NOV 11-13, 2019

SUSTAINABLE AG EXPO
&
INTERNATIONAL SUSTAINABLE WINEGROWING SUMMIT

SAN LUIS OBISPO, CALIFORNIA

Managing Insects that Vector Pathogens: Leafroll & Red Blotch

Kent Daane, Monica Cooper, Rodrigo Almeida,
Kai Blaisdel, Alexis Billings, Kelsey Schall (UC Berkeley)
Houston Wilson (UC Riverside)

Grape leafroll associated virus

Grape red botch (associated virus)

Both pathogens impact crop vigor, yield and quality,
(reduced photosynthesis, delayed fruit maturation, lower Brix, fruit chemistry)

Outline – Vector Control and GLRaV

- GLRaV Control Programs
  - a) leafroll and mealybugs
  - b) leafroll epidemiology (difference with GRBV)
- Mealybug Controls
  - a) insecticides – current studies
  - b) biological controls – a review
  - c) mating disruption
- Areawide or strategic control for GLRaV

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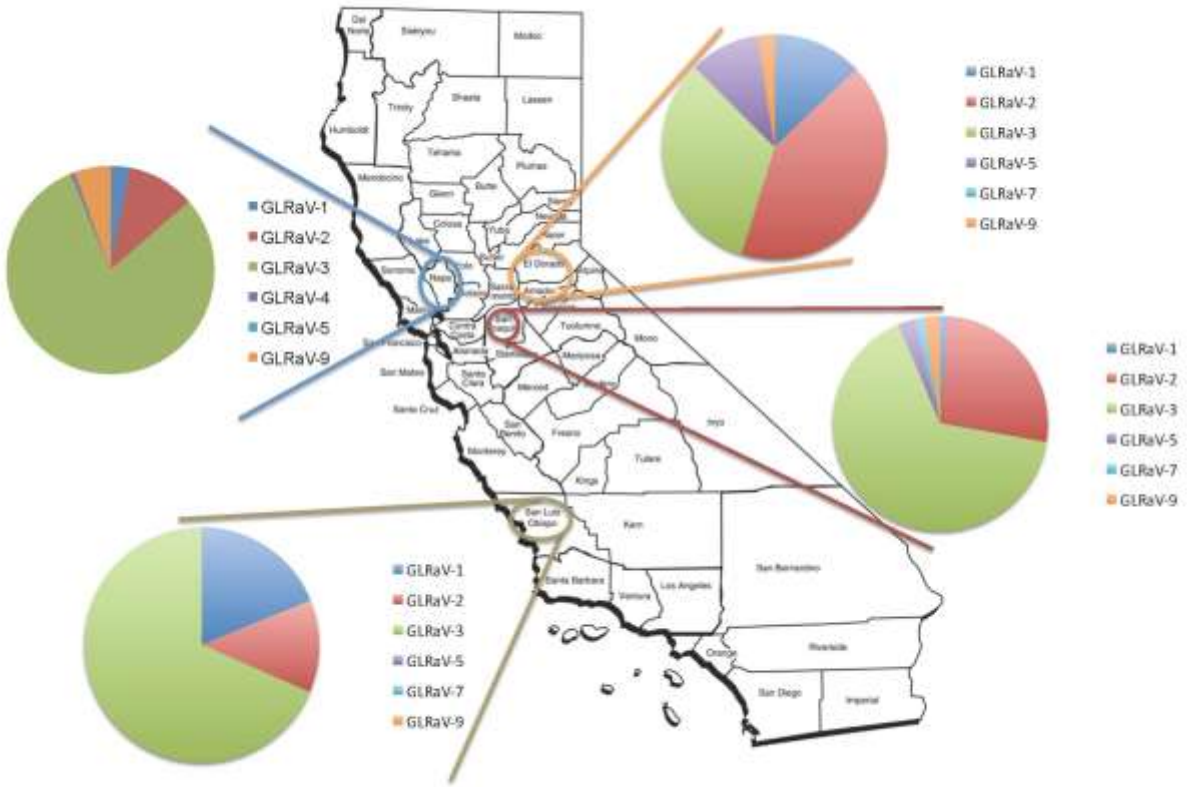
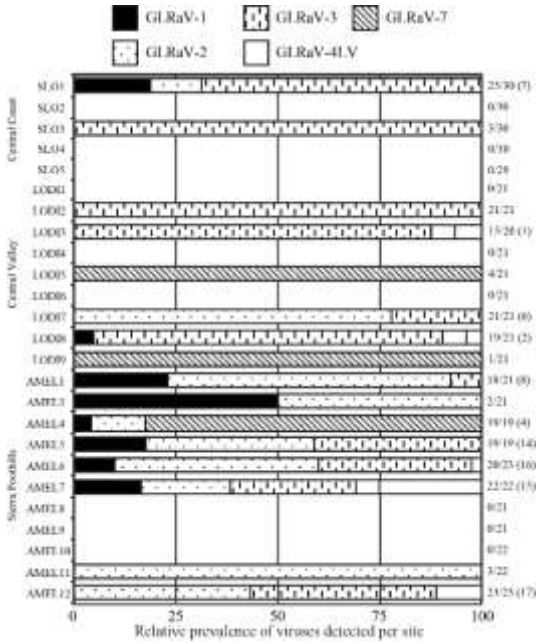
Which leafroll species (or strain) do you have?

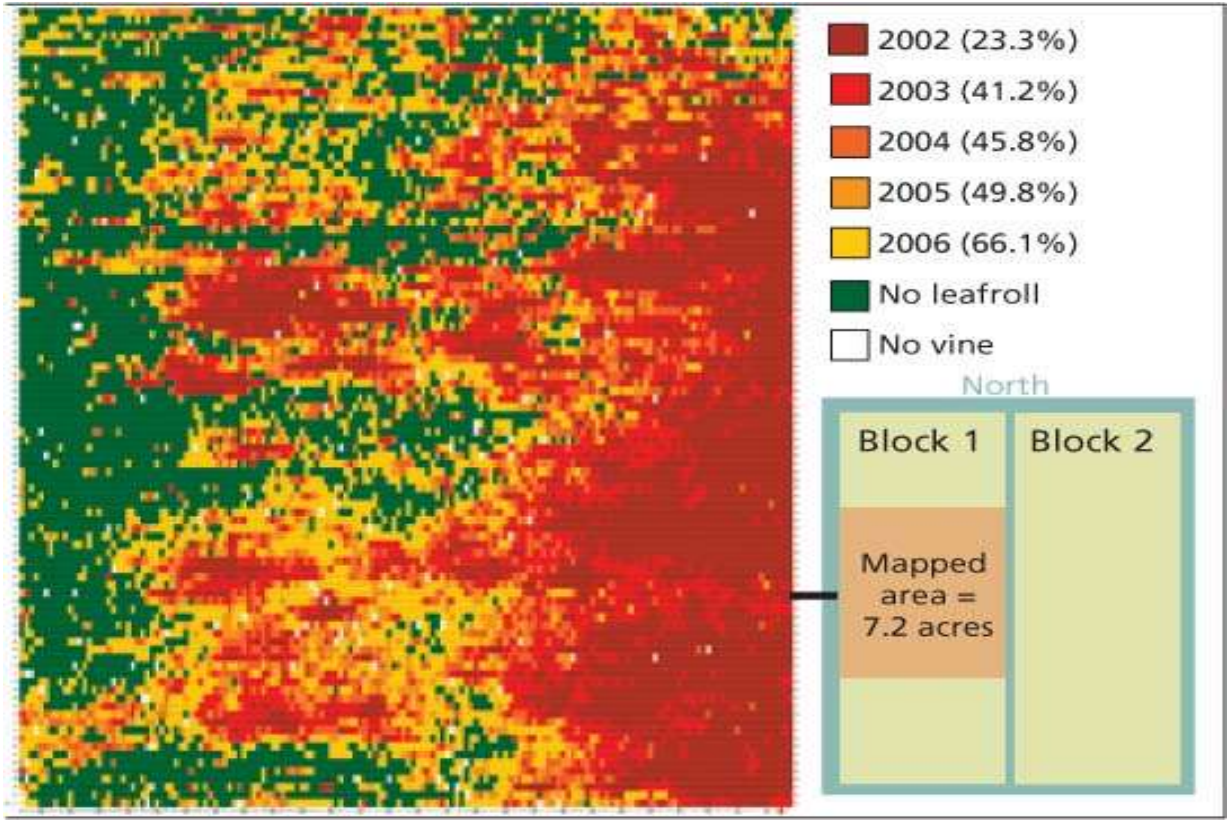




Sharma et al. PLoS One. 2011

Mealybugs are also vectors grape leafroll associated viruses (GLRaVs)

photo courtesy of Deborah Golino



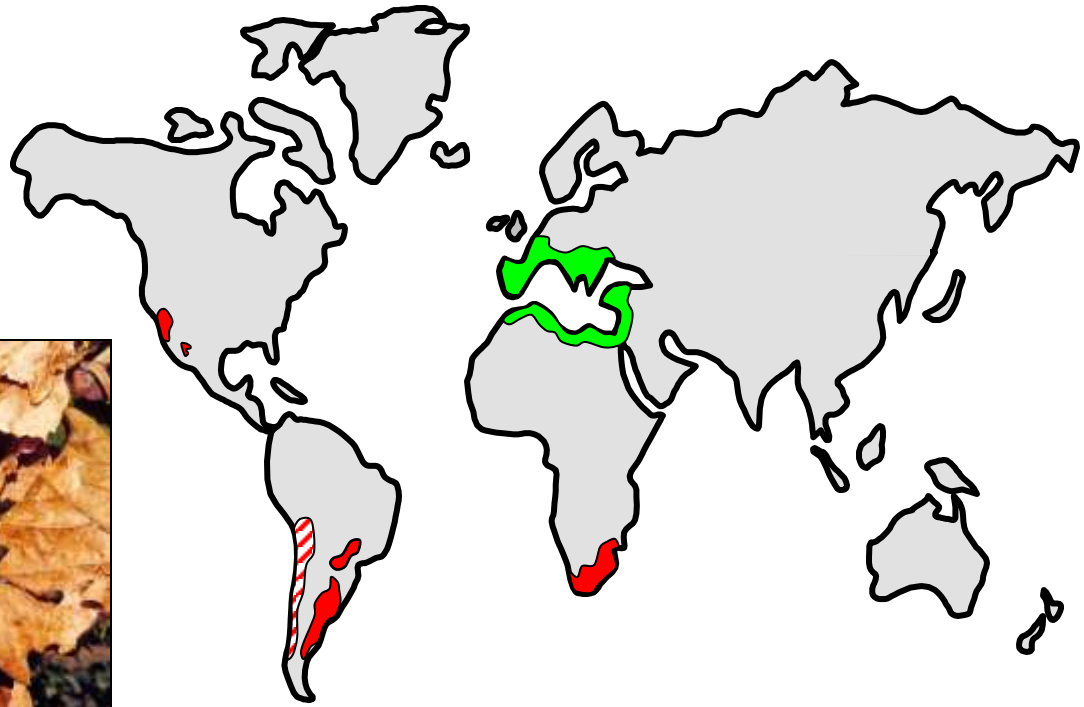
Importance of vectors in movement of GLRaV are seen in Deborah Golino's 2002-2006 mapping of annual movement

GLRaV Insect Vectors

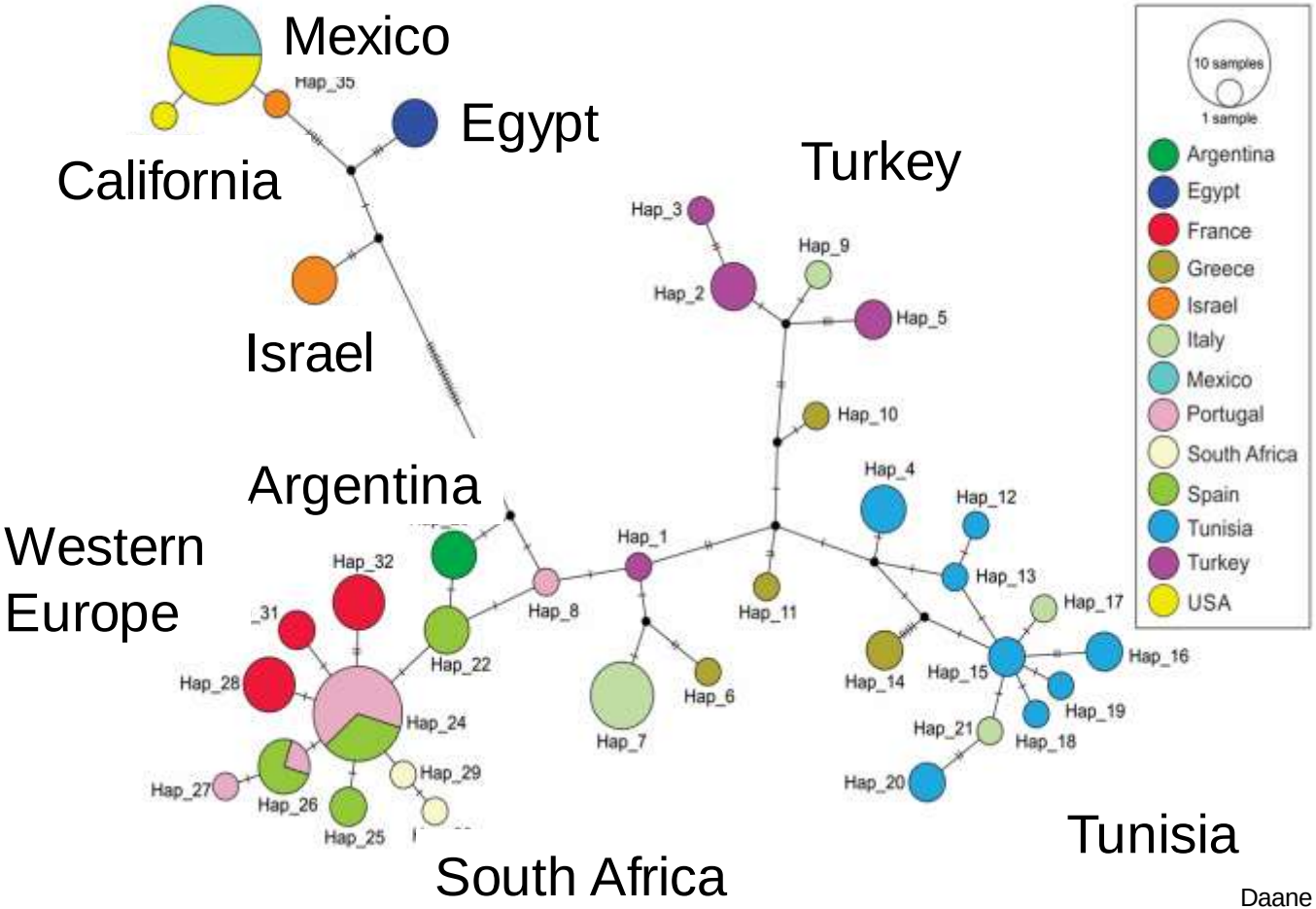
- >700 plant viruses
- ca. 70% have insect, mite, nematode or fungal vectors
- GLRaV–3 is a closterovirid… and most closterovirids are vectored by whiteflies, aphids, soft scales and mealybugs

Which vector do you have?
In California, 7 MB & 3 scale species known as vectors of GLRaV

Vine MB is a Mediterranean native – probably brought in by a grower

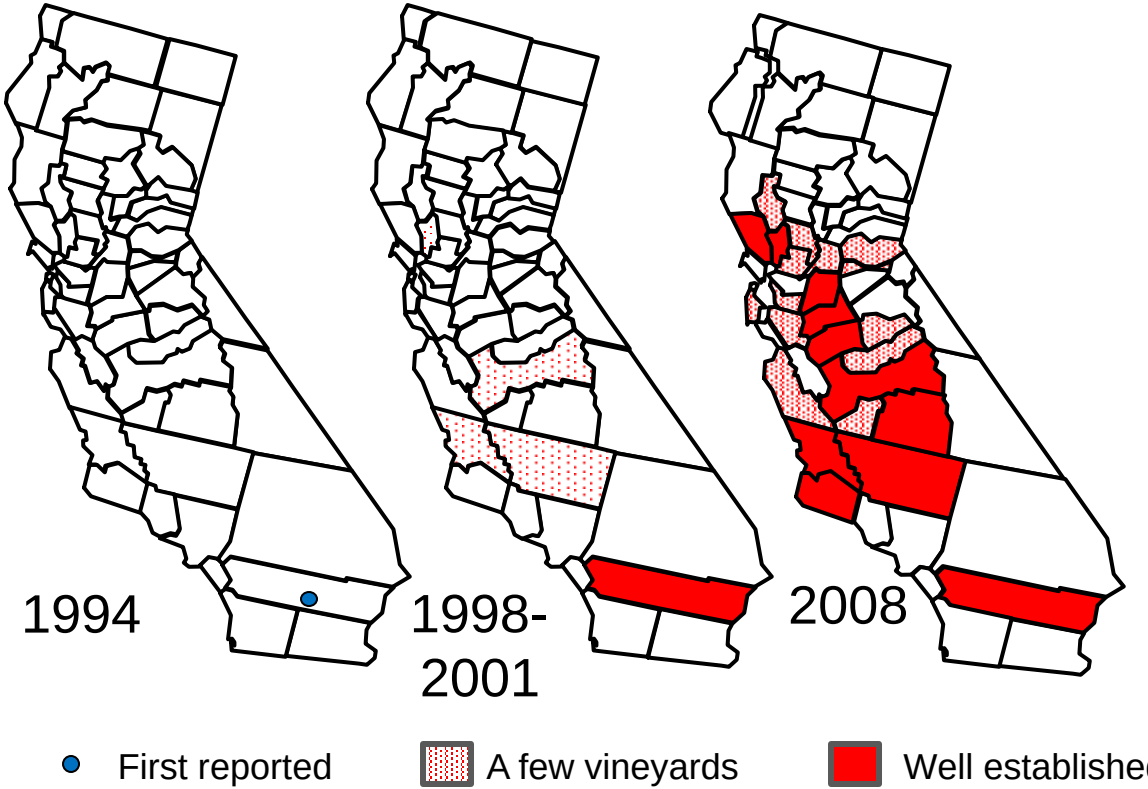


Daane et al. 2017, PLoS One



Daane et al. 2017, PLoS One

Vine MB as an Invasive Species in California



There is no vector-pathogen specificity or fidelity

Tsai et al. 2010, J Econ Ent
Wistrom et al. 2016, J Econ Ent

Key Transmission Facts – Acquisition

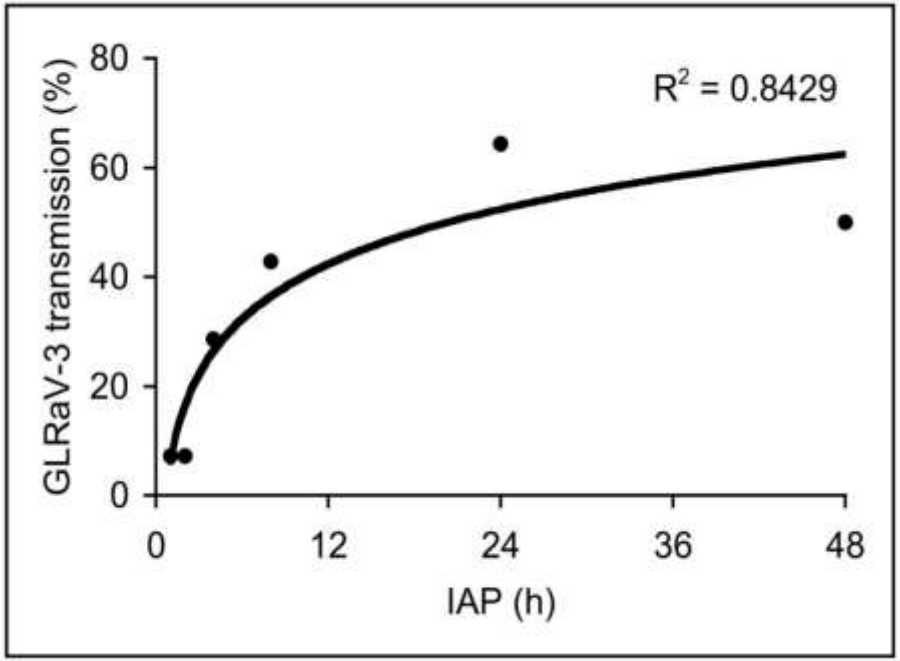
Crawlers **acquired** (AAP) virus w/in 1 hr, peaked at 24 hr

Tsai et al. *Phytopath*. (2008)

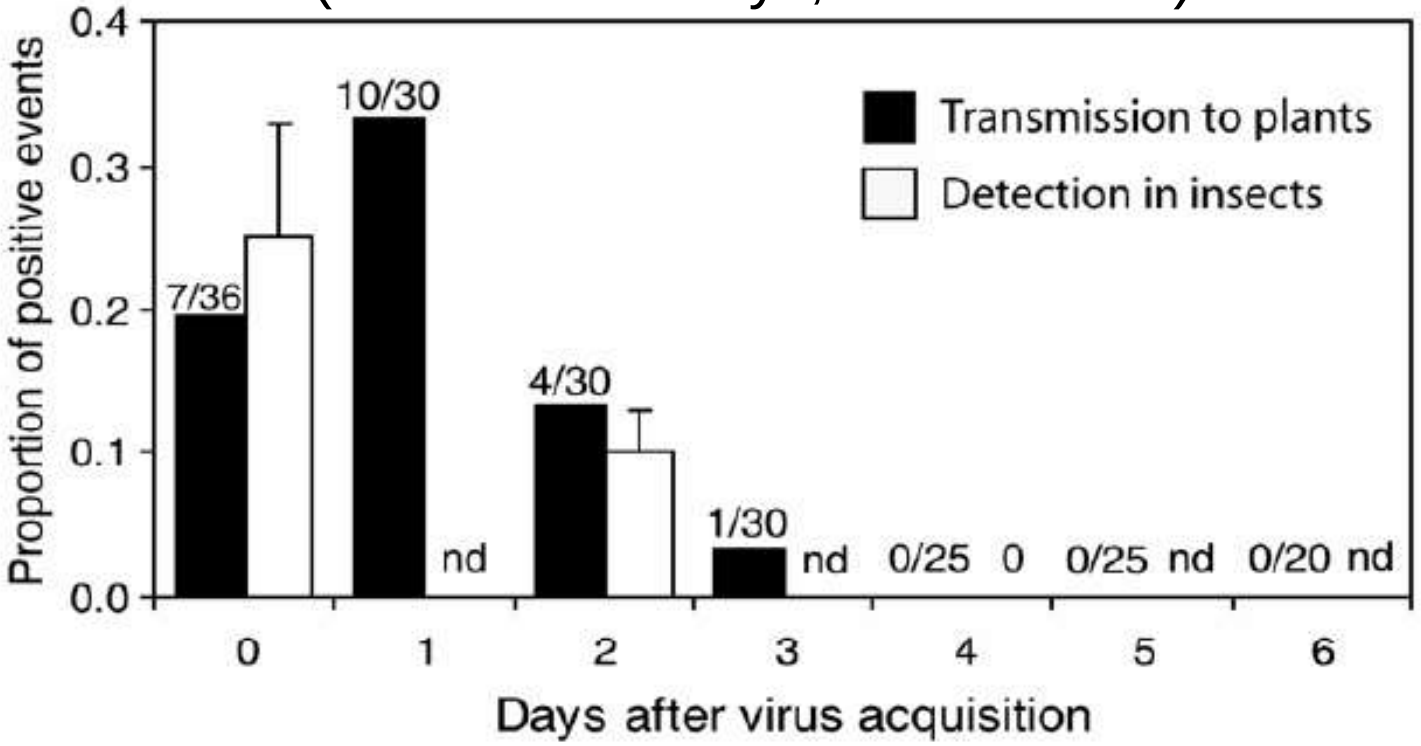
Key Transmission Facts – Acquisition

Crawlers **transmitted** (IAP) virus w/in 1 hr, peaked at 24 hr

Tsai et al. *Phytopath*. (2008)



Semi-persistent transmission
(lost after 4-5 days, or each molt)



Tsai et al 2008, Phytopathology

Transmission efficiency

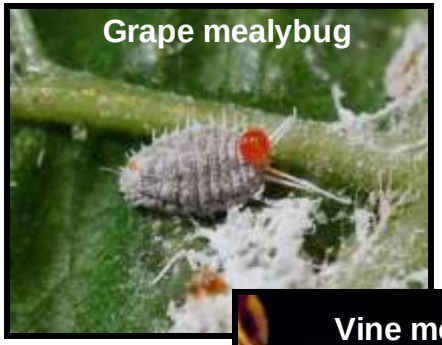
0.1 vs 100% efficiency equals
"1 in 1000" MB vs "1" MB for transmission

MB efficiencies for GLRaV-3

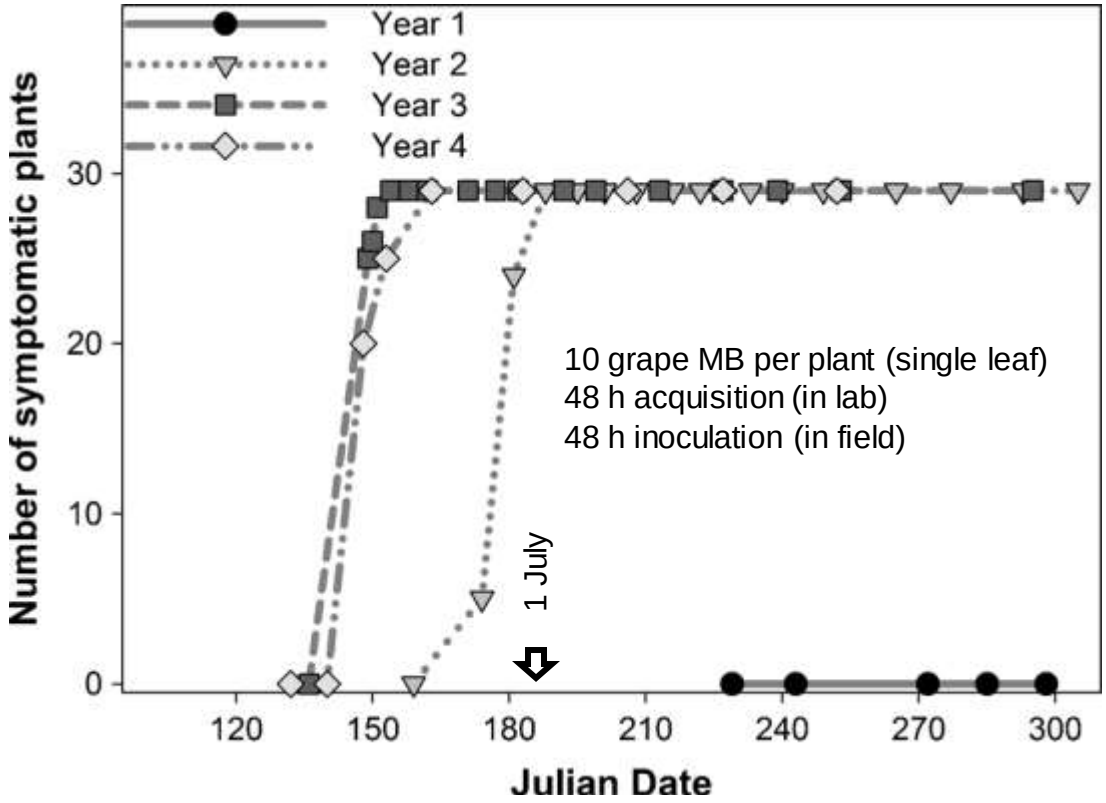
Vine MB
Grape
Obscure
Longtailed
Gill's

} 5-50% lab
1-30% field

Percentage efficiency is variable and dependent on vector, virus, vineyard and environment.



How long before GLRaV Symptoms occur?



Blaisdell et al. 2016 *European J Plant Pathology*

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In 1952-53, in a Tulare Co. table grape vineyard with a history of grape mealybug infestation, excellent control (<1%) was achieved with low rates of parathion [summary]

The Grape Mealybug

a dormant season parathion spray reduced infestation to 1% at harvest

Fred Jensen, E. M. Stafford, and R. A. Break

Parathion sprays applied to field plots—in Tulare and Fresno counties—during the dormant season controlled grape mealybug in 1953 better than any other material tested, and confirmed results of trials in 1952.

The sprays proved so effective that less than 1% of the fruit was infested at harvest. During the last thirty years many materials and methods were tried for control of the mealybug but no satisfactory treatment was found.

Grape mealybugs cause occasional heavy losses in table grape vineyards. The honeydew they exude makes the grapes sticky and the presence of the whitish waxy mealybugs in the fruit clusters is unsightly. Often the honeydew drips onto the cluster from a mealybug feeding on a petiole or leaf. A black sooty mold usually grows on this honeydew, contributing to the general unattractive appearance. The fruit clusters with a recognizable infestation are either rejected in the field or culled out at the packing house.

The mealybug populations vary con-

especially the cordons and arms, from both above and below. The mealybugs overwinter beneath the bark as newly hatched larvae. The young larvae remain in clusters either in the cottony material of the previous egg mass, or in close proximity, until late in the dormant season, at which time they migrate toward the bases of the spurs or canes.

The foliage sprays applied during May covered the leaves and canes as well as the arms and spurs. From ⅝ to ¾ gallon of material was applied per vine. At that time the half-grown mealybugs are found on the arms or spurs, or succulent wood, or out on the young shoots, fruit clusters, petioles and leaves.

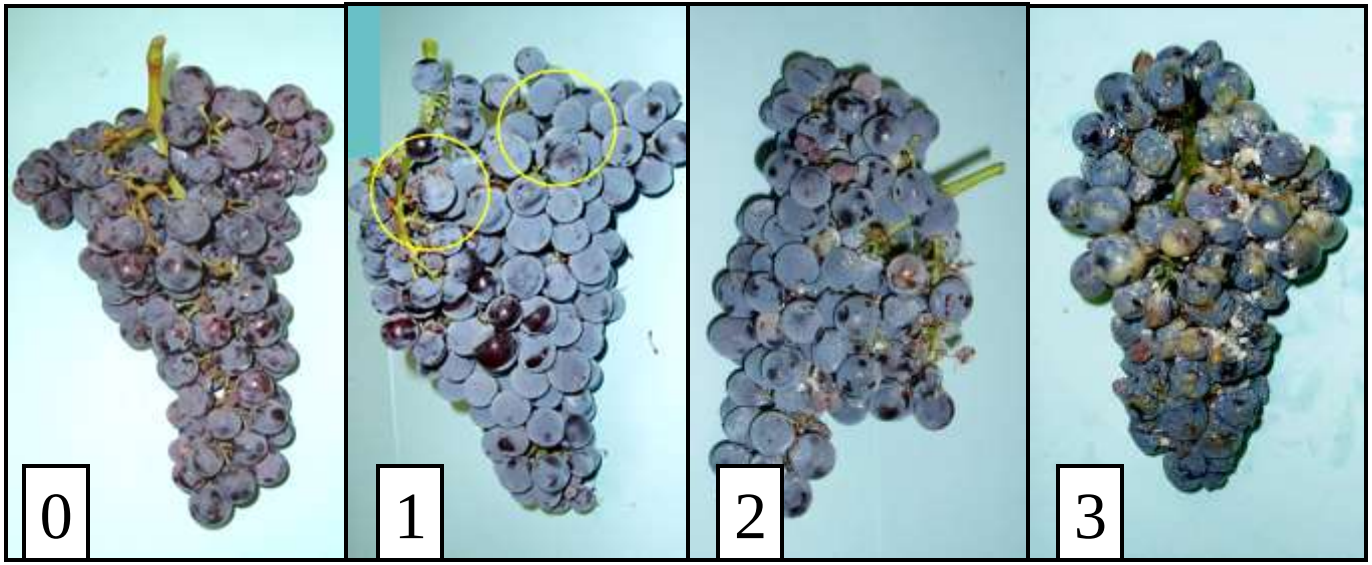
The plots were evaluated prior to harvest by counting the number of clusters containing either mealybug, the honeydew exudate, or both. From 200 to 900 clusters were examined in each plot. For dormant spraying, trials were made with parathion, malathion, EPN, lime-sulfur, and sodium arsenite. All gave some degree of control. The parathion sprays gave a higher degree of control than did

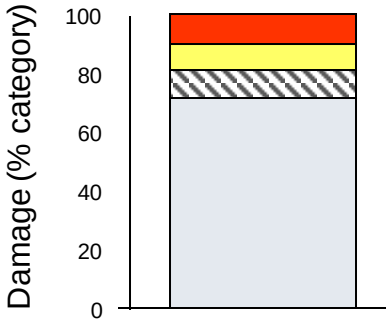
Mealybug and honeydew on grape berries.

parathion emulsifiable concentrates did not prove superior to the use of the emulsifiable concentrates alone.

The dormant parathion sprays were applied on dates ranging from late January to the end of March. No great differences in control were apparent within this period. Perhaps the later sprays were slightly better. The young mealybugs migrate toward the spurs near the end of the dormant season and might be expected to be more easily killed in the less protected positions.

The cost of using 600 gallons per acre in the dormant season ranges from $15.00 to $25.00 per acre for labor and materials. One low gallonage dormant parathion spray was applied using a little less than one half gallon per vine. Some benefit was evident but the result was decidedly inferior to the heavier applications. Because one pint of the emulsi-

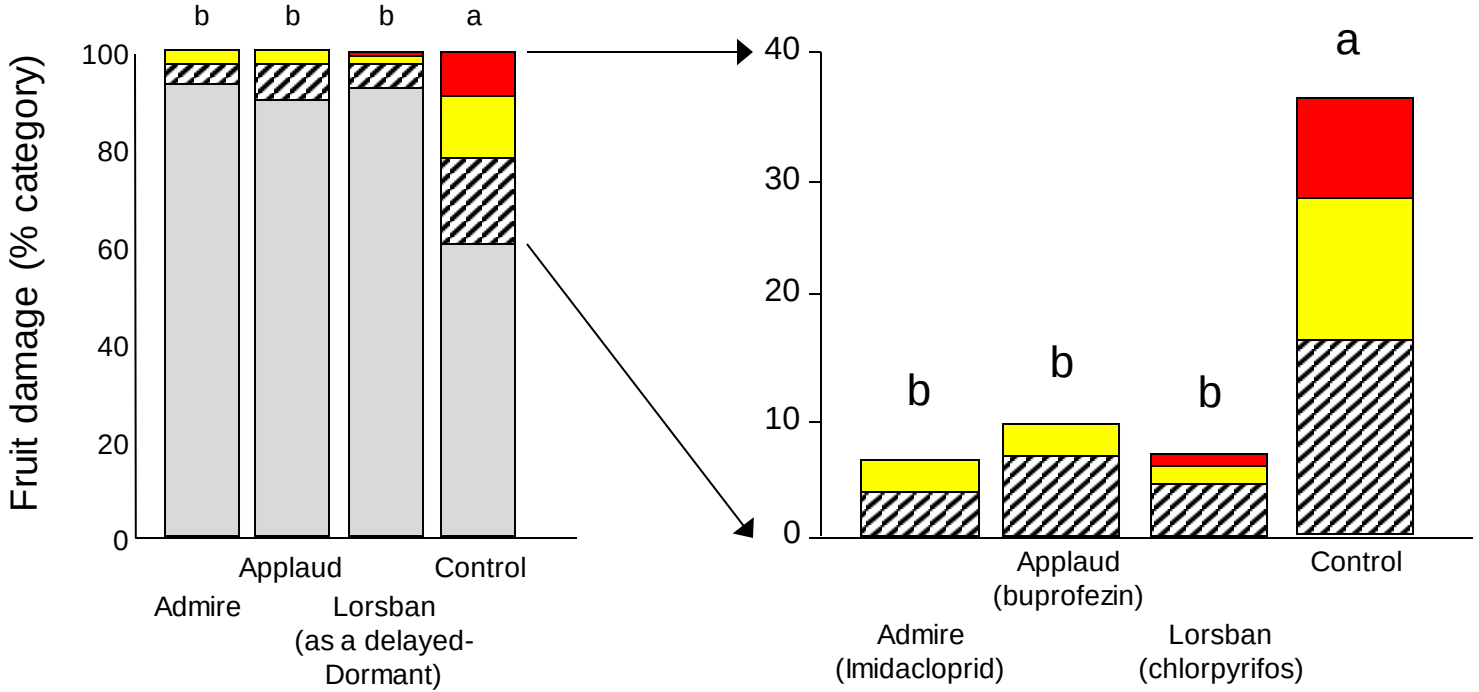




Rating system for fruit damage

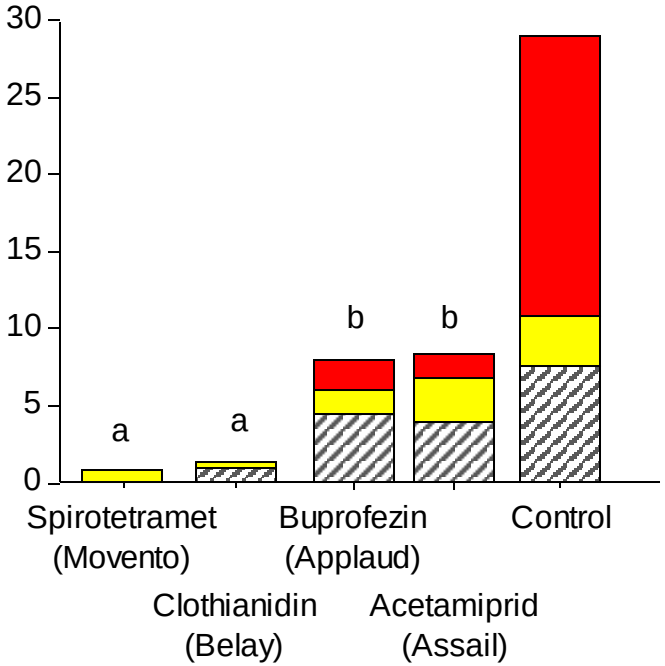
- “3” Severe damage / lost cluster
- “2” Partial damage
- “1” Minor damage
- “0” No damage

In the 1990s, Chemical Industry and UC sought alternates to in-season OPs and Carbamates



Daane et al. 2006 Cal Ag

Since the 1990s, there are many novel materials.
Here, I focus on Movento, Admire, Applaud, Belay, Assail, & Lorsban



Wunderlich et al. unpubl data

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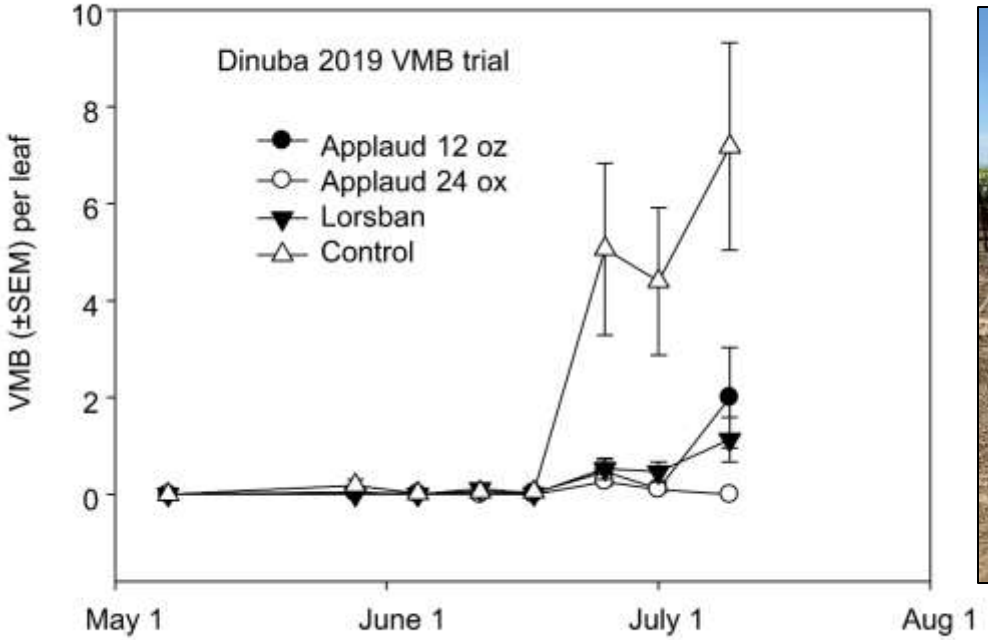
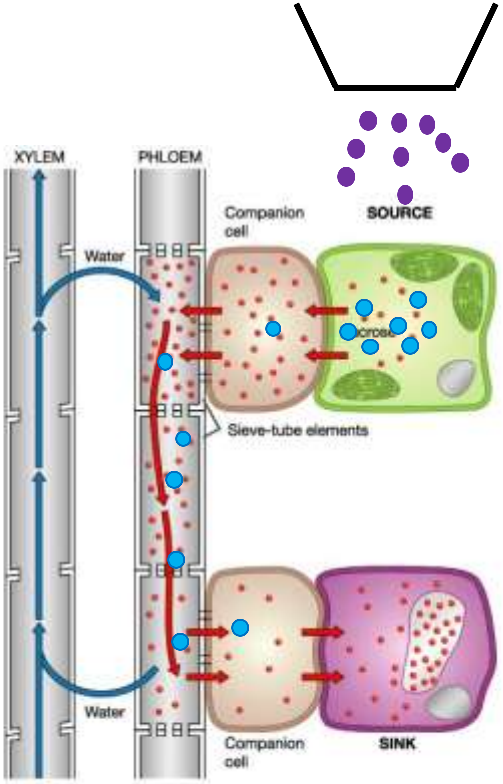


Daane et al. unpubl data

Understanding the systematic uptake of pesticide

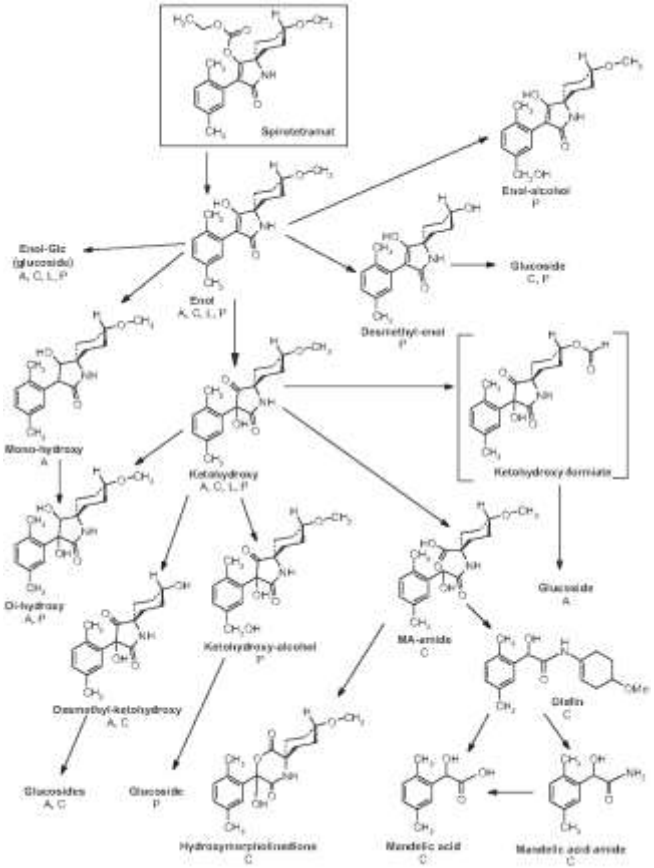
Foliar spray

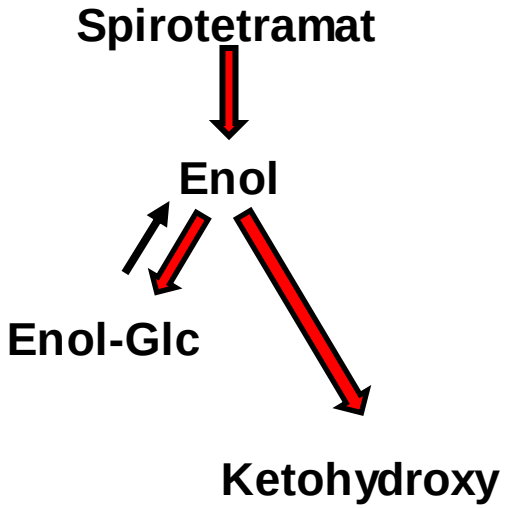
Spirotetramat (SPTA)



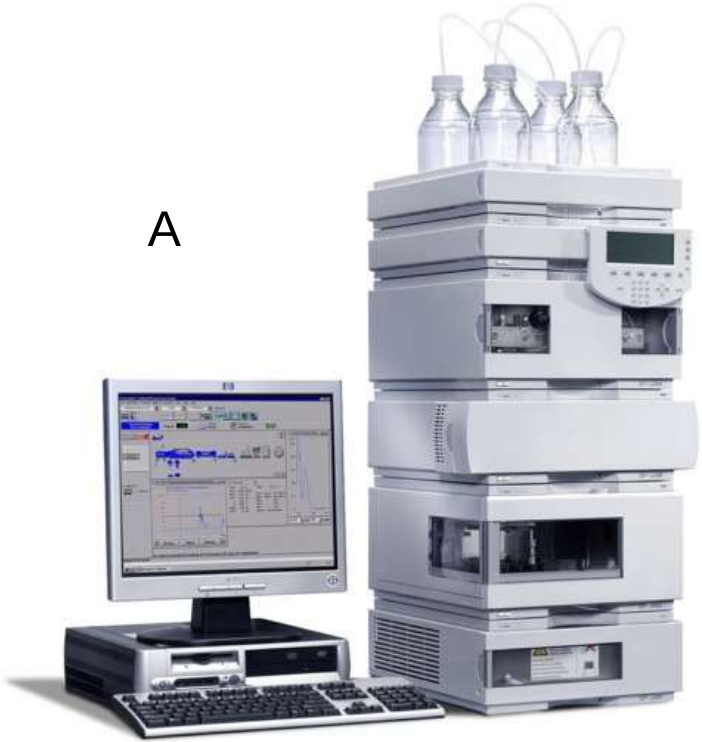
Spirotetramat metabolite (SPTA Enol)

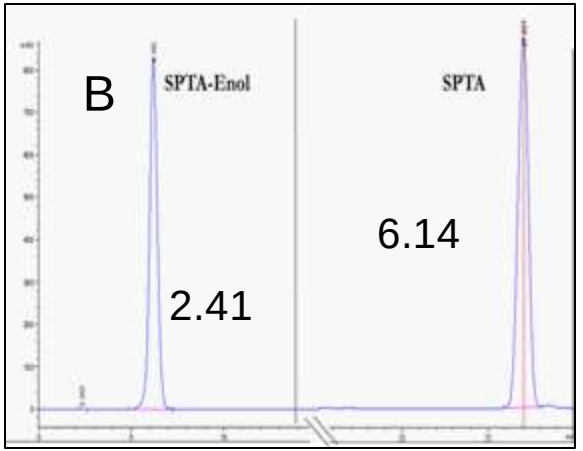
Modified after: http://www.uic.edu/classes/bios/bios100/lectf03am/translocation.jpg

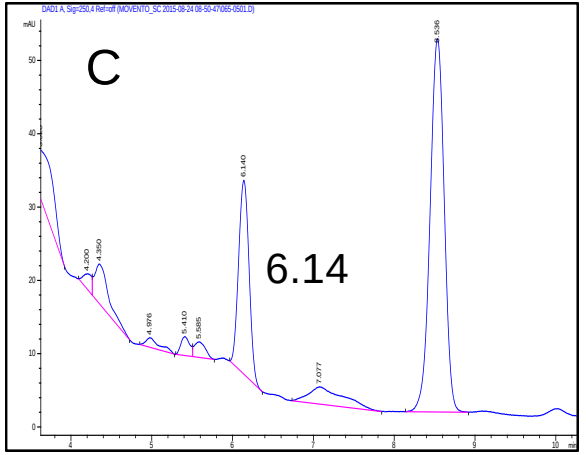

Spirotetramat
Enol-alcohol
P
Enol-Glc
(glucoside)
A, C, L, P
Enol
A, C, L, P
Glucoside
C, P
Desmethyl-enol
P
Mono-hydroxy
A
Ketohydroxy
A, C, L, P
Ketohydroxy-dumiate
Di-hydroxy
A, P
Ketohydroxy-alcohol
P
MA-amide
C
Glucoside
A
Desmethyl-ketohydroxy
A, C
Diolin
C
Glucosides
A, C
Glucoside
P
Hydroxymorpholinediona
C
Mandelic acid
C
Mandelic acid-amide
C

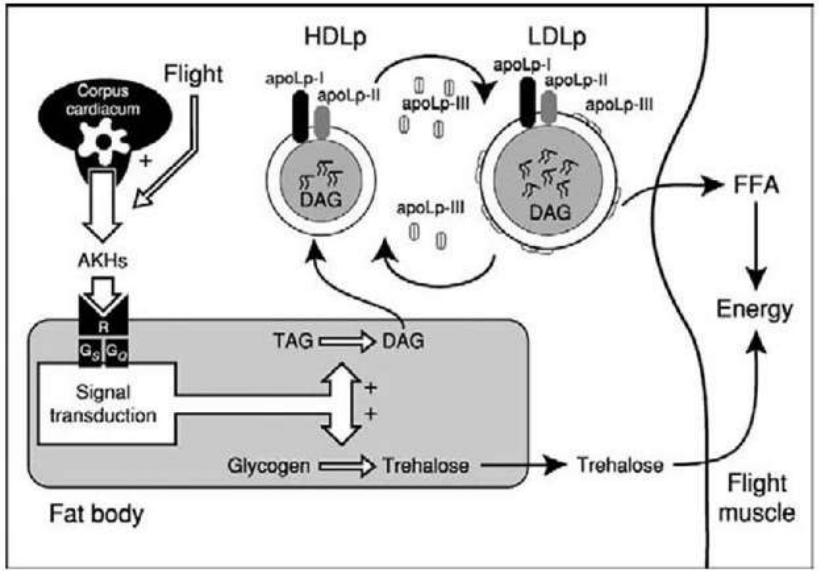

Spirotetramat
Enol
Enol-Glc
Ketohydroxy

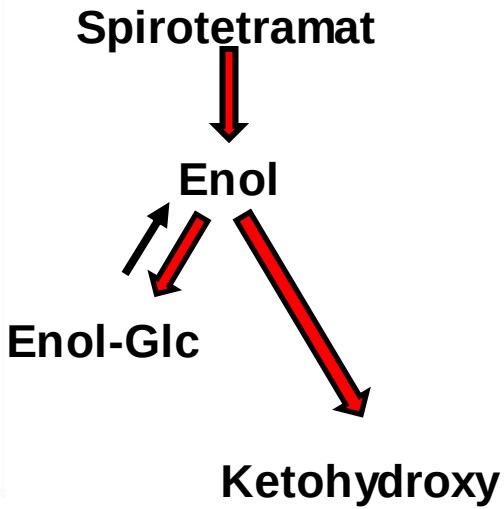
A




B
SPTA-Enol
SPTA
6.14
2.41

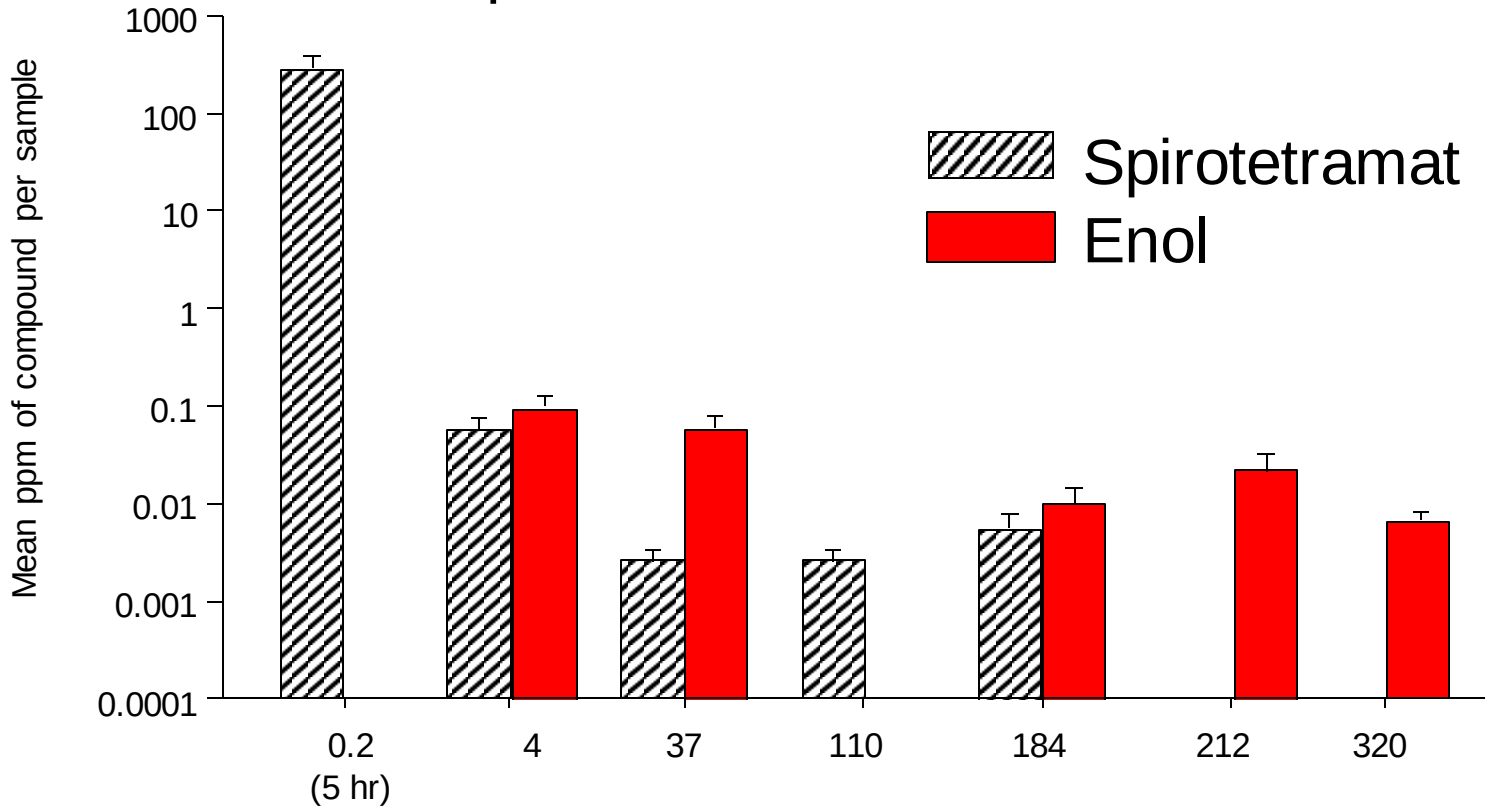

C
6.14
6.140
4.200
4.350
4.976
5.410
5.585
7.077
8.536





Spirotetramat is a tetronic acid derivative and acts as a lipid biosynthesis inhibitor. Lipids (fats, oils, waxes, vitamins, hormones) are essential to an animal's existence. Spirotetramat is effective against juvenile stages (like a growth hormone), but can reduce adult fecundity and fertility. Death also occurs because mealybugs will have their energy transport system disrupted and should cease movement.

Example of some of the results



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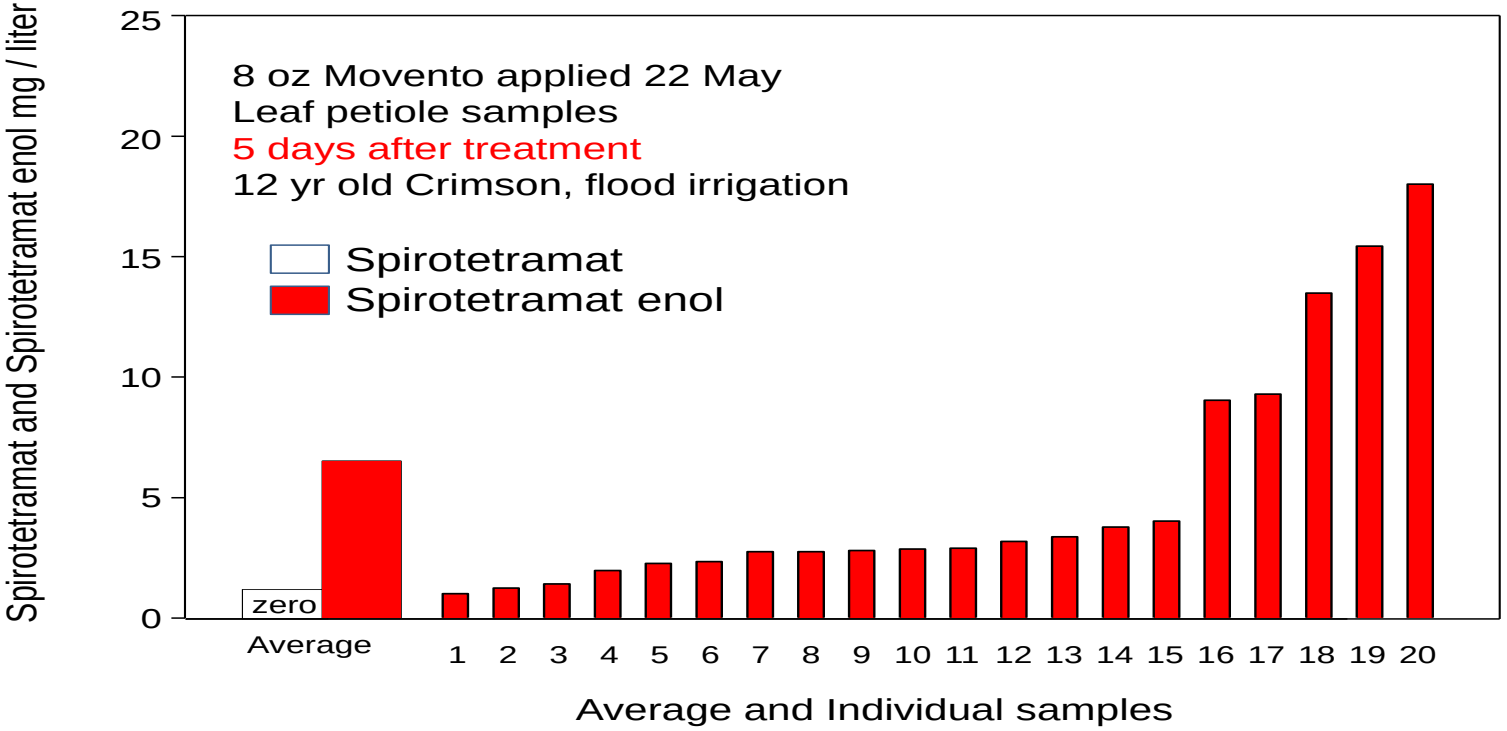

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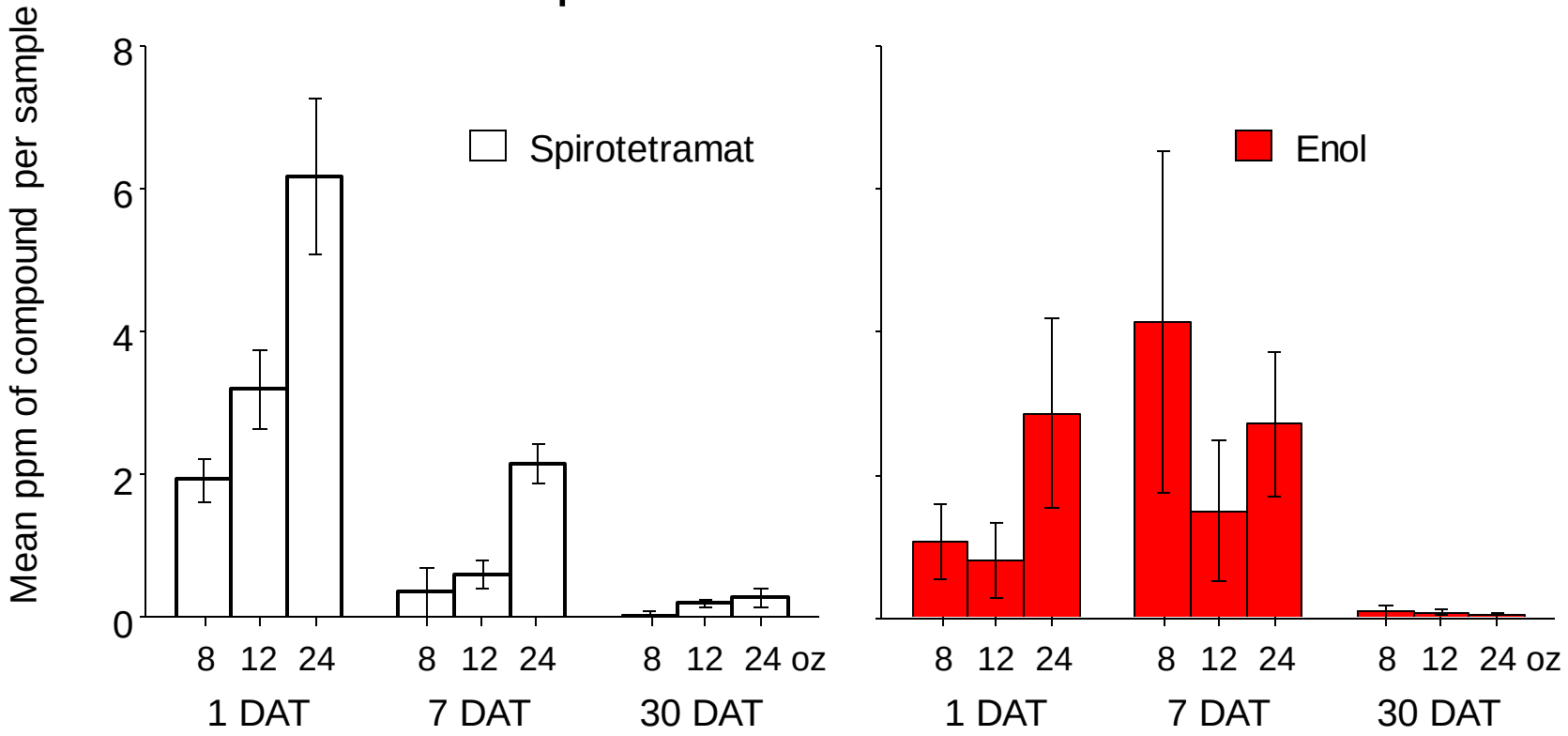

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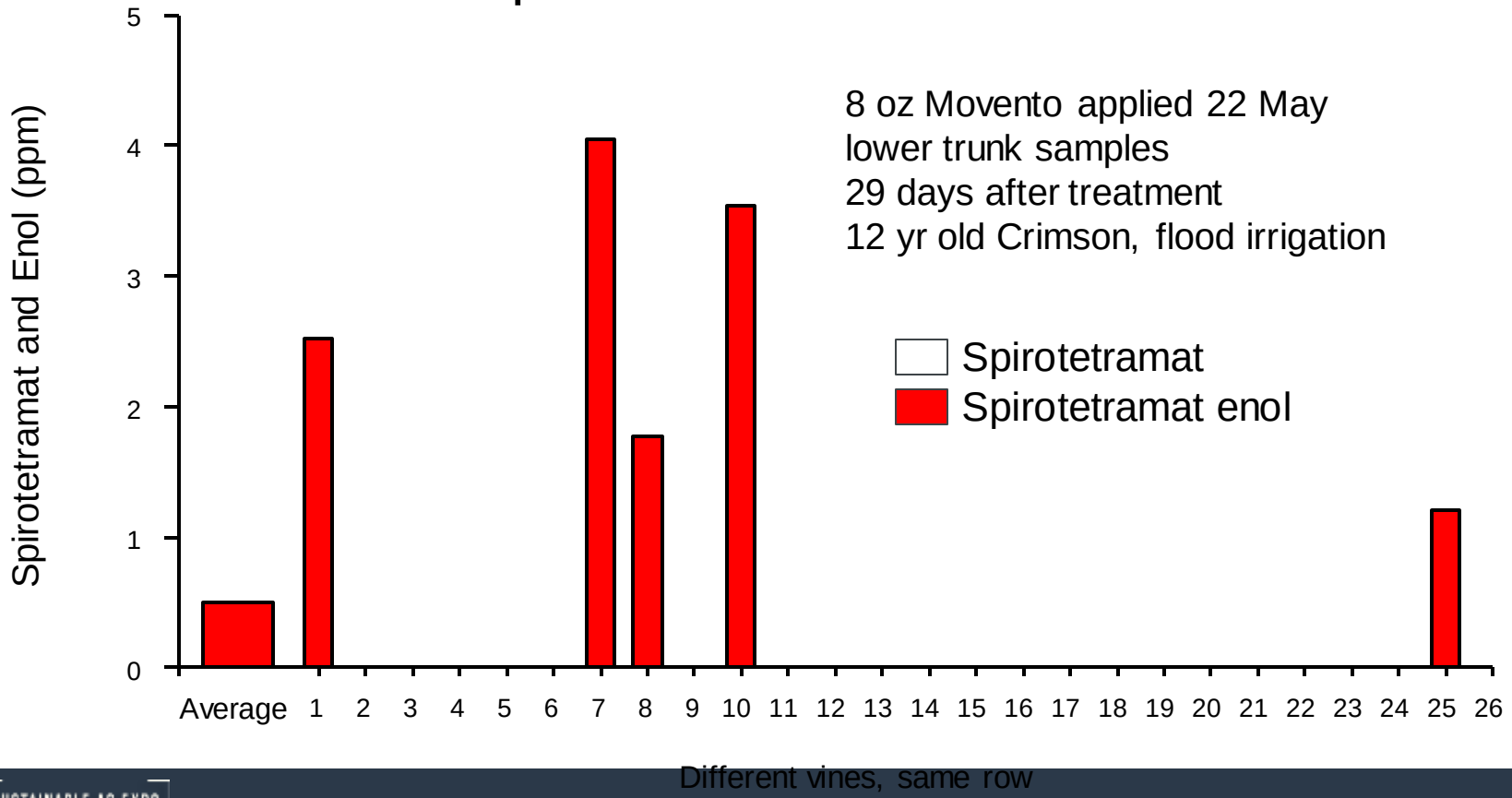
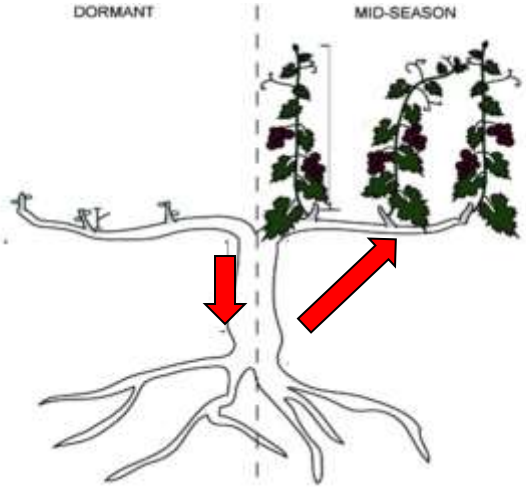
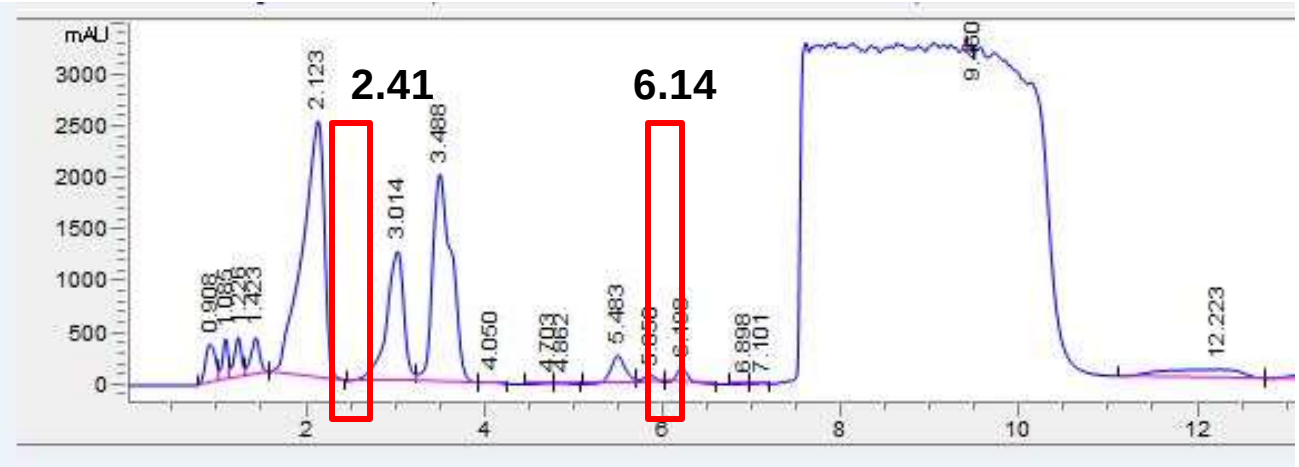


Questions we have been trying to address:

- Timing & methods of application
- Location & age of pest population
- Vine physiology
- Conversion of SPAT to SPAT-Enol?
- Movement of SPAT & SPAT-Enol



Question we are asked: is resistance to Movento developing

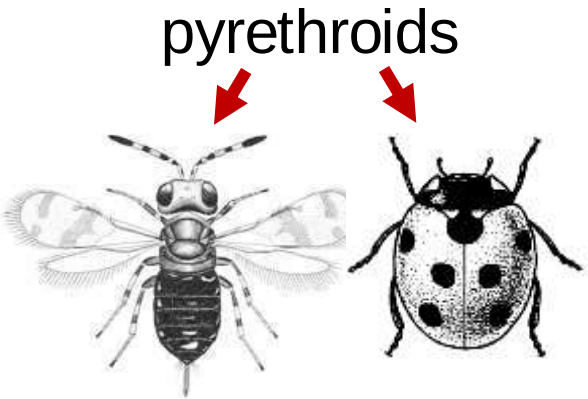


So we have visited a number of farms with large mealybug populations, which have been treated with a number of products, but in most cases we have found an explanation other than resistance is more plausible – in this case we simple can't find the Spirotetramat or Enol in the vine, in other cases the product was applied too late in the season

Green & brown lacewings
Native beetles
Mealybug destroyer beetle
Predaceous midge (fly)
Many parasitoid species

BioControls: *Anagyrus pseudococci* (female – left, male – right)
Imported decades ago for citrus and Comstock MBs, more recently for VMB

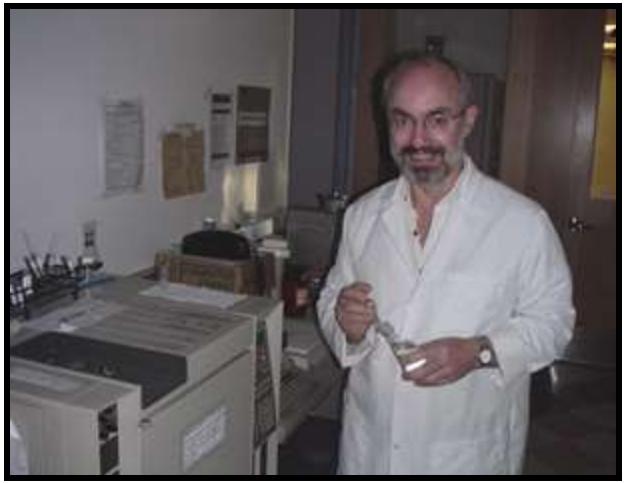
Insecticides and Natural Enemies



For most crops, selection of pesticides is the primary method to conserve natural enemies – even more important the cover crops

At this time, we haven't seen any negative aspects of Movento on natural enemies

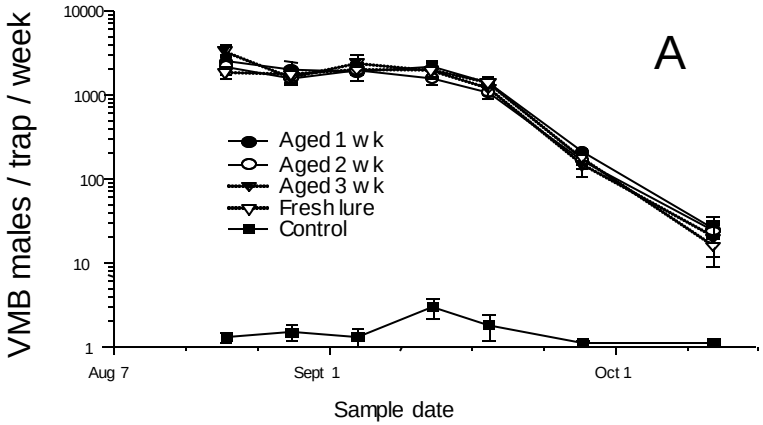
Mating Disruption for the Vine Mealybug

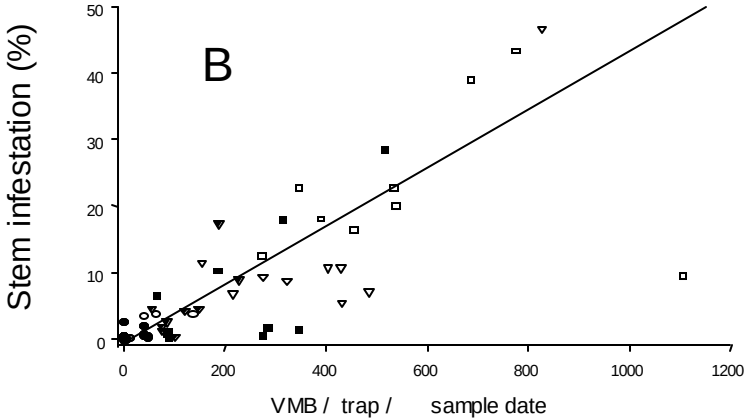


Work began with Jocelyn Millar – a pheromone chemist at UCR and Walt Bentley – UC IPM.

Identified mealybug sex pheromones to monitor mealybug spp. in grapes (Miller et al. 2002 J Econ Entomol)

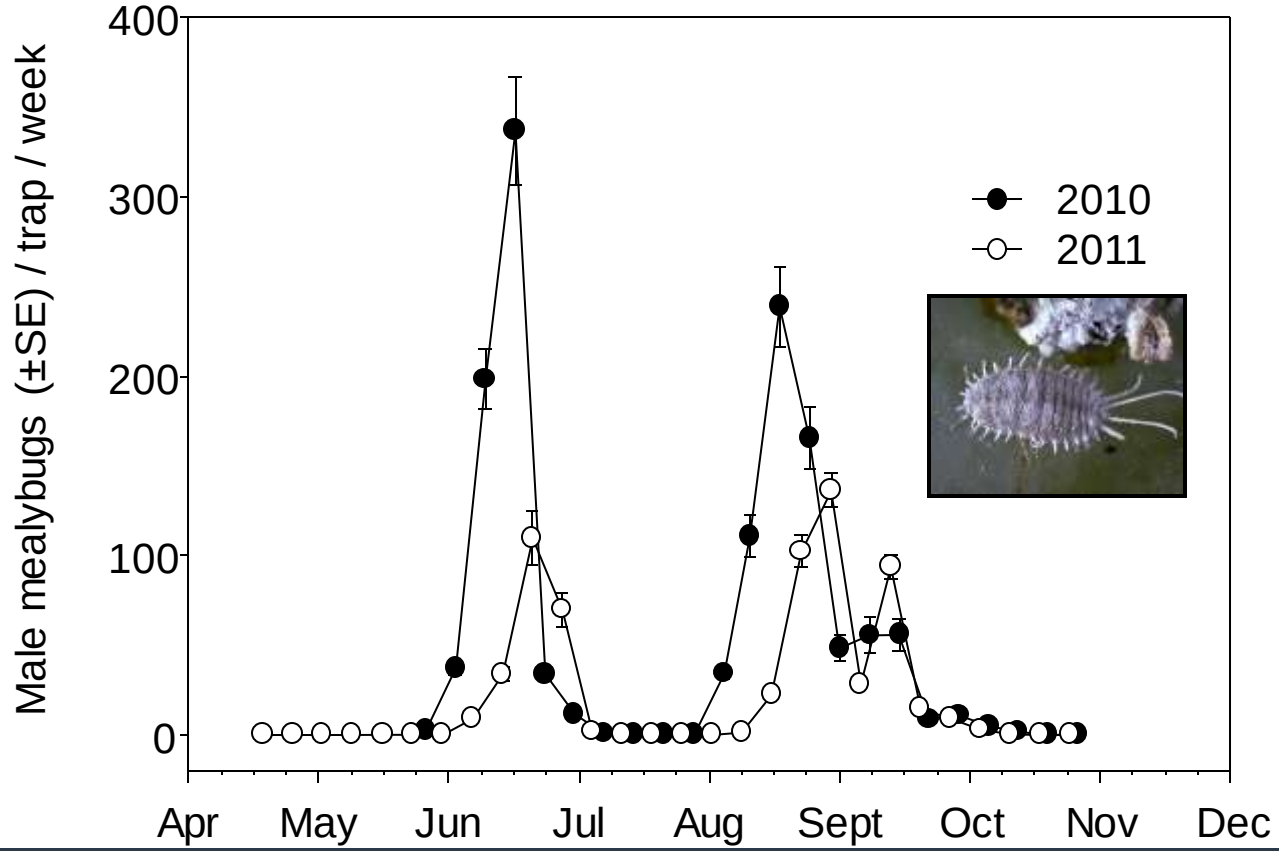
The VMB sex pheromone was relatively inexpensive to produce, and field studies for monitoring VMB suggested the pheromone was both (A) stable and (B) effective





Walton et al. 2004 *Crop Protection*
Millar et al. 2002. *J Econ Ent*

Pheromone trap captures showing GMB in Washington



Small-plot studies with sprayable formulation

Walton et al. 2006. J Econ. Ento

Period: 2003 and 2004*

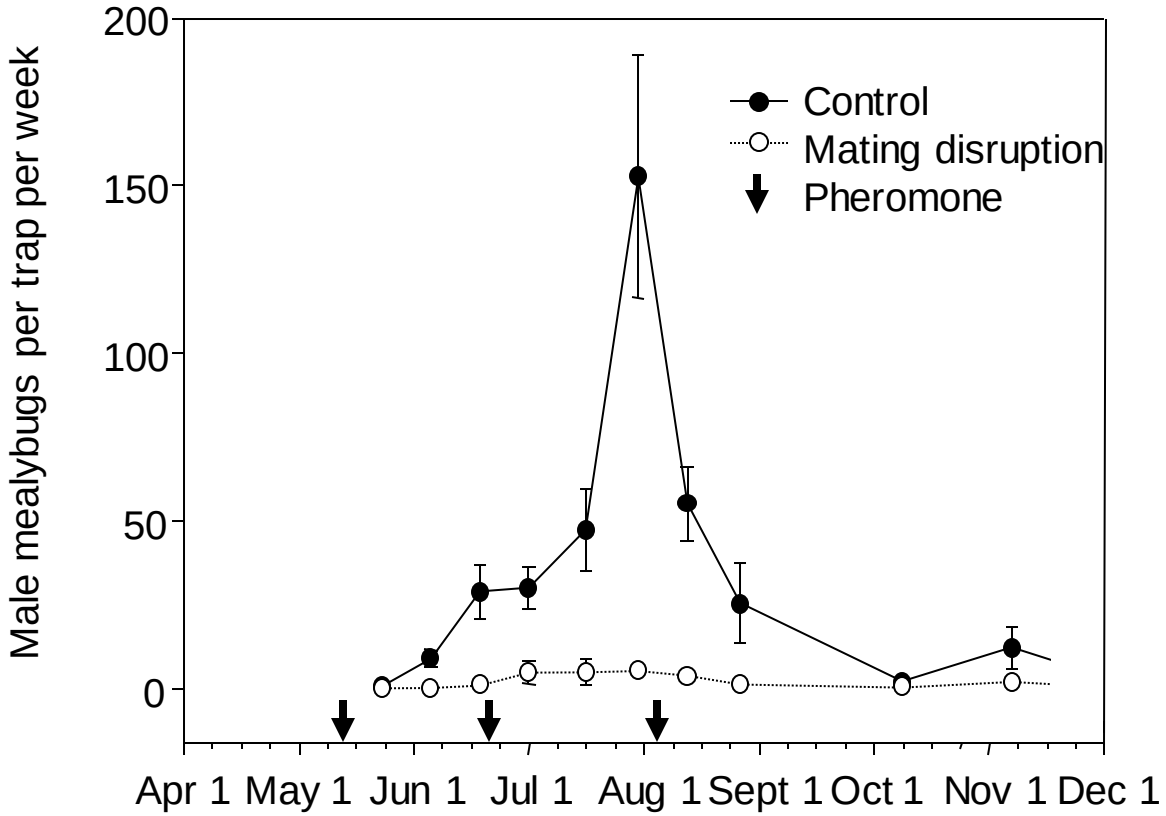
Crop Destruct: Small plots (0.2-0.3 ha) in raisin vineyards

2004 Design: Applied sprayable microencapsulated pheromone (10 g / ha) every 3 wks (20 Apr to 18 Jul); split-plot, 5 reps

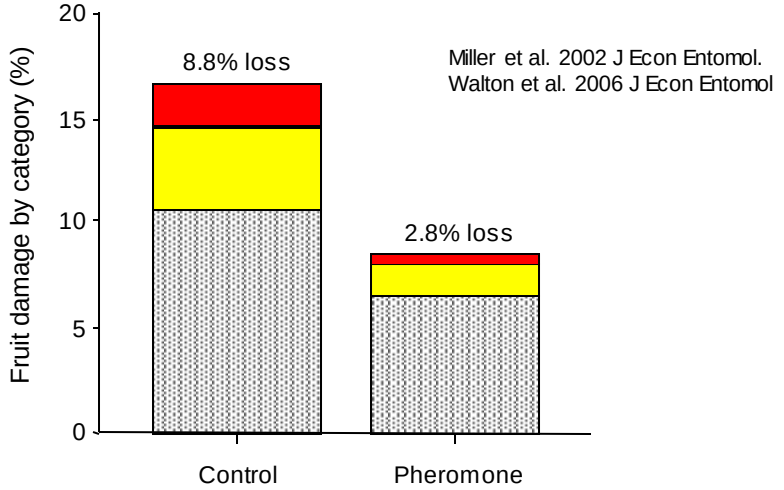
Insecticides: Buprofezin on all plots (in 2003 plots also received chlorpyrifos)

Measured: Male VMB flight, mealybug density via timed-counts, rated crop damage.

Small-plot studies with sprayable formulation



Small-plot studies with sprayable formulation



Methodology (0 – 3 scale)

- Unmarketable cluster (3)
- Mealybug damage (2)
- Honeydew, few VMB (1)
- No damage (0)

Large-plot studies with plastic dispensers

Period: 2005 to 2008, 2016 to present

Experimental permit for use: Large plots (5-20 ha) in raisin and wine vineyards

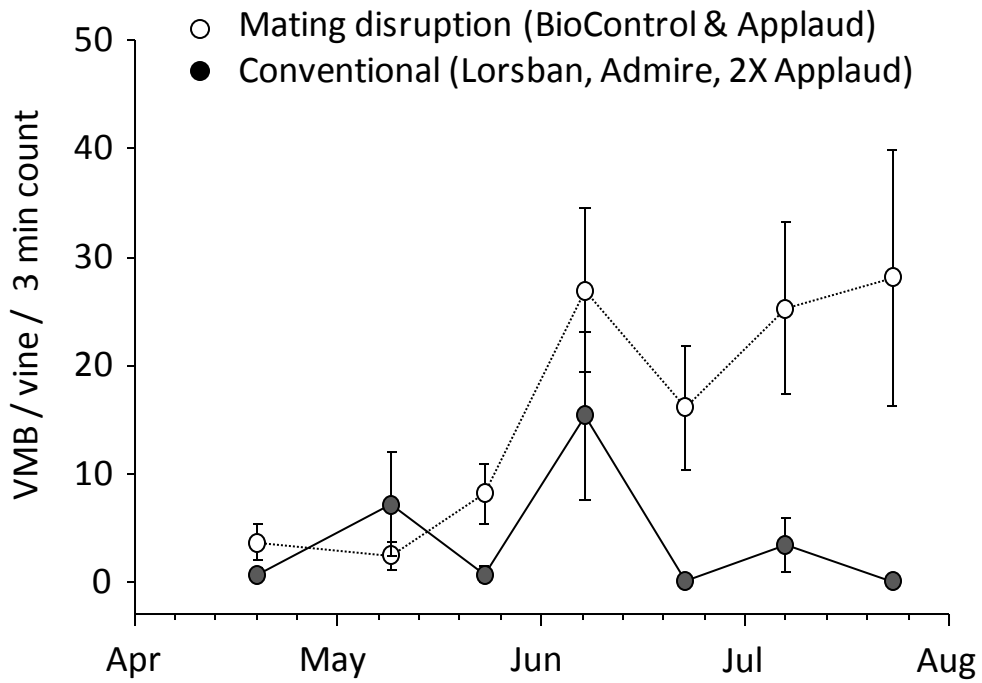
Typically Design: Deployed plastic dispensers (100-150 mg a.i. / dispenser, one application per season, ca. 250 / ac), split-plot, 4-6 reps per region.

Insecticides: Variable (early vs recent studies)

Measured: Male VMB flight, mealybug density via timed-counts, rated crop damage.

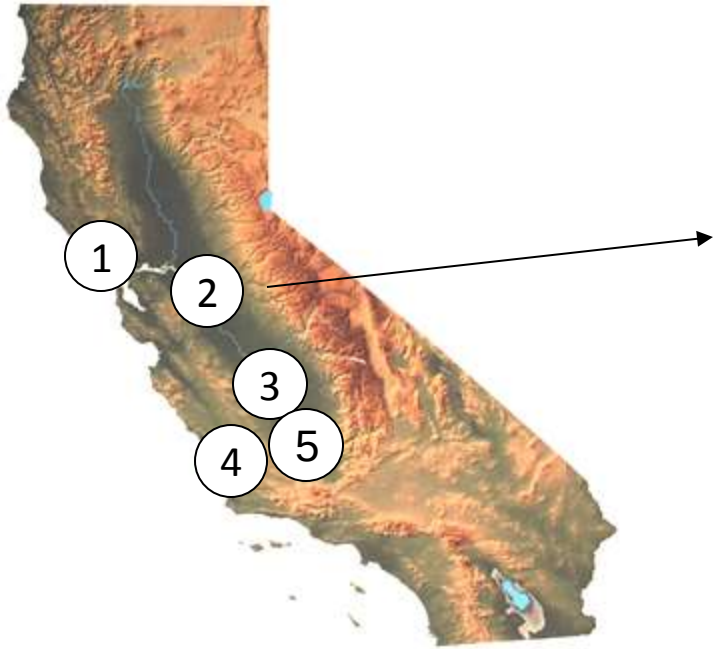
Daane et al. unplublished

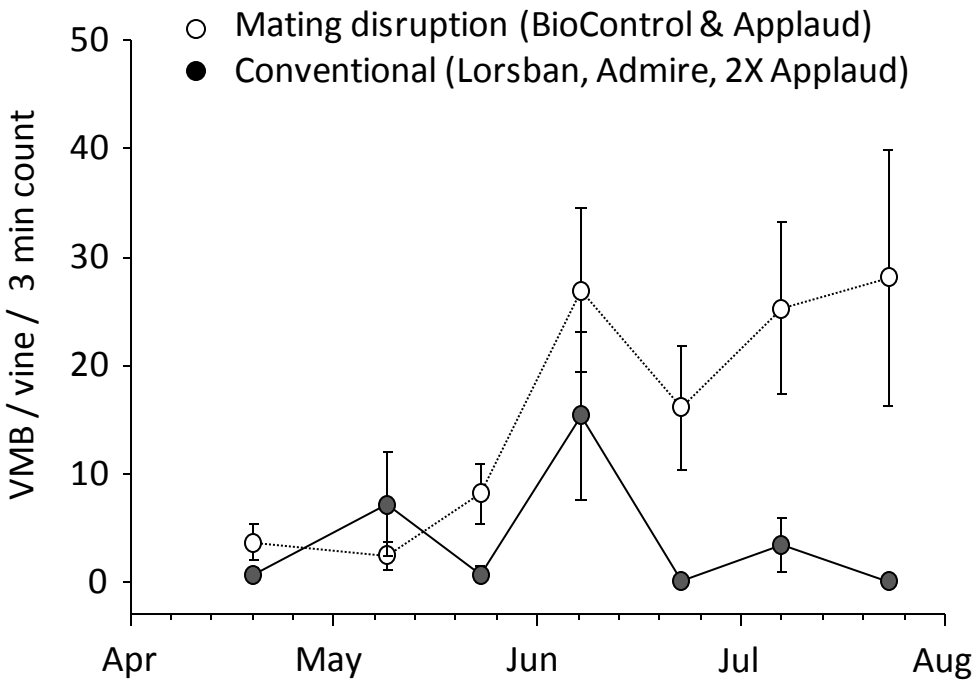
Large-plot studies with plastic dispensers: CONS



Daane et al. unplublished

Large-plot studies with plastic dispensers: CONS





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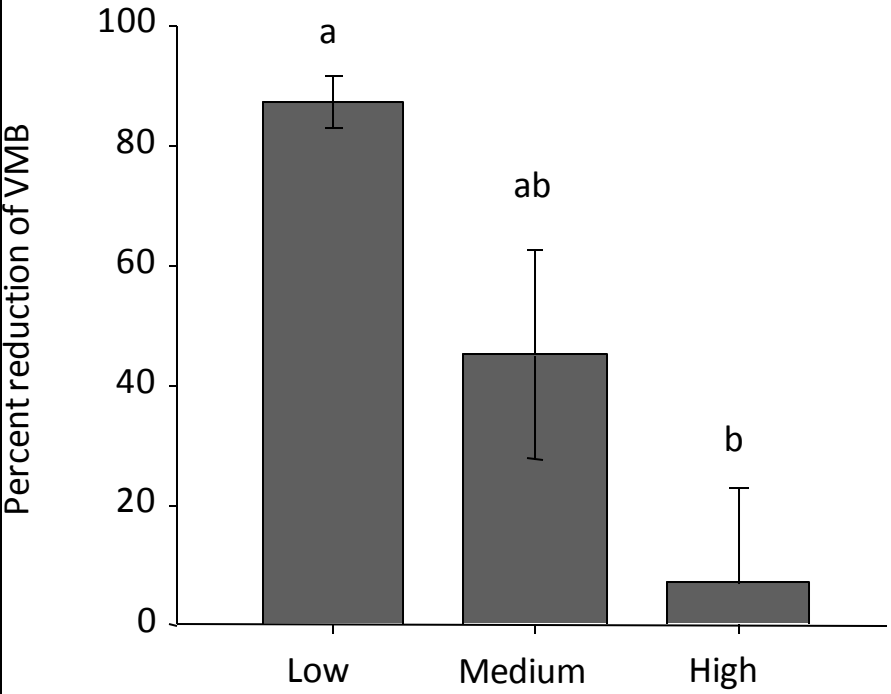
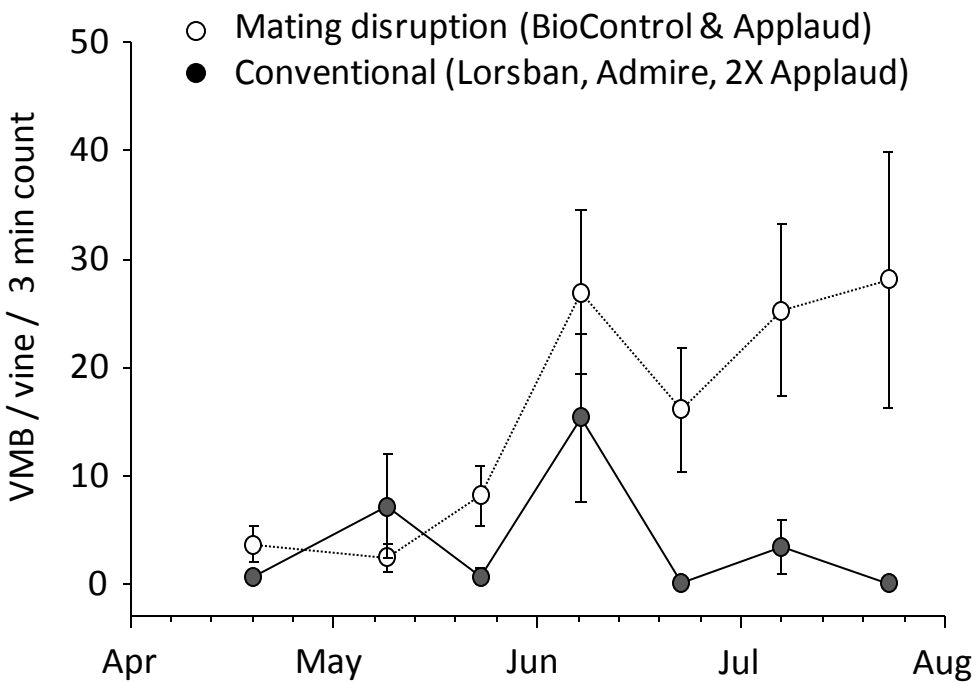
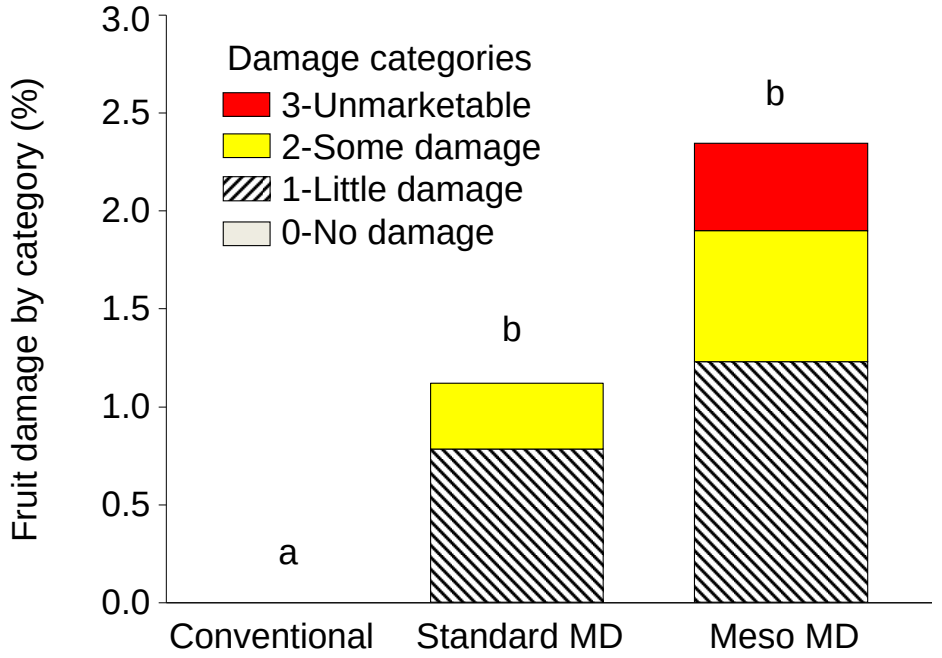
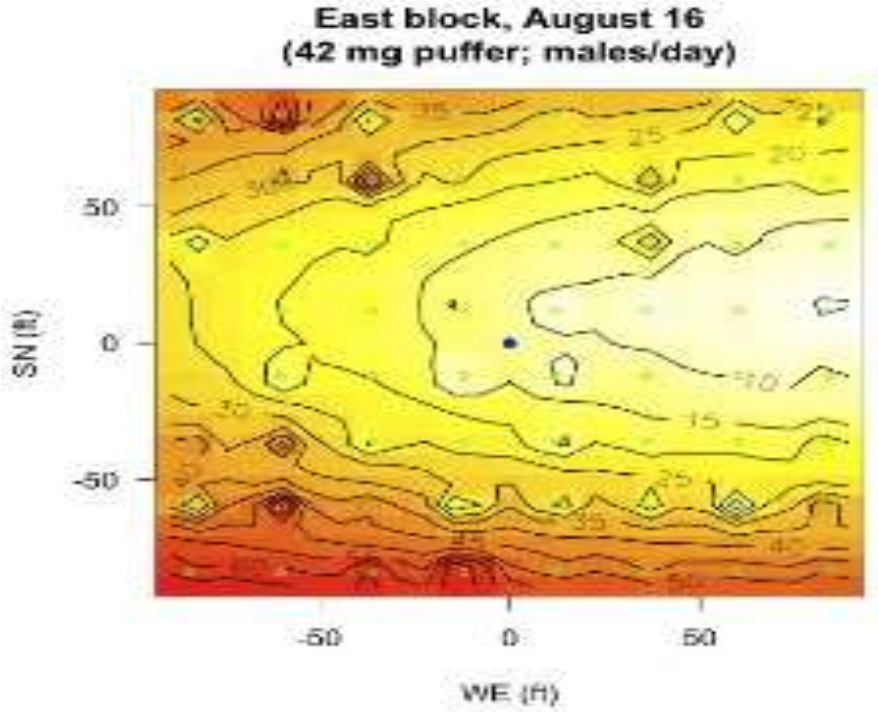




Could “meso” dispensers (50/ha) reduce costs?
Lower labor costs .. but fewer ‘point’ sources

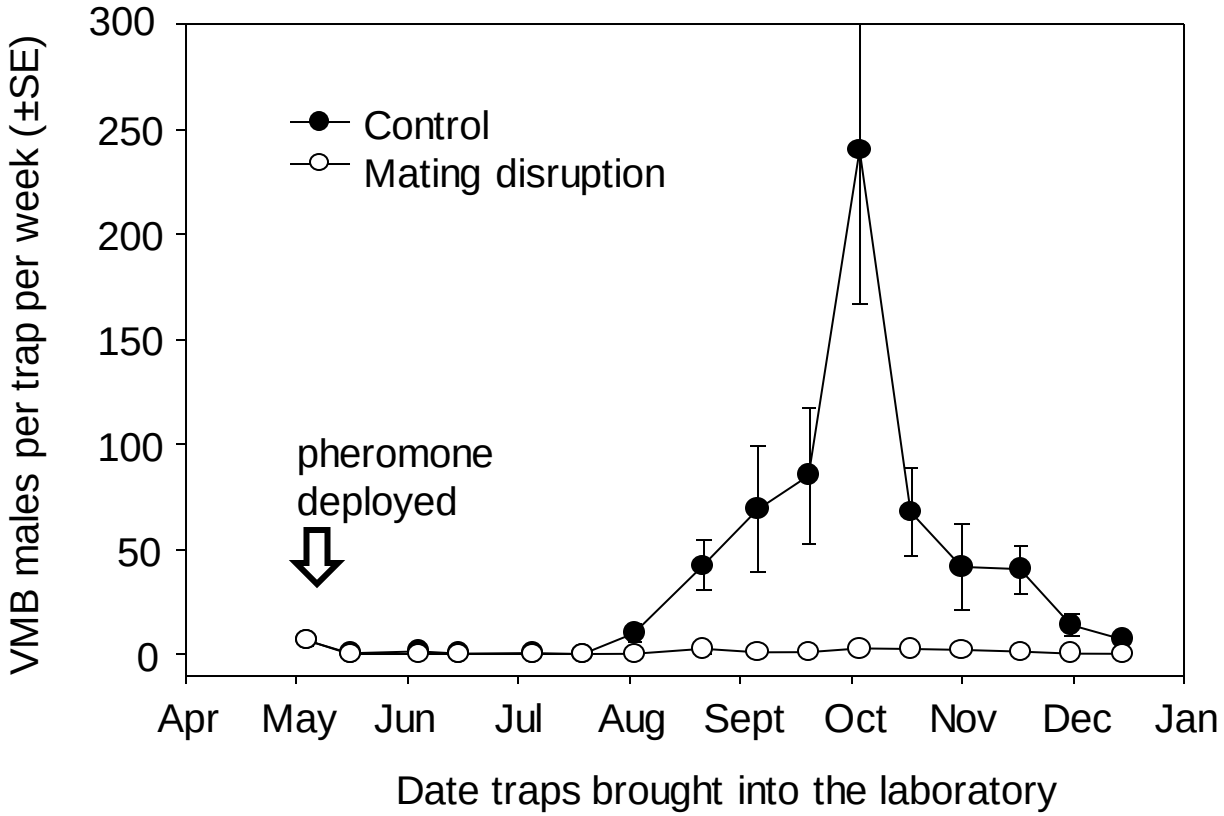


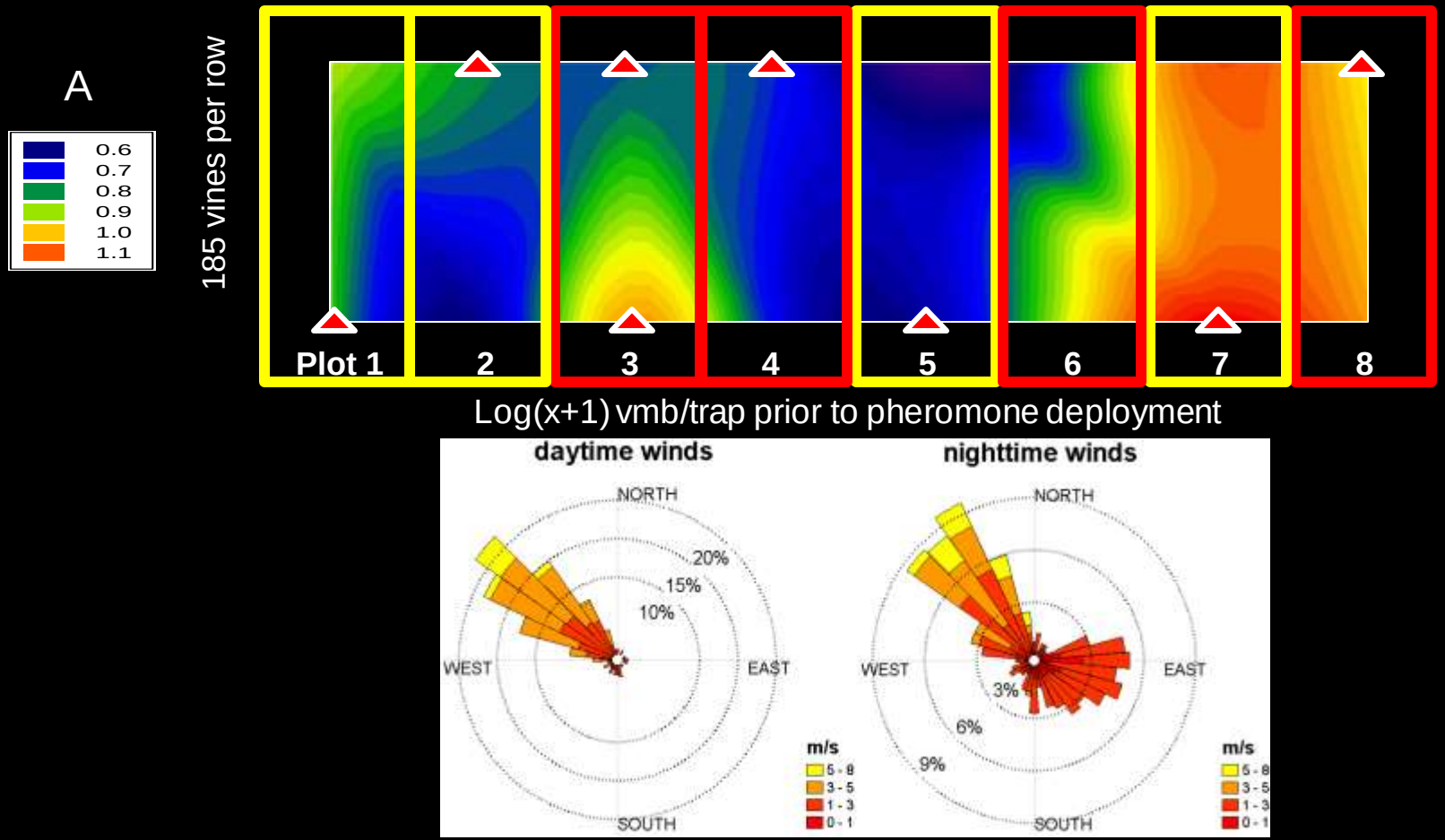
Could “puffers” reduce costs? (Welter & Kurtural)
Lower labor costs & better release control….

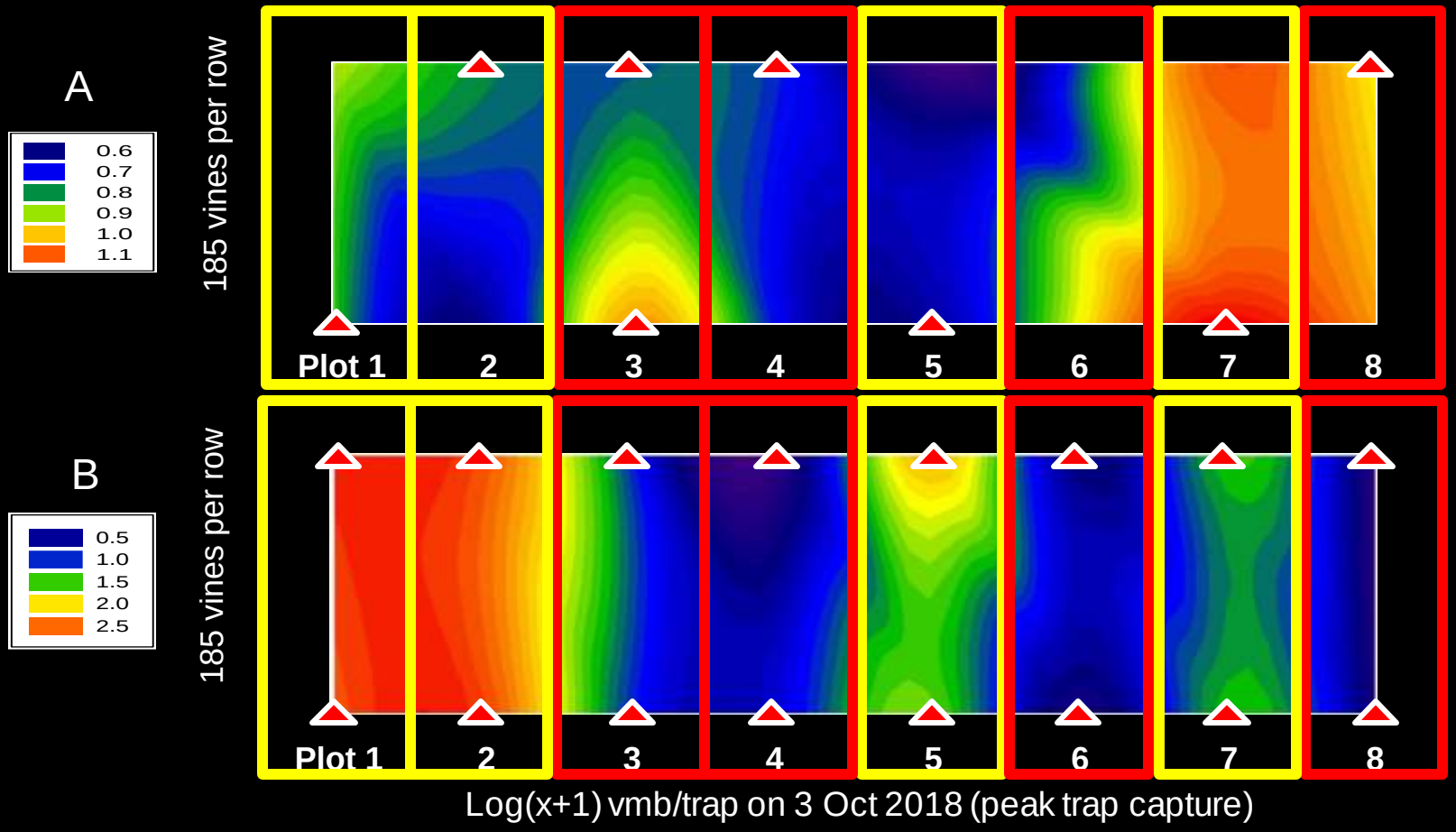


Puffers for pheromone release may reduce costs further, requiring only placement of 4 puffers / ha, and automating pheromone release to time of day

Pacific BioControl Dispensers 2018-2019




A
0.6
0.7
0.8
0.9
1.0
1.1
185 vines per row
Plot 1
2
3
4
5
6
7
8
Log(x+1) vmb/trap prior to pheromone deployment
daytime winds
nighttime winds
NORTH
EAST
SOUTH
WEST
20%
15%
10%
3%
6%
9%
m/s
5 - 8
3 - 5
1 - 3
0 - 1


A
0.6
0.7
0.8
0.9
1.0
1.1
185 vines per row
Plot 1
2
3
4
5
6
7
8
B
0.5
1.0
1.5
2.0
2.5
185 vines per row
Plot 1
2
3
4
5
6
7
8
Log(x+1) vmb/trap on 3 Oct 2018 (peak trap capture)

Outline – Vector Control and GLRaV

- GLRaV Control Programs
  - a) leafroll and mealybugs
  - b) leafroll epidemiology (difference with GRBV)
- Mealybug Controls
  - a) insecticides – current studies
  - b) biological controls – a review
  - c) mating disruption
- Areawide or strategic control for GLRaV

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

Cabernet Sauvignon (2008)

Grape MB & GLRaV-3

Grape MB & Red Blotch (?)

Imagery Date: 10/24/2009 1993 38°25'48.40" N 122°23'59.73" W elev 151 ft Eye alt 2408 ft

Google

Can we simply kill all mealybugs for GLRaV control?

Two annual applications of a combination of either Applaud, Admire, Clutch or Movento

Insecticides
No insecticides

2011
2009
2011
GLRaV3b
2011
2013
2011
2012
2011
2011
2012
2010

GLRaV3a
GLRaV3c
GLRaV3d

Google

Imagery Date: 10/24/2009 1993 38°25'48.40" N 122°23'59.73" W elev 151 ft Eye alt 2408 ft

Can we simply kill all mealybugs for GLRaV control?

Two annual applications of a combination of either Applaud, Admire, Clutch or Movento

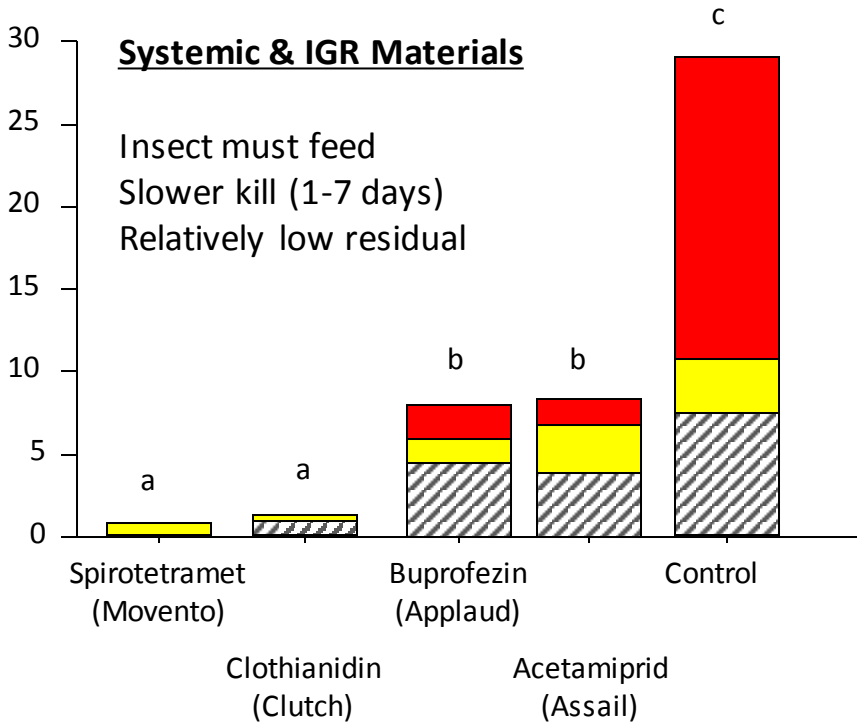
Insect growth regulator
Applaud (Buprofezin)

Neonicotenoids
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)



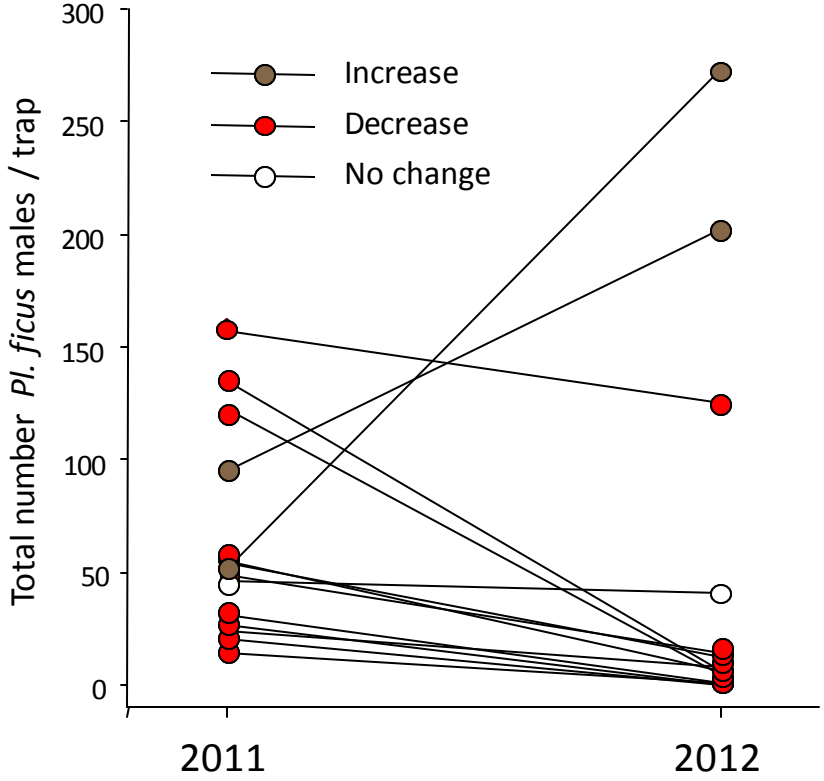
Spray Volume: 100 GPA; Air-blast Sprayer; label rate (Applaud 12 oz per ac)
Clutch & Movento on 21 June 2011, Applaud & Assail on 7 July 2011
Planococcus ficus, Lodi-Woodbridge wine grapes, Lodi, CA

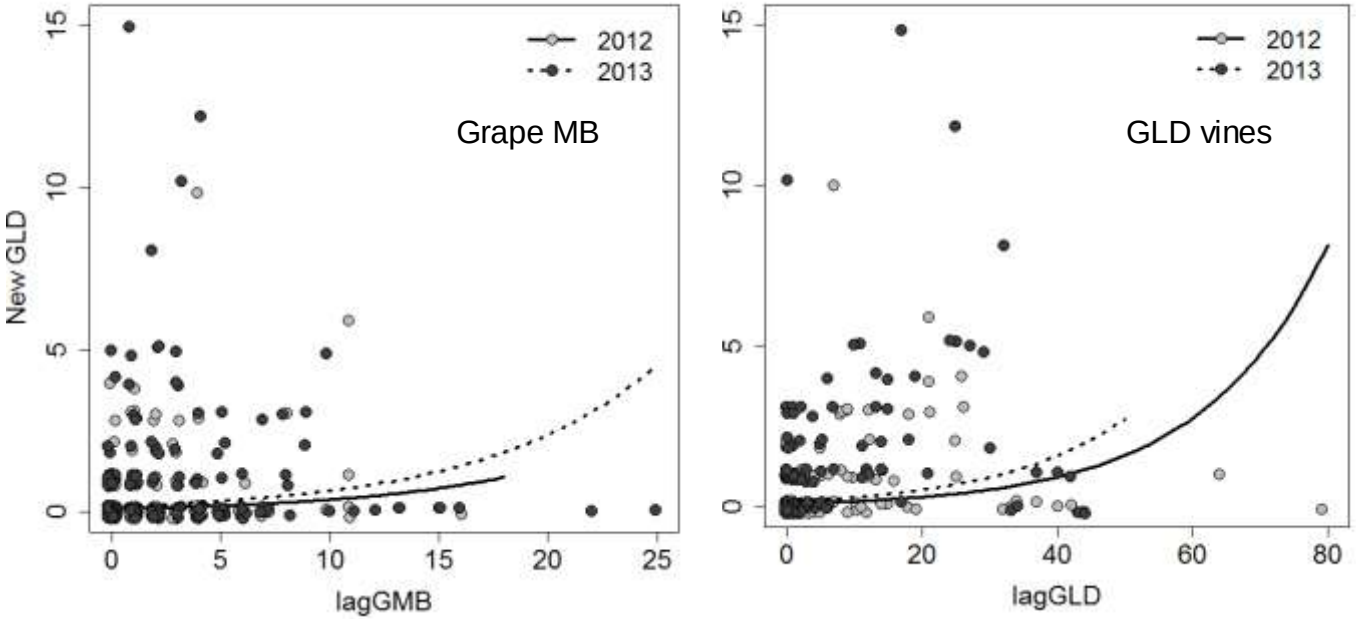
Areawide control trial in Napa (study 2011-2012, ongoing programs)

Comparison of traps in hotspots between years

Numbers of vine MB in traps with total >20 VMB in either year generally decreased between 2011 and 2012, except in two cases.

When proper treatments are not applied the population will increase and spread.

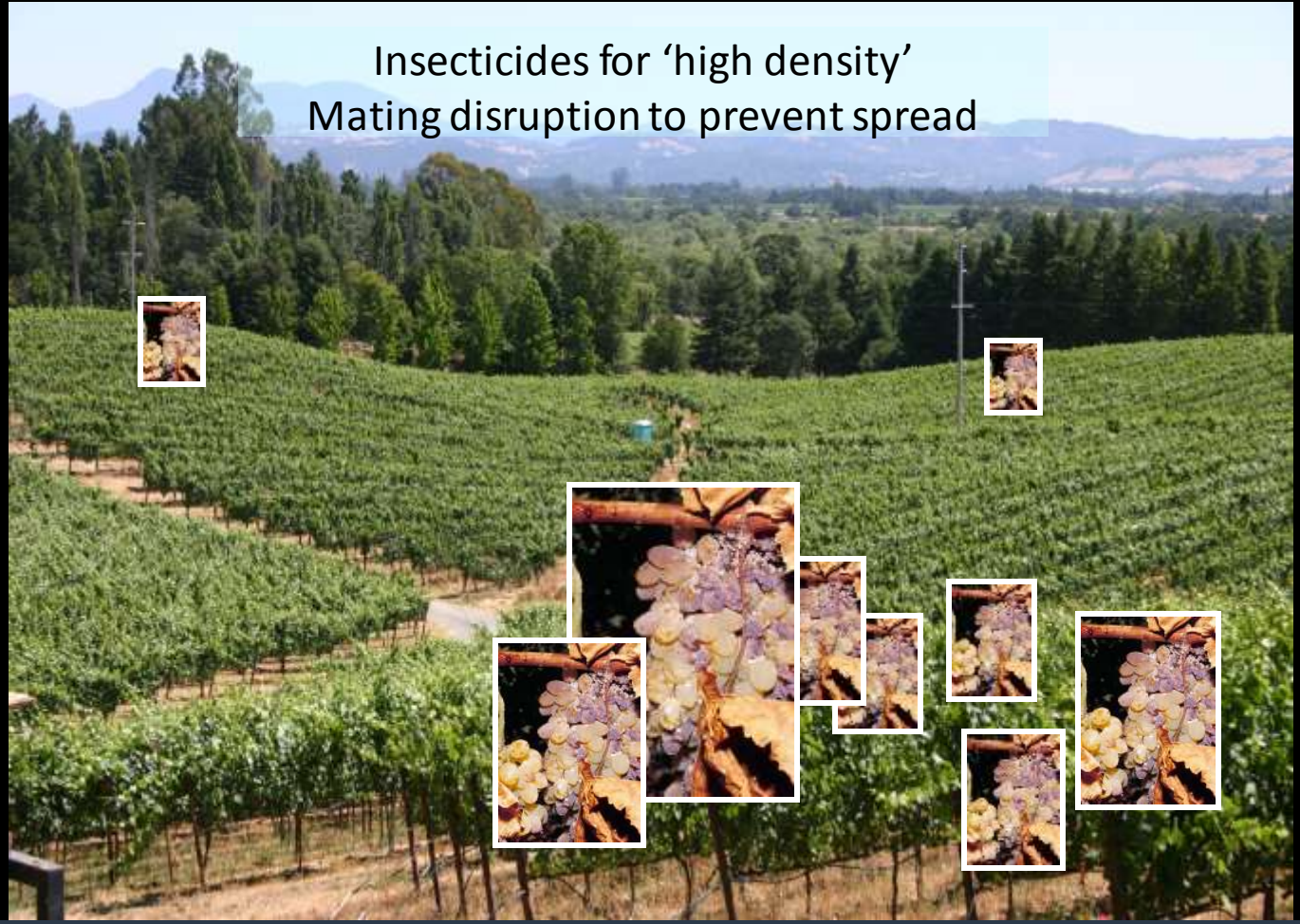




Work from Monica Cooper with 'spatial-temporal' dynamics of the grape mealybug – still one of the more common vectors and is associated with movement of the pathogen when the pathogen is present in the vineyard, suggesting that 'removal of diseased vines [is] a tool to mitigate further damage"

Areawide control trial in Napa (study 2011-2012, ongoing programs)

Rouging infected vines is a key element, and often difficult to accept



Summary 1
Mealybugs will get into the vineyard and are difficult to completely remove.

Summary 2
If there is little/no leafroll, then mealybugs are not a problem.

Summary 3
Weigh the costs of vine removal now vs block removal later.

Conclusions & Questions

- Different mealybug species in California vineyards – all vector GLRaV.
- Chemical controls remain the most common tool: Movento, Belay, Admire (and generic), Assail, Platinum, Venom, Applaud, Sivanto; materials for organic growers are don't provide same level of control.
- Mating disruption for vine mealybug to maintain low densities – a lot more potential with the sprayable formulation.
- Excellent bio-controls for grape MB, and partial bio-control for vine MB; ants have a negative impact on bio-controls and a mating disruption has a positive interaction.
- Mealybugs vector GLDs and this changes control decisions – start thinking about areawide control as the best program.

NOV 11-13, 2019

SUSTAINABLE AG EXPO
&
INTERNATIONAL SUSTAINABLE WINEGROWING SUMMIT

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California

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CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

SUTERRA

The Future Grows Here 50

THE UNIVERSITY OF CALIFORNIA 1868

California Raisins

American Vineyard Foundation

NICHINO AMERICA

UCCE University of California Cooperative Extension

Bayer CropScience

NOV 11-13, 2019

SUSTAINABLE AG EXPO
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Thank you – Questions?

kmdaane@berkeley.edu

Grapevine Red Blotch Virus (GRBV)

Aceratagallia spp.

A. angulatus

Scaphytopius spp.

C. montanus

C. coquilletti

S. festinus (Membracidae)

Melaniolarus sp. (Cixiidae)

Grapevine Red Blotch Virus (GRBV)

Organism	Positive / Total	% Pos.	Pop.	Freq
Erythroneura elegantula	1/161	<1%	High	Low
Aceratagallia spp.	1/59	2%	High	Low
Empoasca sp.	1/51	2%	High	Low
Spissistilus festinus	5/39	13%	Med	Med
Scaphytopius spp.	14/24	58%	Med	High
Acinopterus angulatus	1/31	3%	Med	Low
Melanoliarus sp.	1/23	4%	Med	Low
Caladonus coquilletti	5/8	63%	Low	High
Colladonus montanus reductus	1/2	50%	Low	High

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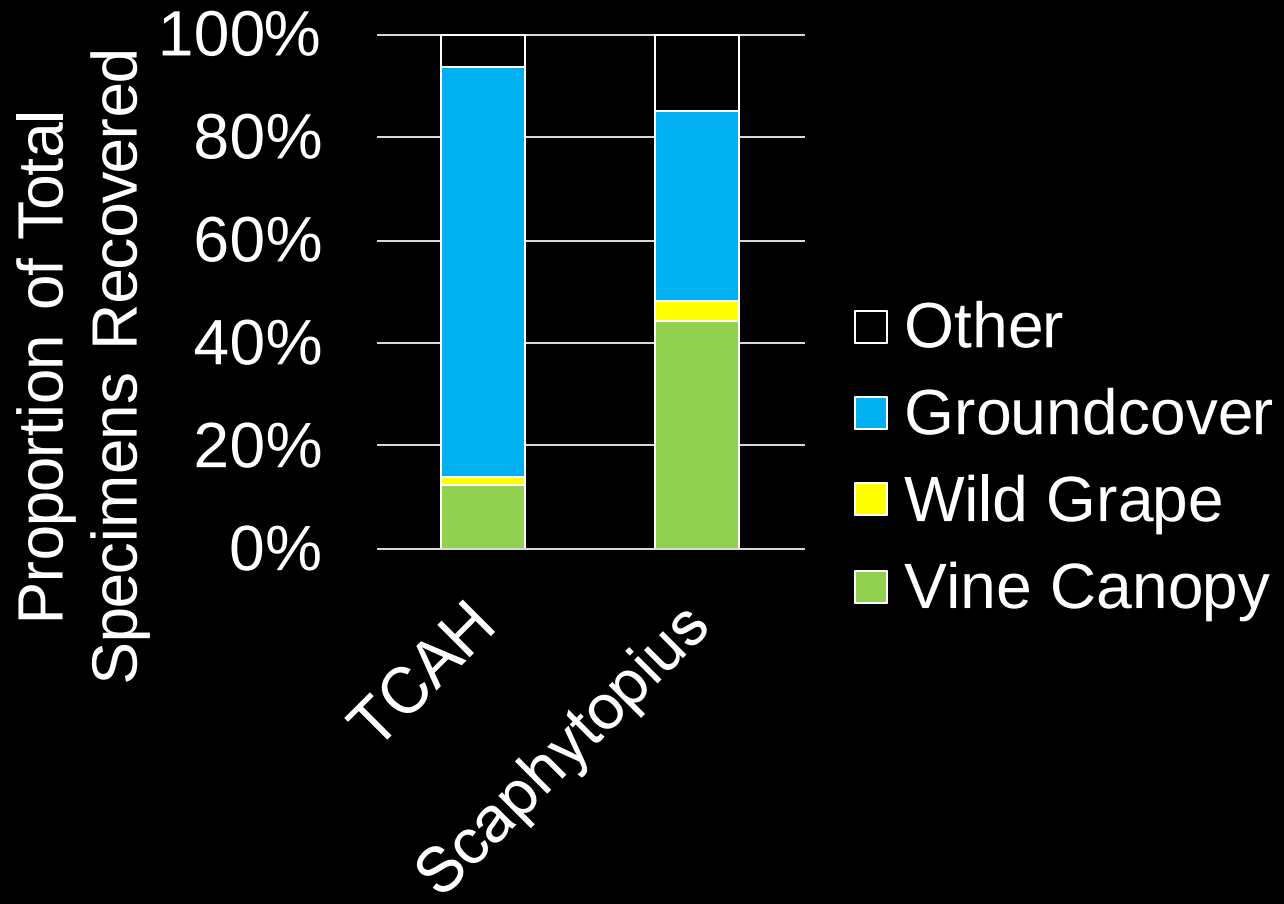
Proportion of Total Specimens Recovered
100%
80%
60%
40%
20%
0%
TCAH
Scaphytopius
Other
Groundcover
Wild Grape
Vine Canopy