2013 Arthropod Pest Management Update – Focus on Pesticide Resistance Management

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Agriculture and Natural Resources

Outline – Avocado Pest Management

- Generally, we have to deal with only two key arthropod pests – avocado thrips and persea mite

- When chemical control is needed, we have relied heavily on the use of abamectin – used heavily starting in 1999 (**2013 will be Year 15**)

- We are extremely fortunate how long abamectin has lasted with only minimal symptoms of resistance

- Abamectin is inexpensive, it is overused, we now have quite effective alternatives, and if we don't start rotating in these new products, growers who overuse the product **are likely to lose abamectin to resistance**

- General observation – avocado thrips levels vary from year to year and from grove to grove - monitoring by a knowledgeable grower or PCA is needed to determine if treatments are needed
  - Weather late winter / spring influences thrips severity
  - Presence of leaf flushes and young fruit favor avocado thrips buildup
  - High levels of predators help slow the buildup of avocado thrips

Monitoring is KEY -- Avoid unnecessary sprays

Monitoring for Avocado Thrips in Spring

- Avocado thrips do best under moderately cool temperatures (68-76 °F)
- Under hot and dry conditions (> 90 °F), populations crash
- Smaller fruit are more susceptible to damage by avocado thrips
- As fruit become larger (1.5 inches or more in diameter) - large numbers of thrips are needed to cause significant levels of fruit scarring

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Context of Chemical Control Research with Avocado Pests

Avocado Thrips, *Scirtothrips perseae*

- Worldwide, few examples of good biological control of pestiferous thrips species (chemical intervention is often required)
  - *Scirtothrips citri* (Citrus thrips)
  - *Scirtothrips aurantii* (South African citrus thrips)
  - *Scirtothrips dorsalis* (Chili / yellow tea thrips)

IRAC Classification of Avocado Thrips Materials

Pesticide	Company	Pesticide Class	IRAC Class
Abamectin (Epi-Mek and generics)	Syngenta, generics	Avermectin, macrocyclic lactone	6
Entrust (2003), Delegate (2007)	Dow	Spinosyn, macrocyclic lactone	5
Sabadilla alkaloids (1997)	MGK (organic plans)	Two plant alkaloids	Unclassified
Danitol (Feb., 2010)	Valent	Pyrethroid	3A
Movento (May, 2011)	Bayer	Lipid biosynthesis inhibitor	23 (same as Envidor)

- **ABAMECTIN - Epi-Mek 0.15 EC, generics**

  - Abamectin is relatively slow in killing avocado thrips
  - Quite persistent in leaves, with control persisting 6-10 weeks or more (increases the potential for resistance)
    - Added oil or surfactant is critical to leaf penetration and persisence (1% oil enough)
  - Also effective in suppressing persea mite populations (supplemental label in 2005)
  - pH of water should be 5-9, better above 6

- **SPINETORAM – Delegate (25%) WG (Dow)**
  - Similar chemistry as spinosad (Success, Entrust) but is a synthetic product (no organic use)
  - Registered on avocados (Tropical Tree Fruits) late in 2007
  - Label specifies use of 4 - 7 oz/ acre; Addition of oil or adjuvent critical to uptake and persistence
  - 4 h REI, 1 day PHI
  - Toxic to bees, see label restrictions
  - More persistent and effective than spinosad (Success, Entrust)
  - Default 0.01 ppm MRL in Japan, expect 0.3 ppm (same as U.S.) late 2013 – if fruit not picked and export likely, probably should not use this material

SPINOSAD – Entrust 80%

- Not as effective as Delegate (less persistent)
- Main use is in organic blocks -- 1.25-3 oz Entrust 80% + an organically approved oil
- pH should be 6 or above (not too acidic)
- An organically approved oil alone is another option for avocado thrips control if ground application is feasible (main organic option for persea mite)

Fenpropathrin = Danitol 2.4 lb ai/ gal (Valent)

- Class 3A synthetic pyrethroid; not translaminar or systemic; added oil fine; Toxic to bees - see label restrictions
- Label lists 16 – 21.33 fl oz/ acre in 100 gpa or more by ground, 50 gpa or more by air
- Label limit of 1 application per season (resistance management); Used in CA for control of citrus thrips since the late 1990's – resistance is a problem in some areas
- 24 h REI, 7 d PHI (label lists 1 day PHI but added PPE requirement for pickers if before 7 days)
- MRL of 2.0 ppm for Japan (U.S. tolerance is 1.0 ppm so PHI should be fine with respect to fruit residues)

Spirotetramat = Movento 2 lb ai/ gal (Bayer)

- Avocado thrips 2ee label allows use on avocados – 10 fl oz per acre, 1 day PHI; label indicates use in 15 gpa or more by ground, 10 gpa or more by air (but consider coverage)
- Still learning how to best use this product – trials needed
- Group 23 pesticide (lipid biosynthesis inhibitor) – activity is highly systemic, slow, and somewhat persistent; addition of oil (1%) or surfactant (research) is critical to uptake
- Product is potentially toxic to honey bee larvae through residues in pollen and nectar but is not toxic to adult bees
  - No label limitations regarding application during bloom (during bloom or on flush likely best on avocado)
- MRL of 0.6 ppm for Japan (same as U.S. tolerance)

- **2009 Avocado Thrips Field Trials – Evaluation of Alternatives to Abamectin**

  - Agri-Mek (standard) vs. Delegate vs. Danitol (2 plots treated with each material per site)

  - 3 field trials in the south (Barcinas, Davis, Hand) and 3 in the north (Holden, Machiltt, Roberts)

  - 2 pre-bloom treatments by air (Davis, Hand), 2 treatments by air at 2/3 leaf expansion (Machlitt, Roberts), two treatments by ground (Barcinas, Holden)

  - Weekly thrips counts by the PCA cooperator; fruit scar counts were taken by Morse lab personnel (Robinson, Urena)

Treatments evaluated in Spring 2009 avocado thrips field trials with pest control advisor cooperators

Treatment	Rates (top of label rates)
Agri-Mek 0.15 EC + oil	20 fl oz/a + 1%
Delegate WG + oil	7 oz/a + 1%
Danitol 2.4 EC + oil	21.33 fl oz/a + 1%
Control (some sites)	Untreated

Each of the 6 field sites were divided into plots large enough to buffer the center monitoring area from adjacent treatments (2 plots for each treatment per site).

The PCA decided on the treatment timing, gallonage, and any additives (but all 3 treatments had the same gpa and additives).

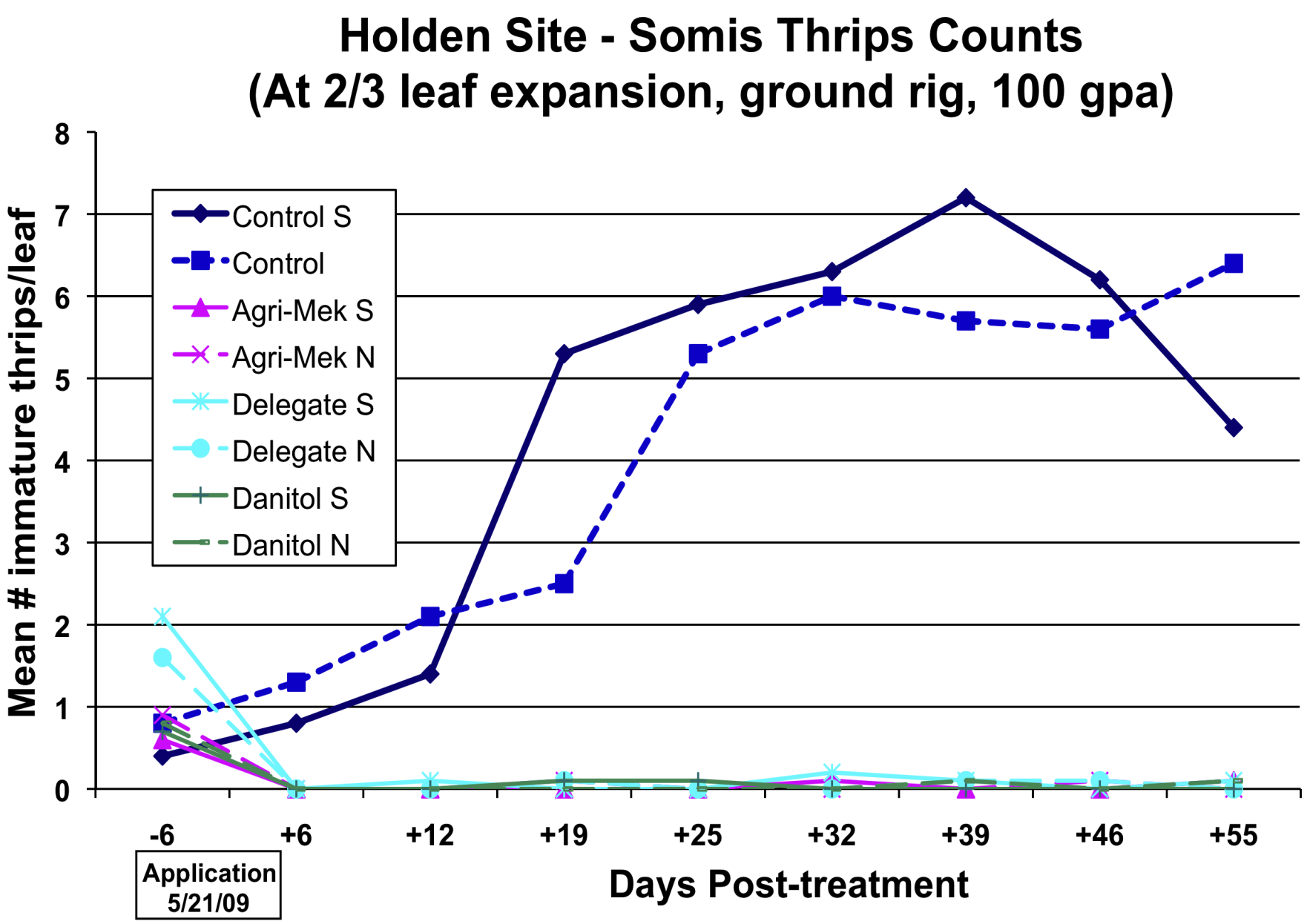
David Holden, 2009 Avocado Thrips Trial, Somis, CA

Applications at 2/3 leaf expansion on 21 May 2009

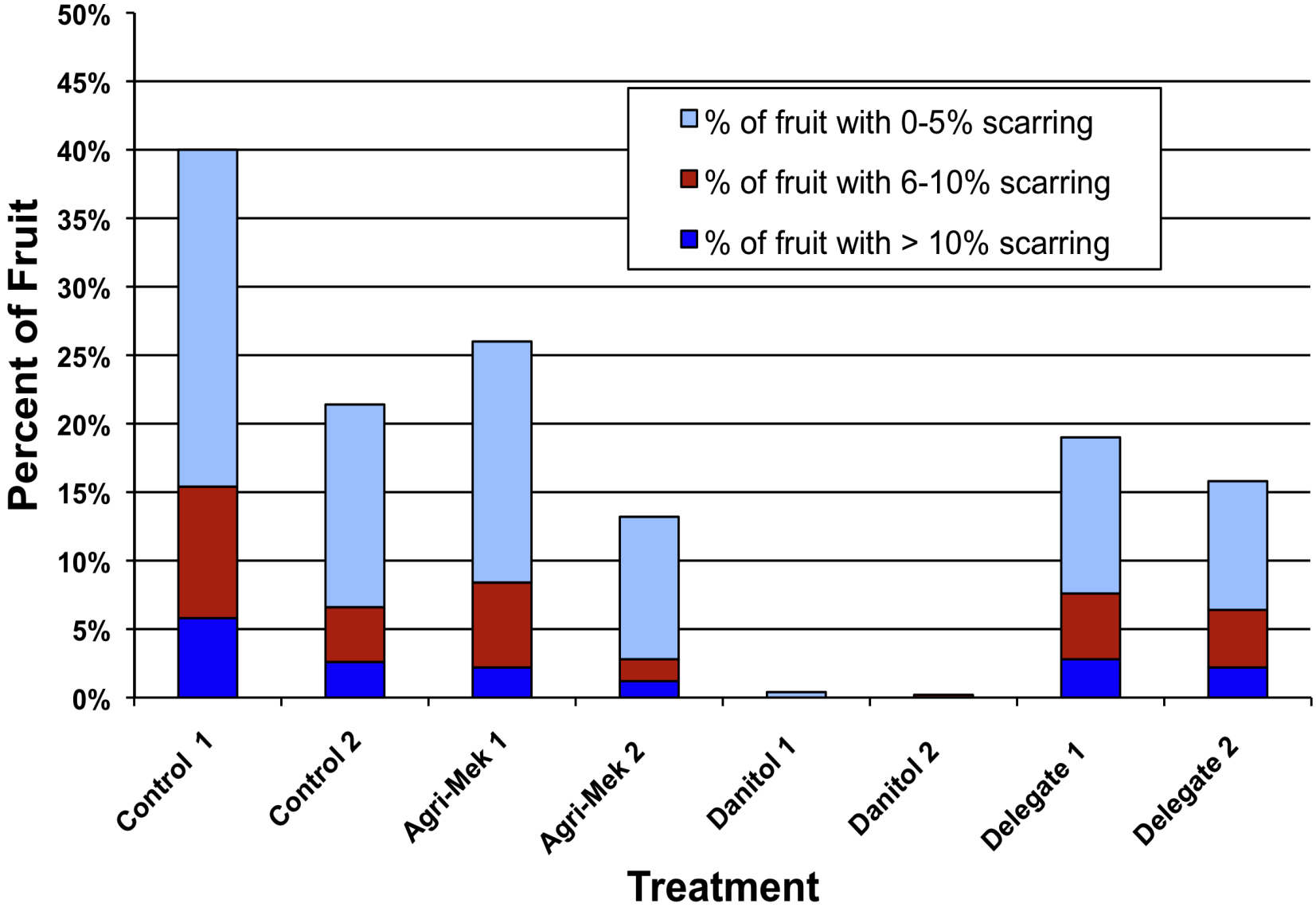
100 gpa by ground spray rig

2 large plots per treatment

Scar counts by Morse lab personnel 24 Sept. 2009, 500 fruit per plot (1000/treatment)


Holden Site - Somis Thrips Counts
(At 2/3 leaf expansion, ground rig, 100 gpa)
Mean # immature thrips/leaf
0
1
2
3
4
5
6
7
8
Control S
Control
Agri-Mek S
Agri-Mek N
Delegate S
Delegate N
Danitol S
Danitol N
-6
+6
+12
+19
+25
+32
+39
+46
+55
Application 5/21/09
Days Post-treatment

Holden Site- Somis, CA



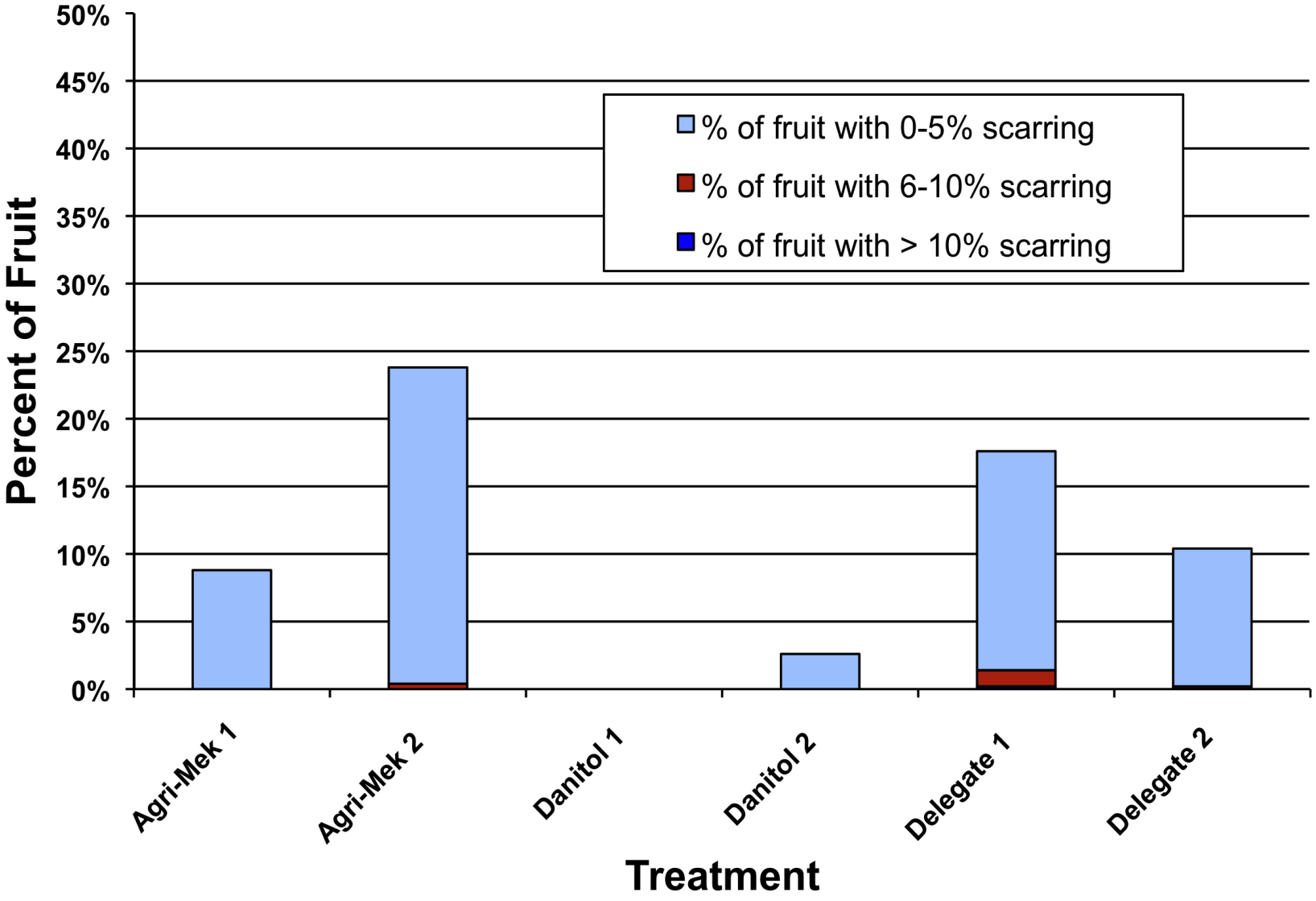
Tom Roberts, 2009 Avocado Thrips Trial, Somis, CA

Helicopter application at 50 gpa, 4 June 2009

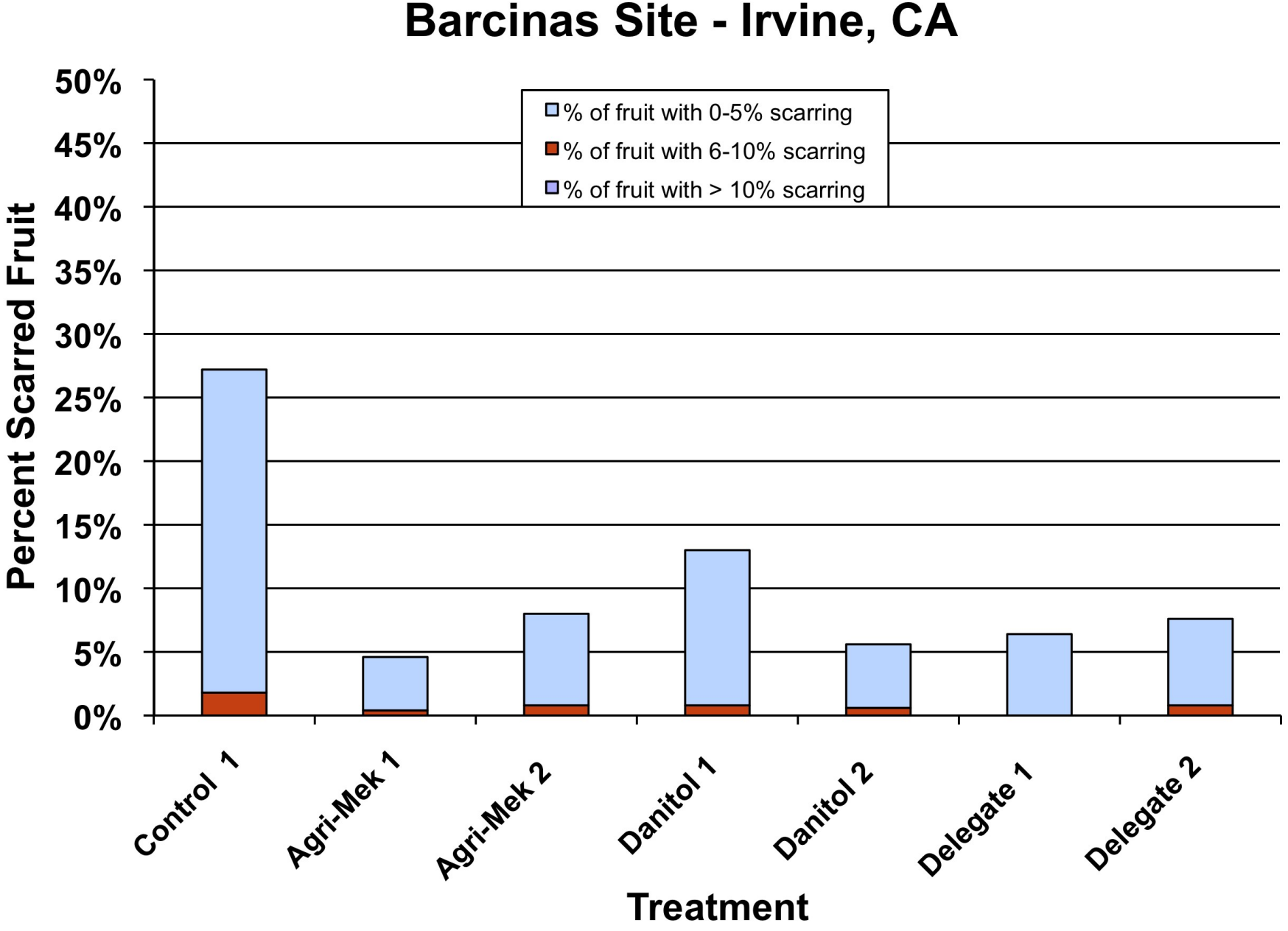
Two 1.5 acre plots per treatment

Scar counts by Morse lab personnel 22 Oct. 2009, 500 fruit per plot (1,000 per treatment)

Roberts Site- Somis, CA



Barcinas 2009 Avocado Thrips Trial, Irvine, CA
Speed sprayer application, 100 gpa, 6-23-09 after fruit set

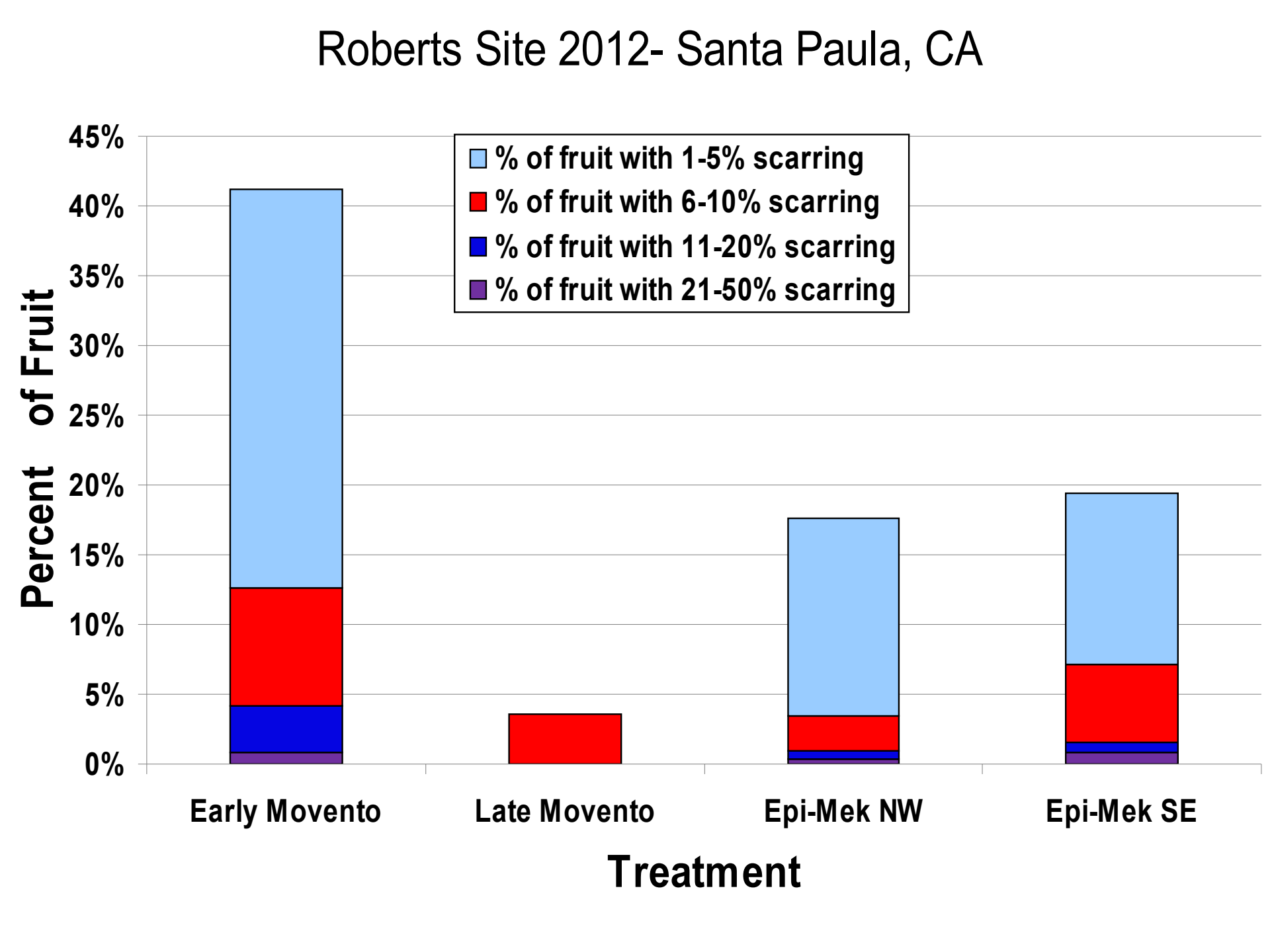

Barcinas Site - Irvine, CA
% of fruit with 0-5% scarring
% of fruit with 6-10% scarring
% of fruit with > 10% scarring
Percent Scarred Fruit
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Control 1
Agri-Mek 1
Agri-Mek 2
Danitol 1
Danitol 2
Delegate 1
Delegate 2
Treatment

Summary – Six 2009 Avocado Thrips Field Trials

- 2009 appeared to be a relatively light thrips year at most locations
- Agri-Mek appeared to be the most effective pre-bloom material at one site, Danitol at the other
- Danitol applied at 2/3 leaf expansion was extremely effective in reducing thrips scarring
- Delegate applied at 2/3 leaf expansion appeared as effective as Agri-Mek, if not more so (beginnings of loss of susceptibility to Agri-Mek at some sites?)
- We really appreciate the excellent PCA cooperation

Speed Sprayer Avocado Thrips Field Trial in Santa Paula, 2012

- PCA Tom Roberts (Integrated Consulting Entomology)
- Mature, > 20 year old Hass avocado trees
- Movento early – 8.5 rows (5 acres NE) treated on May 2 (10 oz Movento, 1.7% NR-415 oil, 240 gpa by speed sprayer) – 50% cauliflower, 50% candles / expanded bloom with flowers
- Movento late – 5 acres SW treated June 1 (same Movento rate) - 95% candles, 5% BB set fruit in jackets
- Abamectin standard - June 1 (10 oz Epi-Mek, 1.7% NR-415 oil)
- Number of immature avocado thrips, adults, *Euseius* predaceous mites, and predaceous thrips assessed on 5 dates, 20 leaves per plot
- Fruit scarring rate by Morse lab personnel on 500 fruit per plot


Roberts Site 2012- Santa Paula, CA
% of fruit with 1-5% scarring
% of fruit with 6-10% scarring
% of fruit with 11-20% scarring
% of fruit with 21-50% scarring
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Percent of Fruit
Early Movento
Late Movento
Epi-Mek NW
Epi-Mek SE
Treatment

3-13 Survey by Tim Spann – Cost of Avocado Thrips Materials

Material	High label rate	Cost per acre#
Epi-Mek	20 fl oz/a	$25.37
Danitol	21.33 fl oz/a	$35.18
Delegate	7 oz/a	$75.36
Movento	10 fl oz/a	$96.83

0.5 gallon per acre NR-415 oil ($10.75 per gallon) was added to the cost of all materials except Danitol (needed for uptake with the others). Date are the mean for 4 suppliers, 2 in the north and 2 in the south (6 suppliers were contacted).

Danitol at 16 fl oz/a ($25.76/a) would be of similar price as Epi-Mek

Try Delegate at 4 oz/a ($45.36/a) (low label rate)

Why is Abamectin Overused?

- Abamectin is now extremely inexpensive (generic competition)
  - Spring avocado thrips treatment often negate the need for a summer/fall persea mite treatment (true more in the "north" than the "south")
- We predict this will not be true for very much longer if we continue to overuse abamectin
- Growers and PCAs are very comfortable with abamectin but not nearly as familiar with the registered alternatives
- It is clear we ALREADY have low level abamectin resistance
  - Several PCAs report less persistent control of avocado thrips or persea mite with abamectin compared with previous years

How Do We Manage Abamectin Resistance?

1. Don't remain in denial / fail to act – abamectin resistance is already present at low levels and will get worse if use patterns don't change

2. WE MUST rotate use of other effective products for avocado thrips and persea mite control, despite them not being as inexpensive as abamectin – learn their strengths and weaknesses now

3. Use abamectin only once every 2-3 years at a particular site

4. At sites where abamectin has been used substantially in the past, use other products NOW

5. Research – New proposal funded by the CAC started 11-1-12 to develop a sensitive biochemical / molecular method to evaluate abamectin resistance in the field – we need a better picture of how bad the situation is and where it is the worst

Other Issues -- Avocado Resistance Management

- Avocado thrips and persea mite are affected by pesticides applied for OTHER pests – consider all pesticides applied over the year
  - Delegate is quite effective against avocado thrips (not persea mite)
  - Movento is registered and is effective against both pests but plant uptake (and conversion to the active enol) is best with bloom applications (not prohibited on the label) – we are still learning how to use this material most effectively
  - Danitol effective against both species (high resistance potential)
- Best advice:
  - Rotate among Envidor and Zeal (FujiMite soon) for persea mite control – evaluate the strengths / weaknesses of each
  - Rotate Delegate, Movento, and Danitol for avocado thrips control
  - Be extremely careful with the frequency of Danitol and abamectin use (both once every 3 years maximum)

Consequences of Abamectin Resistance

- Avocado thrips resistance may spread from grove to grove but largely will be a function of past abamectin use in a particular block – thus, a grower reaps what they sow

- Resistance with abamectin (more so than other materials) likely to be a one-way street – once it appears at moderate to high levels (clear lack of field control), reversion slow if at all

- Persea mite resistance probably even more localized

- Abamectin resistance would then shift resistance pressure to the next most popular chemicals

- Each material lost to resistance can take out that entire class of chemistry for that pest

- It would be wise to reserve abamectin (and Danitol) use for high pest pressure situations

Avocado persea mite

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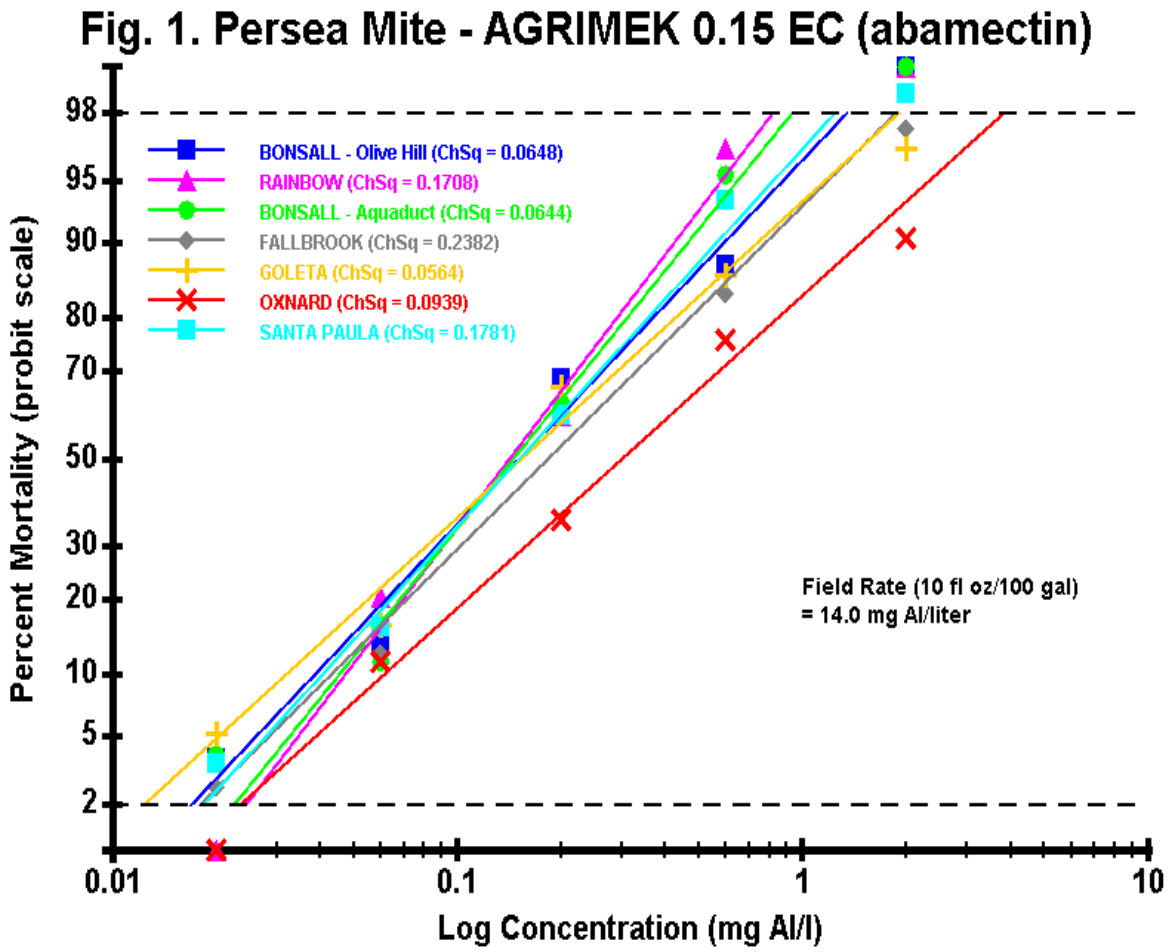
- Many groves do not require a persea mite treatment in a particular year
  - Monitor persea mites on mature leaves
  - In some groves, populations appear cyclical -- high for 2 years or so and then lower
  - Leaf drop tolerance for persea mite feeding (increases when > 7.5-10 % of the leaf surface is damaged) (Hoddle et al.)

- Persea mite also has the potential to develop abamectin resistance
  - Oxnard data from August 2003 after 7 abamectin applications (both spring and fall 2000, 2001, 2002, spring of 2003)



3 chemistries different from abamectin are available (1 more soon)

IRAC Classification of Persea Mite Materials

Miticide (Avo reg. date)	Company	Pesticide Class	IRAC Class
Abamectin (Feb., 1999)	Syngenta, generics	Avermectins, macrocyclic lactone	6
Danitol (Feb., 2010)	Valent	Pyrethroid	3
Envidor (Apr., 2010)	Bayer	Lipid biosynthesis inhibitor	Class 23
Zeal (May, 2012)	Valent	Mite growth inhibitor	Class 10B
FujiMite (**not registered**; Mar.-June 2013)	Nichino	Mitochondrial electron transport inhibitor	Class 21

Spirodiclofen = Envidor 2 SC (Bayer)

- Class 23 chemistry (same class as Movento) (inhibitor of lipid biosynthesis) – may be more effective against immature mites than adults (impacts on egg production?)
- Not translaminar or systemic (error in CAS yearbook thrips article; corrected in this year's CAS persea mite article)
- Addition of oil may reduce efficacy by ground, probably not by air; Is runoff the mechanism by ground?
- Label indicates use of 18-20 fl oz/a; min of 50 gpa by air
- 12 h REI, 2 d PHI, MRL of 2 ppm for Japan (U.S. tolerance 1.0 ppm so PHI should be fine with respect to fruit residues)

Etoxazole = Zeal 72% (Valent)

- Class 10 B (mite growth inhibitor) – so limited impacts on adults ?
- Is somewhat translaminar (error in thrips CAS yearbook article) – likely should add oil or surfactant (not a sticker)
- Label indicates use of 2-3 oz/a in min of 20 gpa by air
- 12 h REI, 1 d PHI
- Default MRL of 0.01 ppm for Japan (U.S. tolerance is 0.2 – so contact Valent rep about PHI to use if fruit are likely to be exported; 1 d PHI for export very likely not enough to meet Japanese MRL)

Fenpyroximate = FujiMite 5EC (0.4 lbs ai/gal) (Nichino)

- Expected CA registration on avocados Mar.-June, 2013
- Class 21 mitochondrial complex I electron transport inhibitor (METI)
- Know of no evidence that oil improves efficacy; contact material, not translaminar or systemic
- Draft label lists 2 pts/a in a minimum of 50 gpa by air, 95 gpa by ground; 24 h REI, 14 d PHI
- Japanese default tolerance of 0.02 ppm (U.S. PHI based on a tolerance of 0.2 ppm – contact Nichino rep for advice)

Summary – Persea Mite Resistance Management

- Abamectin resistance is present at low levels and will make this material ineffective if we do not rotate pesticides
- Abamectin is too effective to lose to resistance
- Losing abamectin to resistance would put added pressure on other products and could result in our progressively losing other products to resistance
- Start learning what the strengths and weaknesses of new products are by trying them under different scenarios
- Start using abamectin once every 3 years maximum
- Also remember the high potential for Danitol resistance, and that Envidor and Movento are in the same class of chemistry

At least 90% of commercial avocado acreage in California is on steep hillsides where helicopter application is the only practical means of applying non-systemic pesticides

Helicopter Spray Coverage

- Using 100 or 75 gpa is more expensive than 50 gpa by air (ca. $1.25/gallon)
  - Growers should consider using better spray coverage depending on tree size and density, **pest population pressure**, levels of natural enemies, **expected crop value**, etc.
- Control of persea mite (or avocado thrips) on large, dense trees is going to be quite a bit better at 100 gpa vs. 75 gpa vs. 50 gpa
- Following data are from a Fall 2011 persea mite spray trial run by Matt Hand (Southern California Entomology) and Joseph Morse
  - Large, dense trees (20 – 30 feet in height)
  - 4 nearby groves selected: Envidor at 50 vs. 100 gpa; abamectin at 50 vs. 100 gpa
  - Results with Envidor similar to those with abamectin
  - 100 gpa much, much more effective than 50 gpa (both products)

Fig. 10. Agri-Mek 0.7 SC at 4.25 fl oz/acre + 4% Omni 6E Oil applied by helicopter at 50 vs. 100 gpa

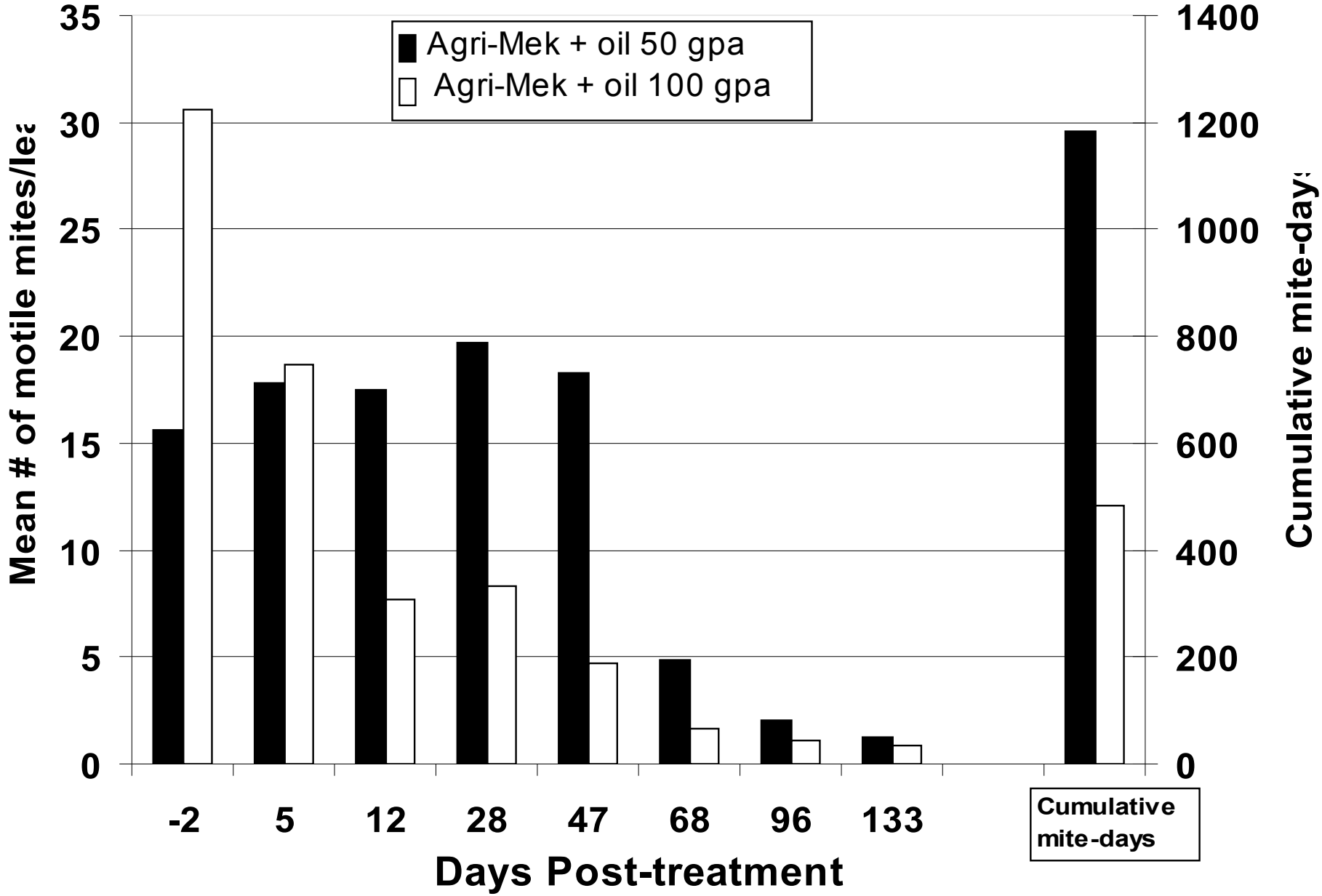
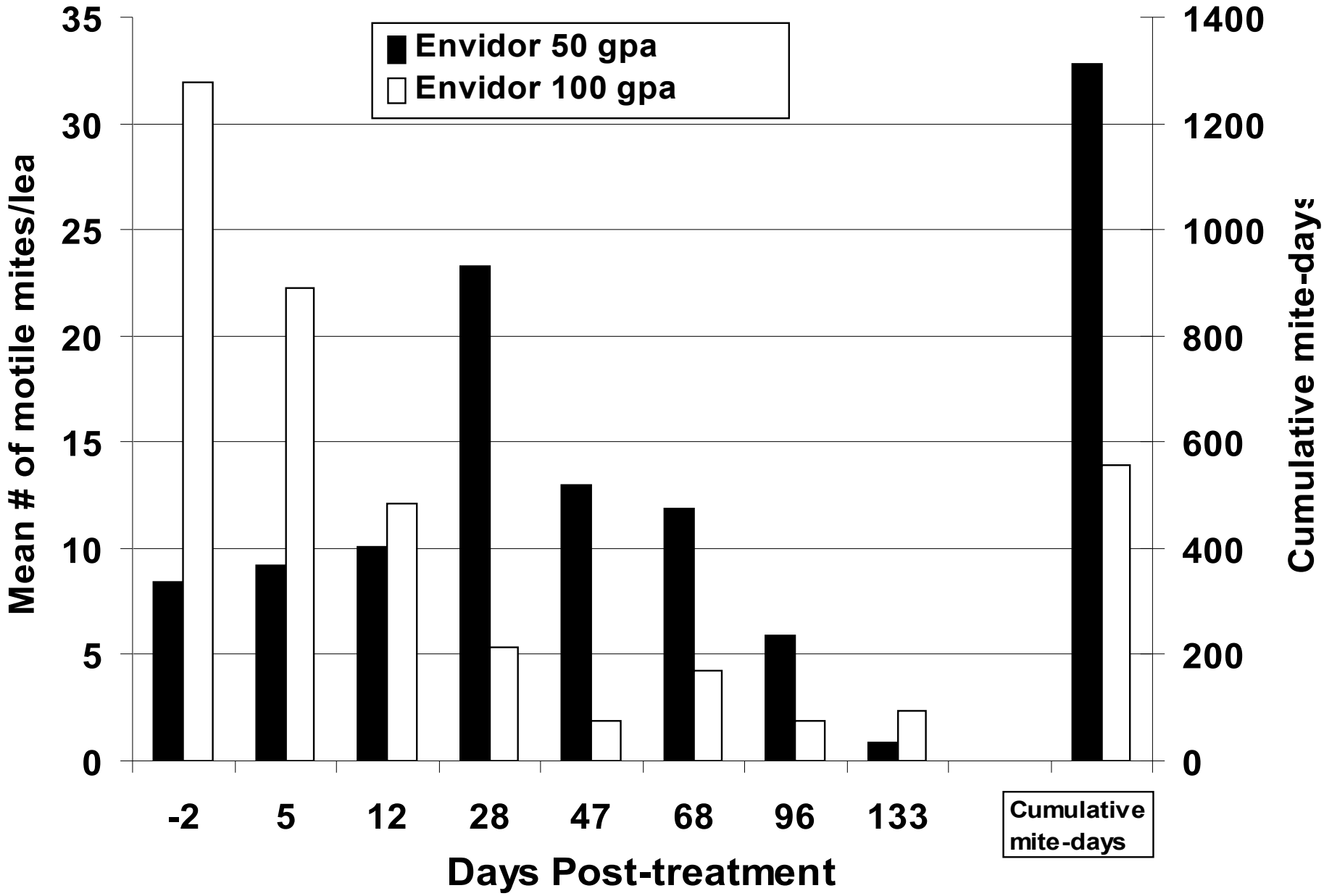


Fig. 11. Envidor 2SC at 20 fl oz/acre (no oil) applied by helicopter at 50 vs. 100 gpa



3-13 Survey by Tim Spann – Cost of Persea Mite Materials

Material	High label rate	Cost per acre#
Epi-Mek	20 fl oz/a	$25.37
Danitol	21.33 fl oz/a	$35.18
Envidor	20 fl oz/a	$52.37
Zeal	3 oz/a	$73.43

0.5 gallon per acre NR-415 oil ($10.75 per gallon) was added to the cost of Epi-Mek and Zeal (needed for translaminar movement) but not for Danitol and Envidor. Date are the mean for 4 suppliers, 2 in the north and 2 in the south (6 were contacted).

Economics of Helicopter Gallonage

100 gpa abamectin plots had 30.6 motiles per leaf pre-treatment vs. 15.6 in 50 gpa plots (1.96 X)

Mite-days at 100 gpa were 40.8% of those at 50 gpa

100 gpa Envidor plots had 32.0 vs. 8.4 in 50 gpa (3.81 X)

Mite-days at 100 gpa were 42.3% of those at 50 gpa

Costs based on Tim Spann's 3-13 survey of helicopter prices (2 co.)

Mean per acre cost	50 gpa	75 gpa	100 gpa
Helicopter alone ($1.20 - $1.25/gal)	$62	$93 (+$31)	$123 (+$61)
+ $30/a material	$92	$123	$153
+ $50/a material	$112	$143	$173

Future Research Priorities on Avocados

- Development of molecular/ biochemical methods that are more sensitive and useful in evaluating the status of abamectin resistance
  - Use these to clearly document the variability in abamectin tolerance
- Optimize the timing and surfactants used with Movento applications; evaluate the impact of avocado thrips treatments on reducing persea mite levels –are summer / fall treatments needed?
- Continue to evaluate new products with different chemistries and facilitate their movement towards registration
  - Bexar (21A) appears promising against avocado thrips
  - Sivanto also (4C) - extremely safe to honey bees, will be labeled on citrus for use during bloom

Acknowledgments and Thanks!

Grower cooperator field trials:

- Grower cooperators

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- Bayer, Dow, Nichino, Syngenta, and Valent

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Powerpoint graphs: Lindsay Robinson

Funding: California Avocado Commission

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Discussion: Resistance Management - Economics

- Abamectin is inexpensive ($25/a) but if we lose it to resistance, it doesn't do us much good
- Wouldn't it be better to have abamectin for use every 3 years rather than not at all? (forced to use solely expensive alternatives – then lose the least expensive of those)
- Danitol at 16 fl oz/a ($26/a) is a similar price as abamectin + oil – we ought to see what this material can do for us
- Envidor (no MRL issues) $52/a but if a persea mite treatment is needed – use it instead of abamectin (try 10 or 15 fl oz/a - $26 or $39/a)
- Movento might be tried at 25 gpa by air (highly systemic) – cost of $125/a vs. abamectin at $88/a if 50 gpa
- Try Delegate at 4 oz/a + oil ($45/a) (MRL late 2013)