as well

Fruit damage by category (%)

<table>
<thead>
<tr>
<th>Damage categories</th>
<th>Conventional</th>
<th>Standard MD</th>
<th>Meso MD</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Unmarketable</td>
<td>a</td>
<td>b</td>
<td></td>
</tr>
<tr>
<td>2-Some damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Little damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-No damage</td>
<td></td>
<td></td>
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Key Transmission Facts - Acquisition

- Crawlers acquired virus w/in 1 hr
- Peak at 24 hr

Key Transmission Facts - Inoculation

- Crawlers inoculated virus w/in 1 hr
- Peak at 24 hr

Can we simply kill all mealybugs for GLRaV control?

In a newly planted block, two treatments: insecticides vs control

Grape MB & GLRaV-3

Cabernet Sauvignon (2008)

Grape MB & Red Blotch (?)
Two annual applications of a combination of either Applaud, Admire, Clutch or Movento
Where did the GLRaV-infected vines appear?

- Insecticides
- No insecticides

**Insect growth regulator**
Applaud (Buprofezin)

**Neonicotinoids**
Admire (Imidacloprid)
Clutch (Clothianidin)
Assail (Acetamiprid)

**Biosynthesis inhibitor**
Movento (Spirotetramet)

**OPs and Carbamates**
Lorsban (Chlorpyrifos)*
Lannate (Methomyl)*
Dimethoate*

*Listing here materials still effective and still registered (leafhoppers)

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Spray Volume: 100 GPA; Air-blast Sprayer; label rate (Applaud 12 oz per ac)
Clutch & Movento on 21 June 2011, Applaud & Assail on 7 July 2011
*Planococcus ficus*, Lodi-Woodbridge wine grapes, Lodi, CA
Vectors of Viral Pathogens in Vineyards

1. GLRaV Factors that Impact Control
   a) mealybug and leafroll species
   b) facts about mealybug-leafroll epidemiology

2. GLRaV Control Programs
   a) mealybug insecticides: which are best
   b) vineyard/areawide resistance management

3. What do We Know about Red Blotch
   a) grape damage
   b) insects as vectors
A Leafhopper-Transmissible DNA Virus with Novel Evolutionary Lineage in the Family Geminiviridae Implicated in Grapevine Redleaf Disease by Next-Generation Sequencing

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1 Department of Plant Pathology, Washington State University, Integrated Agriculture Research and Extension Center, Prosser, Washington, United States of America, 2Eukka Genomics, Sugar Land, Texas, United States of America

Abstract

A graft-transmissible disease displaying red veins, red blotches and total reddening of leaves in red-banded wine grape (Vitis vinifera L.) cultivars was observed in commercial vineyards. Next-generation sequencing technology was used to identify etiological agents associated with this emerging disease, designated as grapevine redleaf disease (GRD). High quality RNA extracted from leaves of grape cultivars Merlot and Cabernet Franc with and without GRD symptoms was used to prepare cDNA libraries. Assembly of highly informative sequence reads generated from illumina sequencing of cDNA libraries, followed by bioinformatic analyses of sequence contigs resulted in specific identification of taxonomically disparate viruses and viroids in samples with and without GRD symptoms. A single-stranded DNA virus, tentatively named Grapevine redleaf-associated virus (GRlAv), and Grapevine fanleaf virus were detected only in grapevines showing GRD symptoms. In contrast, Grapevine redleaf-associated virus and Citrus exocarps Yucatan virus were present in both symptomatic and non-symptomatic grapevines. GRlAv was transmitted by the Virginia creeper leafhopper (Euphyllura ziczac Walsh) from grapevine-to-grapevine under greenhouse conditions. Molecular and phylogenetic analyses indicated that GRlAv, almost identical to recently reported Grapevine Cabernet Franc-associated virus from New York and Grapevine red blotch-associated virus from California, represents an evolutionarily distinct lineage in the family Geminiviridae with genome characteristics distinct from other leafhopper-transmitted geminiviruses. GRD significantly reduced fruit yield and affected berry quality parameters demonstrating negative impacts of the disease. Higher quantities of carbohydrates were present in symptomatic leaves suggesting their possible role in the expression of redleaf symptoms.

Introduction

Nearly seventy viruses and other infectious sub-cellular obligate parasites, collectively referred to as graft-transmissible agents (GTAs), have been documented in grapevines (Vitis spp.) [1, 2]. Among all diseases caused either directly or indirectly by these GTAs, grapevine leafroll disease is considered as the most economically important disease affecting plant vigor and longevity and causing significant losses in fruit yield and impacting berry quality attributes [3, 4]. Other virus diseases, such as maize wood complex, fanleaf infectious degeneration and flax complex, represent a group of disorders distributed widely in several grape-growing countries around the world [1, 2]. Besides these ‘traditional’ virus diseases, which can cause significant problems to grape production, other diseases due to GTAs have limited geographic distribution causing relatively less economic damage to grape production.

In addition to viruses, several viroids belonging to the family Pospiviroidae are ubiquitous in cultivated grapevines [6, 7, 8]. They are Hop stunt viroid (Hsvd), genus Helvetica; Grapevine yellow speckle viroid 2 (Gysvd-2), genus Acyrntriphivelovirinae; and 2 (Gysvd-2), genus Apernaviridae; Citrus exocarps viroid (Cevid, genus Pospiviroidae) and Australian grapevine viroid (Agvd, genus Acyntriphivelovirinae). Although these viroids are found in symptomless grapevines, Gysvd-1 has been implicated in vein-banding and yellow speckle symptoms, likely due to a synergistic interaction between Gysvd-1 and Grapevine fanleaf virus (Gfhev, genus Nepovirus, family Luteoviridae) [10, 11]. Besides their negative impacts on yield and quality of grapes, the introduction and subsequent spread of viruses and other GTAs to healthy vineyards is of great concern for sanitation and grapevine
Insects scheduled for testing

<table>
<thead>
<tr>
<th>Common name</th>
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<tbody>
<tr>
<td>Western grape leafhopper</td>
</tr>
<tr>
<td>Variegated leafhopper</td>
</tr>
<tr>
<td>Virginia creeper leafhopper</td>
</tr>
<tr>
<td>Potato leafhopper</td>
</tr>
<tr>
<td>Blue-green sharpshooter</td>
</tr>
<tr>
<td>Vine mealybug</td>
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<tr>
<td>Grape mealybug</td>
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<tr>
<td>Obscure mealybug</td>
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<tr>
<td>European fruit Lecanium scale</td>
</tr>
<tr>
<td>Grape phylloxera</td>
</tr>
<tr>
<td>Aphids</td>
</tr>
<tr>
<td>Grape whitefly</td>
</tr>
<tr>
<td>Mites</td>
</tr>
</tbody>
</table>
Red blotch data from a GLRaV trial 2008-2014

- Insecticides
- No insecticides

GLRaV3a
GLRaV3c
GLRaV3d

GLRaV3b

Red Blotch block (?) removed in 2010
Grape Red Blotch Associated Virus

1) GRBaV has been present since first PCR tests of “false GLRaV” in 2011

photo courtesy of M. Fuchs
Grape Red Blotch Associated Virus

2) In 2014, ‘symptomatic vines’ initially (2011-2012) testing negative for GLRaV showed 136 of 156 tested GRBaV-positive.

In 2015 – over 300 ‘symptomatic’ vines – some from 2014, some not, some different.
Grape Red Blotch Associated Virus

3) ...9 of 156 positive for leafroll (primers),
...11 tested positive for GRBaV & GLRaV
Grape Red Blotch Associated Virus

4) There was no insecticide impact and... ...there was a random dispersal of GRBaV infected vines - no pattern of insect spread
Results from field-collected insects

14 of 15 vines tested positive

7 of 14 LH 'groups' tested positive
(4-32 LH per vine were tested)

Coordinated with these surveys, we collected and tested leaf petioles and western grape LH from GRBaV symptomatic vines.
‘PCR-positive’ does NOT confirm vector!
Conclusions

1) Movento continues to be the best product for vineyard mealybugs. Application methods (e.g., timing) for optimal performance may vary and we are studying the movement of Movento to better understand this.

2) Biological controls help, but can be incomplete.

3) Mating disruption can help suppress the population, but may best be used in an areawide, annual program.

4) GLRaV movement can be suppressed using rouging and an areawide mealybug control program - but this can be expensive and does not guarantee no future losses.

5) We have not shown an insect to be the Red Blotch vector.