Use of Chemical Ecology for Detection and Management of Insect Pests

Jocelyn Millar
University of California, Riverside

Asian citrus psyllid
Vine mealybug
Applications for Insect Pheromones:

• Sampling and Monitoring
  – Presence
  – Flight phenology, timing
  – Damage thresholds
  – Quarantine

• Control strategies
  – Mating disruption
  – Attract and kill
  – Mass trapping
Pheromone-baited traps

Bottom line: we appear to have tremendous power to manipulate insect populations
Need for new and “better” pheromones:

• Increasing rate of introduction of new pests
  – Red palm weevil
  – Light brown apple moth
  – European grapevine moth

• Increasing importance of “old” pests
  – Stink bugs, other bugs
  – Navel orangeworm
  – Mealybugs
Increasing importance of old pests:

- Fundamental changes in crop protection
  - Transgenic plants
  - Pheromone-based mating disruption
- Loss of insecticide registrations
- New diseases transmitted by insects
- Now, more than ever, need for Integration of pest management practices.
  - Systems approach
Other types of attractants:

• Plant-derived compounds
  – Plant odors alone (pear ester, codling moth)
  – Plant odors enhance pheromones

• Food-based odors
  – Medfly and other fruit flies
  – Noctuid moths (Peter Landolt)
Which types of insects can we detect and manage most effectively with chemical ecology?

• The $64$ question:
Some good characteristics:

- Short adult lifetime; nonfeeding adults
- Limited, defined host range
- Limited time window/number of generations
- Crop characteristics
  - High value/limited acreage
  - Canopy/foliage height, shape, characteristics
- Well defined pheromone chemistry
  - Stability of the pheromone
- Strong activity of the pheromone
- Economics
California examples of effective chemical ecology tools:

• Pink bollworm
• Oriental fruit moth
• European grapevine moth
• Citrus leafminer
• Vine mealybug
• Some fruit flies (Mexfly, melon fly)
Recent example of successful use of pheromones for a native insect

Mating disruption of western poplar clearwing moth

- Long generation time (2 years)
- Short activity window
- Well defined acreage (plantations)
- Well-defined chemistry
  - Long-lasting pheromone
• The other $64$ question:

Which types of insects are we less likely to be able to detect and manage effectively with chemical ecology?
Insects that are NOT good candidates for development of chemical ecology tools:

- No evidence for use of powerful pheromones
- Long adult lifetime with feeding adults
- Broad host range
- Multiple generations
- Crop characteristics
  - Low value/large acreage
  - Canopy/foliage height, shape, characteristics
- “Bad” pheromone chemistry
  - Unstable
  - Expensive
Possible examples of insects with less likely prospects for **effective** pheromones:

- Glassy-winged sharpshooter
- Asian citrus psyllid
- Tea shot-hole borer
- Gold spotted oak borer
- Diaprepes root weevil
Example of a difficult species:

Carob moth in dates

- Pheromones very unstable
  - Use a mimic
- Multiple generations, almost year-round
- Crop characteristics
  - Little foliage to hold pheromone in the canopy
- Environmental characteristics
  - Wind, heat, strong sunlight
How can we be most effective in the 21st century?

Development of pheromones for detection of invasive pests, worldwide.

• Detection
• Demarcate distribution as early as possible
• Eradication

Successful models:
- Japanese beetle
- Pink bollworm
- Mediterranean fruit fly
Recent examples of pheromone projects from UCR:

Mealybugs infesting grapes and other crops:

Vine mealybug

Obscure mealybug

Longtailed mealybug

Grape mealybug
Mealybug honeydew, wax, and associated sooty mold on grapes.

Photo: Larry L. Strand/ UCIPM
Leafroll viruses transmitted by mealybugs
Male mealybug, ~ 1 mm long

Photo: Rebeccah Waterworth
Gas chromatograph

Injector → GC detector

humidified air stream

30 m column in oven

EAD

Amplifier

GC Recorder output

Time

EAD Recorder output (EAG)
Coupled gas chromatography-electroantennogram analysis of pheromone extracts

Gold wire in electrodes is 0.2 mm diameter!
Top trace: GC analysis
Bottom, inverted trace, antennal response
Trapping male mealybugs
2. Mealybug control with pheromones: Mating disruption of vine mealybug

- Commercialized in 2008
  - 35,000 acres treated in California in 2011
- Works best at low initial population densities
- Formulated as discrete retrievable dispensers.
Lure longevity in the field

Treatment: $F_{5, 19} = 3.26, P = 0.0272$

Longtailed mealybug

Average count of mealybugs/block

Age of Lures (weeks)

Control 0 1 2 4 8 12

abc ab c d
Using mixtures of pheromones to monitor several species in one trap

Result: No species are strongly inhibited by the pheromones of other species
Correlation between pheromone traps and manual sampling

Result: Good correlation in nursery crops, for longtailed mealybug
Scale insects on Mexican avocados entering California

- From February 2007, fresh Mexican avocados shipped into California year-round

- 7 exotic scale spp. found, 2 new to science

- 92% of boxes had live scales; ~50 million live scales entered CA 9/07-4/08

First target of pheromone identification: *Acutaspis albopicta*
Male *Acutaspis*
Analysis of pheromone extracts by GC-EAD

- GC trace
- Antennal response
Preliminary bioassay results

Males highly attracted to synthetic pheromone
Pheromone traps for detection of *Acutaspis*

- Detection of invasions, new infestations at earliest possible moment.
- Determine range, rate of spread, key tool for monitoring success of eradication
- Provide a method of monitoring and certifying Mexican orchards as being free of this scale
With Mark and Christina Hoddle: Identify pheromone of Red Palm Weevil found in California

Photo CISR-UCR

Photo John Kabashima
Key questions:

1. Which species of Red Palm Weevil do we have in California?
   → *R. ferrugineous*?
   → *R. vulneratus*?
   → Another, undescribed species?

2. What is its pheromone?
   1. Are there other important components to the attractant in addition to the pheromone?
Portable system for collecting pheromone from multiple samples in Indonesia
Mark, inserting pheromone collection trap
Christina, collecting pheromone in Sumatra
Gas chromatography analyses of extracts of males, females, and sugar cane control

1: 4-methylnonan-5-one
2: 4-methylnonan-5-ol
Bottom line:

- Pheromone appears to consist of the same components as for *R. ferrugineous*
- Host plant co-attractants are critically important for good attraction
  - Fresh cut palm logs and fermenting palm hearts
Pheromone of a native insect, *Prionus californicus*
Jim Barbour, Idaho
Why *Prionus californicus*???

→ A major insect pest of hops in US
STATS ON TAP

Annual Beer Consumption by State

Montana’s 706,064 21+ residents consumed the largest amount of alcohol in the U.S. at 43.9 gallons per capita.

Utah’s 1,737,907 21+ residents consumed the least amount of alcohol in the U.S. at 30.8 gallons per capita.

Reno, NV has the highest rate of alcoholism in the U.S.

Under Kentucky law, a person is considered sober until he or she “cannot hold on to the ground.”

QUICK BEER FACTS:
- In the U.S., a barrel of beer contains 31 gallons.
- Americans drink more beer on July 4th than any other day of the year.
- Beer is the most popular alcoholic beverage in America and accounts for about 85% of the volume of alcoholic beverages sold in the United States each year.

Sources: Beer Institute: Shipment of Malt Beverages and Per Capita Consumption By State 2008 (Preliminary); Comedy Zone Beer Trivia; BeerFacts.net
**P. californicus** life history

- **Adults**
  - Emerge in late June-July
  - Exhibit traits associated with pheromone production
    - Sexual dimorphism in antenna
    - Sedentary females
    - Active nocturnally
    - Adults do not feed
      - Short lived (2-4 weeks)
      - Must locate mates quickly
    - Female calling behavior
Testing traps:
BONUS: Pheromone structure is highly conserved:

Georgia:
*Prionus laticollis*
*Prionus imbricornis*

Arizona:
*Prionus aztecus*
*Prionus linsleyi*

Western US:
*Prionus lecontei*
*Prionus integer*

Norwich, UK:
*Prionus coriarus*
Mass trapping results

![Graph showing the mean (± SE) number of males captured at different spacings of traps (18 m and 36 m). The graph compares pheromone-treated traps (dark gray) and control traps (light gray).]

- 18 m spacing: 88% reduction in males reaching sentinel female
- 36 m spacing: 75% reduction in males reaching sentinel female
Mating disruption results

Mean (± SE) no. of males captured

Spacing of traps (m)
**Bottom line:**

*Prionus* pheromone is highly effective for:
- Monitoring
- Trapping
- Possibly mating disruption

Control strategy chosen will depend on a combination of economics and efficacy.
Summary

• Chemical ecology tools can be crucial components of IPM
• Not all insects have chemical ecology that can be exploited for IPM
• Chemical ecology tools can be useful for both native and exotic pest detection and management
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- CDFA

Prionus californicus:
- Western regional IPM grant

Invasive scale species:
- California Avocado Commission
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