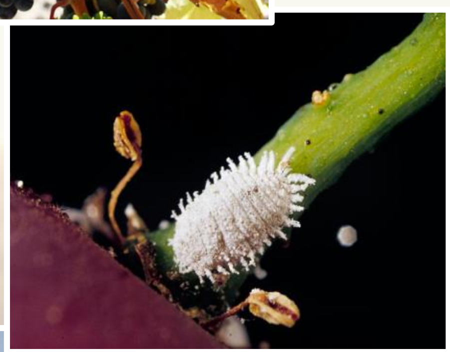
2017 SUSTAINABLE AG EXPO



Best Management Practices for the Monitoring and Control of Mealybug Vectors of Grape Leafroll Virus

Brian Hogg, Kai Blaisdell, Valeria Hochman-Adler, Monica Cooper, Deborah Golino, Rodrigo Almeida, and Kent Daane

Grape vine leafroll associate virus:
We will discuss insecticides for control of the 'epidemic' leafroll scenario that growers were initially worried about.

Vectors of Viral Pathogens in Vineyards

1. GLRaV Factors that Impact Control
    a) mealybug and leafroll species
    b) facts about mealybug-leafroll epidemiology
2. Vector (Mealybug) Controls
    a) insecticides for mealybug: which are best
    b) pheromones for monitoring and control
    c) biological controls
3. Areawide Control Programs?
    a) monitoring
    b) insecticide resistance
    c) mating disruption in Napa

Vectors of Viral Pathogens in Vineyards

1. GLRaV Factors that Impact Control
   a) mealybug and leafroll species
   b) facts about mealybug-leafroll epidemiology
2. Vector (Mealybug) Controls
   a) insecticides for mealybug: which are best
   b) pheromones for monitoring and control
   c) biological controls
3. Areawide Control Programs?
   a) monitoring
   b) insecticide resistance
   c) mating disruption in Napa

GLRaV Insect Vectors

- >700 plant viruses
- ca. 70% have insect, mite, nematode or fungal vectors

GLRaV Insect Vectors

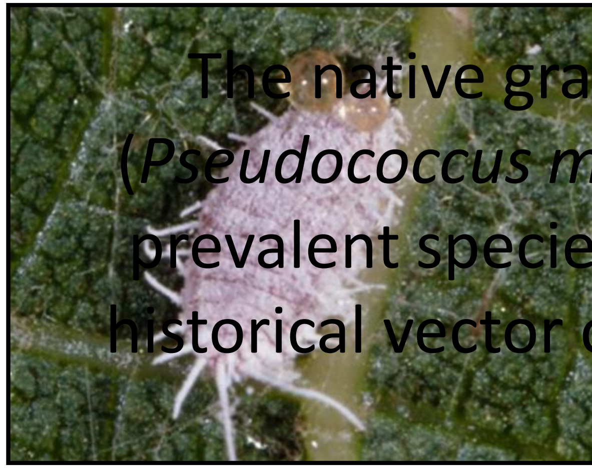
- >700 plant viruses
- ca. 70% have insect, mite, nematode or fungal vectors
- most GLRaVs are closterovirids…

and most closterovirids are vectored by whiteflies, aphids, soft scales and mealybugs

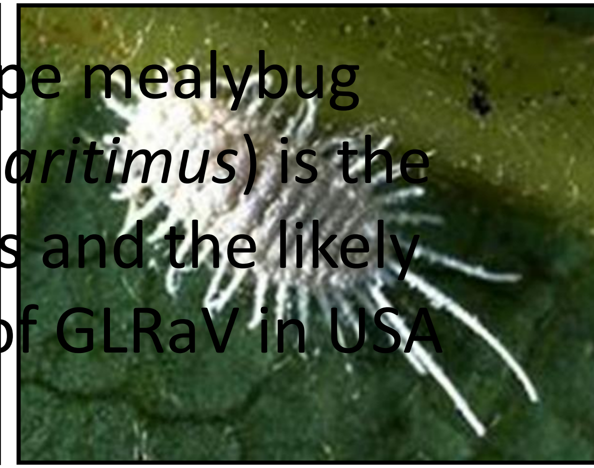
GLRaV-3 Mealybug Vectors in California

Grape mealybug

Obscure mealybug



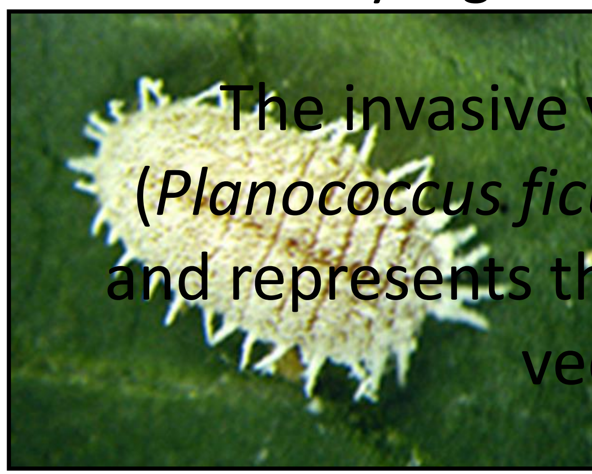
Longtailed mealybug



The native grape mealybug (*Pseudococcus maritimus*) is the prevalent species and the likely historical vector of GLRaV in USA

Vine mealybug

Citrus mealybug



Gill's mealybug

The invasive v
(*Planococcus ficu*
and represents th
vec

Rosciglione and Gugerli, 1987, Engelbrecht and Kasdorf 1990, Golino et al. 2002, Charles et al. 2006, Tsai et al. 2011

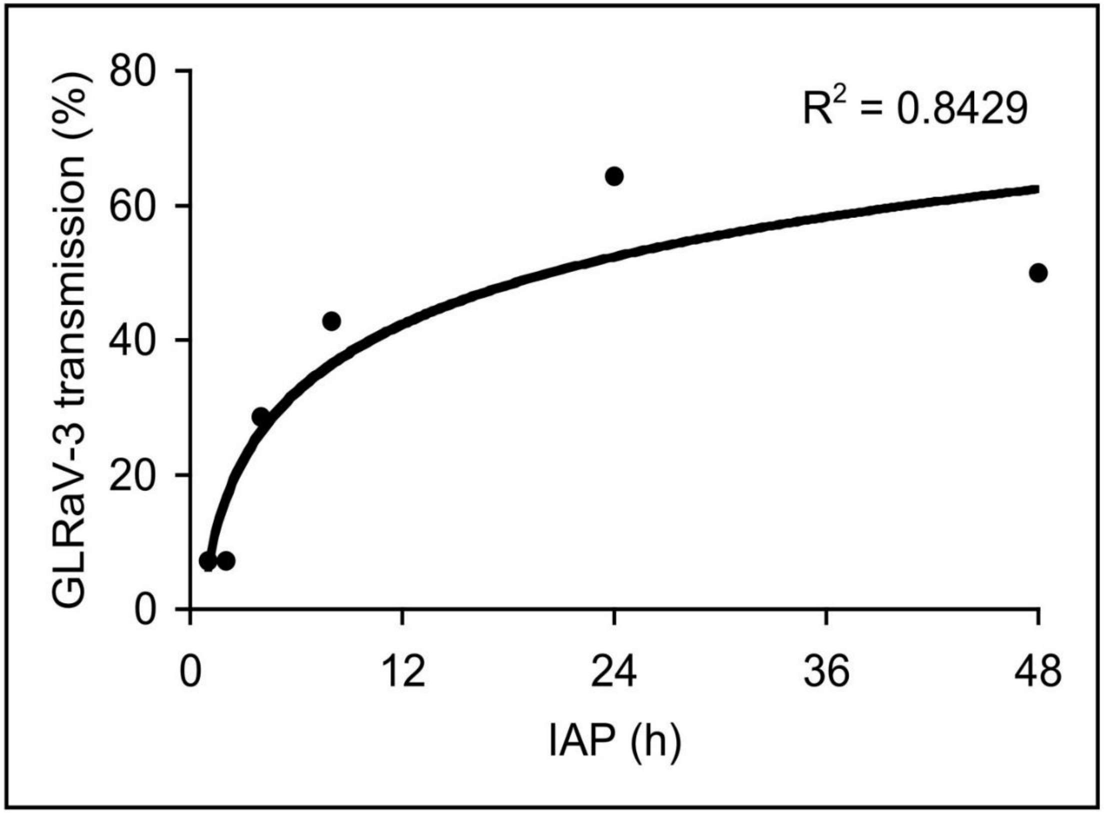
Key Transmission Facts – Acquisition

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

Tsai, Almeida et al. *Phytopath*. (2008)

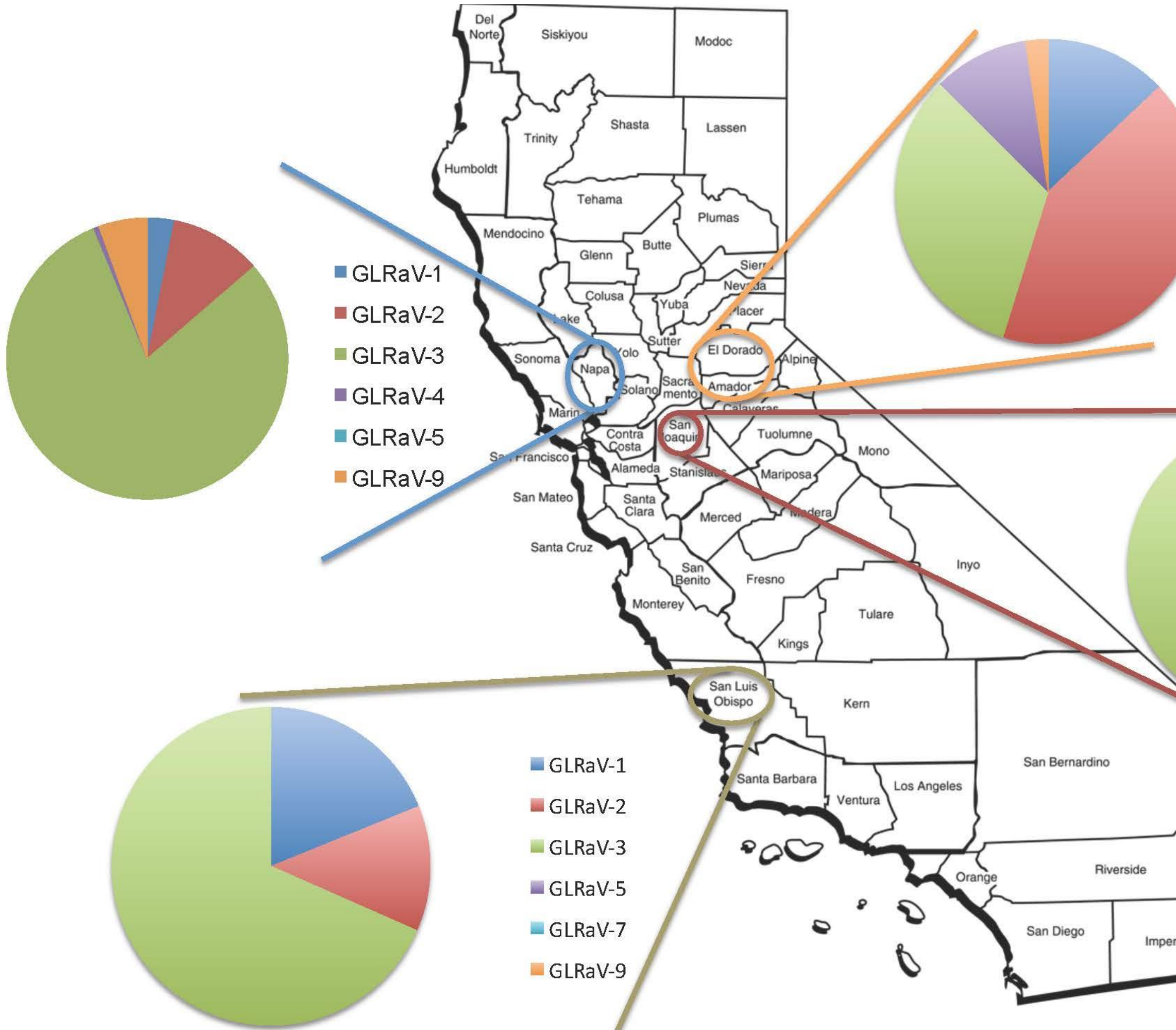
Key Transmission Facts – Inoculation

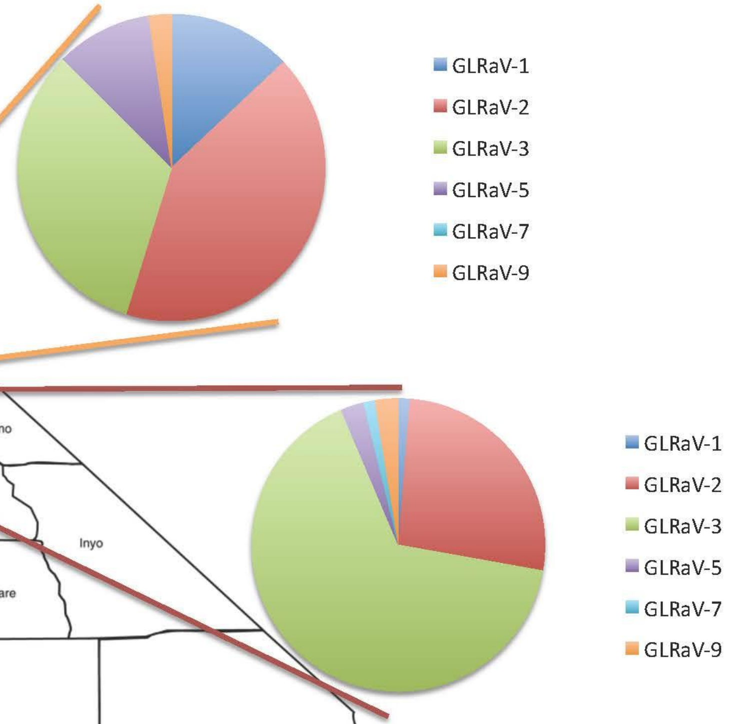
- Crawlers **inoculated** virus w/in 1 hr
- Peak at 24 hr



Tsai, Almeida et al. *Phytopath*. (2008)

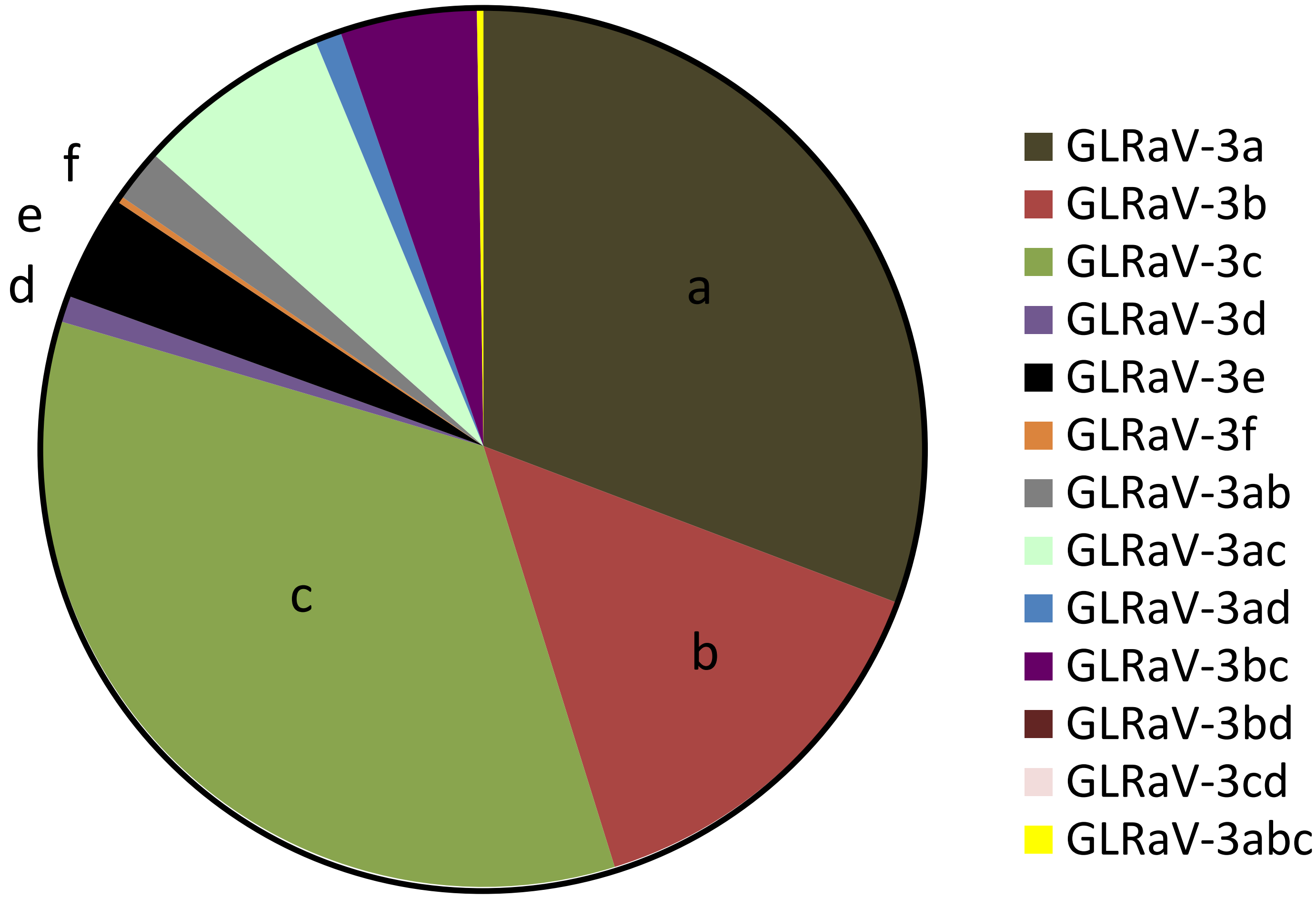
Which leafroll species (or strain) do you have?





Sharma et al. PLos One. 2011

Eight GLRaV-3 strains found (to date) in Napa vineyards, with multiple stains in some vineyards.



Sharma et al. PLos One. 2011

Vectors of Viral Pathogens in Vineyards

1. GLRaV Factors that Impact Control
   a) mealybug and leafroll species
   b) facts about mealybug-leafroll epidemiology
2. Vector (Mealybug) Controls
   a) insecticides for mealybug: which are best
   b) pheromones for monitoring and control
   c) biological controls
3. Areawide Control Programs?
   a) monitoring
   b) insecticide resistance
   c) mating disruption in Napa

The Grape Mealybug

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

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

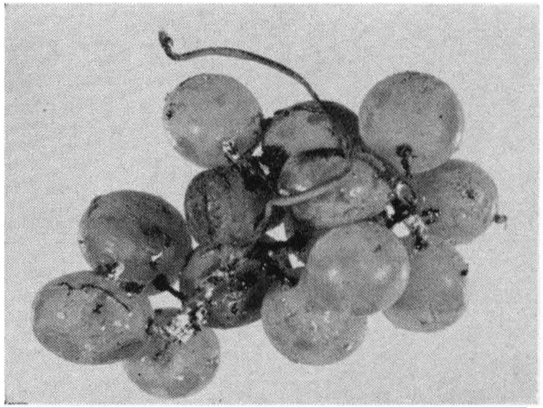
Parathion sprays applied to field plots—in Tulare and Fresno counties—during the dormant season controlled grape mealybug in 1953 better than any other material tested, and confirmed results of trials in 1952.

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-

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



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-

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

Chemicals losing effect against grape mealybug

Donald L. Flaherty
William L. Peacock
Larry Bettiga
George M. Leavitt

Grape mealybug, a pest of table grapes in California's San Joaquin Valley, can be particularly damaging to Ribier and Emperor table grapes, especially in bunches that contact the bark. Before the 1940s, occasional losses occurred, but infestations were mostly spotty and frequently disappeared the following year.

Increasing and more persistent grape mealybug populations developed in the late 1940s, starting in the southern San Joaquin Valley's Delano-Earlimart table grape district and spreading to other grape areas. Extensive use of DDT and other synthetic insecticides to control grape leafhoppers in table grapes apparently had disrupted natural controls of grape mealybug. Populations of the mealybug are seldom high in raisin and wine grapes where pesticides are used considerably less.

(Nesbitt), in early spring. We were particularly interested in the possibilities of the dinoseb-containing materials, Premerge 3 and Dow General, the latter an oil-soluble and water-emulsifiable formulation.

The grape mealybug control trials were conducted during 1978-81 in an Emperor table grape vineyard in Terra Bella (Tulare County) with a history of intensive treatments for grape mealybug and other grape pests. In the trials we applied parathion in each of the four years. Other insecticides varied from year to year and included dinoseb (Premerge 3, Dow General), permethrin (Ambush), chlorpyrifos (Lorsban 4E), and methidathion (Supracide 2E). An untreated check was also included.

During the four years, replications varied from five to seven for each treatment in a complete randomized block with six to nine vines per plot. Treatments were applied in early March and evaluated each year just before harvest in September. All bunches in each plot were thoroughly inspected for signs of mealybug infestation—including honeydew, mealybugs, and egg masses—and the percentage of infested bunches recorded. We considered that economic losses would occur above 2 percent infestation.

In April 1978 and 1979, 50 leaves (10 leaves from each block) were sampled to determine effects of the various treatments on spider mites and predaceous mites. Previous published studies had shown that early-season predation is important for effective control of spider mites in vineyards. Willamette mite was the only spider mite species present in

Data from 1978 and 1981 grape mealybug control trials (table 1) validate reports that

Parathion
Dinoseb
Permethrin
Chloroyrifos
Methidathion

Dow General, an oil-soluble formulation of dinoseb, was somewhat better with a 4.6 percent infestation. Ambush, a pyrethroid, was very poor, resulting in 16 percent infestation.

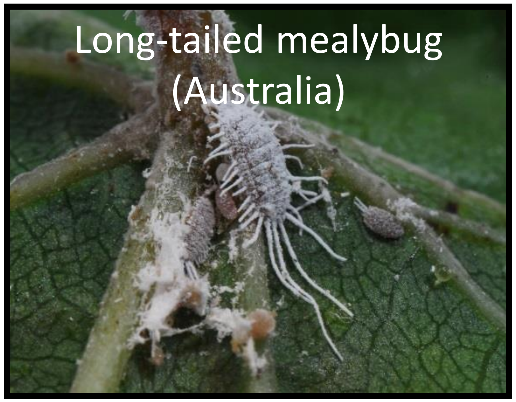
Results from 1980 were not recorded in table 1, because the grower inadvertently treated the vineyard, including the trial area, in July with parathion dust, an ineffective attempt at mealybug control. We were able to observe that Lorsban 4E at 1 pound a.i. per acre plus oil was more effective than Supracide 2E at 1.25 pounds a.i. per acre plus oil. However, in the 1981 trial Lorsban was no better than parathion at 2.5 pounds a.i. per acre.

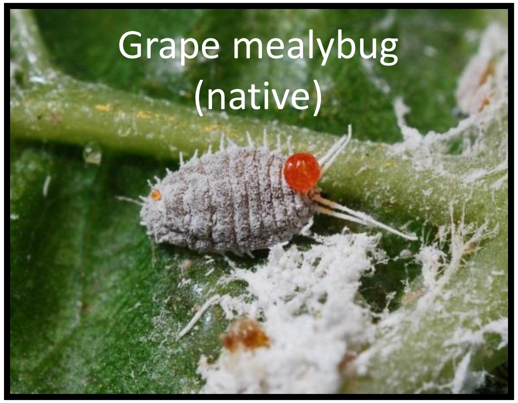
It is disturbing that control with even 5 pounds a.i. of parathion in 1981 was approaching 2 percent infestation. Perhaps grape mealybug is developing even greater resistance to parathion. As mentioned, this

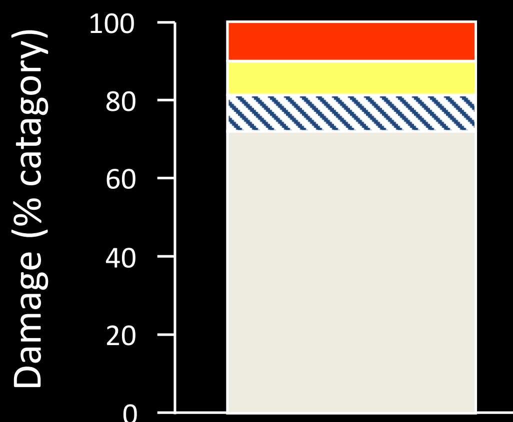
TABLE 1. Effects of dormant treatments on grape mealybug, Emperor table grapes, Terra Bella, California, 1978, 1979, 1981

	Infested bunches†

Vine MB causes more damage
1) more eggs, more generations
2) feeds on leaves
3) more honeydew excretion



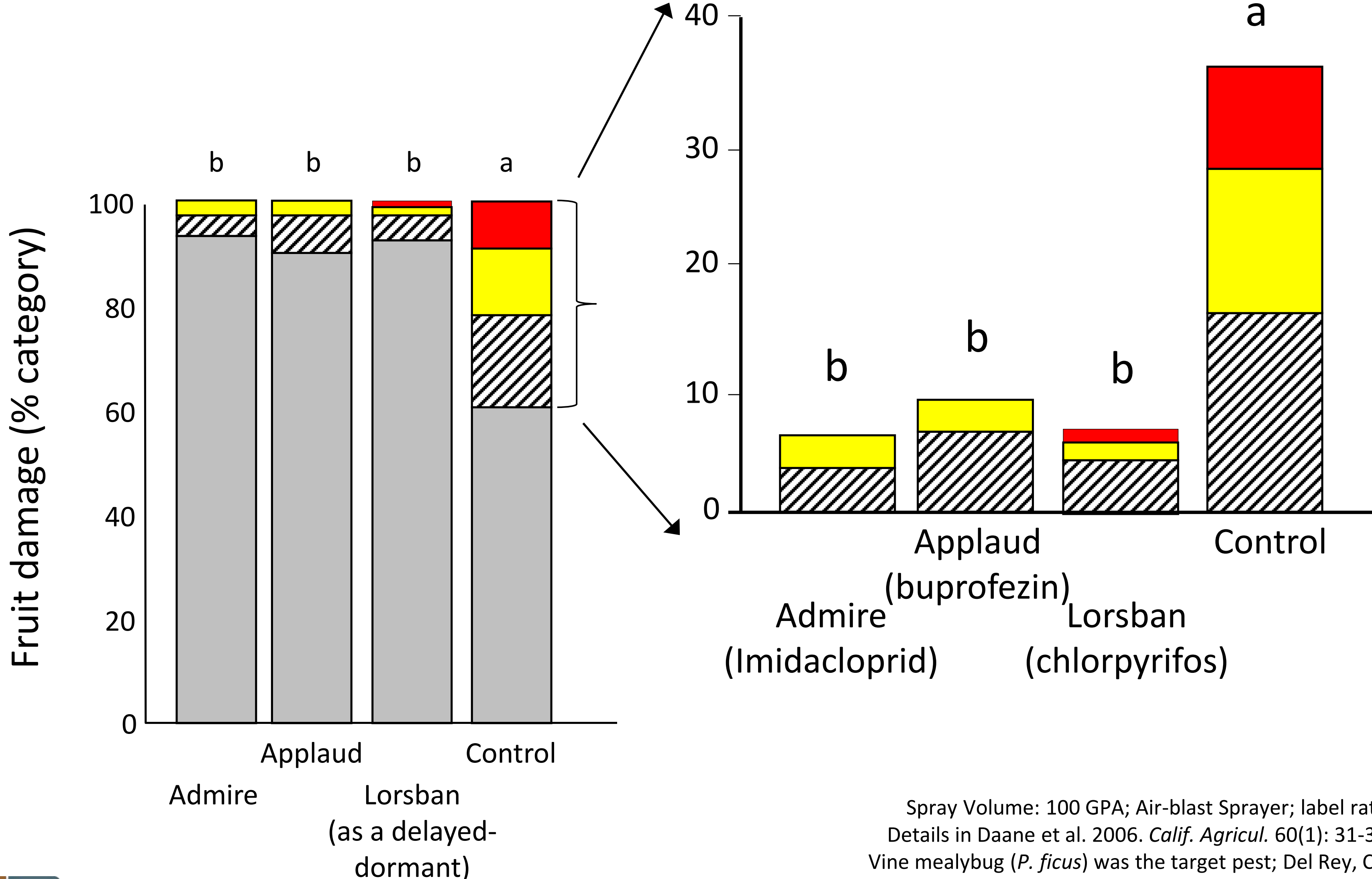




Rating system for fruit damage

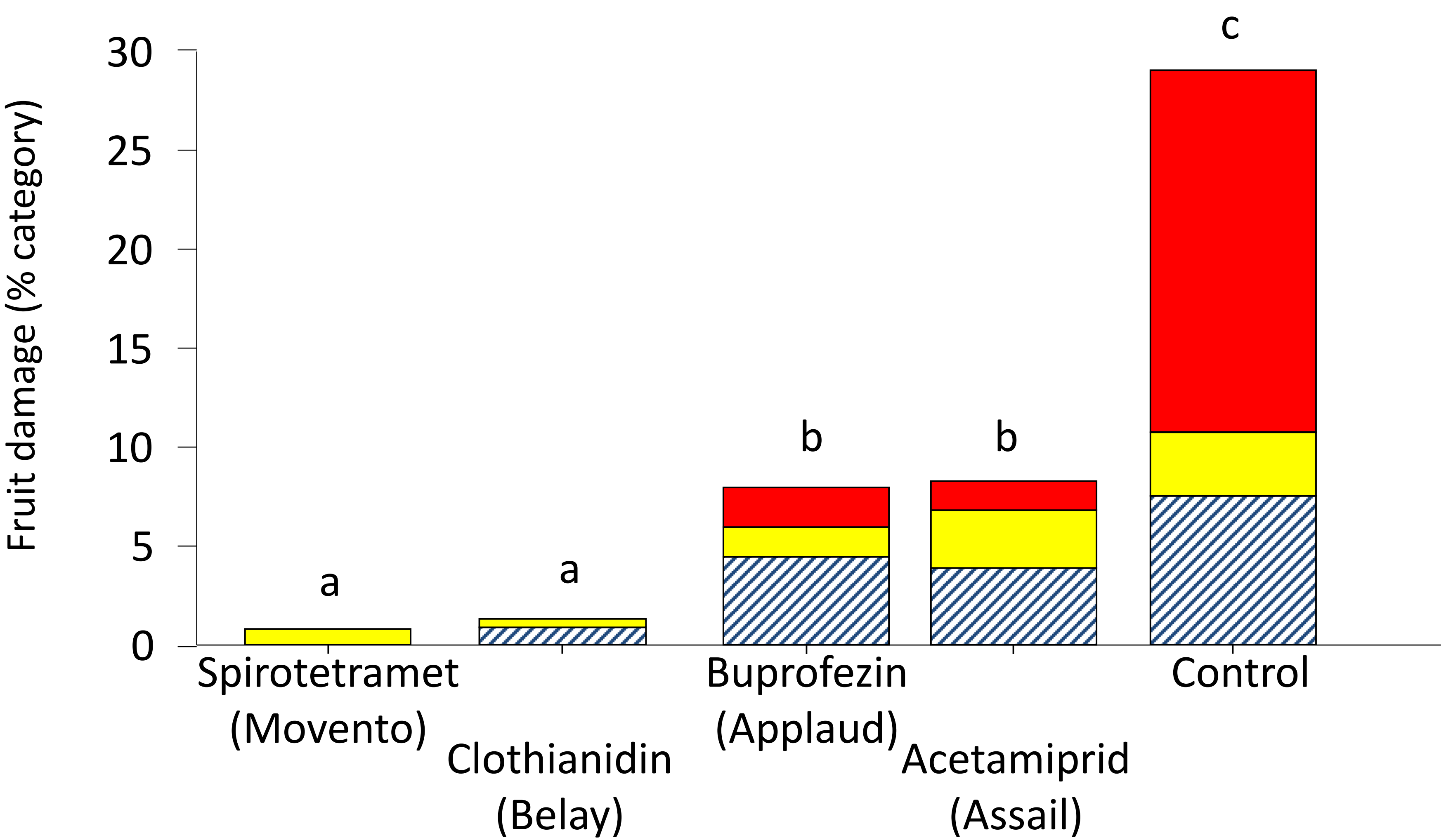
- "3" Severe damage / lost cluster
- "2" Partial damage
- "1" Minor damage
- "0" No damage

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



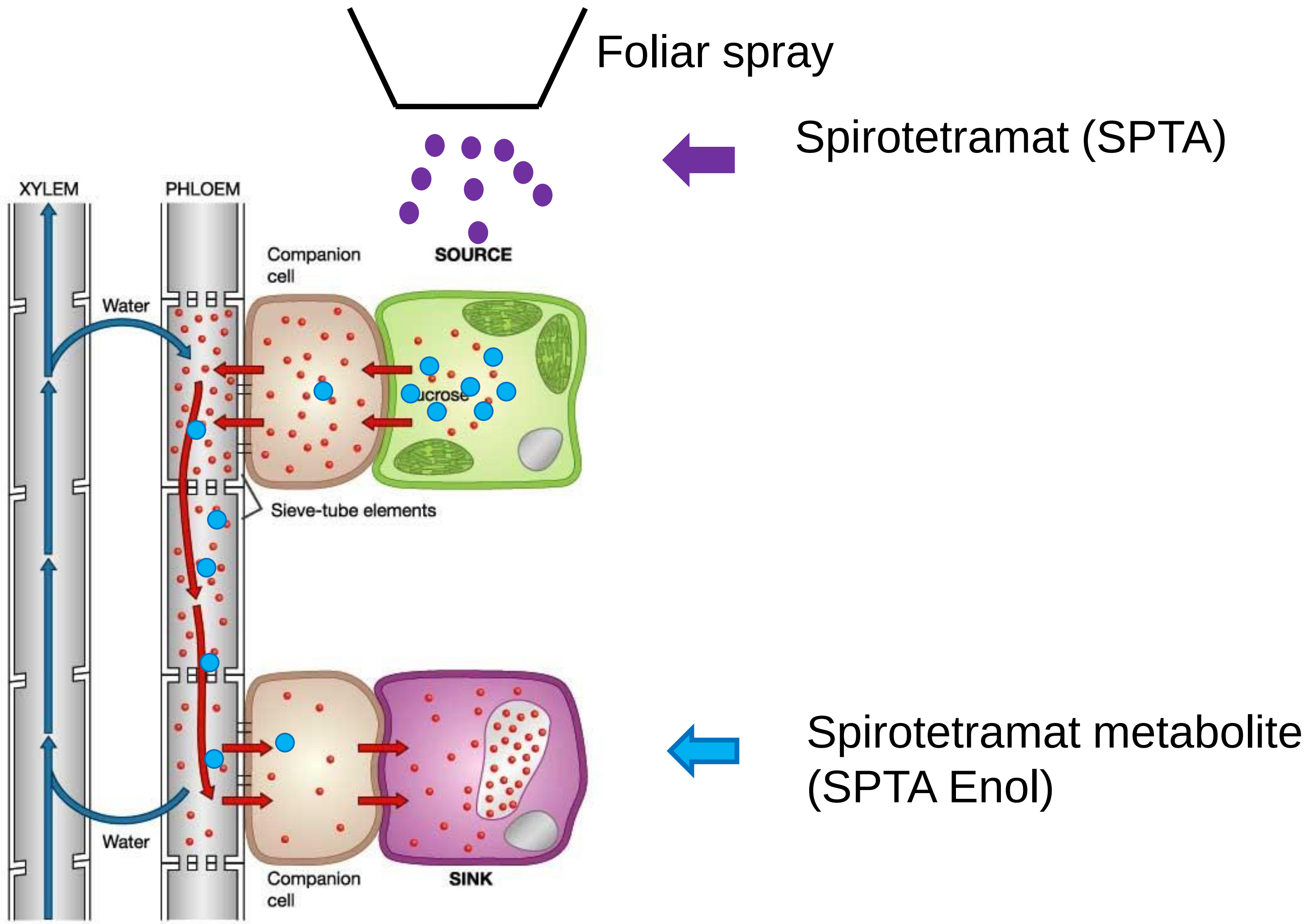
Spray Volume: 100 GPA; Air-blast Sprayer; label rate.
Details in Daane et al. 2006. *Calif. Agricul.* 60(1): 31-38.
Vine mealybug (*P. ficus*) was the target pest; Del Rey, CA.

Since the 1990s, more effective materials have been added to the tool box

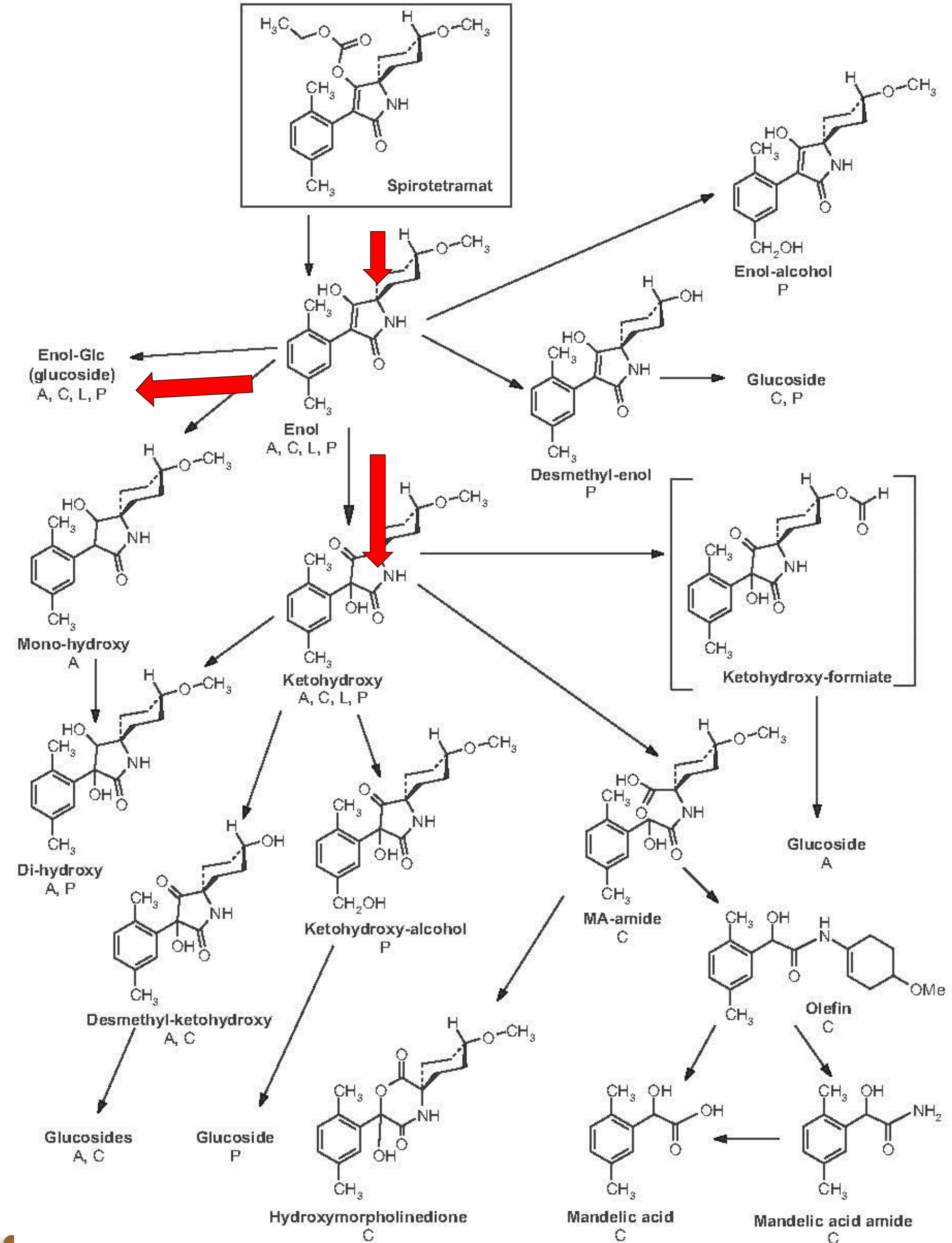


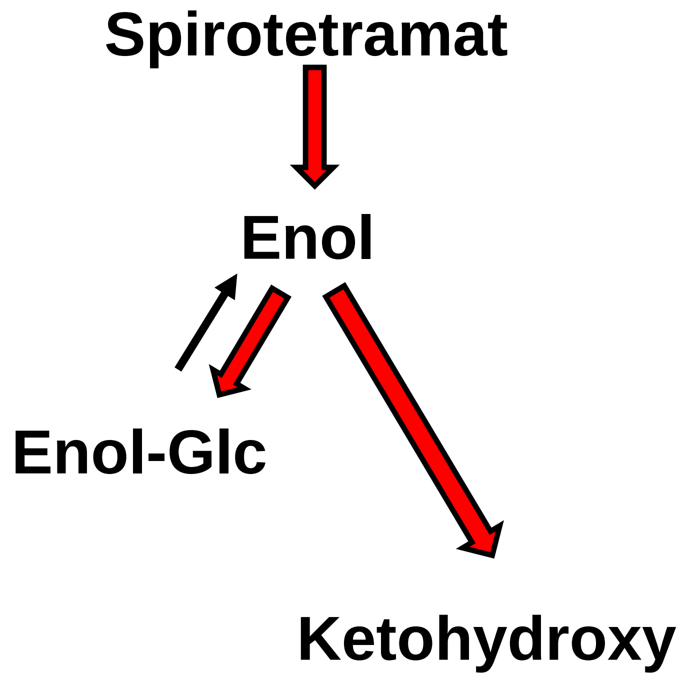
Spray Volume: 100 GPA; Air-blast Sprayer; label rate (Applaud 12 oz per ac)
Belay & Movento on 21 June 2011, Applaud & Assail on 7 July 2011
Planococcus ficus, Lodi-Woodbridge wine grapes, Lodi, CA

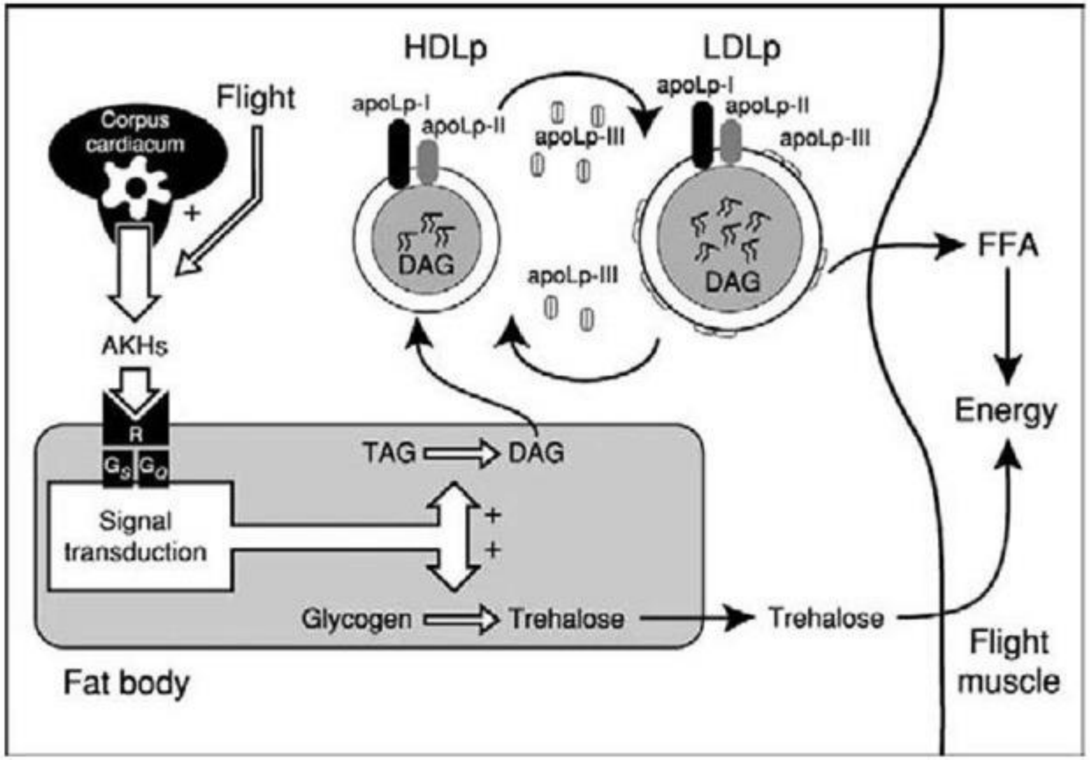
Understanding the systematic uptake of pesticide

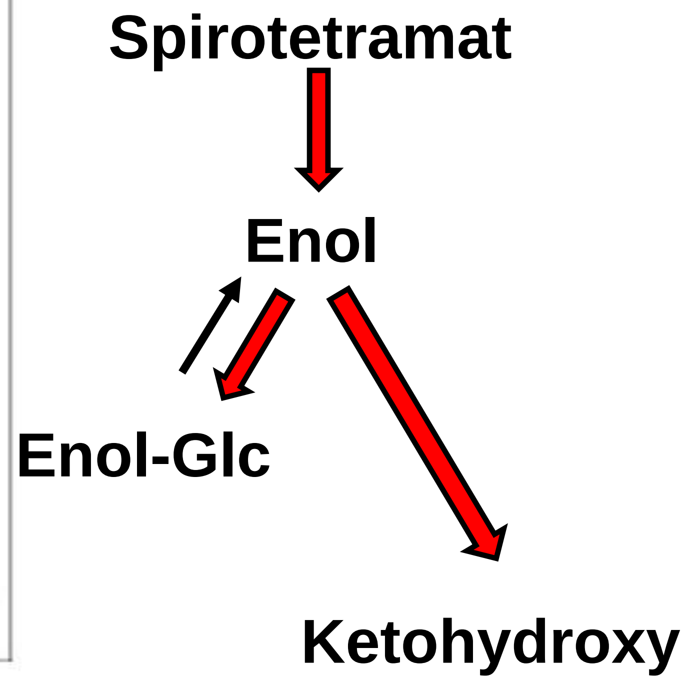


Modified after: http://www.uic.edu/classes/bios/bios100/lectf03am/translocation.jpg

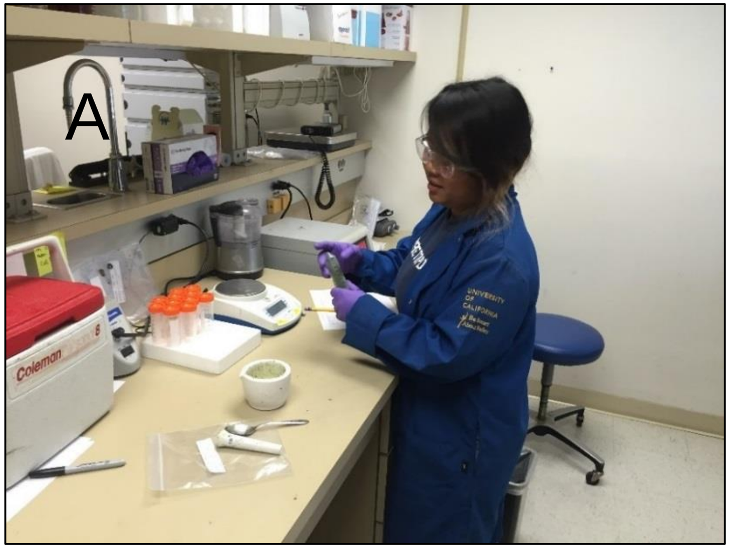

Spirotetramat
Enol
A, C, L, P
Enol-Glc
(glucoside)
A, C, L, P
Enol-alcohol
P
Desmethyl-enol
P
Glucoside
C, P
Mono-hydroxy
A
Ketohydroxy
A, C, L, P
Ketohydroxy-formiate
Glucoside
A
Di-hydroxy
A, P
Desmethyl-ketohydroxy
A, C
Ketohydroxy-alcohol
P
MA-amide
C
Olefin
C
Glucosides
A, C
Glucoside
P
Hydroxymorpholinedione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

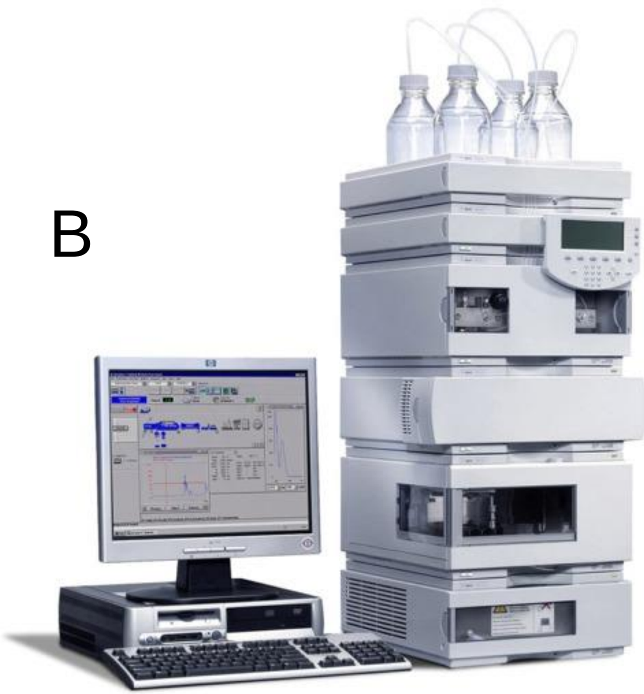

Spirotetramat
Enol
Enol-Glc
Ketohydroxy

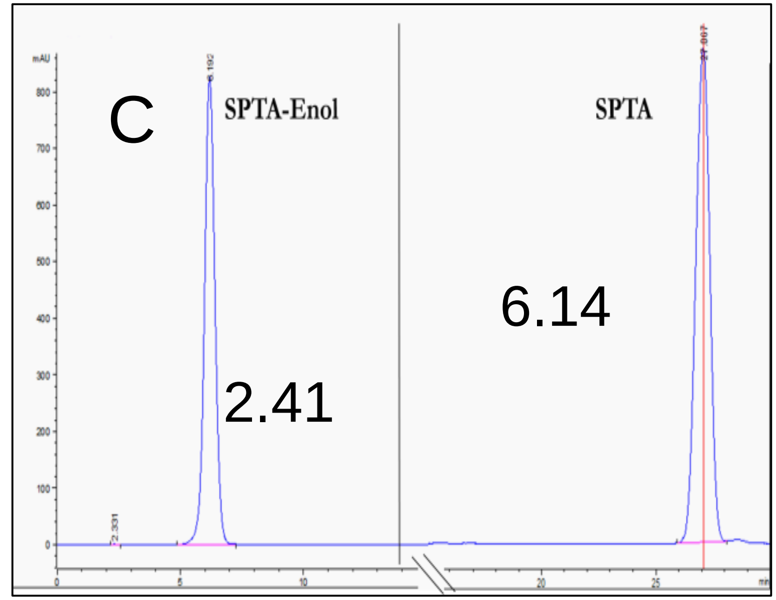


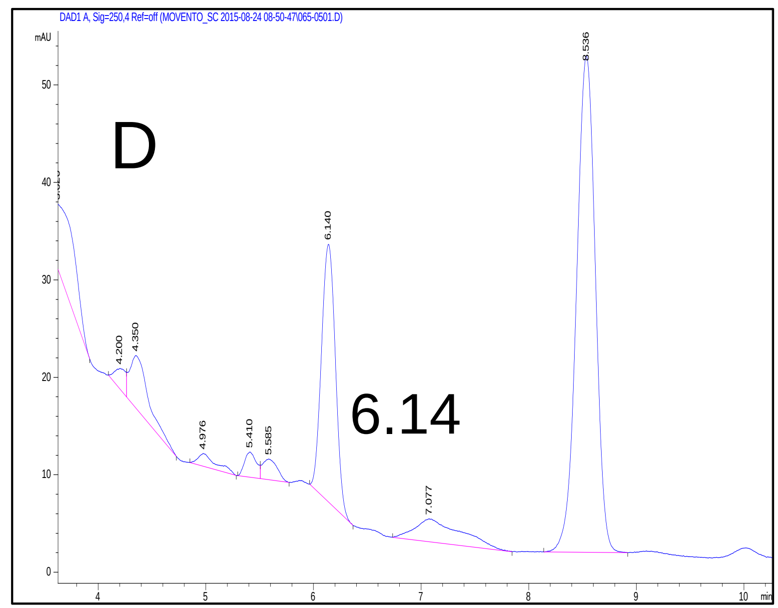


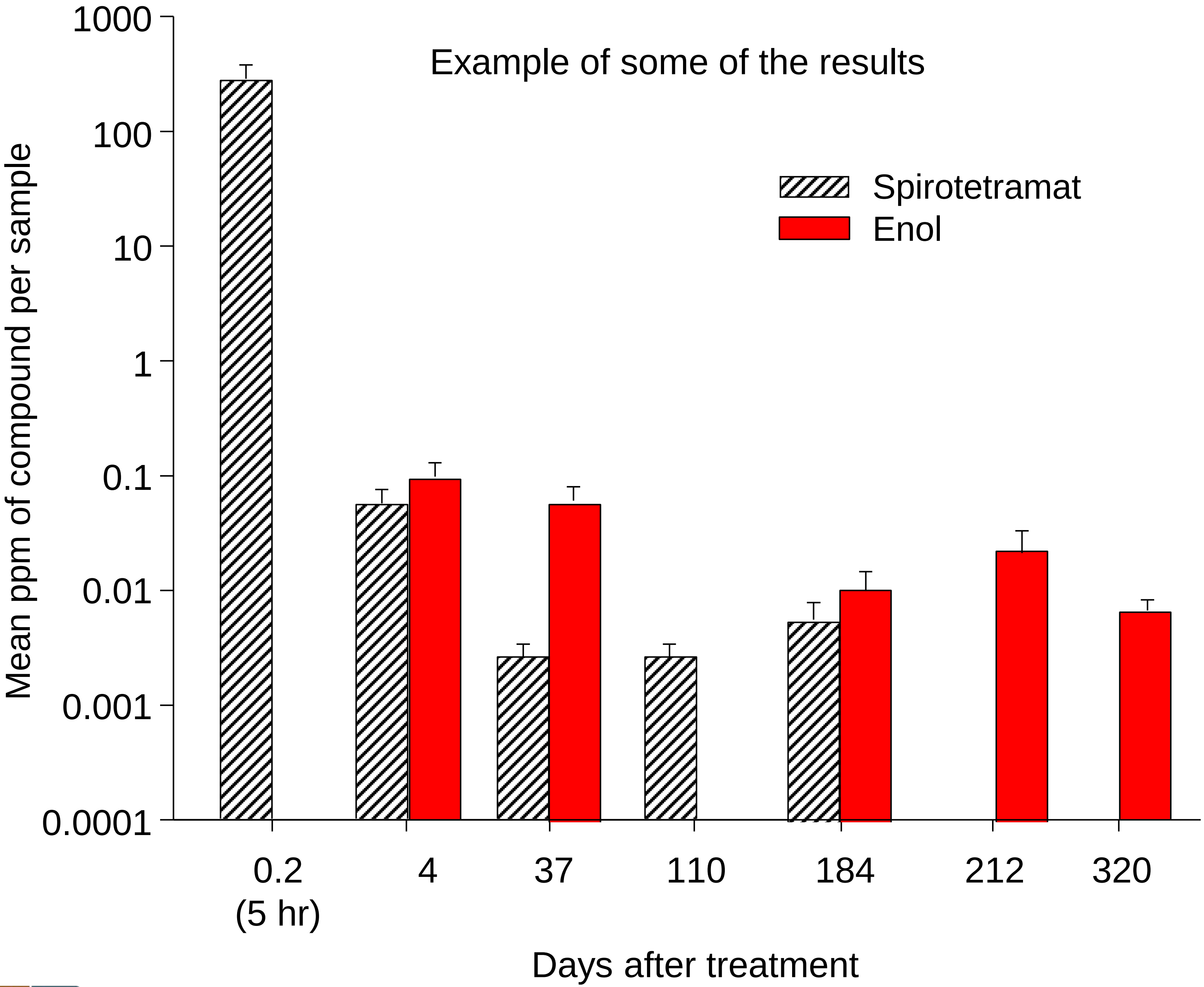
Spirotetramat is a tetronic acid derivative and acts as a lipid biosynthesis inhibitor. Lipids (fats, oils, waxes, vitamins, hormones) are essential to an animal's existence. Spirotetramat is effective against juvenile stages (like a growth hormone), but can reduce adult fecundity and fertility. Death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


A


B

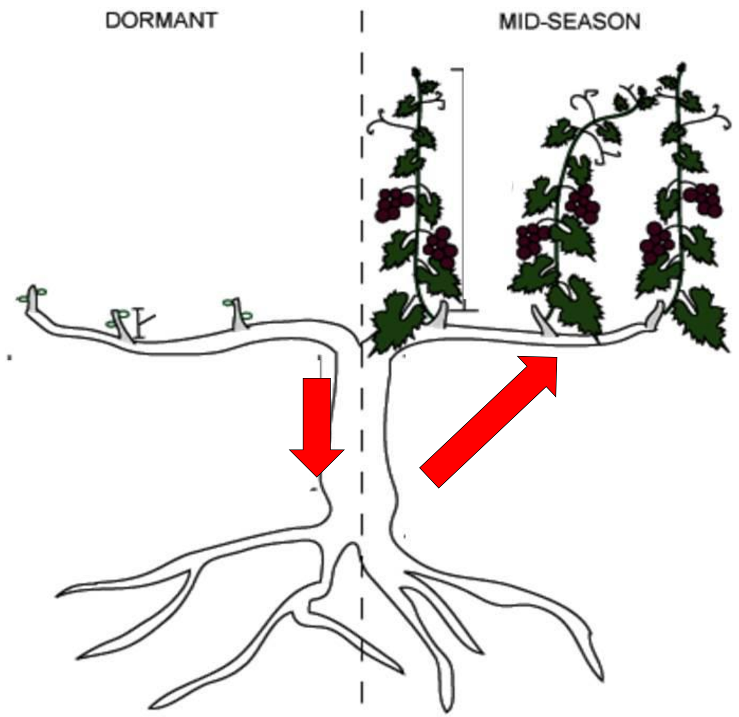

C
SPTA-Enol
SPTA
6.14
2.41
mAU
min

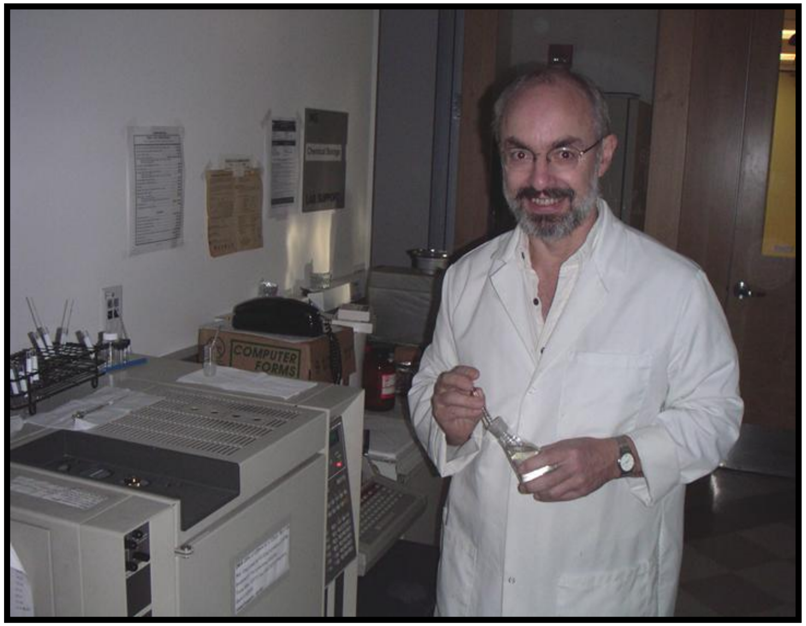

DAD1 A, Sig=250,4 Ref=off (MOVENTO_SC 2015-08-24 08-50-47\065-0501.D)
D
mAU
8.536
6.140
6.14
4.200
4.350
4.976
5.410
5.585
7.077
min


Example of some of the results
Spirotetramat
Enol
Mean ppm of compound per sample
1000
100
10
1
0.1
0.01
0.001
0.0001
0.2
(5 hr)
4
37
110
184
212
320
Days after treatment

Questions we have been trying to address:

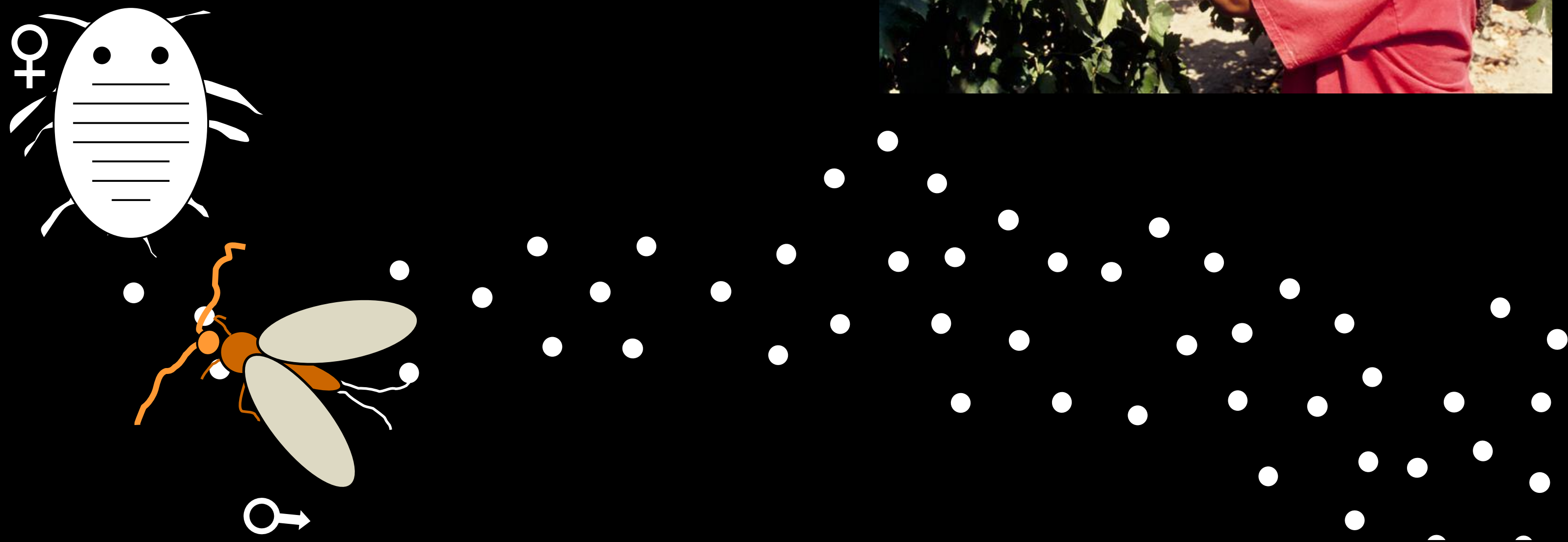
- Timing & methods of application
- Location & age of pest population
- Vine physiology
- Conversion of SPAT to SPAT-Enol?
- Movement of SPAT & SPAT-Enol





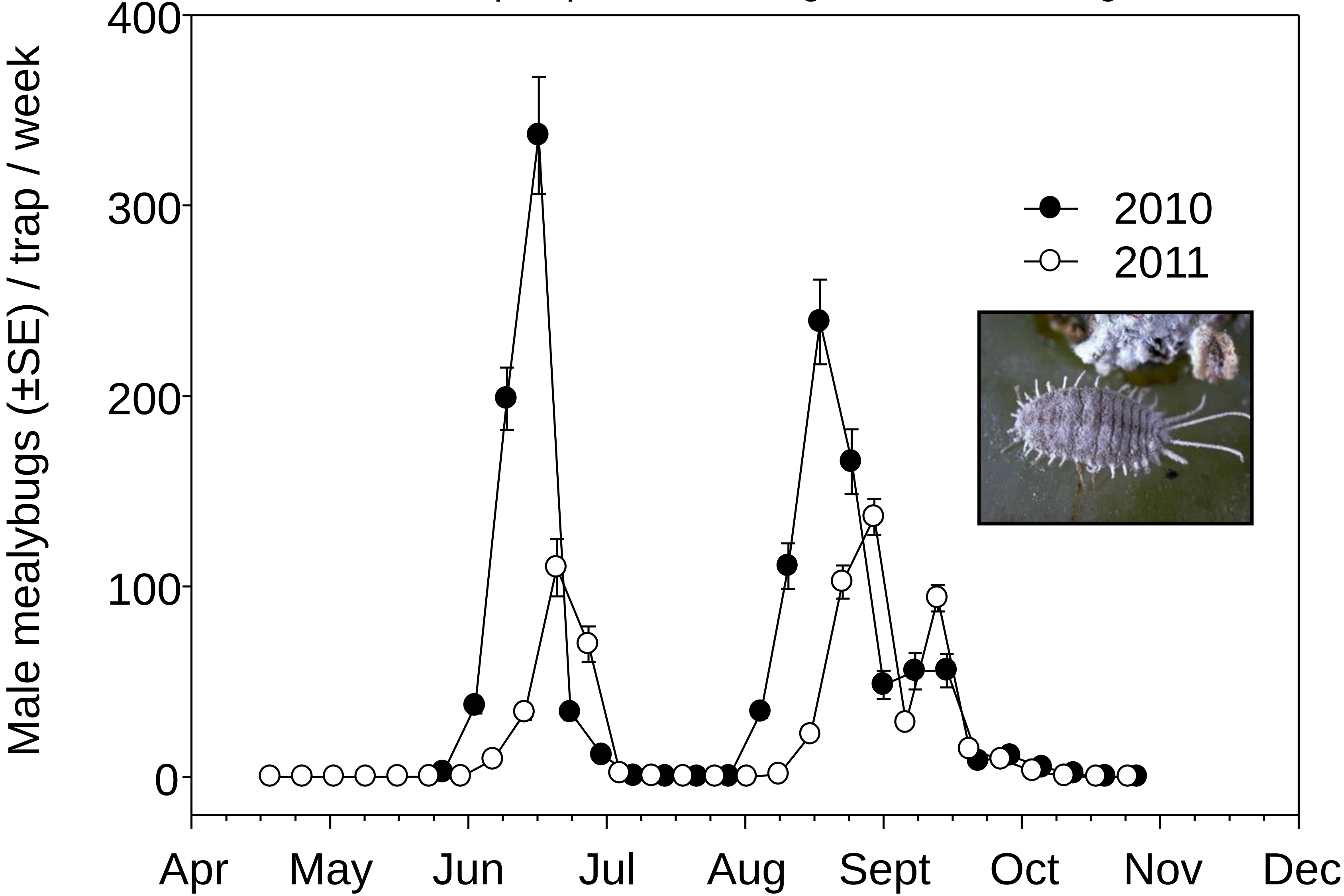
Development of mating disruption – led by pheromone chemist Jocelyn Millar, who has identified mealybug sex pheromones (Walt Bentley)

Identified and synthesized sex pheromone



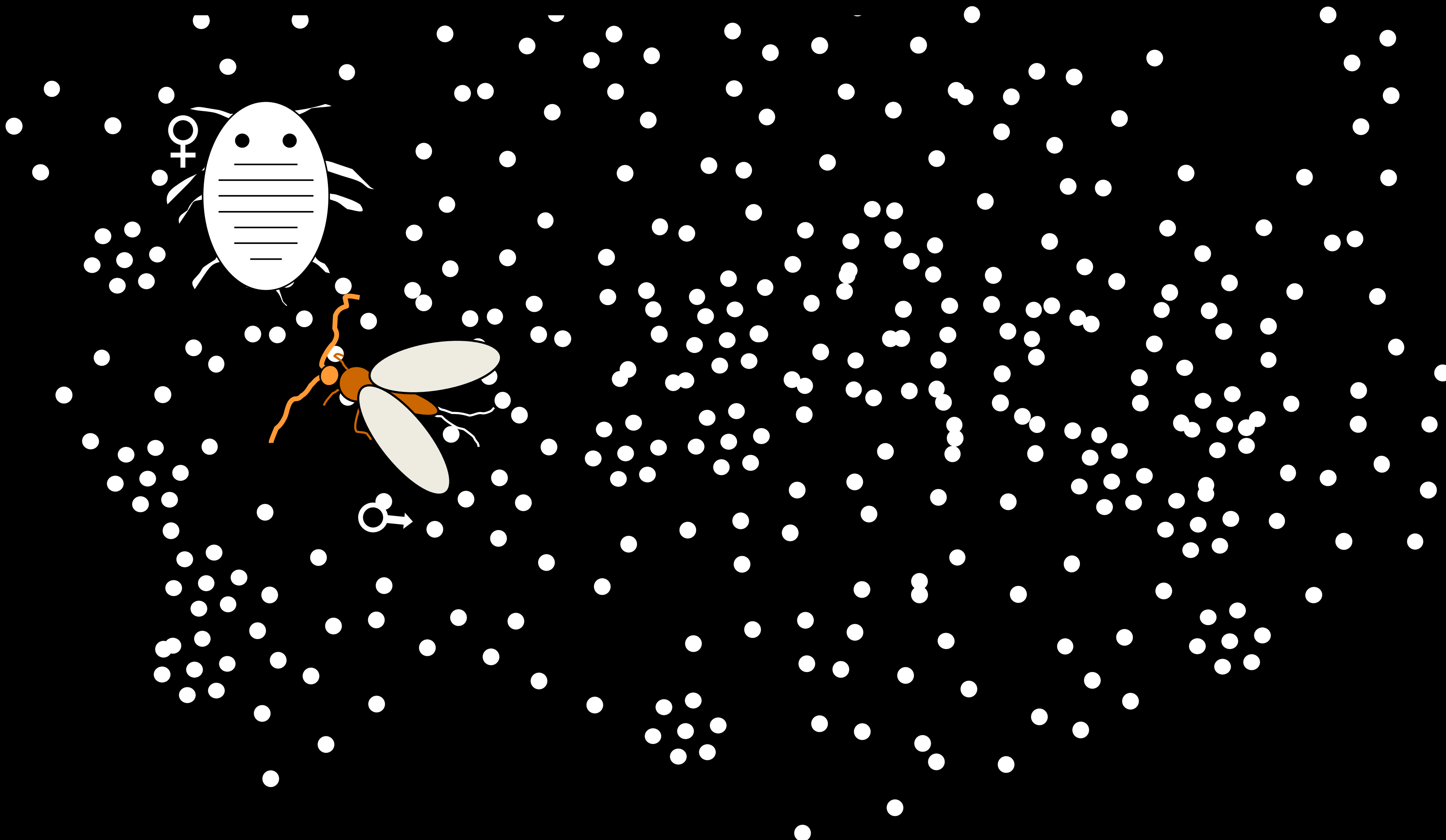
Female emits sex pheromone

Pheromone trap captures showing GMB in Washington



Bahder, Rayapati, Daane, Millar & Walsh. 2013.
Journal of Economic Entomology.

Mating disruption - synthesized sex pheromone



Small-plot studies with sprayable formulation

Walton, Daane, Bentley, Millar, Larsen & Malakar-Kuenen. 2006. *Journal of Economic Entomology* 99: 1280-90.

Period: 2003 and 2004*

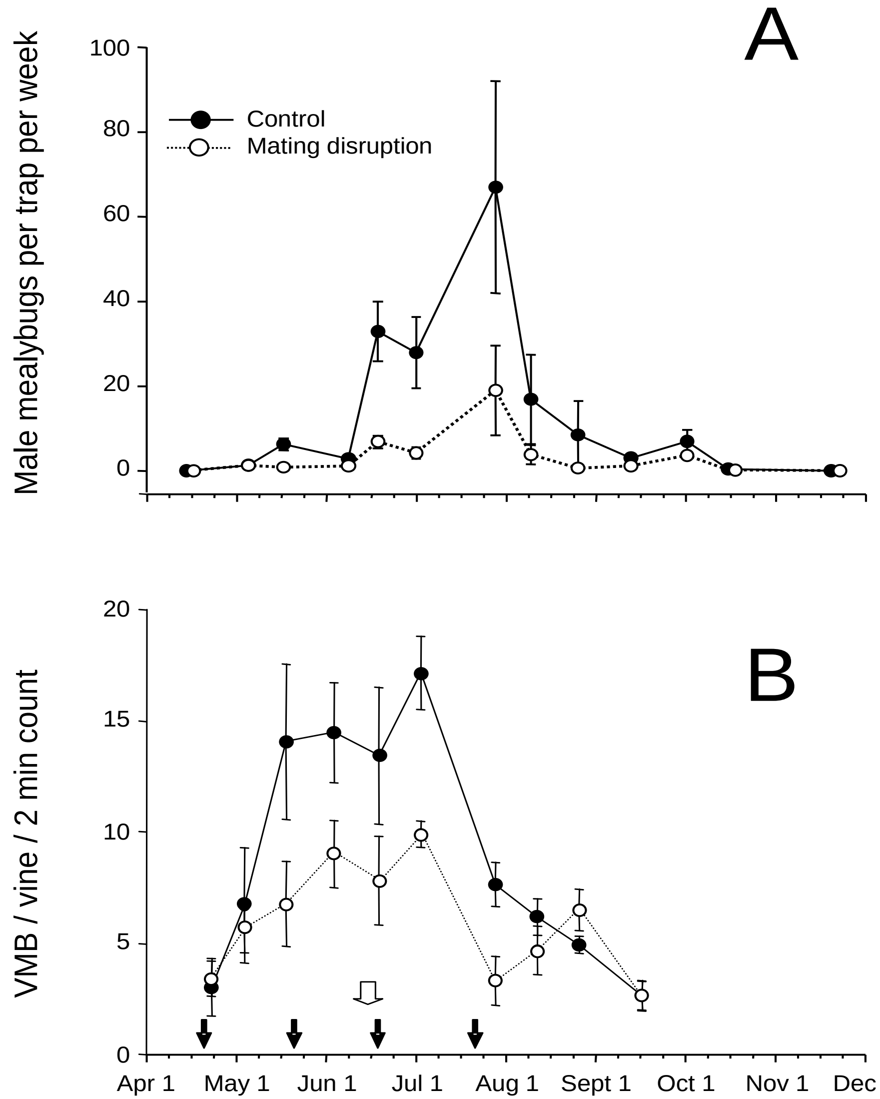
Crop Destruct: Small plots (0.2-0.3 ha) in raisin vineyards

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.

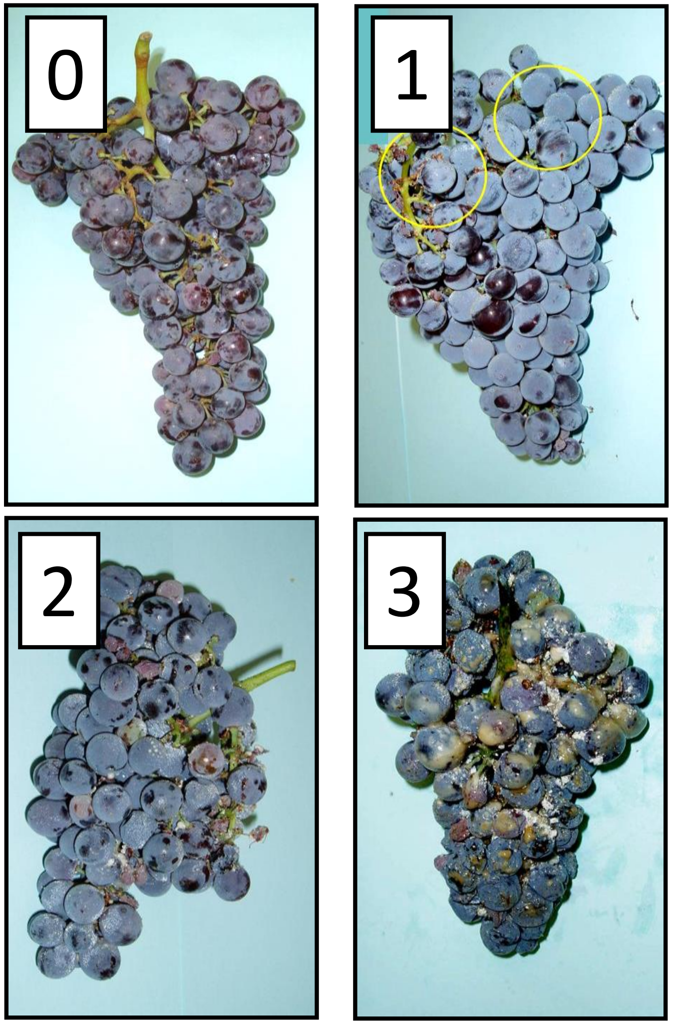
Small-plot studies with sprayable formulation

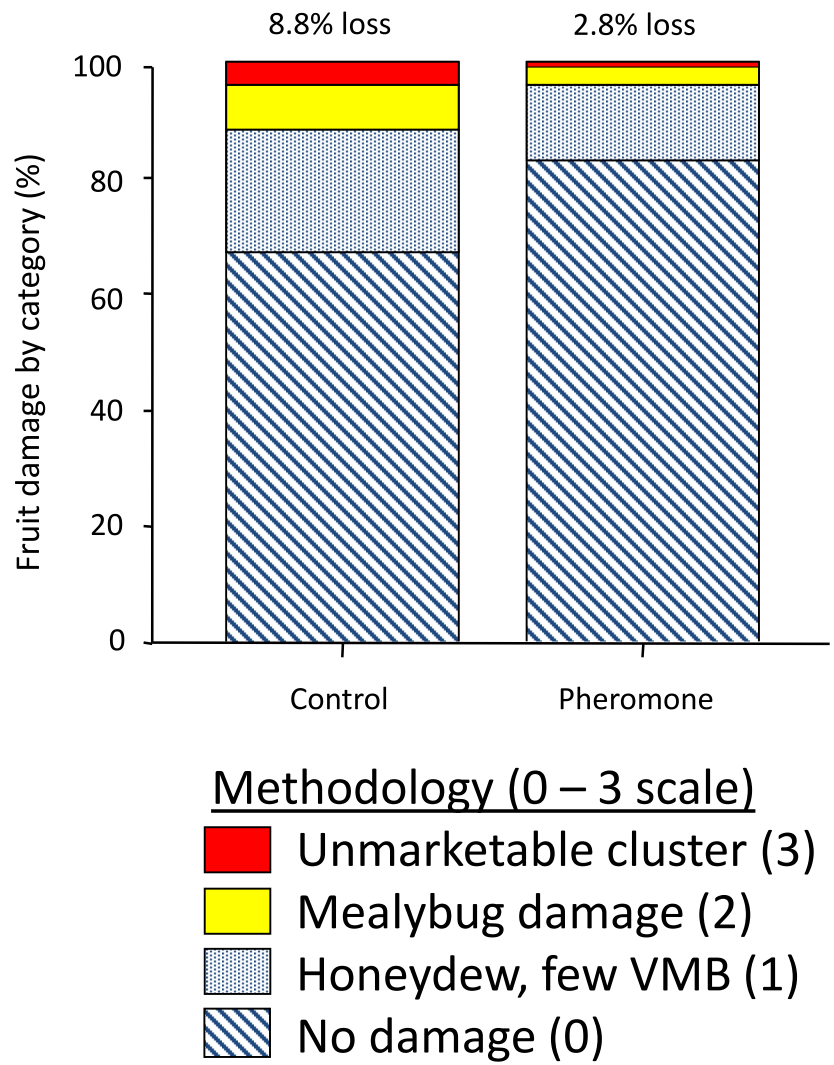


Walton, Daane, Bentley, Millar, Larsen & Malakar-Kuenen. 2006. *Journal of Economic Entomology* 99: 1280-90.

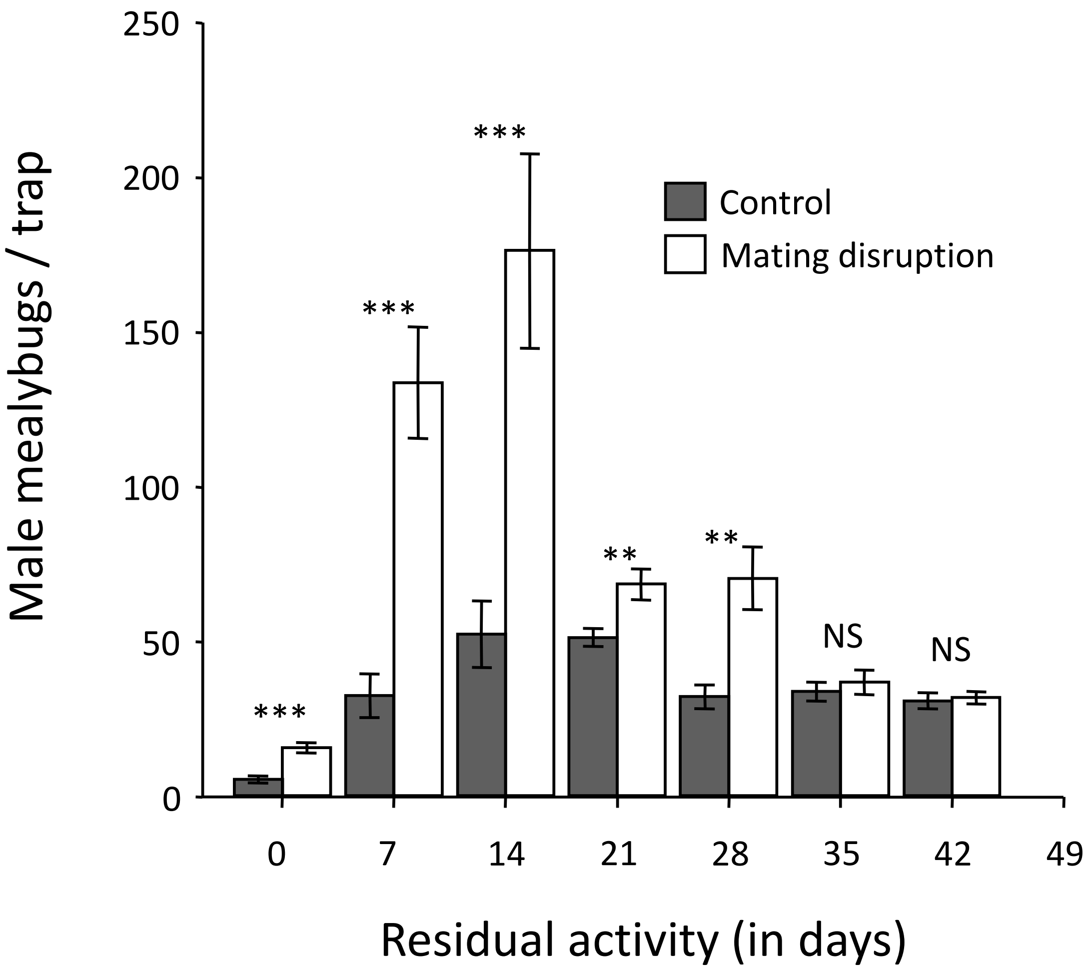
Small-plot studies with sprayable formulation

Walton, Daane, Bentley, Millar, Larsen & Malakar-Kuenen. 2006. *Journal of Economic Entomology* 99: 1280-90.

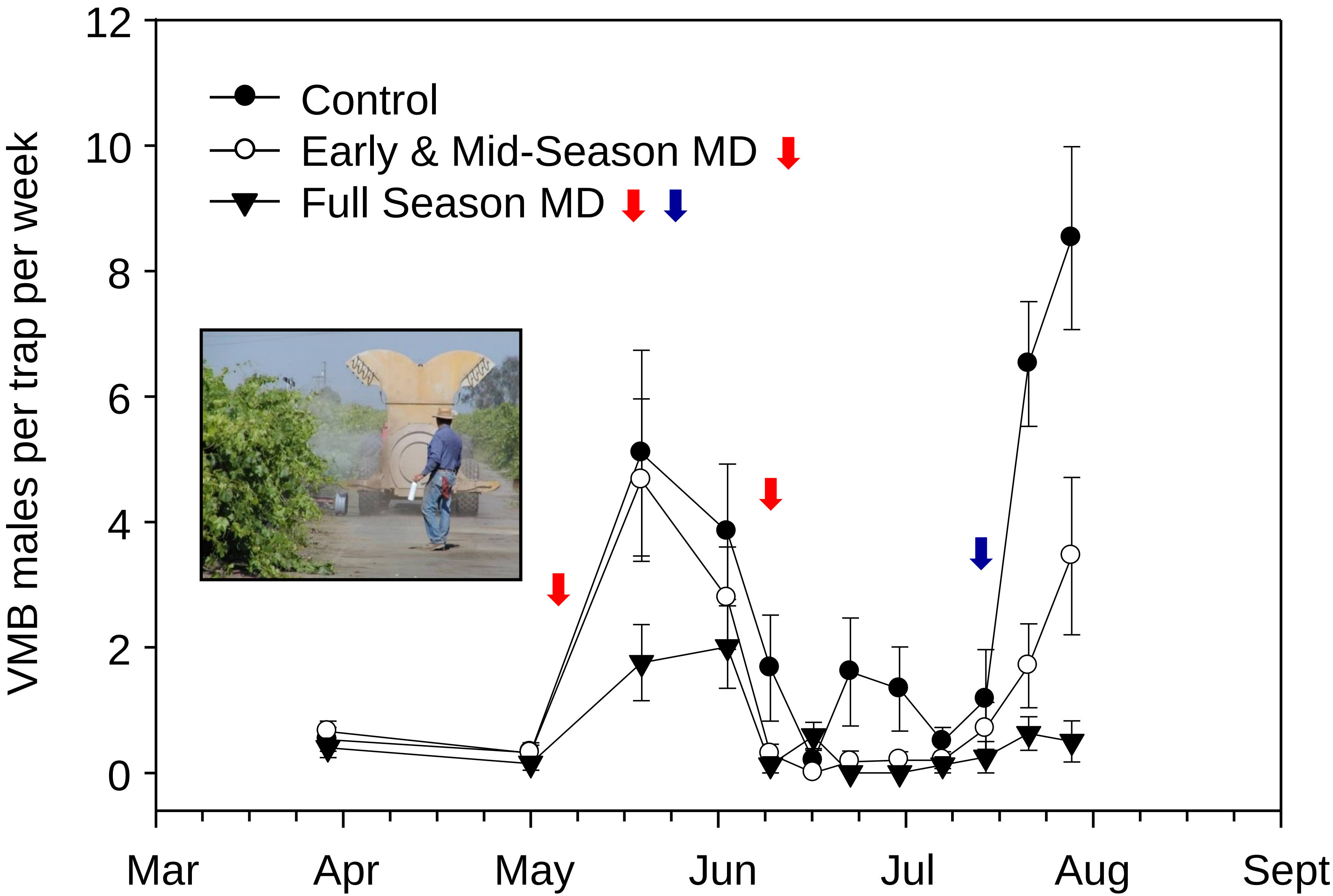




Small-plot studies with sprayable formulation



Walton, Daane, Bentley, Millar, Larsen & Malakar-Kuenen. 2006.
Journal of Economic Entomology 99: 1280-90.



Daane et al. unplublished, 2017 study

Large-plot studies with plastic dispensers

Daane et al. unplublished

Period: 2005 to 2008

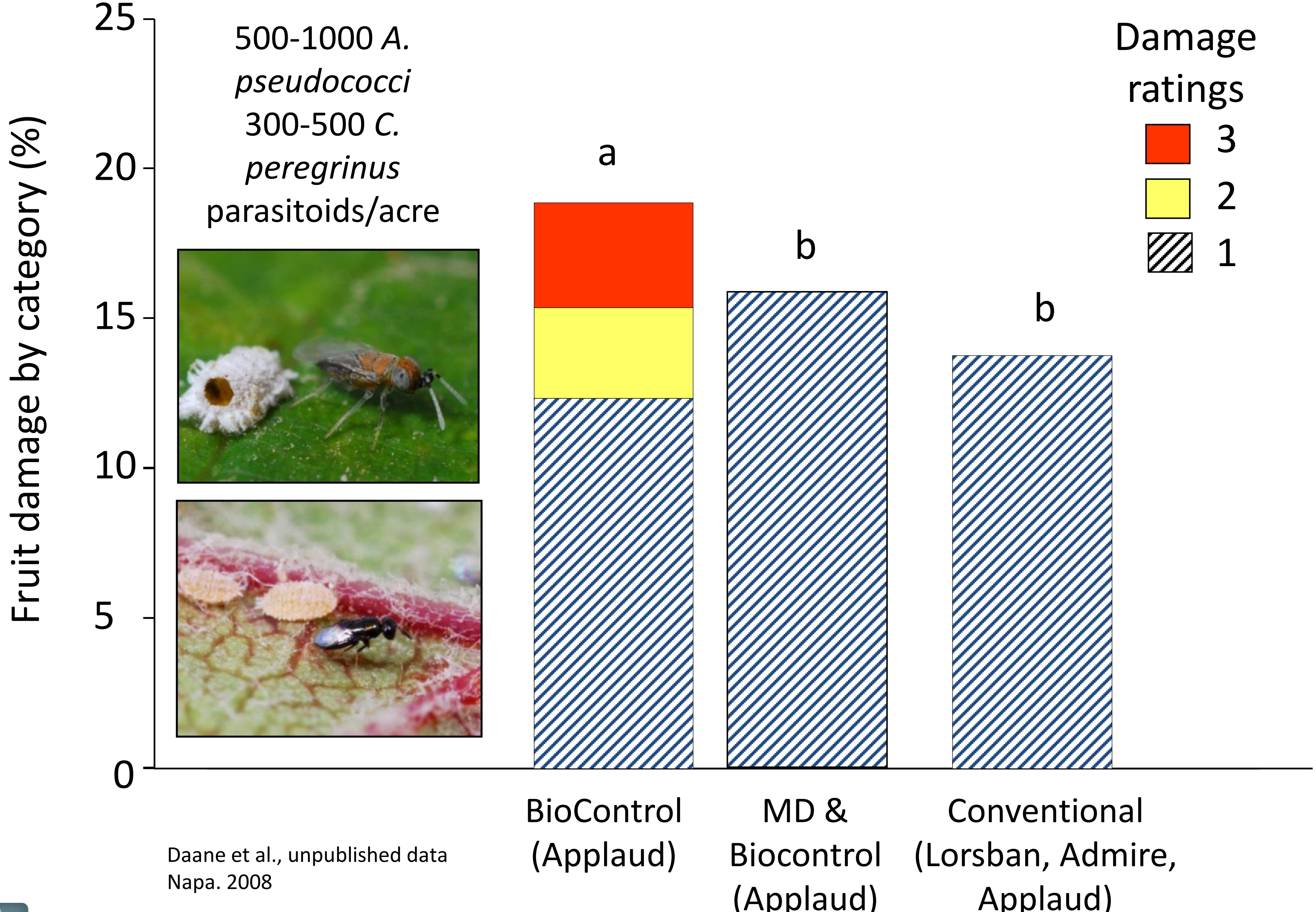
Experimental permit for use: Large plots (5-20 ha) in raisin and wine vineyards

Typically Design: Deployed plastic dispensers (100-150 mg a.i. / dispenser, one application per season, ca. 500 / ha), split-plot, 4-6 reps per region

Insecticides: Variable

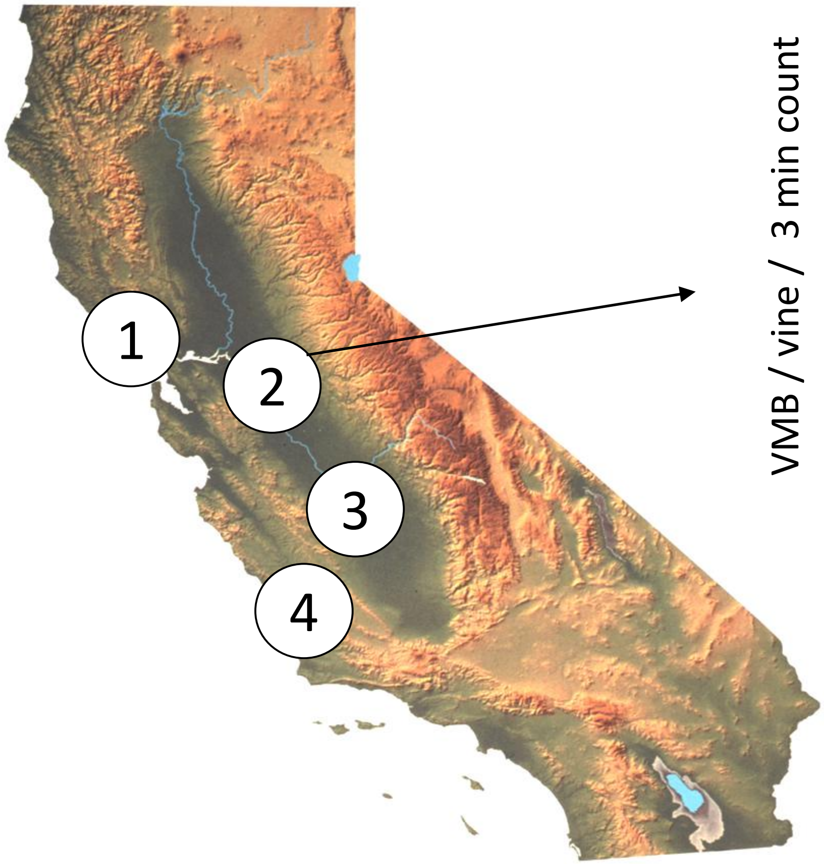
Measured: Male VMB flight, mealybug density via timed-counts, rated crop damage.

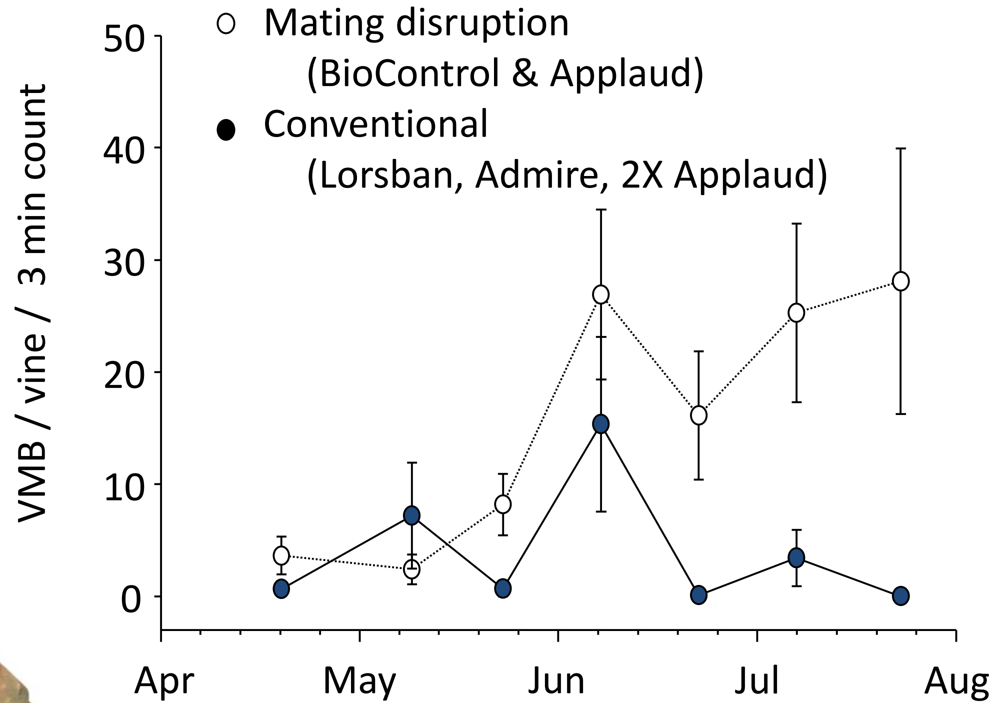
Mating Disruption May Improve Bio-Control



Daane et al., unpublished data
Napa. 2008

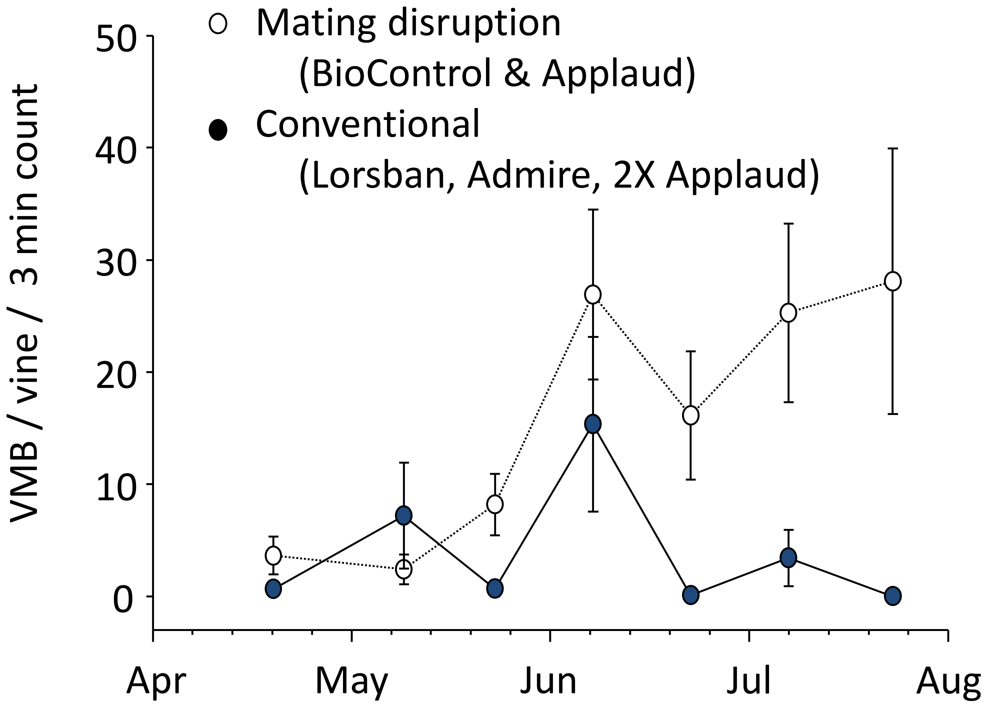
Large-plot studies with plastic dispensers: CONS





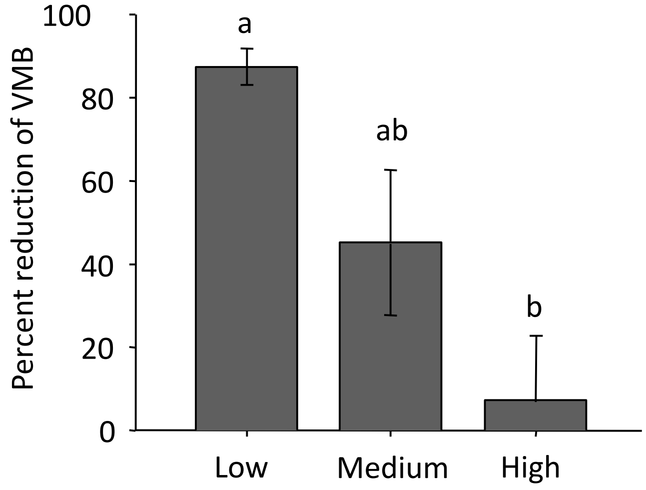
Daane et al. unplublished

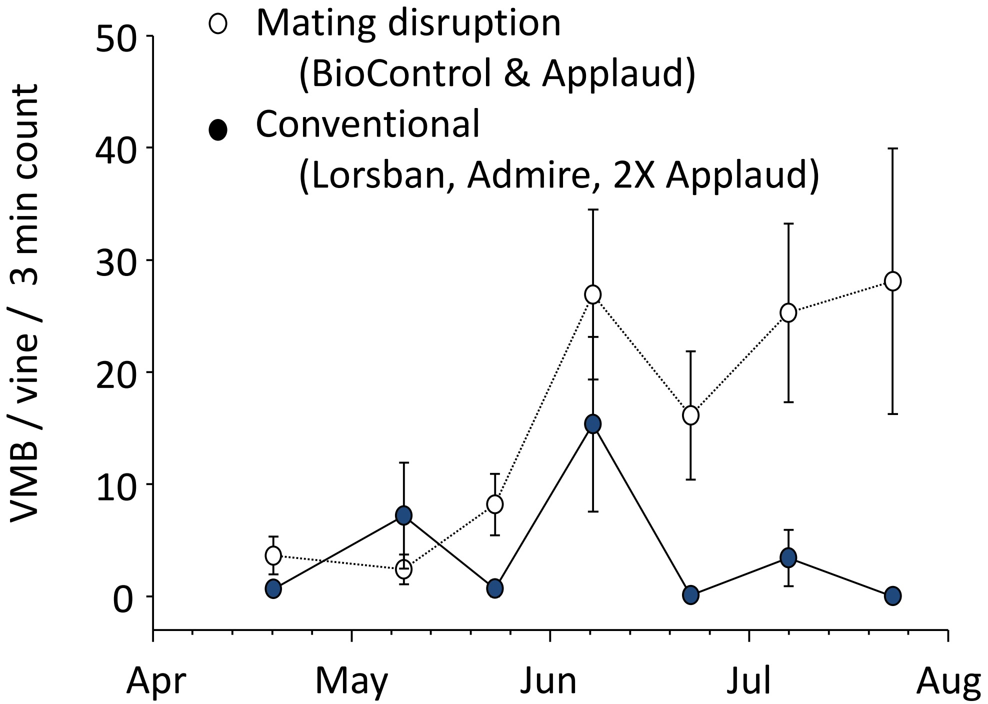
Large-plot studies with plastic dispensers: CONS



Daane et al. unplublished

Large-plot studies with plastic dispensers: CONS





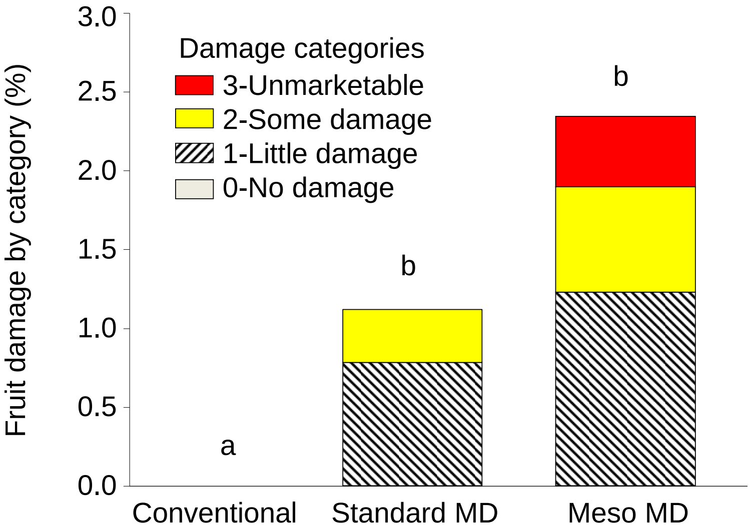
Daane et al. unplublished

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

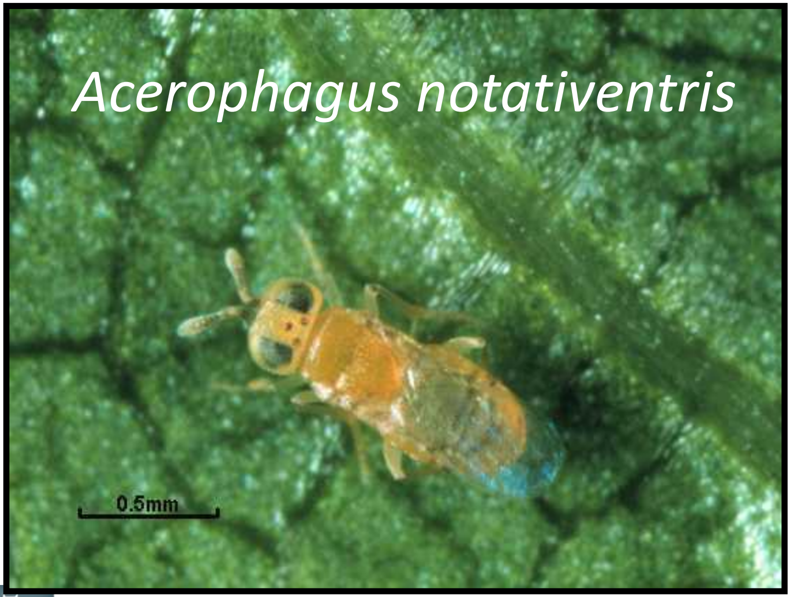
Could "meso" dispensers reduce costs? Lower labor costs .. but fewer 'point' sources

'meso dispensers' may reduce costs, requires placement of 50 / ha, but they did not perform as well



California parasites of “Grape MB” complex

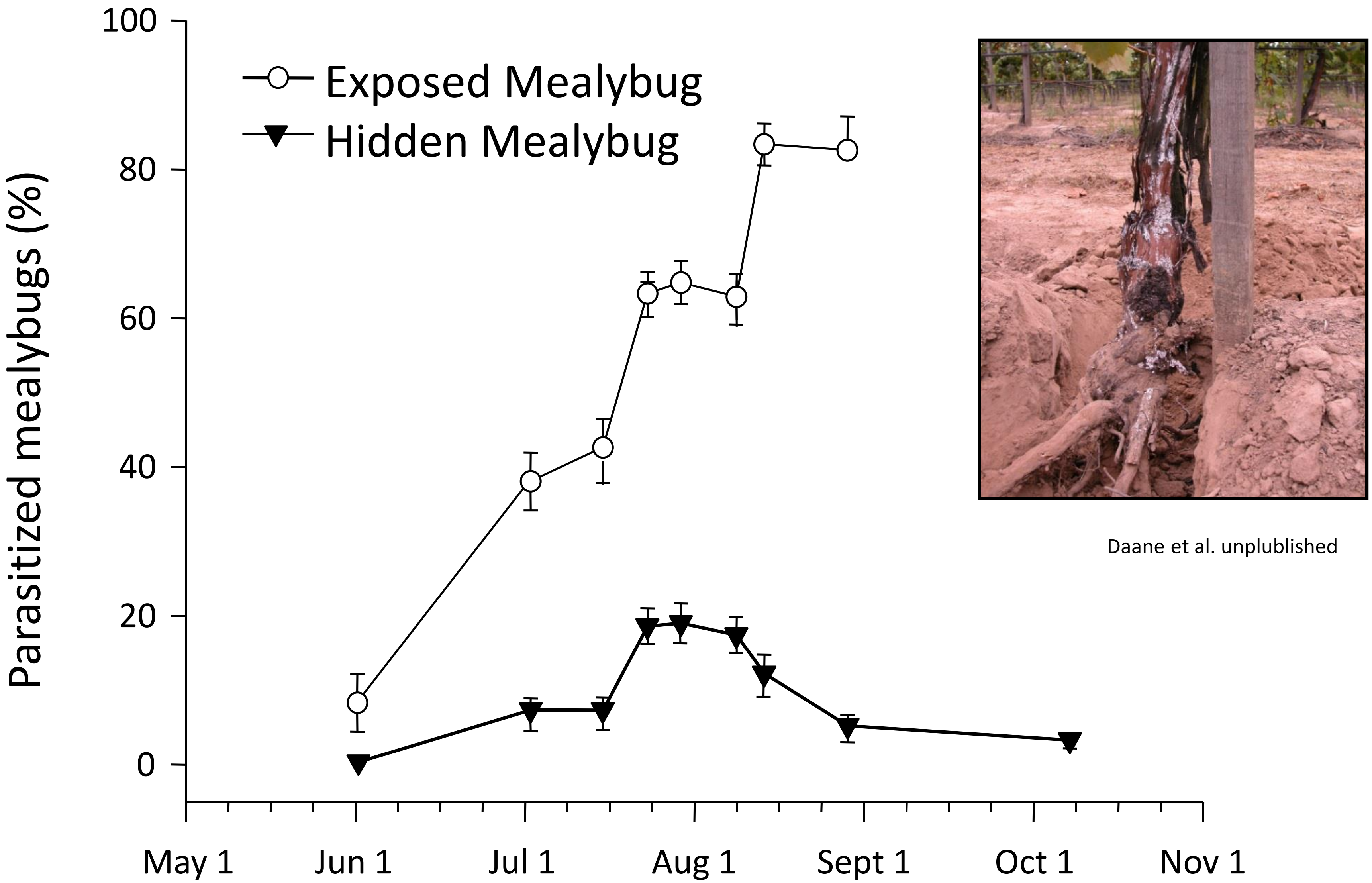
Grape mealybug parasitoids
- found in all regions
- provide effective control
- disrupted by cultural practices
  - insecticides
  - high vine vigor



What controls are available for organic?

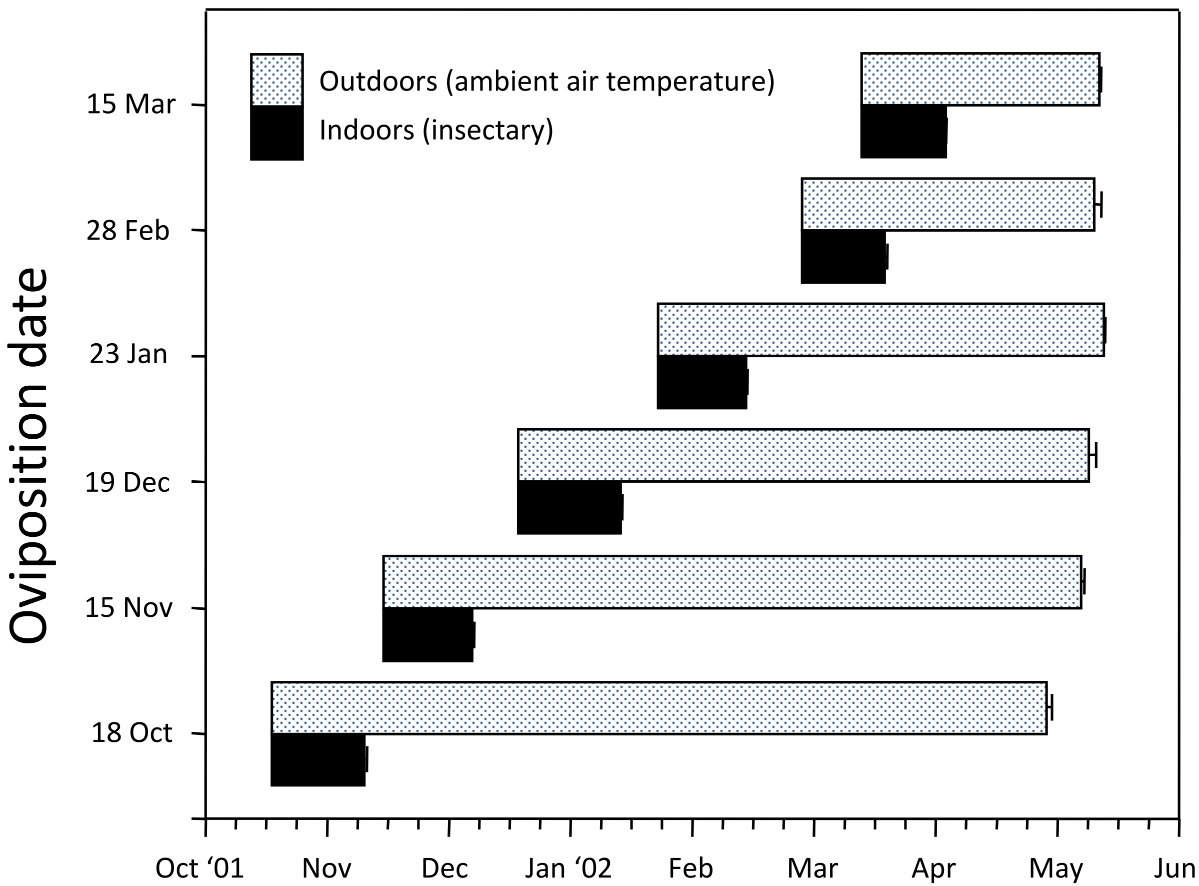

Anagyrus pseudococci – female
“Israel” – similar California, S. Italy
“N. Italy” – released 2006-08
“E. Spain” – imported 2008

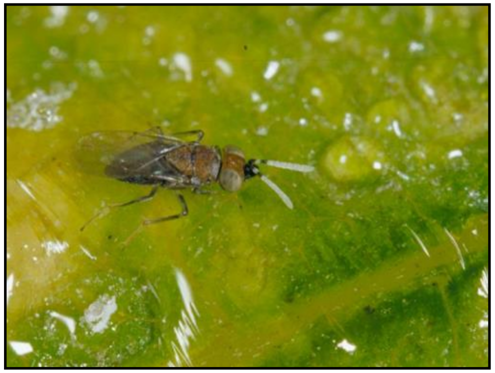
Problem I: mealybug location



Daane et al. unplublished

Problem II. Parasite Overwintering Biology





A. pseudococci oviposition and adult emergence dates

Daane, Malakar-Kuenen, Walton et al. 2005. *Biol. Control*

Ant / homopteran mutualism – both animals benefit

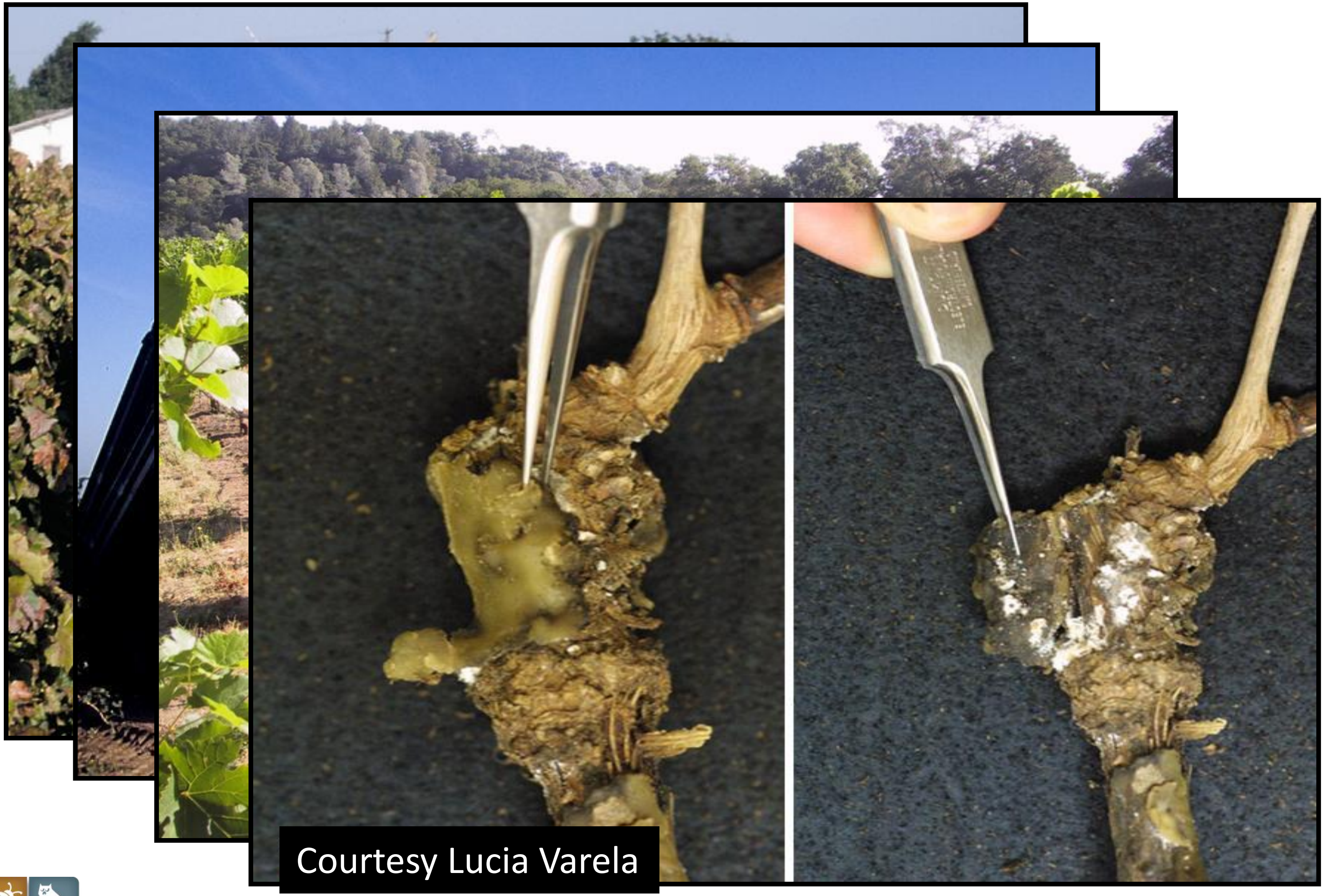
Daane et al. 2007 Ecol. Entomol
Nelson et al. 2007. Envion. Entomol,
Daane et al. 2008. J Econ Entomol
Cooper et al. 2008 Calif Agricul

© Alex Wild

Vectors of Viral Pathogens in Vineyards

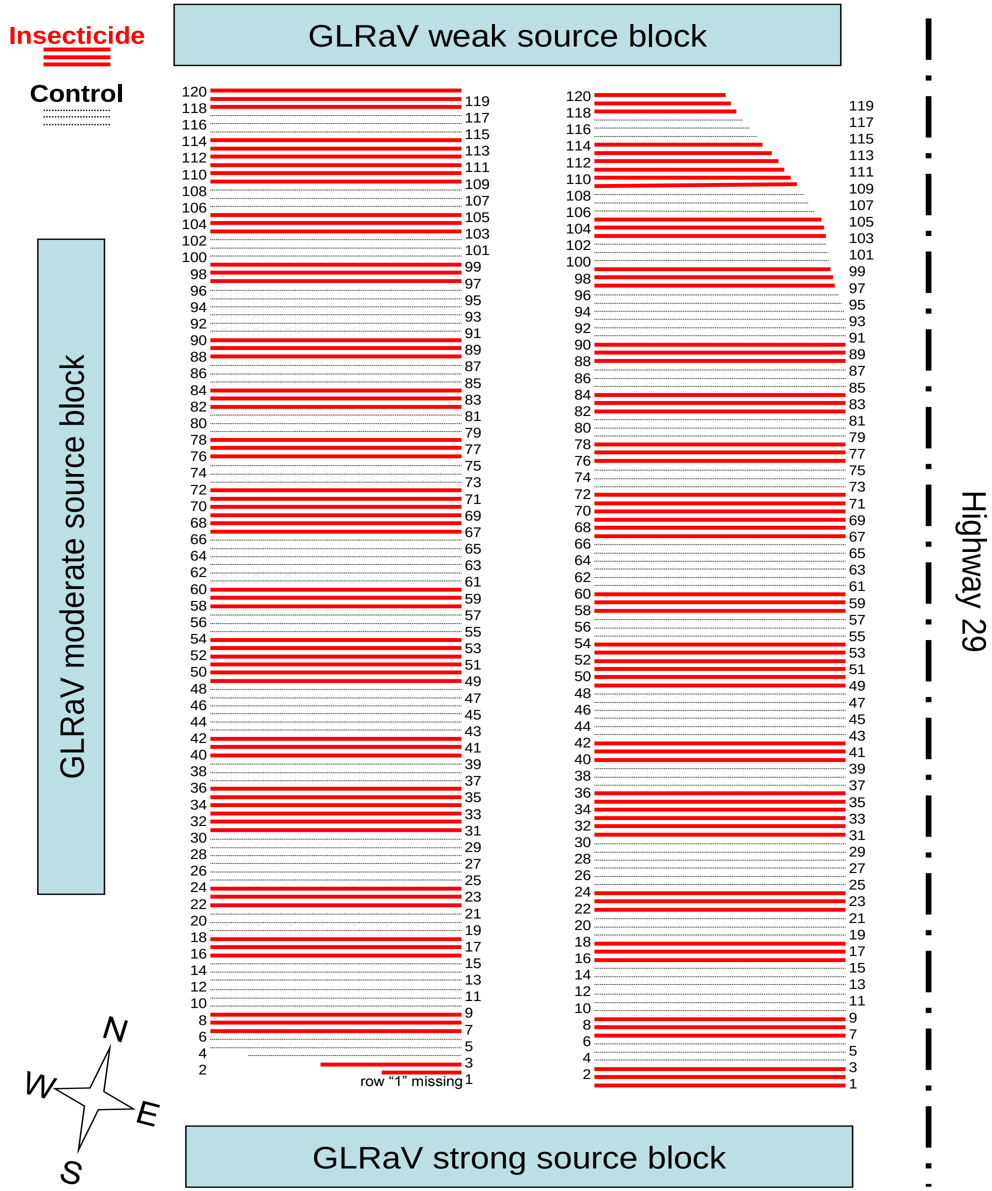
1. GLRaV Factors that Impact Control
   a) mealybug and leafroll species
   b) facts about mealybug-leafroll epidemiology
2. Vector (Mealybug) Controls
   a) insecticides for mealybug: which are best
   b) pheromones for monitoring and control
   c) biological controls
3. Areawide Control Programs?
   a) monitoring
   b) insecticide resistance
   c) mating disruption in Napa

Dispersal Mechanisms Were Poorly Known



Keeping the mealybug out of the vineyard and using effective insecticides when needed remains the best controls. UC personnel worked farmers, industry and PCAs to develop better insecticide programs.

Can we simply kill all mealybugs for GLRaV control?



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

Where did the GLRaV-infected vines appear?

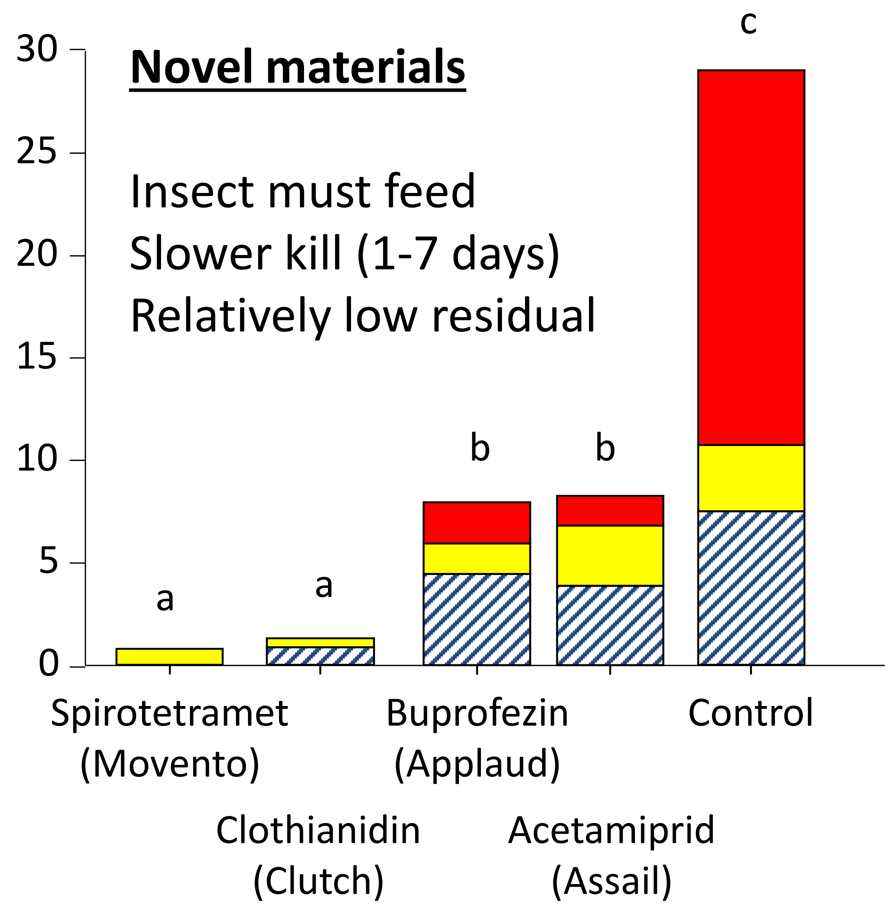
Insect growth regulator
Applaud (Buprofezin)

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)

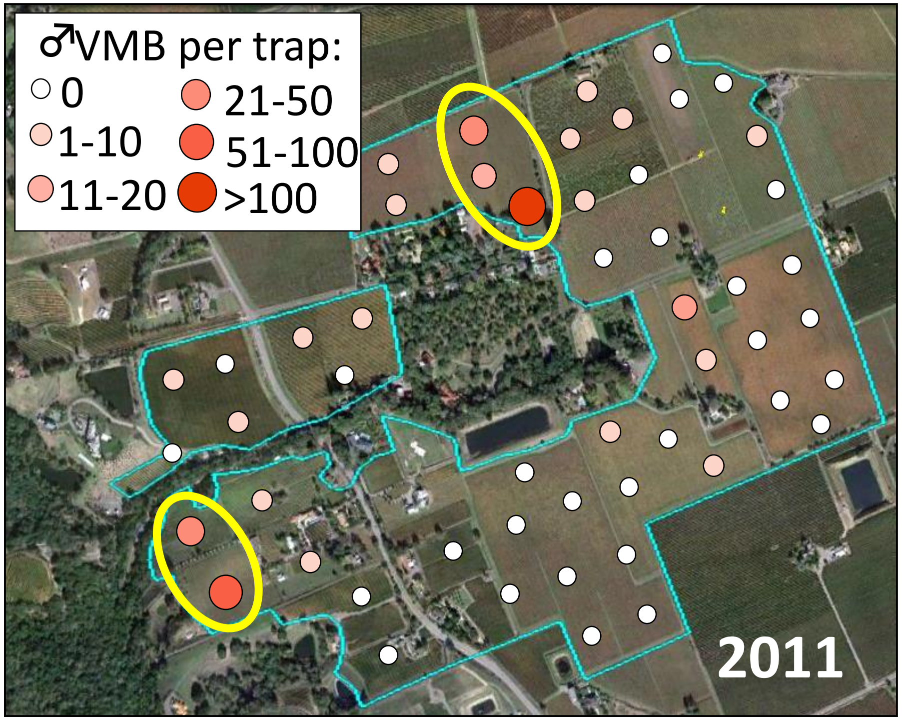


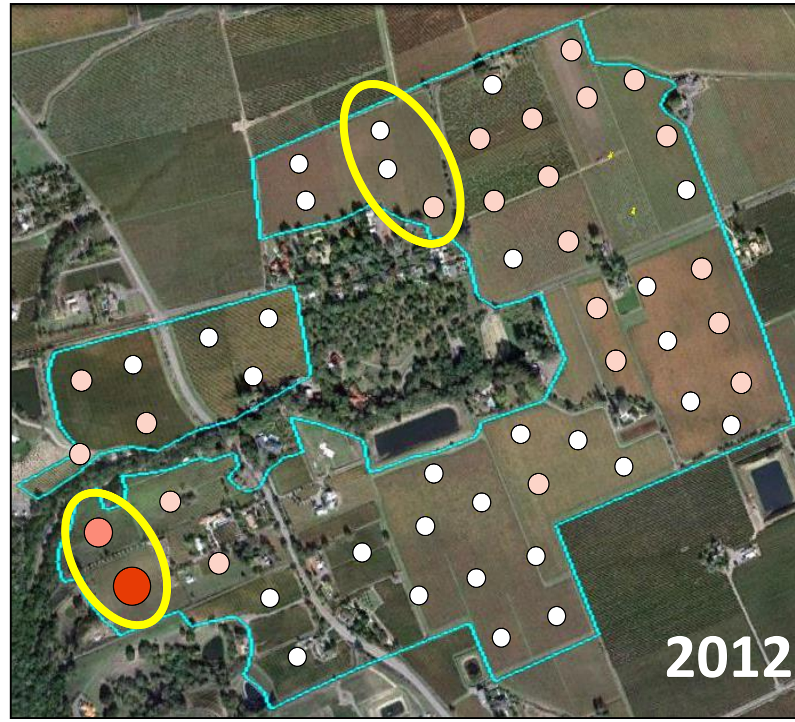
Spray Volume: 100 GPA; Air-blast Sprayer; label rate (Applaud 12 oz per ac)
Clutch & Movento on 21 June 2011, Applaud & Assail on 7 July 2011
Planococcus ficus, Lodi-Woodbridge wine grapes, Lodi, CA

Areawide control trial in Napa (2011-2012)

For Grape Leafroll Associated Viruses
- we know the vectors
- - we know their transmission efficiency
- we know the effectiveness of controls

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



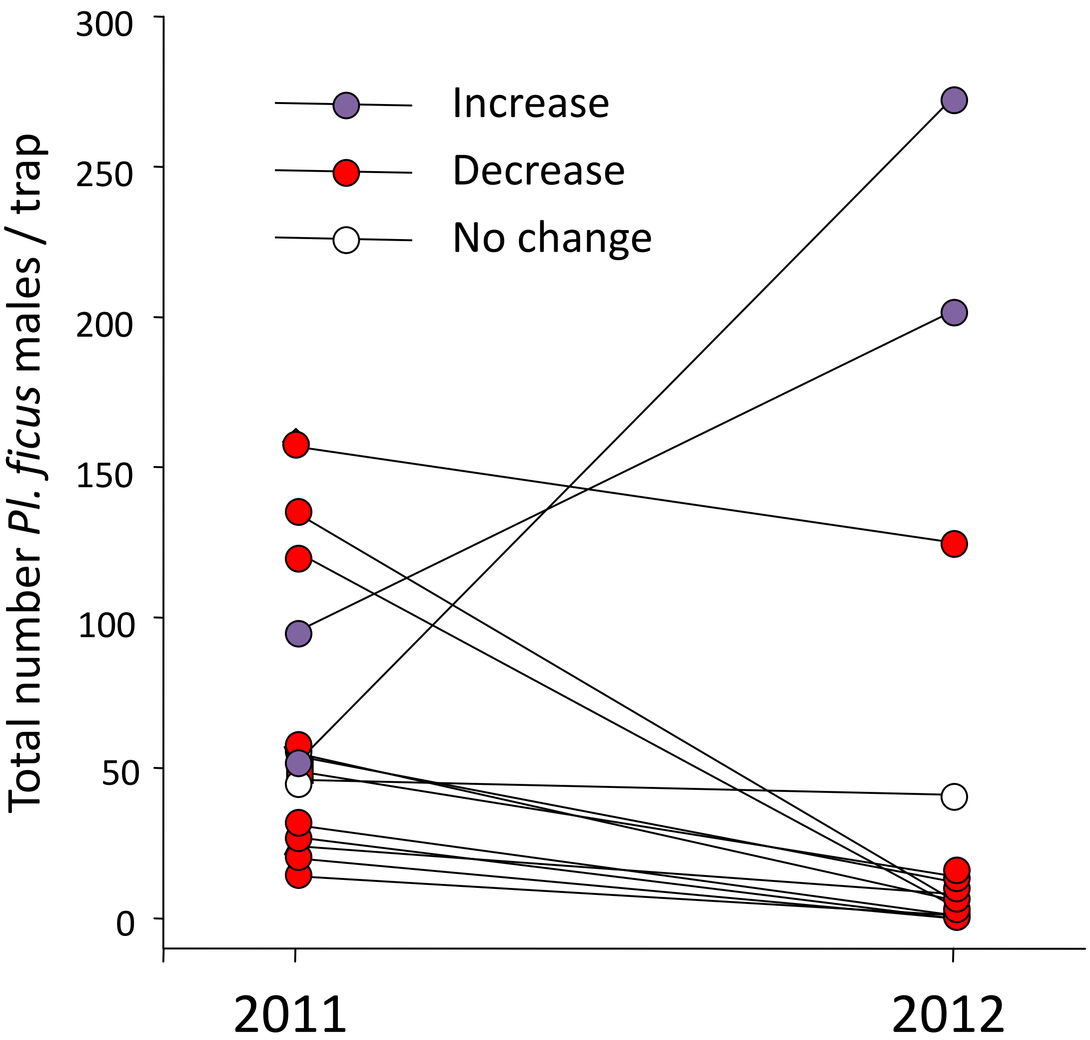


Results for 1 of 3 sites, shows that further spread can be prevented, and that farmers must work together.

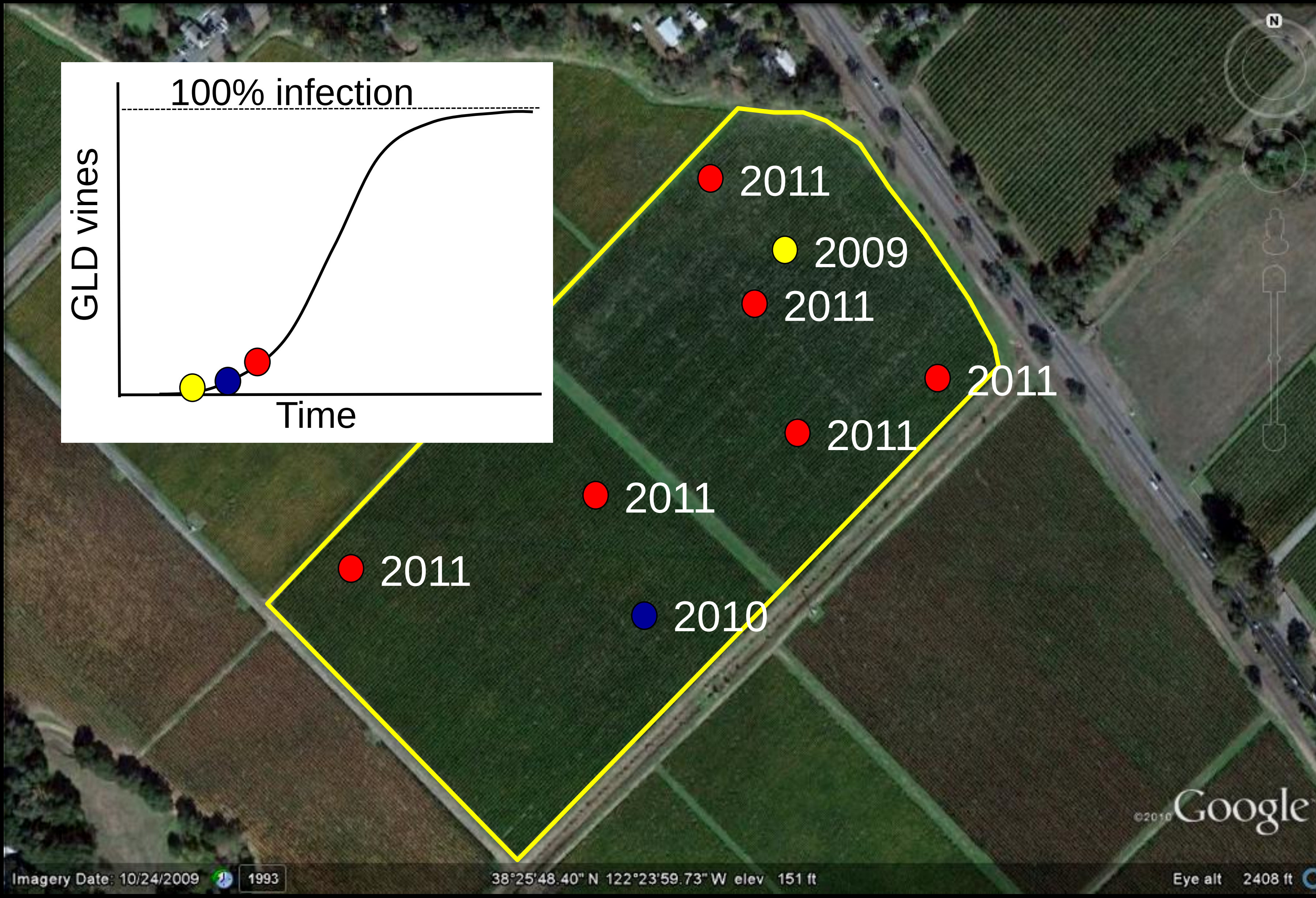
Comparison of traps in hotspots between years

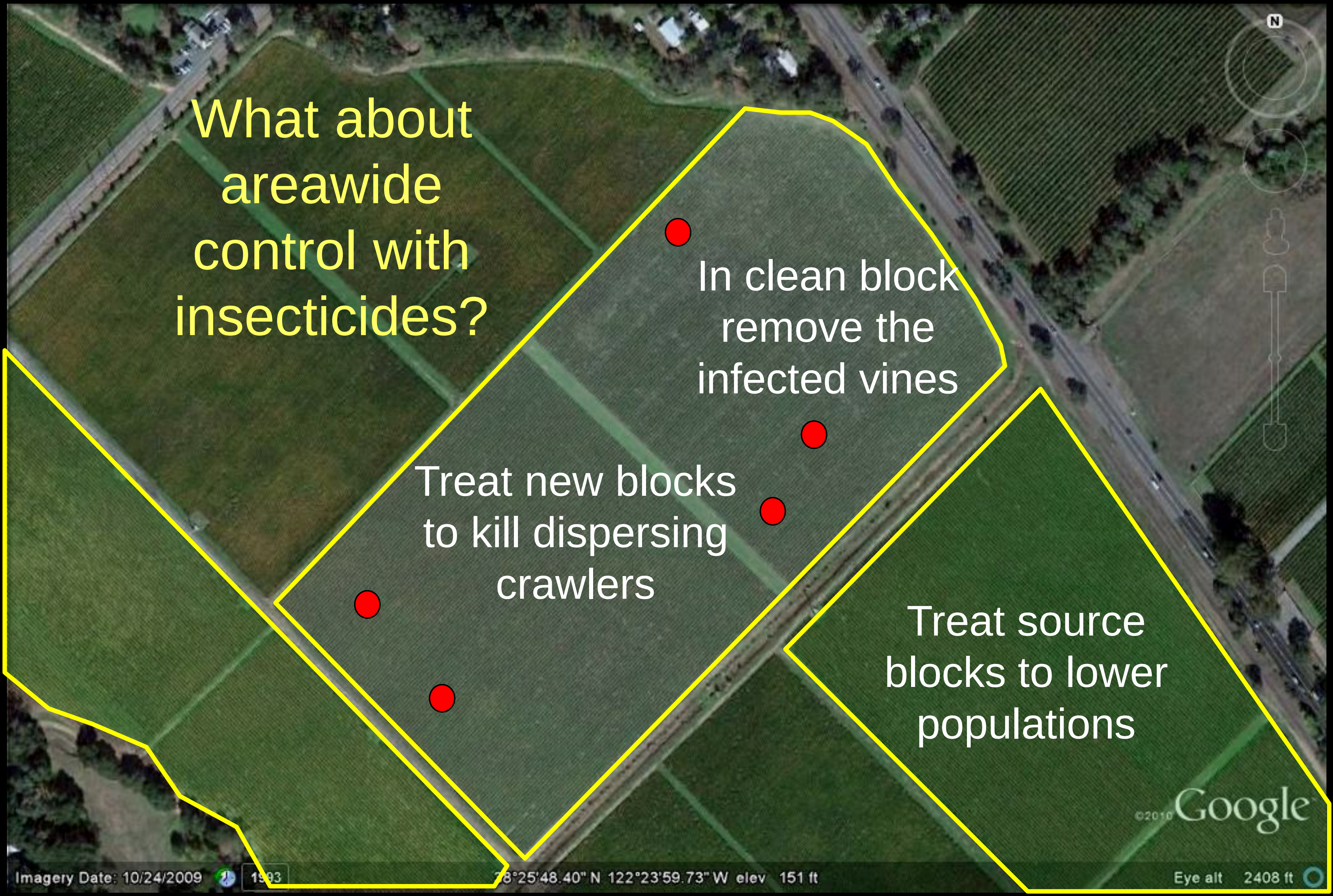
Numbers of vine MB in traps with total >20 VMB in either year generally decreased between 2011 and 2012, except in two cases.

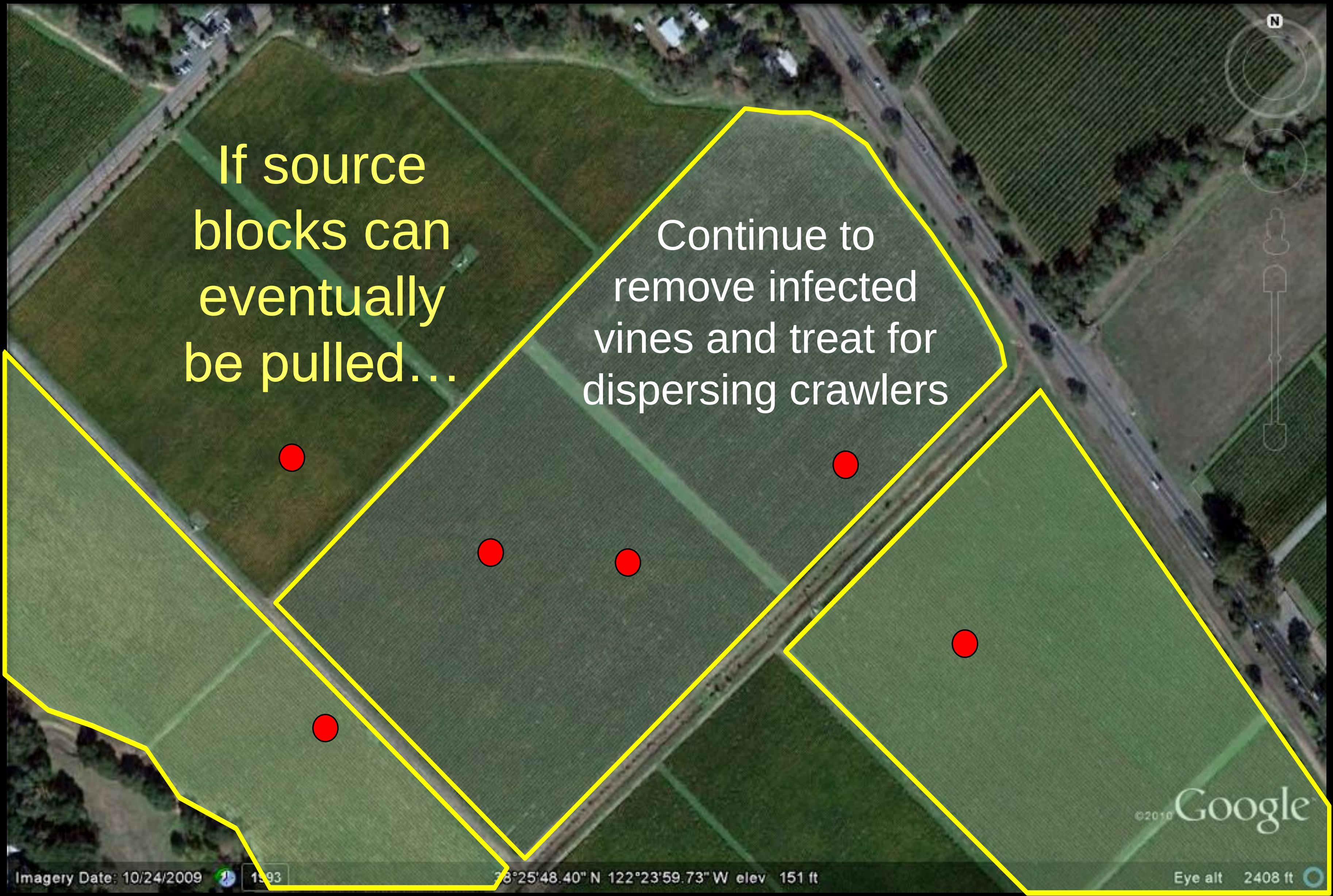
When proper treatments are not applied the population will increase and spread.




Insecticides for 'high density'
Mating disruption to prevent spread


100% infection
GLD vines
Time
2011
2009
2011
2011
2011
2011
2011
2010
©2010 Google
Imagery Date: 10/24/2009
1993
38°25'48.40" N 122°23'59.73" W elev 151 ft
Eye alt 2408 ft


What about areawide control with insecticides?
In clean block remove the infected vines
Treat new blocks to kill dispersing crawlers
Treat source blocks to lower populations
©2010 Google
Imagery Date: 10/24/2009
Eye alt 2408 ft



If source blocks can eventually be pulled…
Continue to remove infected vines and treat for dispersing crawlers
Imagery Date: 10/24/2009
38°25'48.40" N 122°23'59.73" W elev 151 ft
Eye alt 2408 ft
©2010 Google

Conclusions & Questions

1) Different mealybug species in California vineyards.
2) Sampling using visual counts is tedious (pheromone traps).
3) Chemical controls remain the most common tool: Movento, Belay, Admire (and generic), Assail, Platinum, Venom, Applaud, Sivanto (flupyradifurone), Sequoia (sulfoxaflor, check registration).
4) Mating disruption for vine mealybug to maintain low densities – a lot more potential with the sprayable formulation.
5) There are 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 and selective insecticides has a positive interaction with mating disruption
6) Mealybugs vector GLDs and this changes control decisions – start thinking about areawide control as the best program.