Monitoring And Management Of Mealy Plum And Leaf-curl Plum Aphids Using Sex Pheromones

Emily J. Symmes
Frank G. Zalom
Department of Entomology
University of California, Davis

Mealy plum aphid (MPA)
Hyalopterus pruni

Leaf-curl plum aphid (LCPA)
Brachycaudus helichrysi

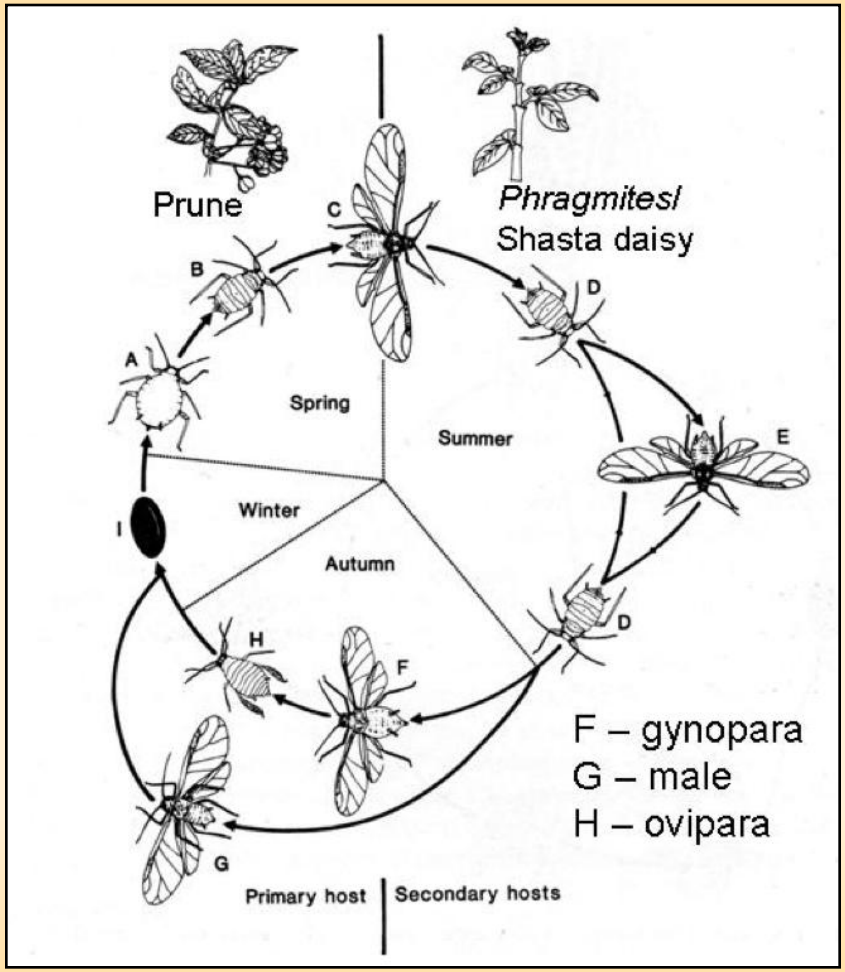
Current Practices

- **Monitoring**
  - **Dormant spur sample - eggs**
  - **Problems**
    - **Reliability, implementation**

- **Management**
  - **Dormant insecticide treatment**
    - **Pyrethroid ± oil**
  - **Problems**
    - **Water quality**

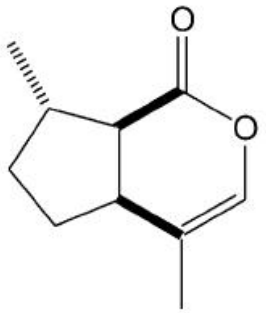
- **Potential for improvement**

Aphid Life Cycle

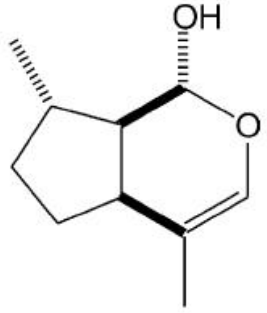


Aphid Chemical Ecology: Sex Pheromones

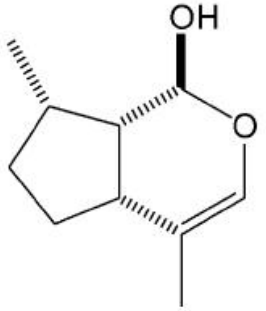
Aphid Species	
Scientific name	**Common name**
Acyrthosiphon pisum	Pea aphid
Aphis fabae	Black bean aphid
Aphis spiraecola	Spirea aphid
Brevicoryne brassicae	Cabbage aphid
Cryptomuzys spp.	Currant aphids
Dysaphis plantaginea	Rosy apple aphid
Macrosiphum euphorbiae	Potato aphid
Megoura viciae	Vetch aphid
Myzus persicae	Green peach aphid
*Phorodon humuli**	Damson hop aphid
Rhopalosiphum padi	Bird cherry-oat aphid
Schizaphis graminum	Greenbug
Sitobion avenae	Grain aphid
Sitobion fragariae	Black-berry ceral aphid
Tuberocephalus mamonis	Peach aphid



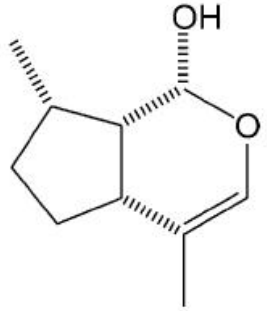
1



2



3



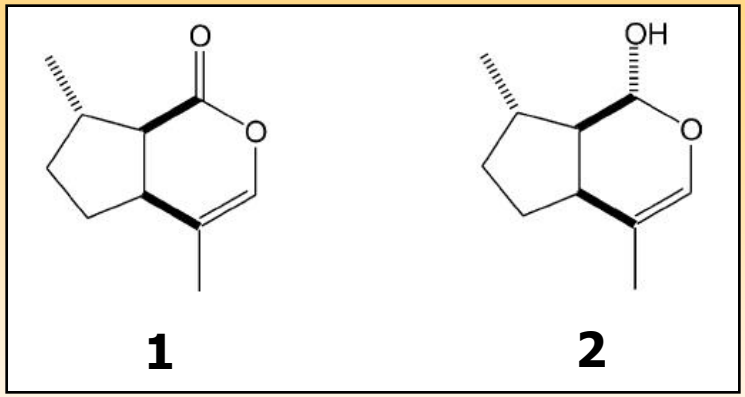
4

(4a*S*, 7*S*, 7a*R*)-nepetalactone (1)

(*1R*, 4a*S*, 7*S*, 7a*R*)-nepetalactol (2)

(1*S*, 4a*R*, 7*S*, 7a*S*)-nepetalactol (3)

(1*R*, 4a*R*, 7*S*, 7a*S*)-nepetalactol (4)



1 2

(4a*S*, 7*S*, 7a*R*)-nepetalactone (1)

(1*R*, 4a*S*, 7*S*, 7a*R*)-nepetalactol (2)

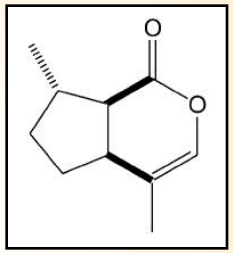
MPA: 3.4:1 (lactone:lactol)

LCPA: 2.6:1 (lactone:lactol)

Symmes, EJ, SY Dewhirst, MA Birkett, CAM Campbell, K Chamberlain, J Pickett, FG Zalom. 2012.The sex pheromones of mealy plum (*Hyalopterus pruni*) and leaf-curl plum aphids (*Brachycaudus helichrysi*): identification and field trapping of male and gynoparous aphids in prune orchards. Journal of Chemical Ecology 38: 576-583.

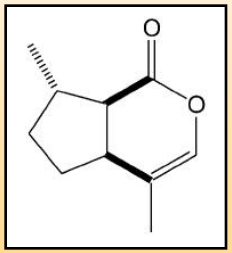
Nepetalactone

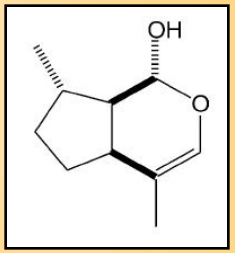
- **Obtained in high yield from fresh plant material**
  - **Catnip, *Nepeta cataria* (Lamiaceae)**
  - **Steam distillation process**



Nepetalactol

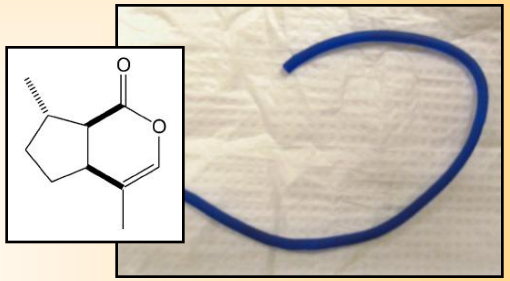
- **Obtained via chemical reduction of nepetalactone**
  - **Sodium borohydride, $NaBH_4$**
  - **92% desired isomer**

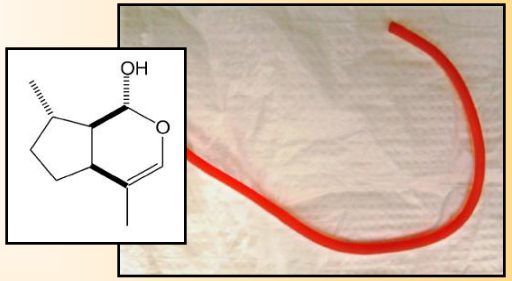




Pheromone Lures

- **Flexible PVC rope**
  - **5% extrusions**
- **Prevents UV degradation & oxidation**
- **Slow, consistent release rate**
  - **Stable release profile for >1 month**
- **Nepetalactone**
  - **Standard lure length = 4cm**
  - **Release rate = min. 200 μg/day**
- **Nepetalactol**
  - **Standard lure length = 8cm**
  - **Release rate = min. 200 μg/day**
- **Cut to different lengths to deploy desired pheromone ratios & release rates**





Research Objectives

I. Monitoring:

- **Investigate whether aphid sex pheromones may be used to develop monitoring protocol for MPA & LCPA in prune orchards**

II. Management:

- **Explore the use of aphids sex pheromones for mating disruption of MPA & LCPA in prune orchards**

2008 – 2012 Field Studies

- **2008 Ratio Tests**
  - Examined pheromone activity toward LCPA & MPA in orchard environment
  - Tested various pheromone ratios for impacts on LCPA & MPA trap catches
  - Compared numbers of natural enemies trapped by pheromone ratio treatments

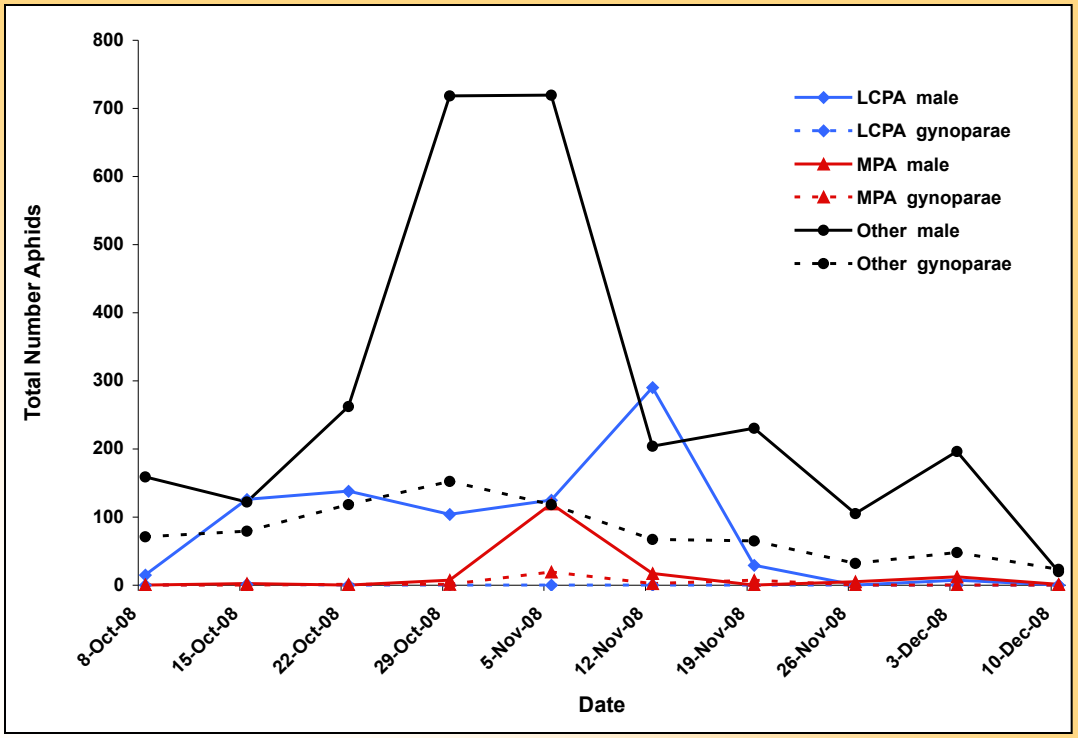
- **2010 – 2011 Trap Comparison-Monitoring Study**
  - Examined relationships among fall trap catches & subsequent population & damage measures
  - Compared monitoring parameters among multiple trap design-pheromone baiting status combinations

- **2011 – 2012 Monitoring Study**
  - Examined relationships among fall trap catches & subsequent population & damage measures

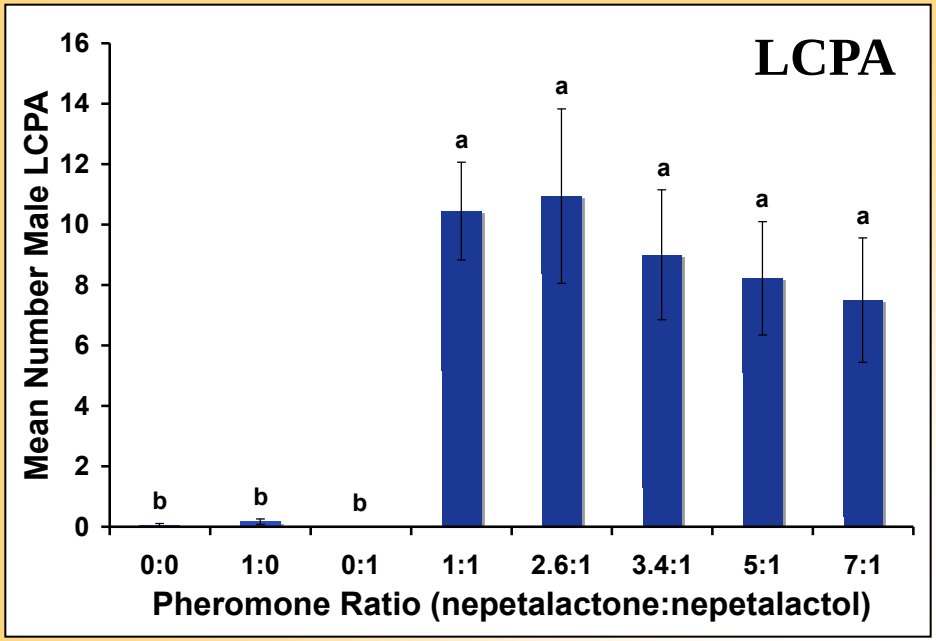
- **2011 – 2012 Mating Disruption Experiment**
  - Determined effect of pheromone treatment on subsequent population measures

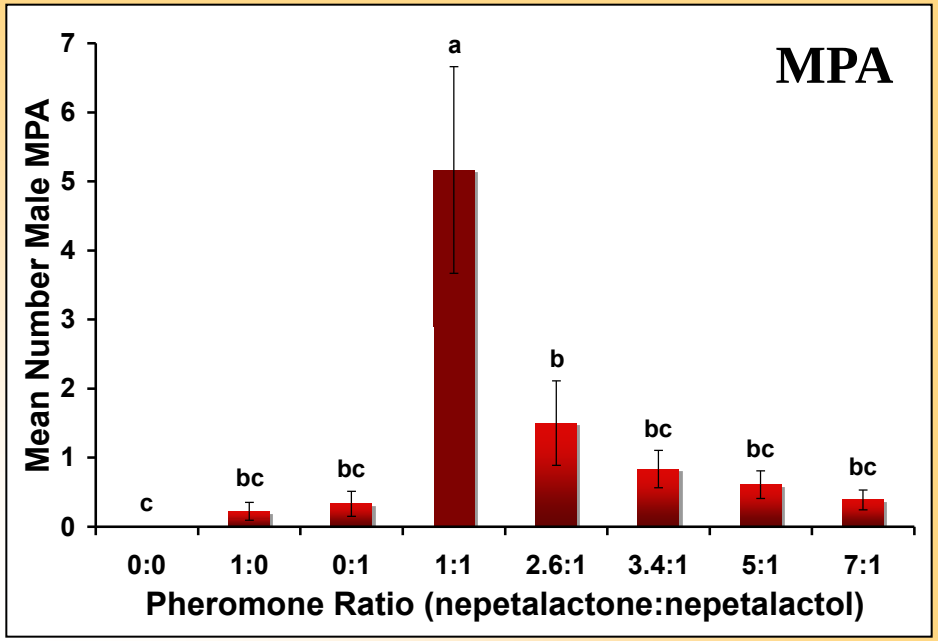
2008 Ratio Tests

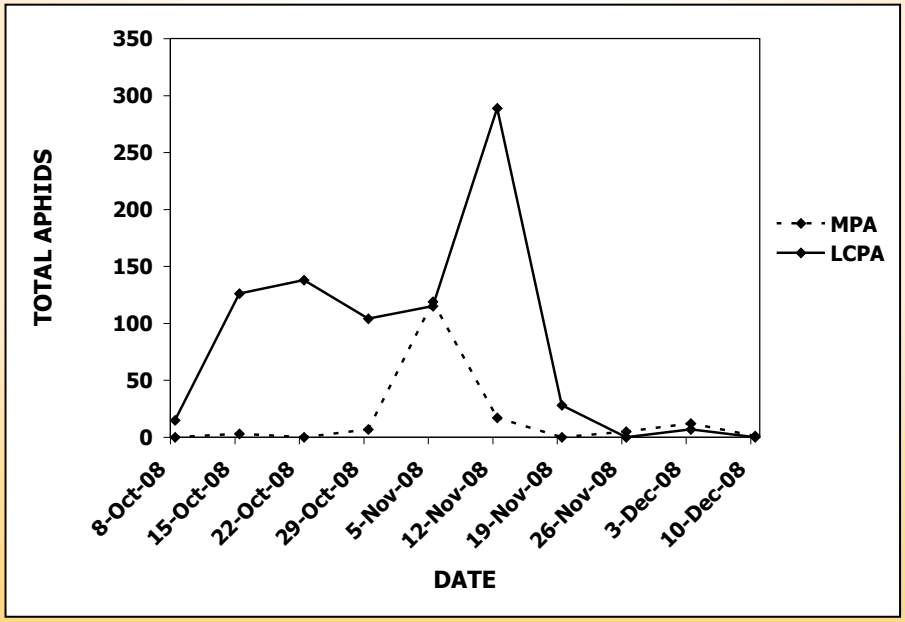
Sutter & Yolo Counties
4 orchards (18 replicates)
8 pheromone ratio treatments

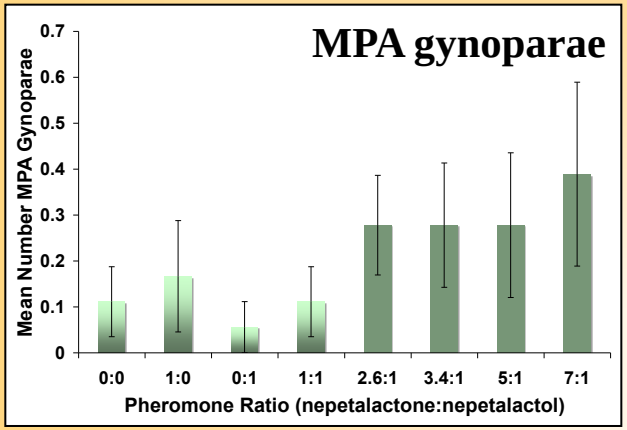


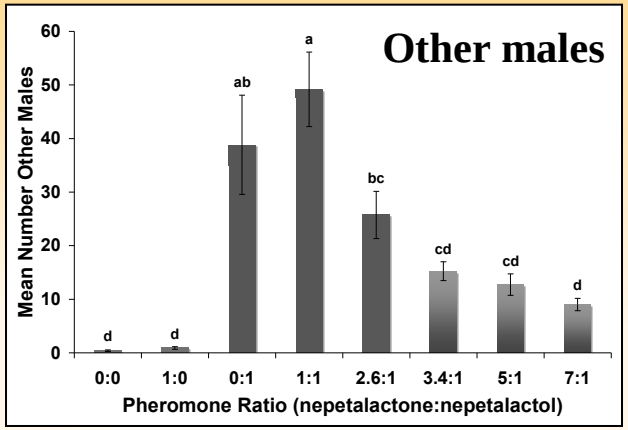
Pheromone ratio (lactone:lactol)	Total number male aphids			Total number gynoparae		
	LCPA	MPA	Other	LCPA	MPA	Other
0:0	1	0	7	0	2	57
1:0	3	4	16	0	3	71
0:1	0	6	699	0	1	204
1:1	188	93	885	0	2	108
2.6:1	197	27	463	0	5	100
3.4:1	162	15	274	0	5	80
5:1	148	11	229	0	5	78
7:1	135	7	162	1	7	75

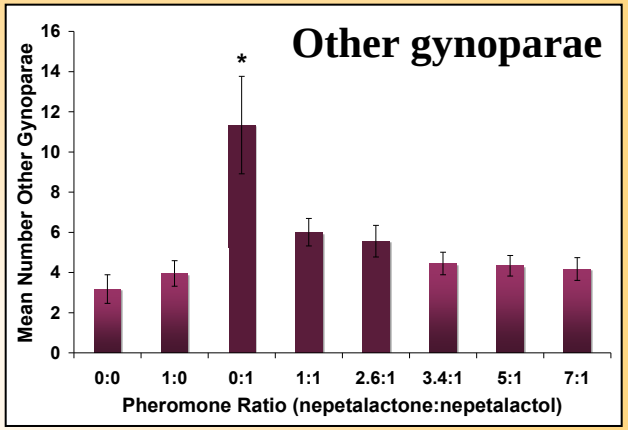

LCPA
Mean Number Male LCPA
16
14
12
10
8
6
4
2
0
b
b
b
a
a
a
a
a
0:0
1:0
0:1
1:1
2.6:1
3.4:1
5:1
7:1
Pheromone Ratio (nepetalactone:nepetalactol)


MPA
Mean Number Male MPA
7
6
5
4
3
2
1
0
c
bc
bc
a
b
bc
bc
bc
0:0
1:0
0:1
1:1
2.6:1
3.4:1
5:1
7:1
Pheromone Ratio (nepetalactone:nepetalactol)


TOTAL APHIDS
350
300
250
200
150
100
50
0
8-Oct-08
15-Oct-08
22-Oct-08
29-Oct-08
5-Nov-08
12-Nov-08
19-Nov-08
26-Nov-08
3-Dec-08
10-Dec-08
DATE
MPA
LCPA

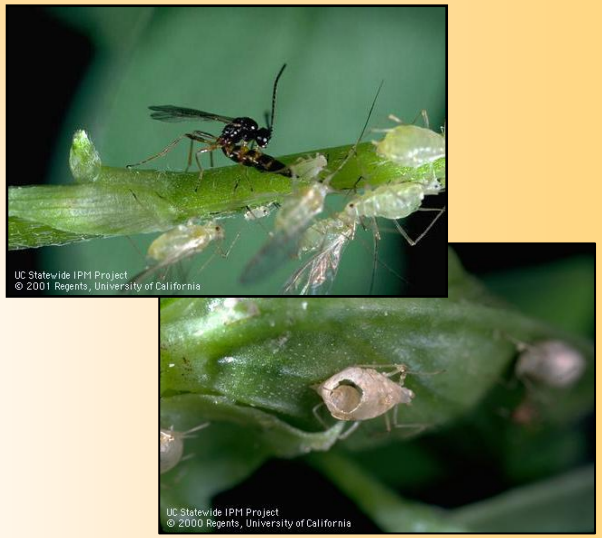




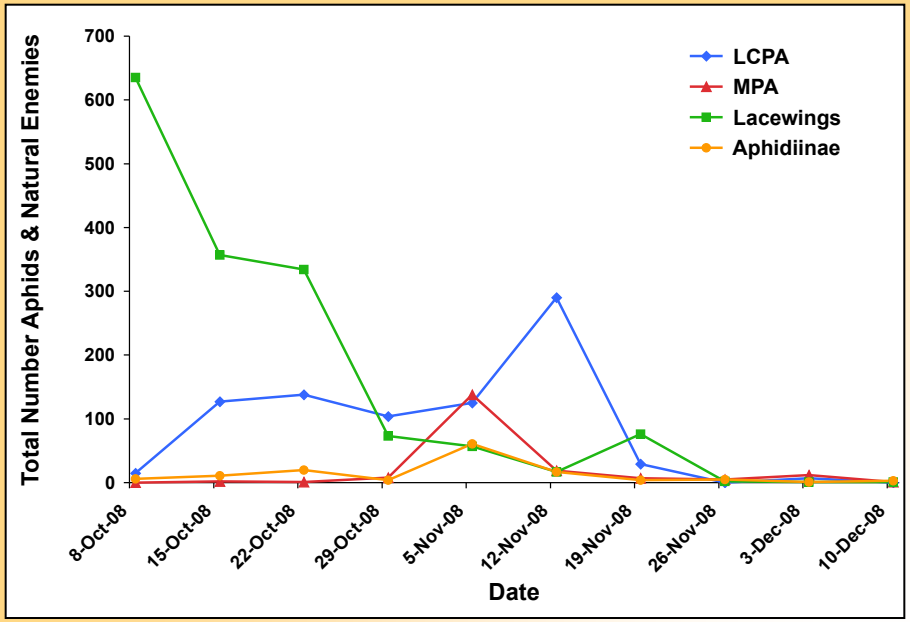


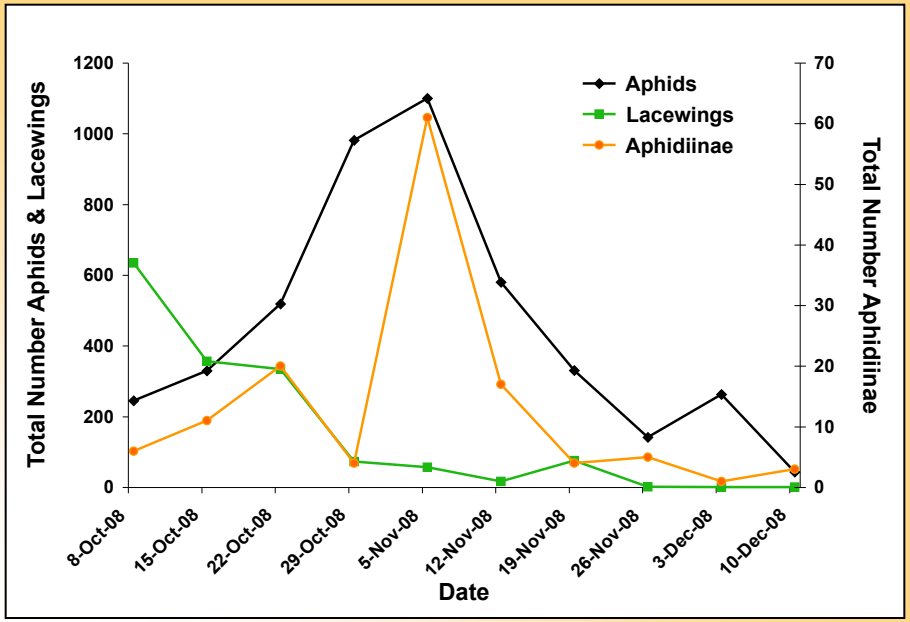
Pheromone ratio (lactone:lactol)	Total number male aphids			Total number gynoparae		
	LCPA	MPA	Other	LCPA	MPA	Other
0:0	1	0	7	0	2	57
1:0	3	4	16	0	3	71
0:1	0	6	699	0	1	204
1:1	188	93	885	0	2	108
2.6:1	197	27	463	0	5	100
3.4:1	162	15	274	0	5	80
5:1	148	11	229	0	5	78
7:1	135	7	162	1	7	75

Sex pheromones as kairomones for natural enemies

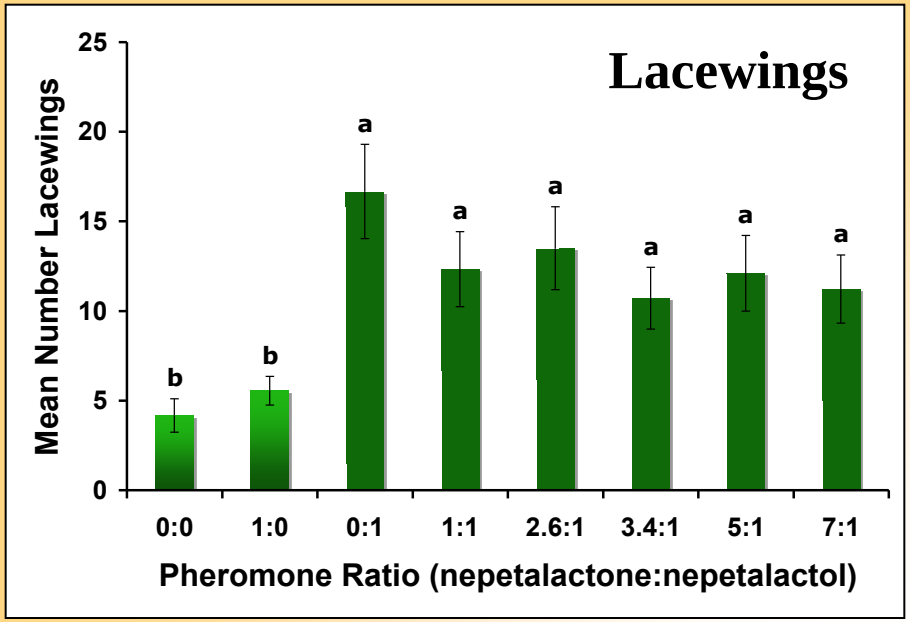


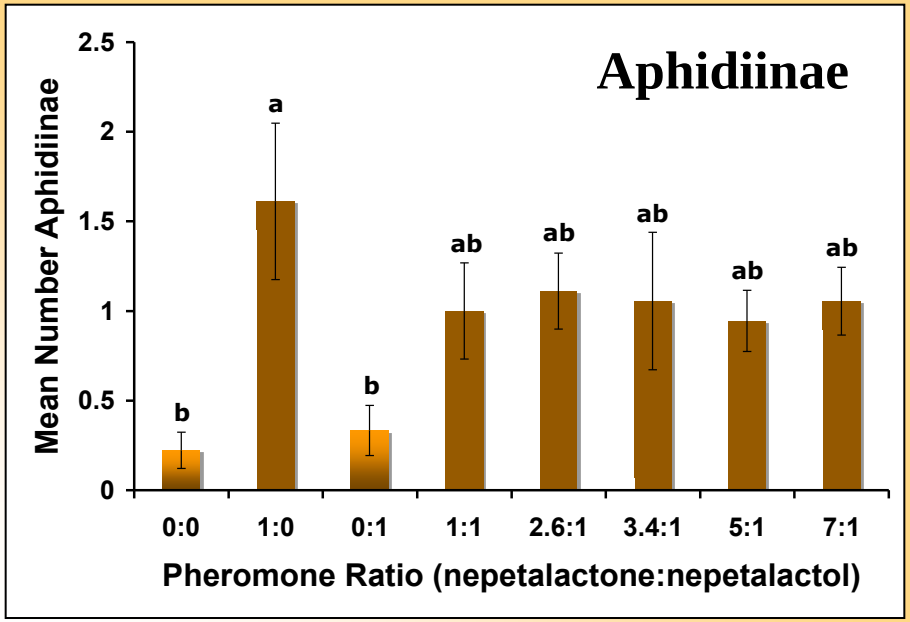
Pheromone ratio (lactone:lactol)	Total number natural enemies	
	Adult green lacewings	Female Aphidiinae
0:0	75	4
1:0	100	29
0:1	300	6
1:1	222	18
2.6:1	243	20
3.4:1	193	19
5:1	218	17
7:1	202	19





Pheromone ratio (lactone:lactol)	Total number natural enemies	
	Adult green lacewings	Female Aphidiinae
0:0	75	4
1:0	100	29
0:1	300	6
1:1	222	18
2.6:1	243	20
3.4:1	193	19
5:1	218	17
7:1	202	19





Pheromone ratio (lactone:lactol)	Total number natural enemies	
	Adult green lacewings	Female Aphidiinae
0:0	75	4
1:0	100	29
0:1	300	6
1:1	222	18
2.6:1	243	20
3.4:1	193	19
5:1	218	17
7:1	202	19

2008 Ratio Tests – Summary

- **Confirmed pheromone activity toward male LCPA & MPA in orchard environment**
- **Identified ratios that resulted in highest trap catches of male LCPA & MPA**
  - **1:1 ratio effective for both species**
- **Found that pheromone lures & specific ratios impact trap catches of lacewings & parasitoids**
  - **Potential use for management**
- **Distinct population peaks for LCPA & MPA activity**
  - **Implications for early treatment timing**

2010 – 2011
Trap Comparison-Monitoring Study

Sutter County
4 orchards (7 replicates)
8 treatments (4 trap designs, all + & - pheromone lure)
1:1 nepetalactone:nepetalactol pheromone ratio

Parameters compared among trap design-pheromone treatments:

- **Efficiency (aphids trapped)**
- **Selectivity (non-target arthropods trapped)**
- **Predictive value (relationships between fall aphid catches & overwintering egg densities; spring population & damage assessments not available)**
- **Economics (convenience of use, ease of processing, cost)**

Trap Designs

Commercial traps - Pherocon® (Trécé, Inc., Adair, OK, USA)

- **IIB trap (delta traps)**
- **AM/NB trap (yellow sticky cards)**
- **V tent trap (white sticky cards) - deployed as 2-sided sticky card**

Experimental water traps

Trap Design-Pheromone Baiting Status Treatments

DLT-

WST-

WT-

YST-

DLT+

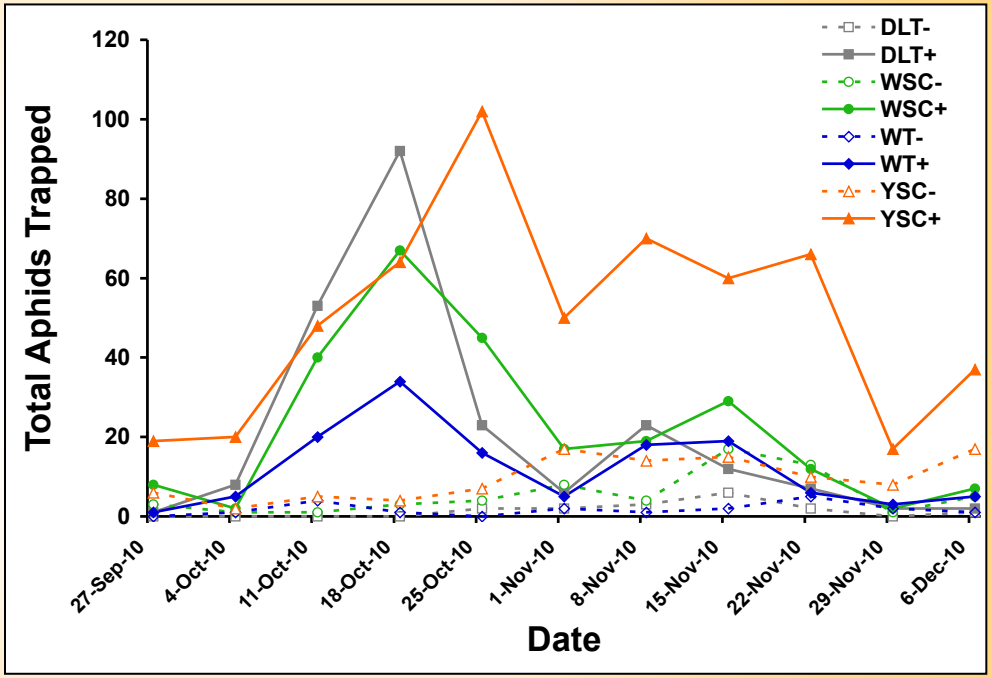
WST+

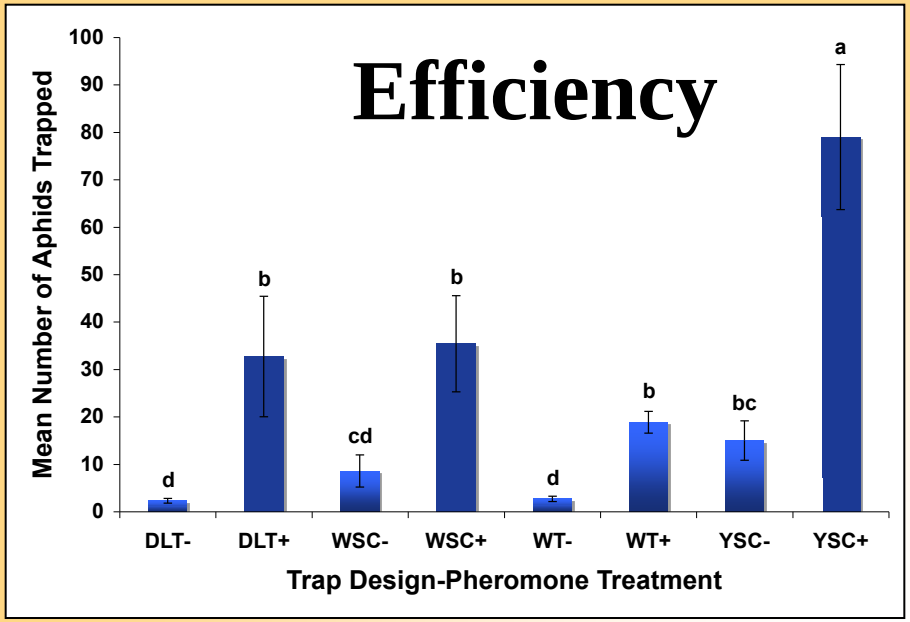
WT+

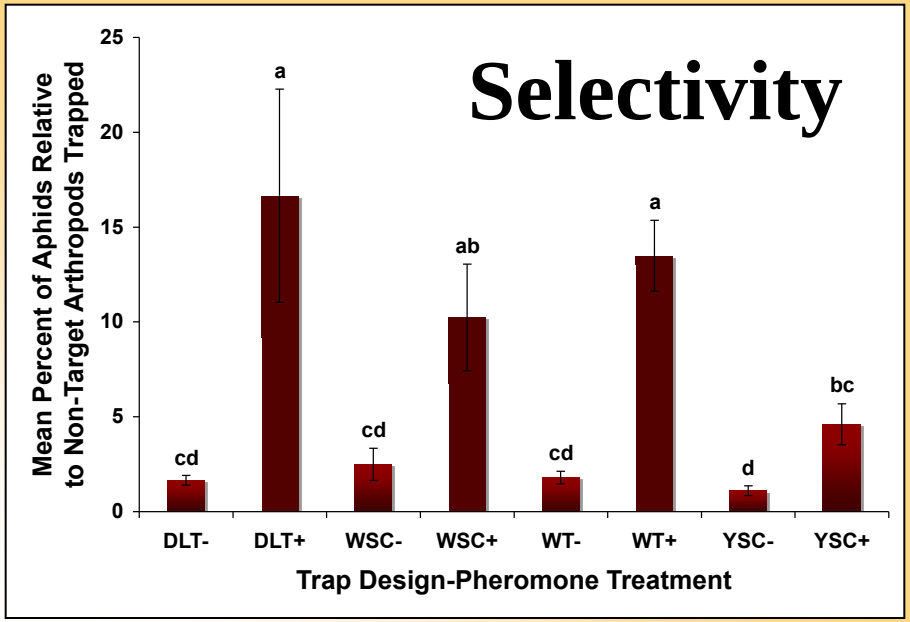
YST+

2010 – 2011
Trap Comparison-Monitoring Study

Trap Design		Pheromone Baiting Status	Total aphids
	DLT	–	16
		+	229
	WSC	–	60
		+	248
	WT	–	19
		+	132
	YSC	–	105
		+	553

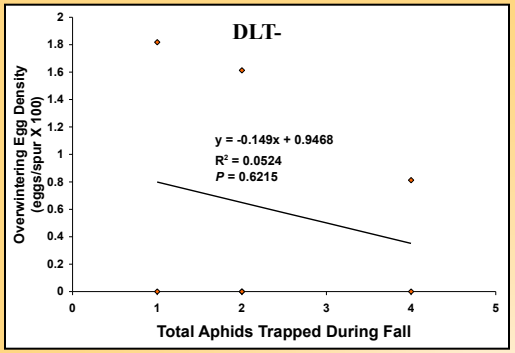


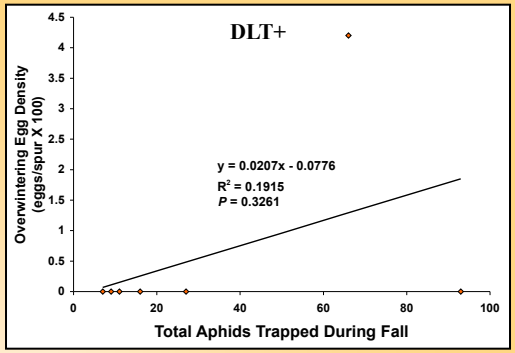


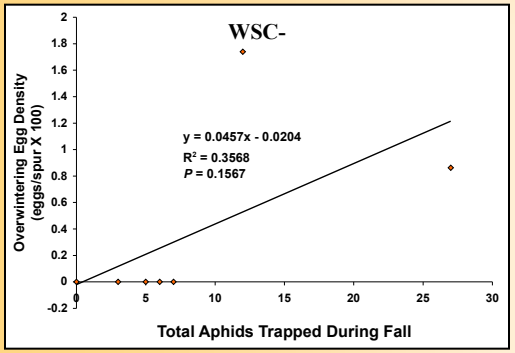


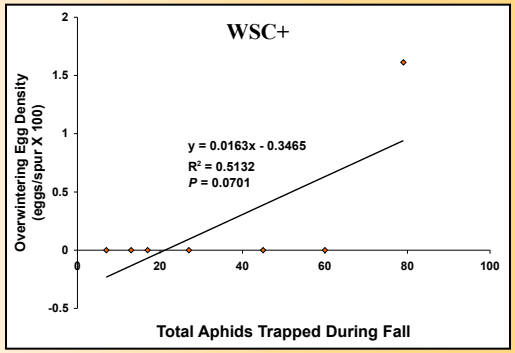
Trap Design		Pheromone Baiting Status	Total Trapped	
			Aphids	Non-target Arthropods
	DLT	–	16	933
		+	229	986
	WSC	–	60	2381
		+	248	2055
	WT	–	19	1078
		+	132	873
	YSC	–	105	8909
		+	553	13488

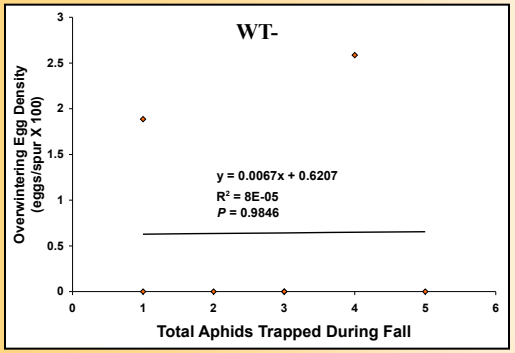
Predictive Value

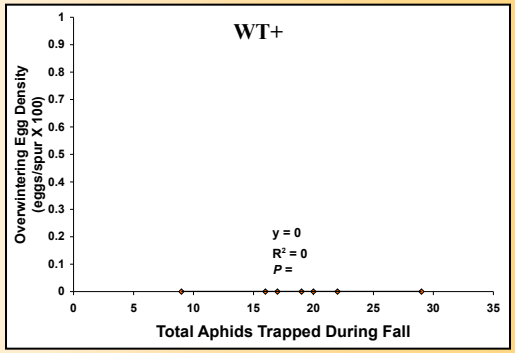


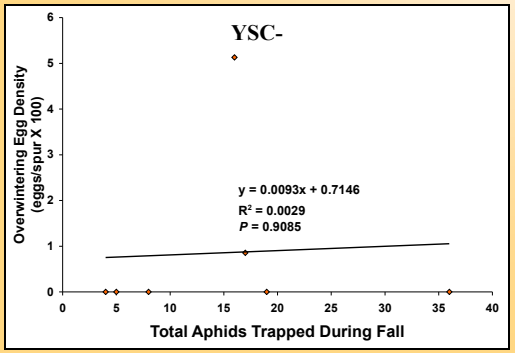


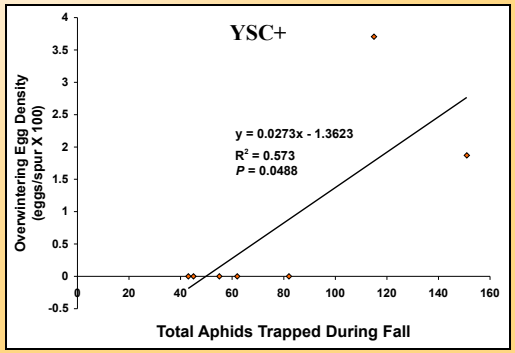












Trap Design-Pheromone Treatment	Mean number (± SE) aphids trapped	Mean (± SE) overwintering egg density[a]
DLT–	2.29 ± 0.27	0.61 ± 0.31
DLT+	32.71 ± 12.68	0.60 ± 0.60
WSC–	8.57 ± 3.37	0.37 ± 0.26
WSC+	35.43 ± 10.14	0.23 ± 0.23
WT–	2.71 ± 0.57	0.64 ± 0.42
WT+	18.86 ± 2.30	0.00 ± 0.00
YSC–	15.00 ± 4.17	0.85 ± 0.72
YSC+	79.00 ± 15.28	0.80 ± 0.55

[a] Eggs/spur X 100

Summary of Trap Comparison Parameters

Trap Design-Pheromone Treatment	Efficiency[a]	Selectivity[b]	Predictive Value[c]	Convenience of Use[d]	Ease of Processing[e]	Cost[f]
DLT–	2.29 ± 0.27 D	1.66 ± 0.25 cd	0.6215	1	1	$1.99
DLT+	32.71 ± 12.68 B	16.65 ± 5.62 a	0.3261	2	2	$1.99 + lure
WSC–	8.57 ± 3.37 CD	2.49 ± 0.85 cd	0.1567	3	4	$0.92
WSC+	35.43 ± 10.14 B	10.24 ± 2.80 ab	0.0701	4	3	$0.92 + lure
WT–	2.71 ± 0.57 D	1.80 ± 0.33 cd	0.9846	7	5	$0.56
WT+	18.86 ± 2.30 B	13.48 ± 1.87 a	1.0000	8	6	$0.56 + lure
YSC–	15.00 ± 4.17 BC	1.10 ± 0.25 d	0.9085	5	7	$1.36
YSC+	79.00 ± 15.28 A	4.61 ± 1.08 bc	0.0488	6	8	$1.36 + lure

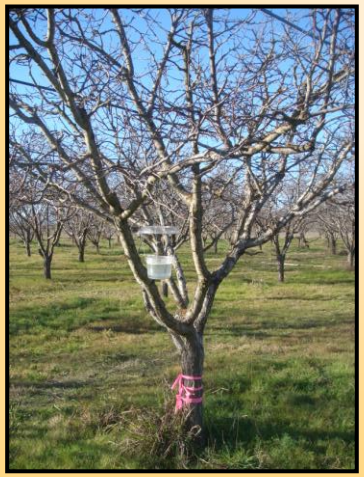
[a] Mean number (± SE) of aphids trapped.
[b] Mean percent (± SE) of aphids relative to non-target arthropods trapped.
[c] Significance (*P*-values) of regression analyses of numbers of aphids trapped during fall in relation to percent overwintering egg densities.
[d] Rank based on preparation time in the lab and handling time in the field (1 = least time required, 8 = most time required)
[e] Rank based on time required to process traps (count aphids) in the lab (1 = least time required, 8 = most time required)
[f] Price ($USD) per trap. Cost of lures not yet determined (experimentally available only). Water traps reusable. All other trap types single-use.

2010 – 2011
Trap Comparison-Monitoring Study – Summary

- **Further confirmation of impact of pheromone baiting on aphid trap catches during fall**
  - **Pheromone lure increased efficiency and selectivity of all trap types**
- **Monitoring parameters differed among trap design-pheromone baiting status treatments**
  - **White sticky card traps promising for practical application**
- **Relationships among fall trap catches & overwintering egg densities require further investigation**
  - **Predictive value**

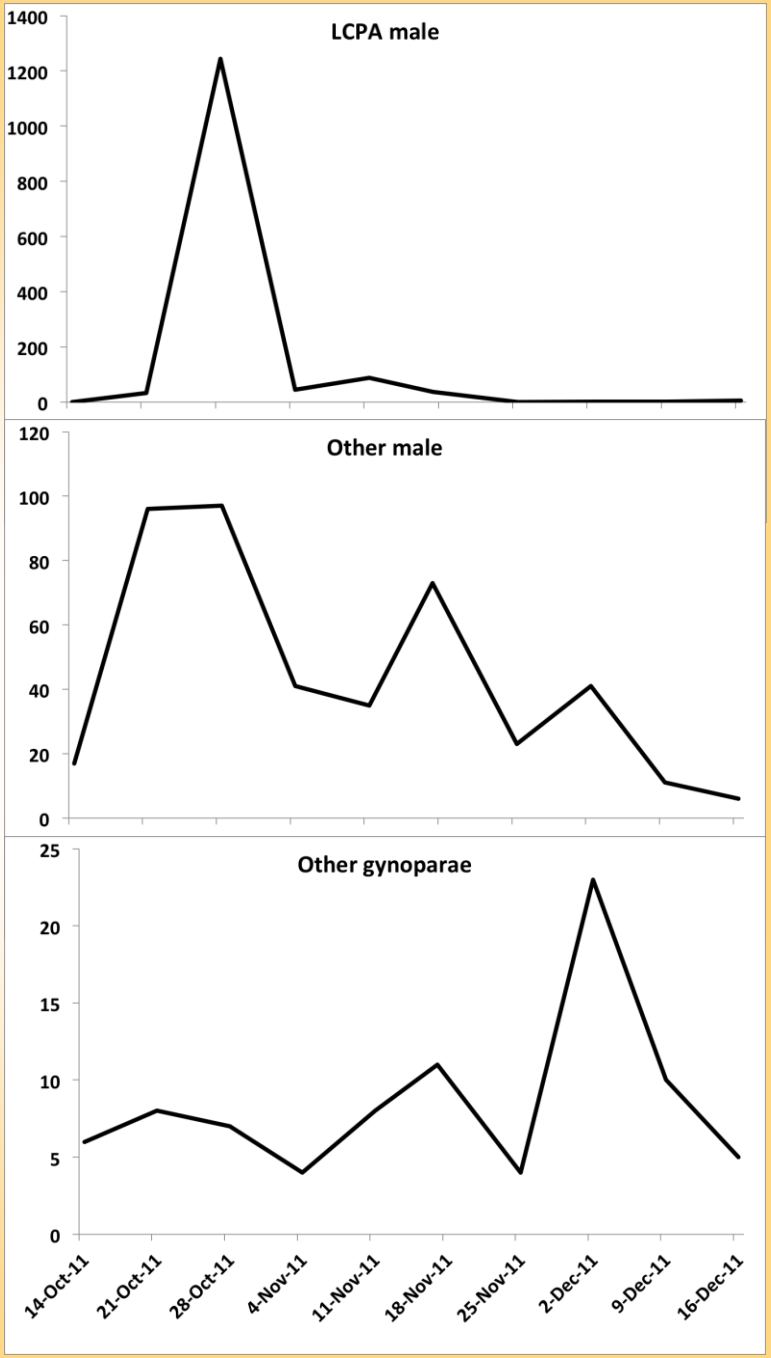
2011-2012 Monitoring Study

- **Can pheromone-based fall monitoring be used to predict subsequent aphid population measures/potential damage???**
  - **Augment/replace current egg sampling recommendation**
- **Tehama County – 5 orchards (25 replicates)**
- **Examined relationships among:**
  - **Fall trap catches, overwintering egg densities, spring population ratings (based on % leaf curl incidence)**

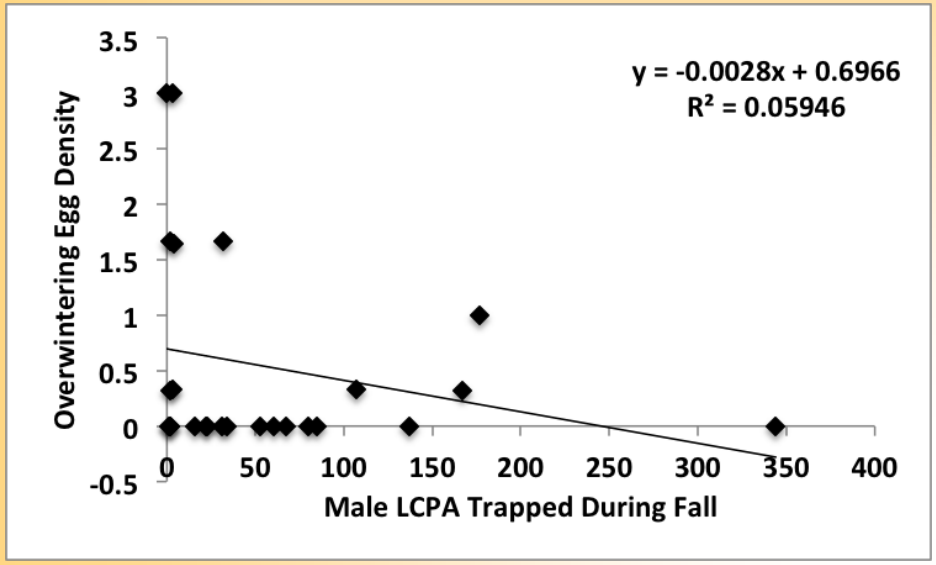


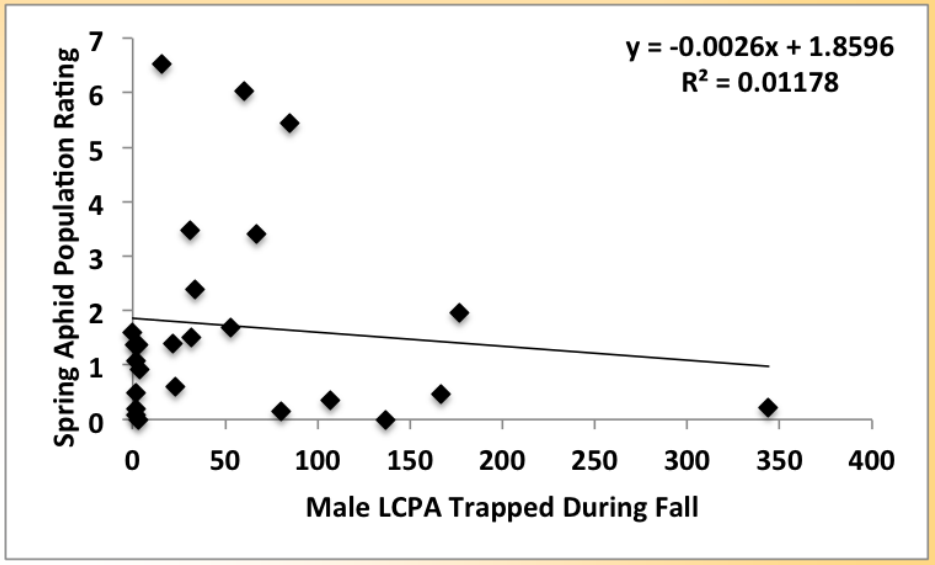
2011-2012 Monitoring Study

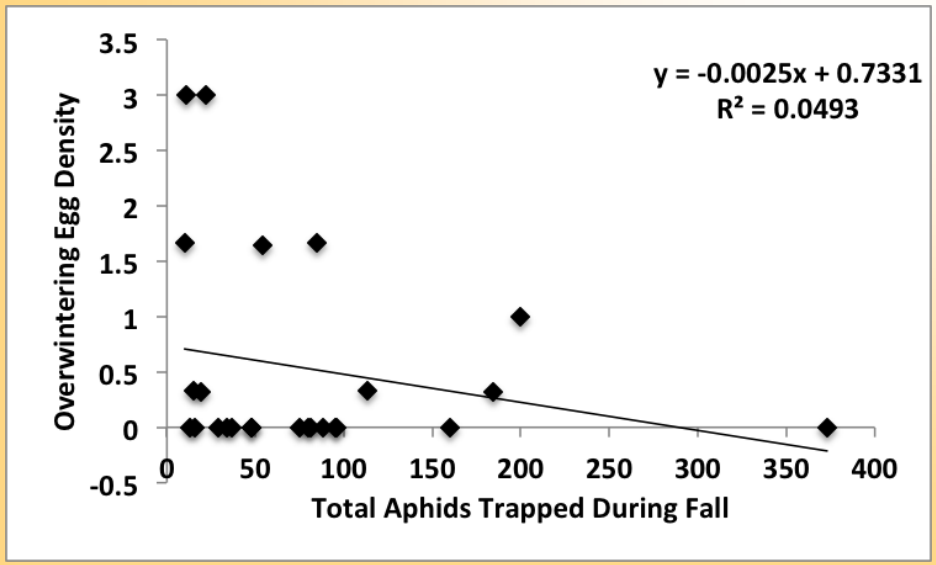
Aphid species	Total aphids trapped
LCPA male	1454
LCPA gynoparae	3 (Oct. 28)
MPA male	1 (Nov. 25)
MPA gynoparae	2 (Oct. 28, Nov 17)
Other male	440
Other gynoparae	86

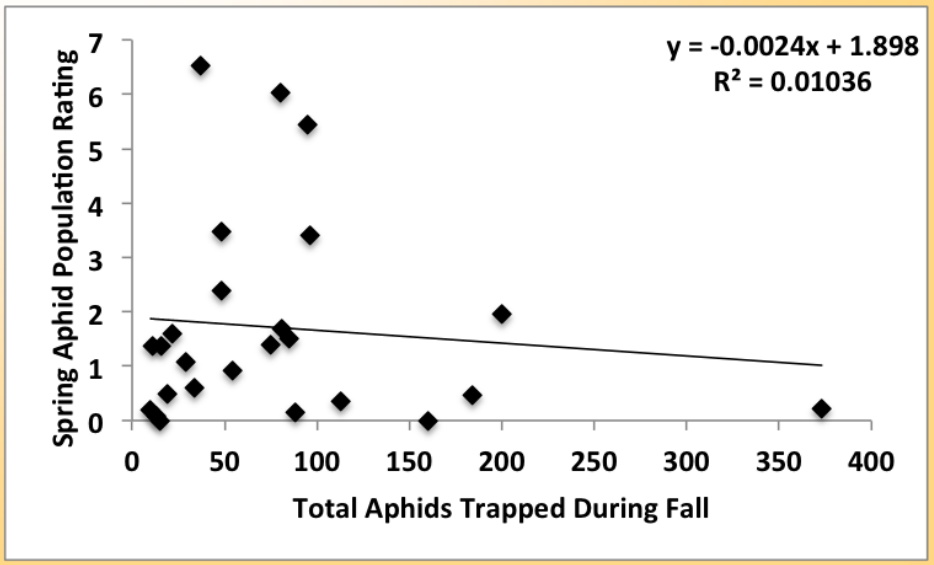


2011-2012 Monitoring Study

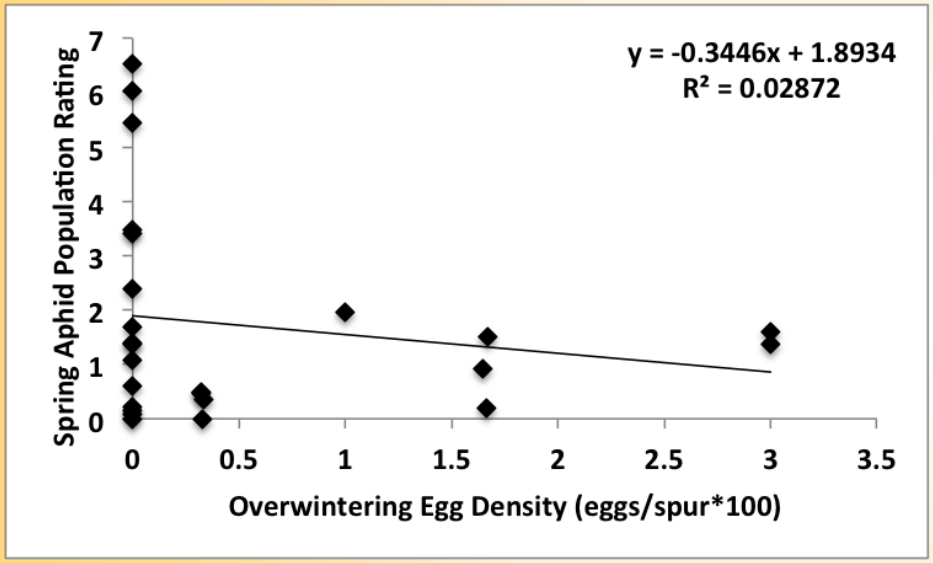


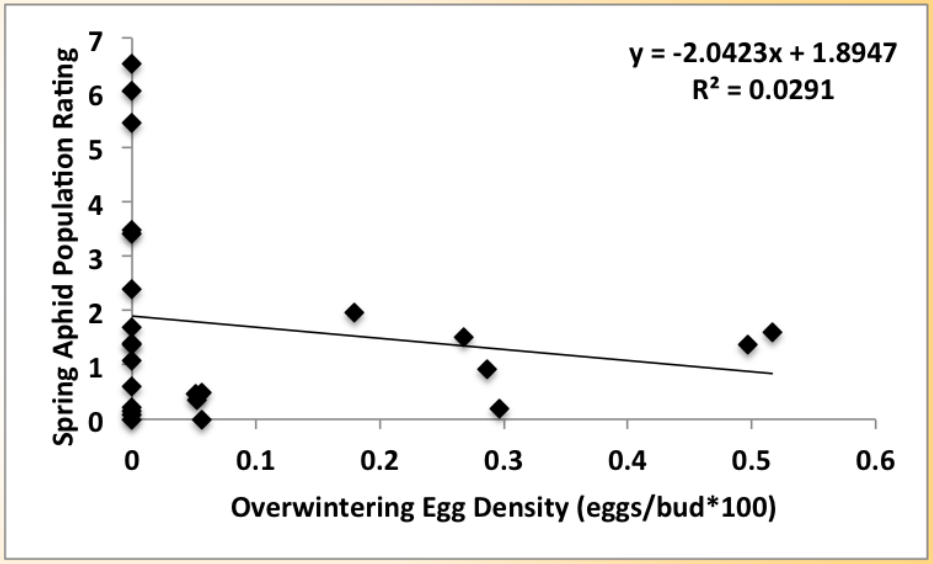






2011-2012 Monitoring Study





2011-2012 Monitoring Study

	Male LCPA vs.				Total Aphids vs.				Egg Density vs. Spring Population	
	Egg Density		Spring Population		Egg Density		Spring Population			
	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
Site 1 (n=6)	N/A	N/A	0.0043	0.00451	N/A	N/A	0.004	0.00388	N/A	N/A
Site 2 (n=5)	-0.0018	0.16942	0.0013	0.06258	-0.0017	0.17864	0.0013	0.06678	0.3041	0.06525
Site 3 (n=5)	0.0016	0.30188	0.0015	0.23863	0.0013	0.24677	0.0012	0.18387	0.9947	0.87376
Site 4 (n=3)	-0.0103	0.0235	0.0214	0.96125	-0.0116	0.0366	0.0193	0.97476	-0.1117	0.11891
Site 5 (n=6)	-0.0237	0.19902	0.0027	0.02084	-0.0293	0.22933	0.0042	0.07124	0.0984	0.14732

2011 – 2012 Monitoring Study – Summary

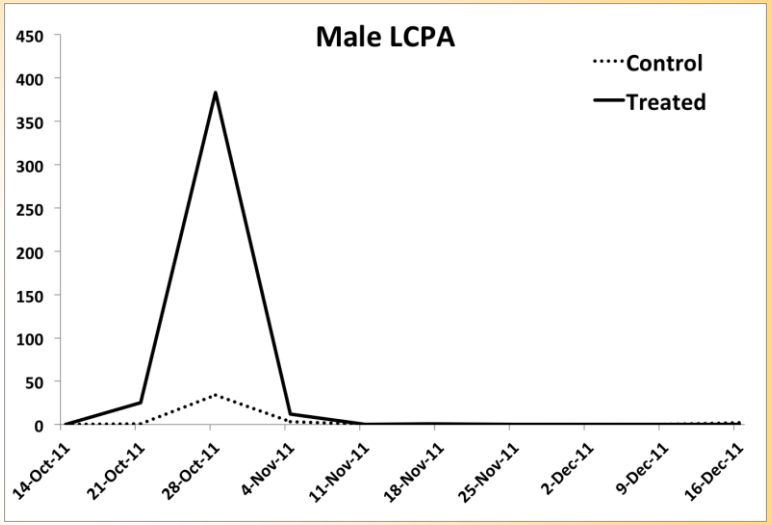
- **LCPA predominant aphid species**
- **Distinct population peak for LCPA activity**
  - **Implications for early treatment timing**
- **No relationship found between overwintering egg densities and spring populations/damage**
  - **Further limits current dormant spur sample recommendations**
- **Overall, found no reliable relationships among fall trap catches, overwintering egg densities, spring populations/damage**
  - **Individual orchards perform better**

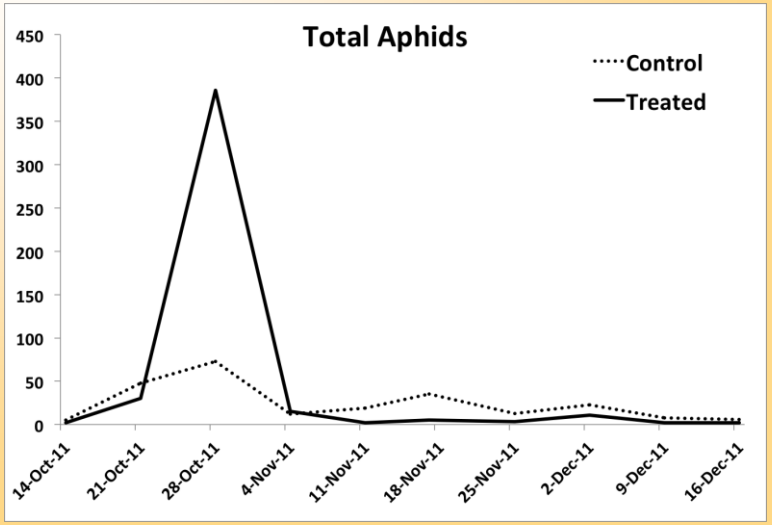
2011-2012 Mating Disruption Experiment

- **Does pheromone treatment impact fall trap catches, overwintering egg densities, ultimately reducing damaging spring populations/damage???**
  - **Alternative to conventional dormant sprays**
- **Tehama County – 5 orchards (5 replicates)**
- **Measures compared between pheromone-treated and no-pheromone control plots:**
  - **Fall trap catches, overwintering egg densities, spring population ratings (based on % leaf curl incidence)**

2011-2012
Mating Disruption Experiment

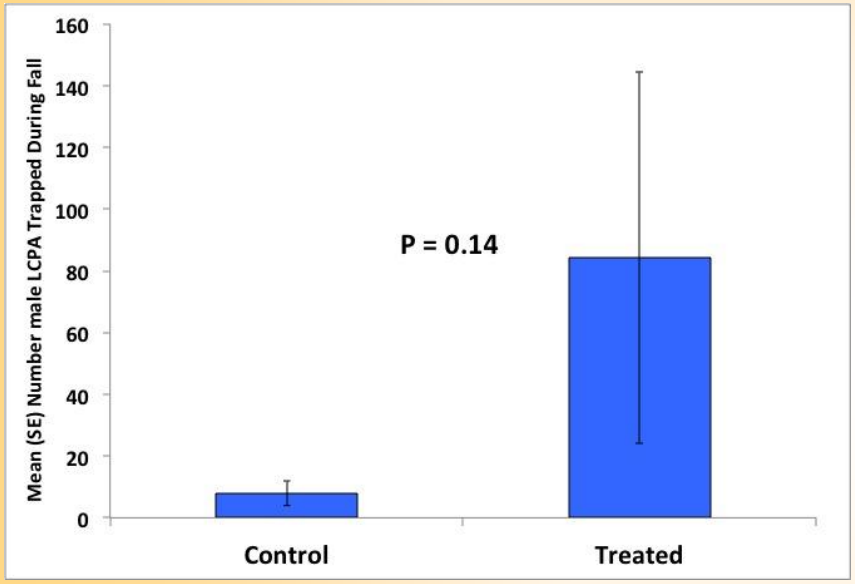
Aphid species	Total aphids trapped	
	Control	Treated
LCPA male	40	421
LCPA gynoparae	1	1
MPA male	0	0
MPA gynoparae	0	0
Other male	180	30
Other gynoparae	21	6
Total aphids	242	458



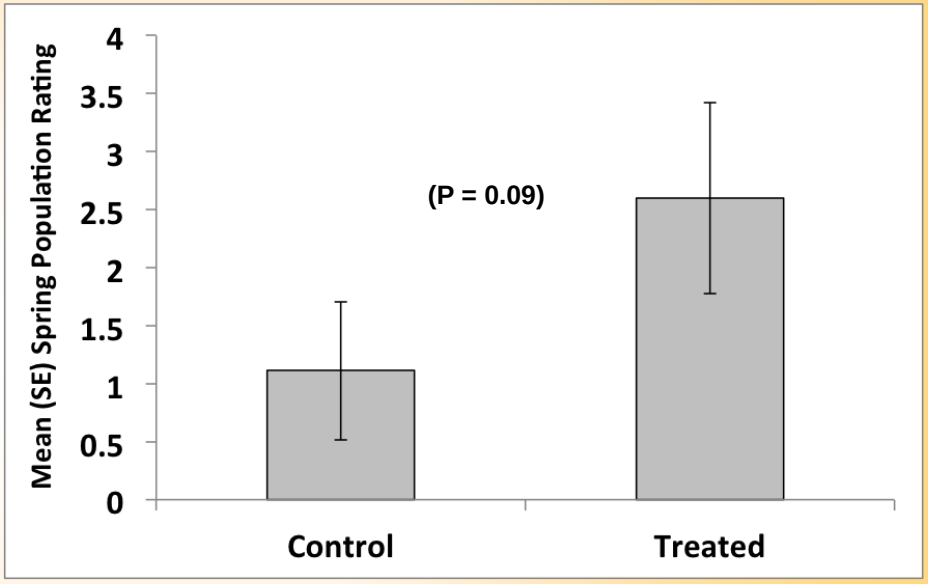


2011-2012 Mating Disruption Experiment

Fall trap catches



Spring population ratings



Overwintering egg densities (NS)

- **3 eggs detected (all in control plot)**
  - **1080 spur samples**
  - **5820 buds (potential oviposition sites)**

2011 – 2012 Mating Disruption Experiment – Summary

- **LCPA predominant aphid species**
- **Distinct population peak for LCPA activity**
  - **Implications for early treatment timing**
- **Found no differences in overwintering egg densities between pheromone-treated and control plots**
- **Found no statistical differences in trap catches between pheromone-treated and control plots**
  - **Statistical significance difficult because of extreme orchard variation**
- **Marginally significant difference in spring population/damage between pheromone-treated and control plots**
  - **Higher in treated plots**
- **Confirms biological activity of pheromone treatment – suggests attraction into treated areas without impacting mating success**
  - **Potential applications??**
- **Modifications in pheromone release rates, amounts, release methods may impact mating disruption success**

So…where are we and what's next?

- **Pheromone lures significantly impact trap catches of male MPA and LCPA**
  - **Males distinguish between different pheromone ratios**
  - **Promising!**

- **Reliability in predictive value for pheromone-based fall monitoring, threshold determination, treatment decisions difficult to establish**
  - **Within and between orchard variation**

- **Distinct, short window of activity peaks of MPA & LCPA in prune orchards**
  - **Good (or bad!) for early treatment**
  - **Good for directing monitoring and management efforts**

- **Mating disruption requires more refinement**
  - **Or use attraction to pheromone-treated areas to employ other population reduction tactics (attract & kill, trap out, entomopathogen dissemination)**

- **…**

- **Funding**
  - **California Dried Plum Board**
  - **CDFA 2010 Specialty Crop Block Grant Program**
- **Rothamsted Research**
  - **LCPA & MPA pheromone IDs**
- **Pheromone chemicals**
  - **Kamlesh Chauhan, USDA-ARS**
- **Pheromone lures**
  - **AgriSense BCS Ltd.**
- **Grower cooperators**
  - **Button-Turkovich Ranches (Yolo Co. orchards)**
  - **Valley View Packing Company (Sutter Co. orchards)**
  - **Henry Ratay, Gregg Avilla, Mindy Nickler, Brendon Flynn, Tyler Christensen (Tehama Co. orchards)**
    - **Rick Buchner & Cyndi Gilles**

- **Symmes, EJ and FG Zalom. 2010, 2011, 2012. Dried Plum Research Report Database. http://ucanr.org/sites/driedplum/**