

# How to Produce Worm-free Apples



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# Wormy Apples



**In Ohio orchards:**

- **Some control failures starting 2002**
- **Main species: codling moth**

# Codling moth: why problems?

- **Biological reasons:**
  - **Good overwintering survival**
  - **Prolonged moth emergence**
  - **Overlapping generations**
  - **3<sup>rd</sup> generation in late summer**
  - **Resistance to organophosphates???**
  - **Other species mixed in?**
- **Management reasons**



# Codling moth: why problems?



- **Biological reasons**
- **Management reasons:**
  - **Skipped cover sprays**
  - **No sprays in late summer**
  - **Low spray volume**
  - **Poor coverage**
  - **Improper alternate-row middle sprays**

# Wormy Apples

- Main species:
  - **Codling moth**
- Other species:
  - **Lesser appleworm** >>>  
(same # generations)
  - **Oriental fruit moth**  
(3-5 generations)

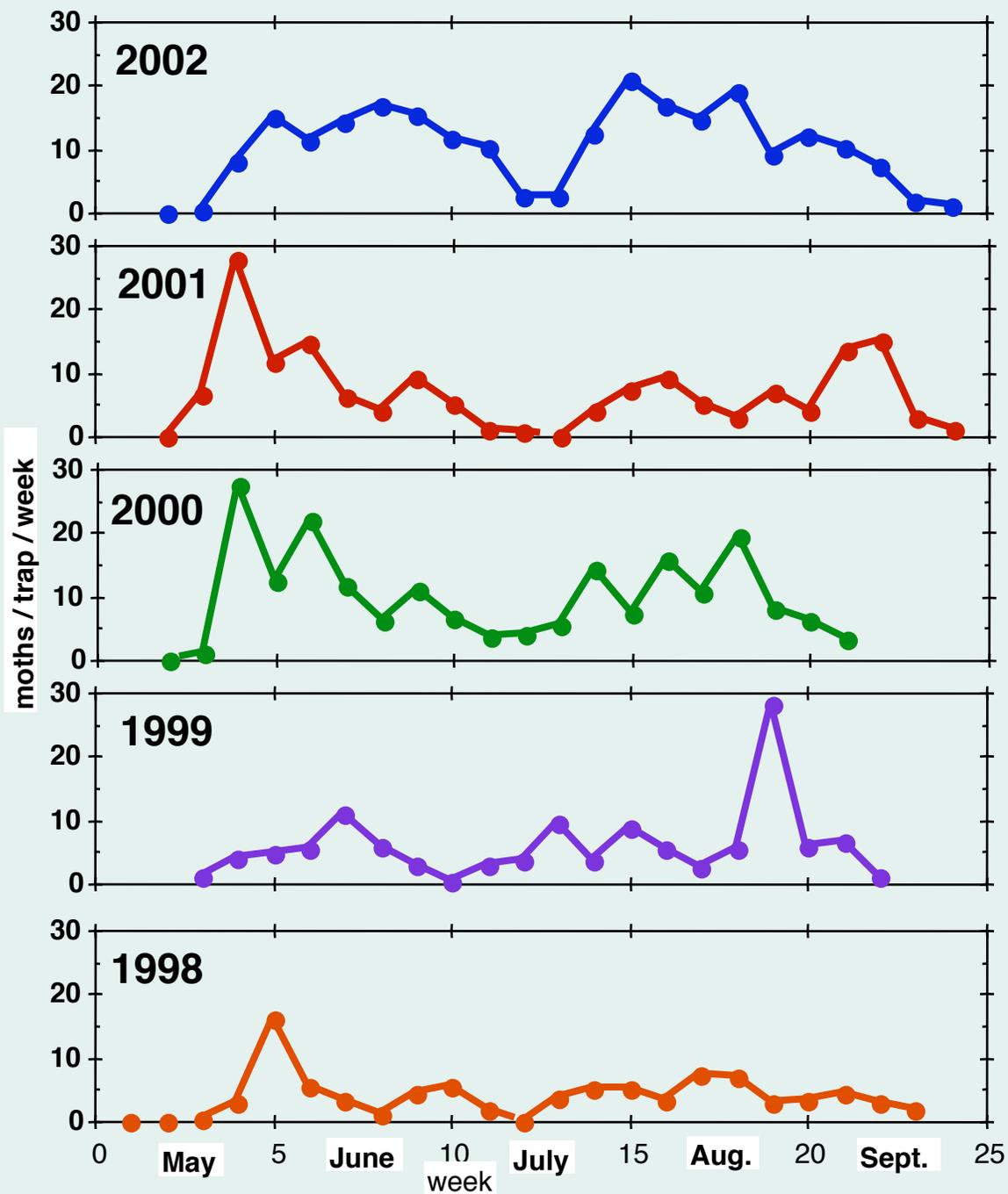


# Codling moth: example of suspected resistance problem

- Research block at Columbus, 2002
- Insecticide sprays:
  - Imidan 3 lb/A at PF, 1C
  - Imidan 2.1 lb/A at 2C, 3C, 4C, (skip 5C), 6C, 7C, 8C
- Damage by codling moth at harvest:
  - 31% of fruit in treated plots
  - 44% of fruit in untreated plots

**Codling moth:  
Mean of 3  
pheromone traps in  
apple orchard at  
Columbus, Ohio**

**Note higher  
numbers each year**



# **Common trend in orchards with worm problem**

- **High trap counts for ~2 years but not much damage in packout**
- **Then high damage in packout**

# Codling moth management



## Factors affecting insecticide efficacy:

- **Timing**
- **Choice of materials**
- **Spray volume**

# Timing for codling moth

- **Use 2 sprays per generation**
- **Apply first spray when eggs begin to hatch**
- **Second spray 14 days later**

# Predicting Codling Moth Egg Hatch



*adult (moth)*



*egg*



*larva*

- Eggs begin to hatch:
  - About 2 to 3 weeks after moths begin to fly
  - More exactly, 250 degree-days (base 50F) after moths begin to fly
- Rule developed ~30 years ago (Mich. '76)

# Traps for Codling Moth

- Trap choices:
  - **Sticky trap**
  - **Multi-Pher (bucket) trap**
- Use pheromone lure
- 'Biofix' is the date that flight begins



# Degree-Days (DD)

- Common way to summarize development time
- Can be used to predict insect activity
- For one day,  $DD = (\text{average temp}) - (\text{threshold temp})$
- Then accumulate DD over consecutive days

# Degree-Days Example

(degrees Fahrenheit)

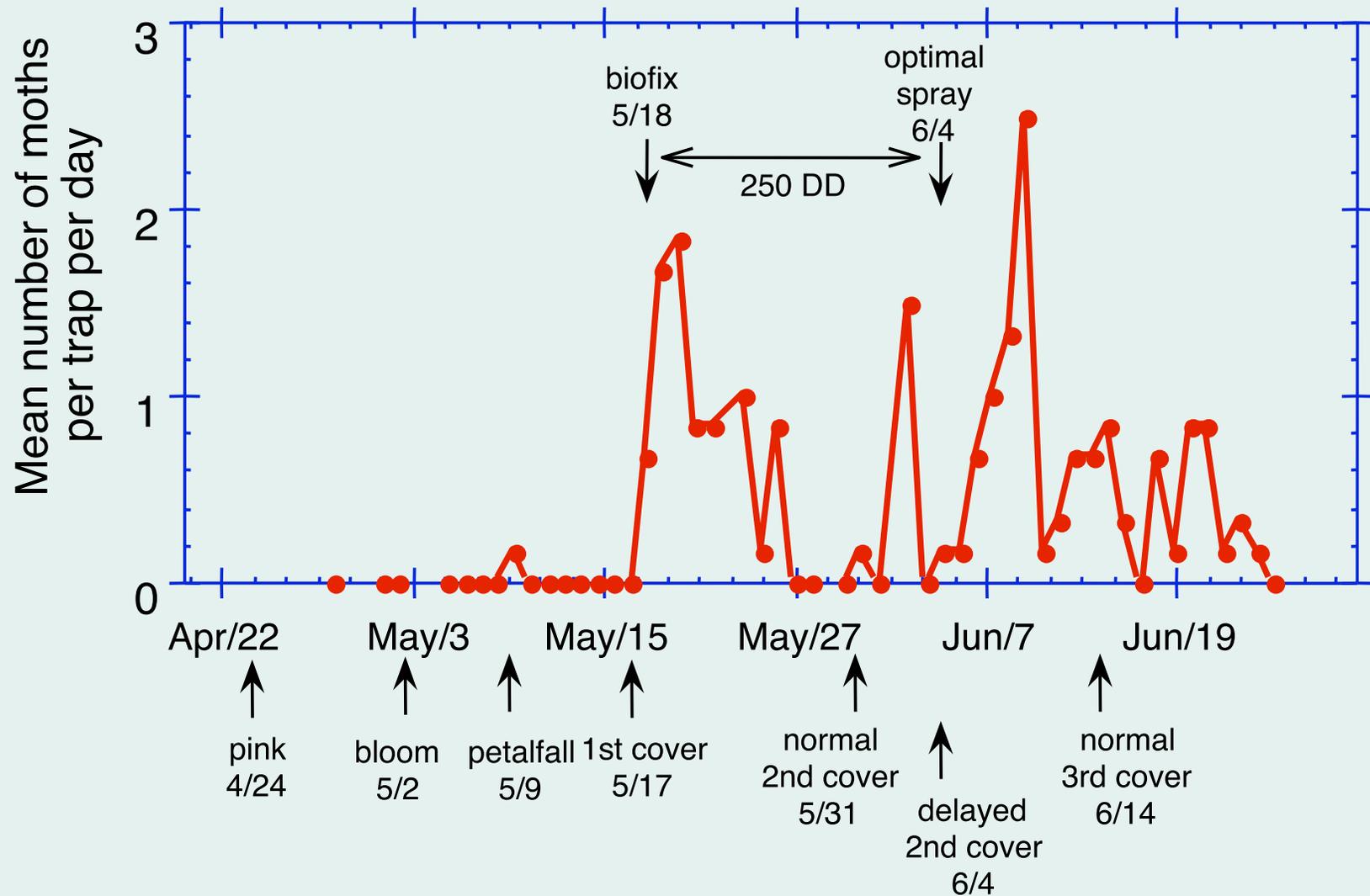
<i>Day</i>	<i>T max</i>	<i>T min</i>	<i>T avg</i>	<i>DD 50</i>	<i>DD Cumulative</i>
<b>1</b>	<b>62</b>	<b>52</b>	<b>57</b>	<b>7</b>	<b>7</b>
<b>2</b>	<b>66</b>	<b>50</b>	<b>58</b>	<b>8</b>	<b>15</b>
<b>3</b>	<b>58</b>	<b>54</b>	<b>56</b>	<b>6</b>	<b>21</b>
<b>4</b>	<b>70</b>	<b>56</b>	<b>63</b>	<b>13</b>	<b>34</b>

# Timing for codling moth

- **1<sup>st</sup> spray:**
  - **250 degree-days after biofix (for most products)**
- **2<sup>nd</sup> spray:**
  - **14 days after first spray**

# Codling Moth, 1996

## Pheromone Trapping at O.S.U. Orchard, Columbus



# Timing for 1<sup>st</sup> spray for codling moth

<i>DD after biofix</i>	<i>Approximate timing</i>	<i>Products</i>
<b>250</b>	<b>1<sup>st</sup> cover</b>	<b>Guthion, Imidan, pyrethroids, Avaunt, Delegate, Altacor</b>
<b>150-250</b>	<b>late petal-fall</b>	<b>Assail, Calypso, Clutch</b>
<b>100-200</b>	<b>mid petal-fall</b>	<b>Intrepid, Confirm</b>
<b>50-75</b>	<b>early petal-fall</b>	<b>Rimon</b>

# Insecticide Resistance Management

- Best rule: Rotate to an insecticide from an unrelated chemical group every pest generation
- Do this in orchards where organophosphates not working well

# Insecticides for codling moth

<b><i>Group</i></b>	<b><i>Product</i></b>
<b>Organophosphates</b>	<b>Imidan, Guthion, Diazinon</b>
<b>Carbamates</b>	<b>Lannate, Sevin</b>
<b>Pyrethroids</b>	<b>Asana, Danitol, Warrior, Proaxis, Decis, Baythroid, Mustang</b>
<b>Neonicotinoids</b>	<b>Assail, Calypso, Clutch</b>
<b>Insect growth regulators</b>	<b>Rimon, Intrepid, Esteem</b>
<b>Ryanodine disruptors</b>	<b>Altacor, Belt</b>
<b>miscellaneous</b>	<b>Avaunt, Delegate, SpinTor</b>

# Keep limitations in mind

<i>Product</i>	<i>PHI</i>	<i>Limit # applic./yr.</i>
<b>Imidan</b>	<b>7</b>	<b>8</b>
<b>Assail</b>	<b>7</b>	<b>4</b>
<b>Delegate</b>	<b>7</b>	<b>4</b>
<b>Rimon</b>	<b>14</b>	<b>4</b>
<b>Altacor</b>	<b>14</b>	<b>4</b>
<b>Belt</b>	<b>14</b>	<b>3</b>
<b>Intrepid</b>	<b>14</b>	<b>4</b>
<b>Guthion</b>	<b>14/21</b>	<b>2</b>
<b>Warrior*</b>	<b>21</b>	<b>5</b>
<b>Calypso</b>	<b>30</b>	<b>2</b>

\* beware, use can flare mites and scale

# A microbial alternative: codling moth granulosis virus

- **Products**

- ‘Cyd-X’
- ‘Virosoft CP4’
- ‘Carpovirusine’

- **Action**

- Granules ingested by young larvae before or during their entry into fruit
- Makes worms sick
- Host death within 3-7 days
- Fruit ‘stings’ can still happen

# A microbial alternative: codling moth granulosis virus

- **Limitations**

- Inactivated if  $>90^{\circ}\text{F}$
- Breaks down in UV light
- Half-life:
  - 4 day in mid-July
  - 8 days in early June

- **How to use**

- Low rate frequently better than high rate
- Apply 7 days after standard product
- Or use at end of each generation
- Best to apply in late afternoon or on cloudy day

# Example of seasonal program using alternatives to O.P.s for codling moth

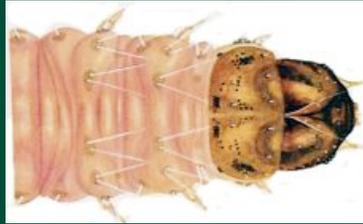
<i>Time</i>	<i>Event</i>	<i>Product</i>
PF	Plum curc.	Guthion or Avaunt
1C	CodMoth-1	Rimon or Altacor
2C	CodMoth-1	Rimon or Altacor
3C	-	virus
4C	CodMoth-2	Assail or Delegate
5C	CodMoth-2	Assail or Delegate
6C	-	virus
7C	-	virus
8C	-	virus

# Caterpillars that feed inside fruit ("Internal Lepidoptera")

- **Apple**
  - Codling Moth
  - Lesser Appleworm
  - Oriental Fruit Moth
- **Peach**
  - Oriental Fruit Moth

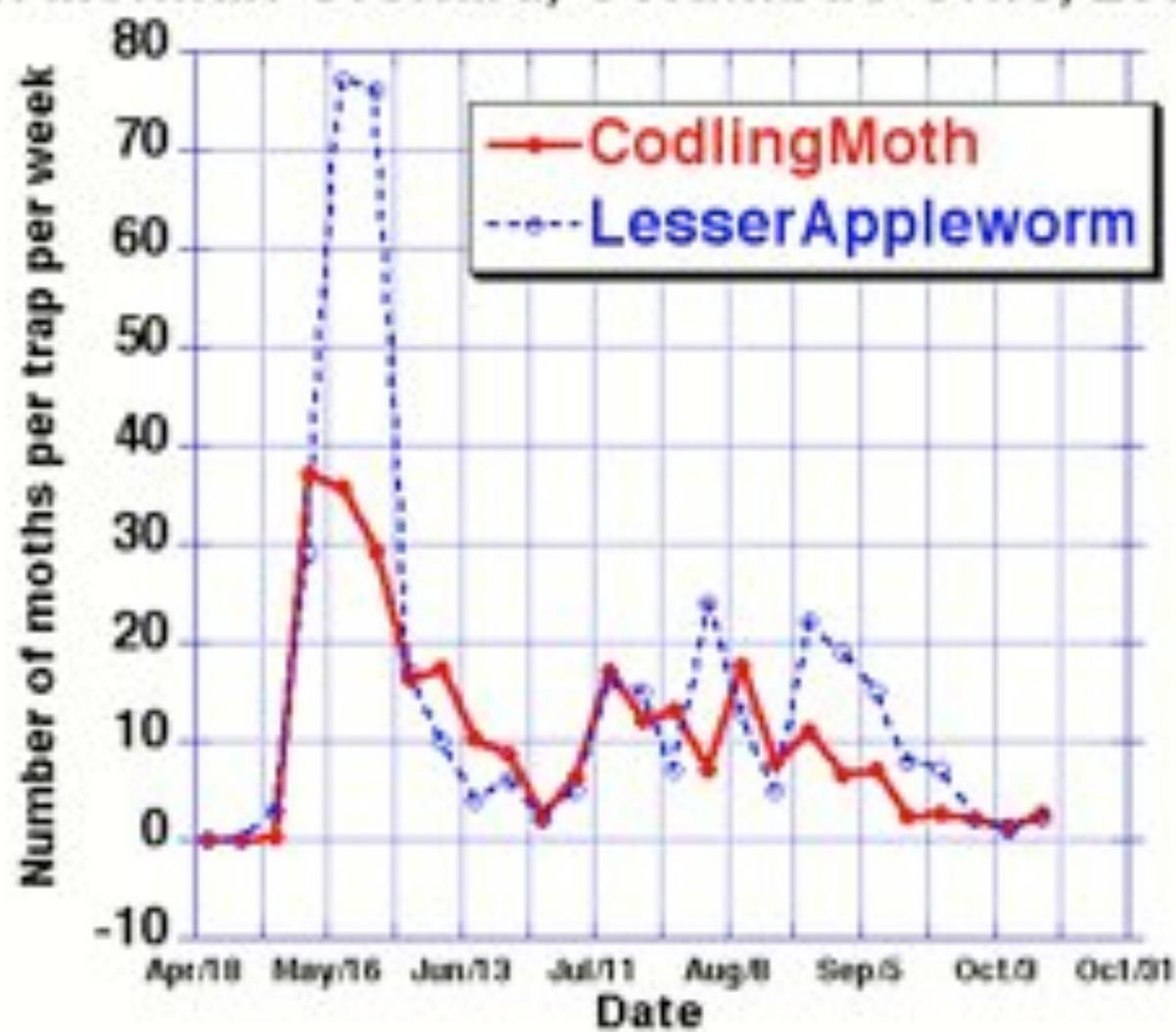


# Differences among species



- Number of generations per year
  - CM & LAW: usually 2, sometimes 3
  - OFM: 3 to 5
- Timing
  - CM & LAW the same (1<sup>st</sup> moth: petalfall)
  - OFM earlier (1<sup>st</sup> moth: early pink)
- Susceptibility to insecticides
  - Differs for some chemicals

# Waterman Orchard, Columbus Ohio, 2004



# Moth I.D.



**Oriental fruit moth**

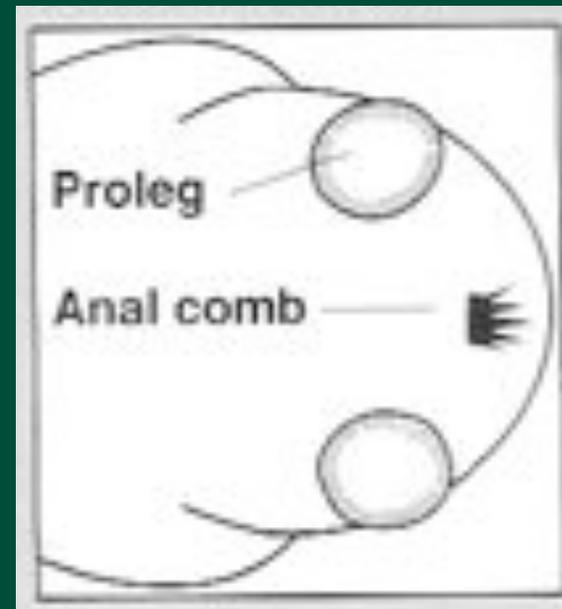
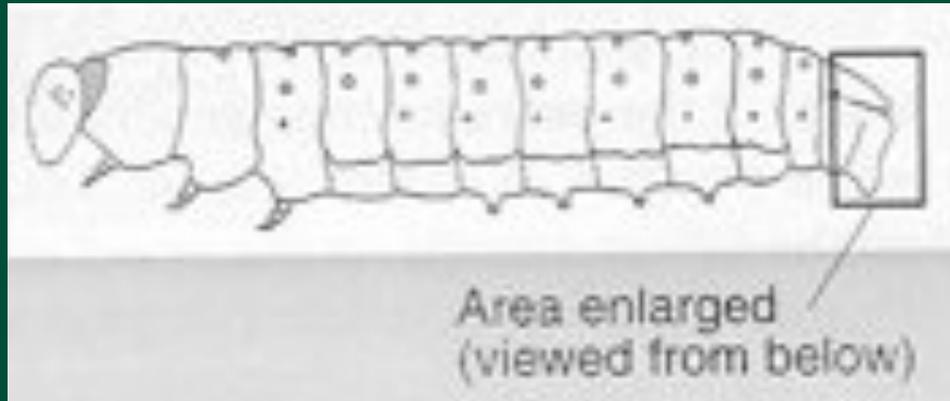


**Lesser appleworm**

- **Moths look same by naked eye**
- **Moths look different by hand lens**
- **OFM caught only in OFM trap**
- **LAW caught in both LAW & OFM traps**
- **If trapping, must use hand lens to I.D.**

# Worm I.D.

- **Codling moth**
  - Larvae do not have anal comb
- **Lesser appleworm & Oriental fruit moth**
  - Larvae have anal comb



# Worm I.D.

- **Codling moth**

- Larvae feed in seeds



- **Oriental fruit moth**

- Larvae feed near but not in seeds

- 1<sup>st</sup> brood larvae in terminal shoots (causes 'flagging')



# Insecticides on apple (PA, NJ, MI)

<i><b>Pest</b></i>	<i><b>Excellent</b></i>	<i><b>Good</b></i>	<i><b>Fair</b></i>
<b>Both CM &amp; OFM</b>	<b>Rimon Altacor Belt Delegate Guthion*</b>	<b>Avaunt Calypso Imidan* Intrepid Lannate</b>	<b>Clutch Proclaim SpinTor Surround</b>
<b>CM</b>	<b>virus</b>	<b>Assail pyrethroids**</b>	<b>Esteem Sevin</b>
<b>OFM</b>	<b>Assail pyrethroids**</b>	<b>Esteem Lorsban Sevin</b>	<b>-</b>

*\*if population is not resistant*

*\*\*pyrethroids: Asana, Baythroid, Danitol, Decis, Proaxis, Mustang, Warrior*

# Managing Oriental fruit moth in Apples



- **Better timing**

- **Trap-based biofix**

- (Biofix is date when traps detect start of sustained flight)

- **Use degree-days, base 45°F:**

- **Spray at 150 degree-days for 1<sup>st</sup> gen.**

- **Spray at 1125 degree-days for 2<sup>nd</sup> gen.**

- **Spray at 2250 degree-days for 3<sup>rd</sup> gen.**

# Managing Oriental fruit moth in Apples

- Better timing
- More water
  - 50 gpa minimum
  - 100 gpa in problem blocks & late
- Higher rates if O.P.s used
  - Imidan 3-4 lb/A
- Rotate insecticides

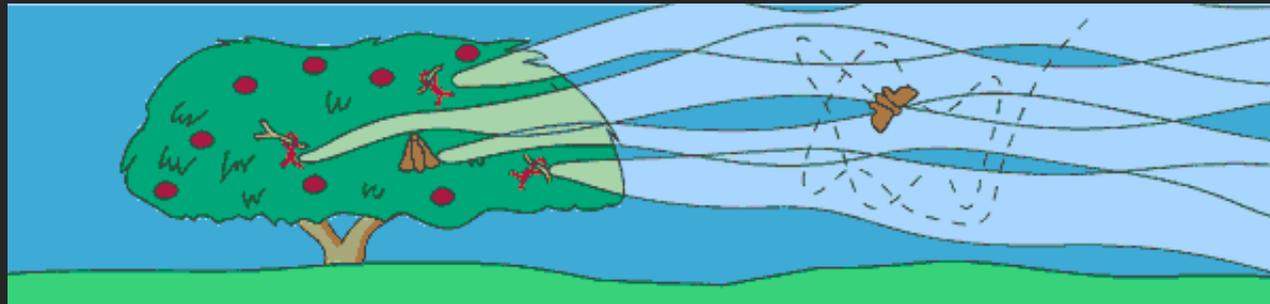


# Codling Moth: Cultural Control

- **Sanitation:**
  - **Clean bins (remove cocoons)**
- **Host reservoir elimination:**
  - **Cut down abandoned orchards**

**Alternative management  
strategy:**

# **Mating Disruption**



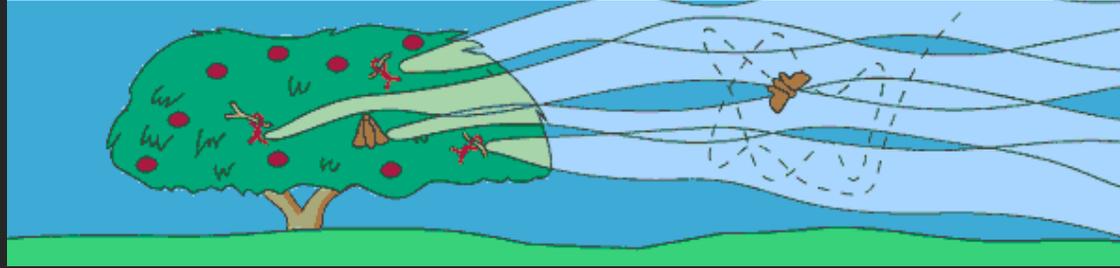
# Insect Pheromones

- What are they? Natural sex attractants
  - Usually scents produced by female moth, detected by male moth
  - For individual species
- Synthetic version made commercially
  - Used as lures in traps for monitoring
    - Few per orchard
  - Used for control by mating disruption
    - Many point sources per orchard

# Mating disruption by pheromones

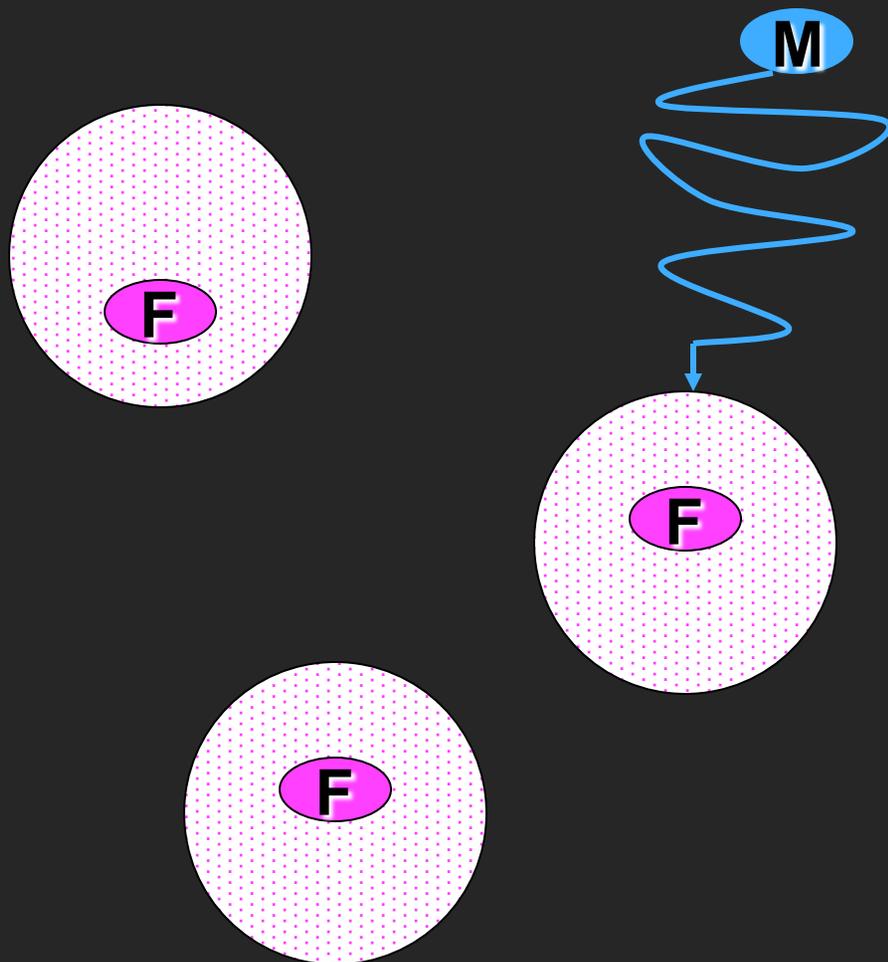
- Goal: control the pest population by preventing mating, thus no fertile eggs to start the next generation
- **Two techniques:**
  - Male confusion technique
  - Attract-and-kill technique

# Male confusion technique

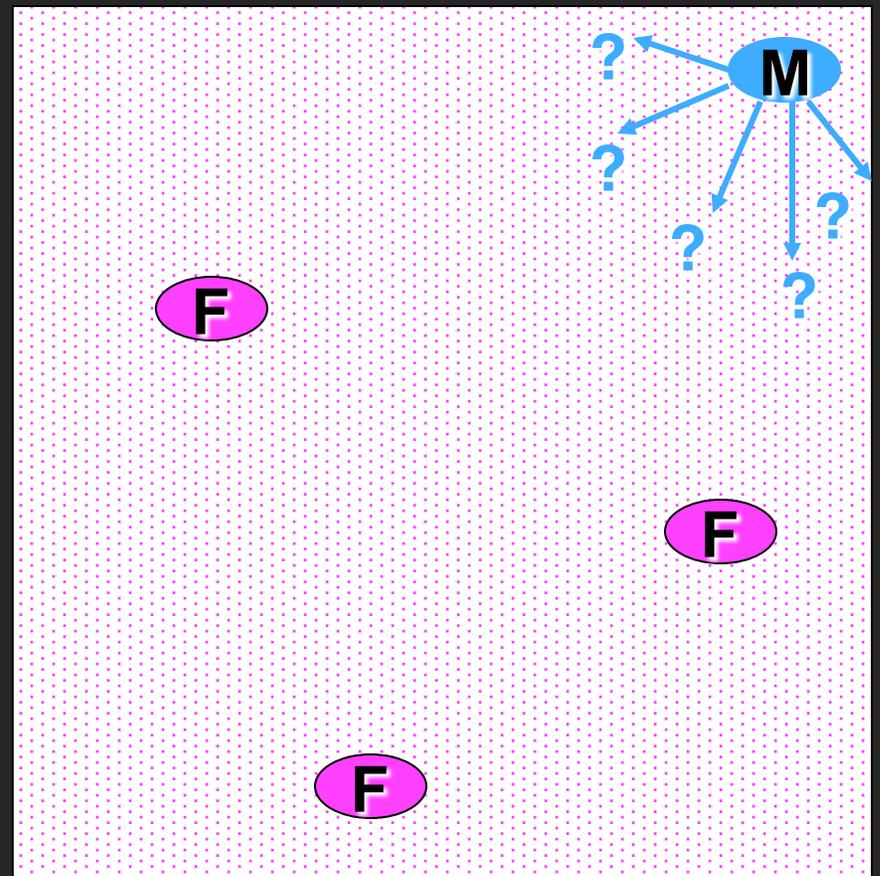


- Saturate the area with scent of female moth's sex pheromone
- Male moths become **confused**, unable to locate real females
- Females do not mate
- No fertile eggs laid

# Normal mating



# Mating disruption by male confusion



# Moth behavior

## *NORMAL:*

Mate finding



Mating



Egg fertilization



Development of  
egg then larva

## *DISRUPTED:*

Mate ~~finding~~

Mate~~ing~~

Egg ferti~~lization~~

Development of  
egg then larva

# Types of Products for Mating Disruption

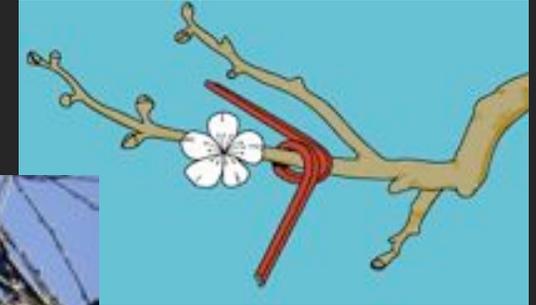
- Manual dispensers

- Twist tie

- Patch

- Clip

- Spiral



- Sprayable micro-encapsulated

- Flakes

- Fibers

- Puffers

- Paraffin wax emulsion



# Mating Disruption Products

- Manual dispensers

- ‘Isomate’ brand

- Original type:  
twist tie (‘rope’)



- Newer twin-tube  
type





## **Isomate dispensers being deployed in northern Ohio**

- **Crew of 10 workers**
- **Covered 70 acres**
- **1 day, 8 AM to 5 PM**
- **200 dispensers/A**
- **1 dispenser in every tree, in every other row**

# Sprayable Pheromone

- Timed-release micro-encapsulated pheromone concentrate
- **Apply by conventional spray equipment**
- Number of applications:
  - 2 per generation
  - Apply just before start of flight period
  - Apply again in 2 weeks

# Pros & cons of mating disruption products

- **Manual dispensers**
  - **Original style**
  - **Last longer (90+ days)**
  - **More labor intensive**
- **Sprayables**
  - **Easier to apply**
  - **Shorter duration (2-4 weeks)**
  - **Problem with rainfastness**



# Attract-and-kill technique

- Pheromone + insecticide (permethrin)
- Distributed in droplets with pheromone concentration equivalent to amount emitted by one real female
- Male moth:
  - is NOT confused
  - does find droplet
  - attempts to mate with droplet
  - dies after contact with droplet

# 'Attract-and-kill' technique



- 'LastCall-CM' for codling moth control
  - Registered 1998 in USA
  - Made by APTIV (Portland, OR)
  - Apply 1200 droplets per acre
- Not widely used due to labor

# Efficacy & use of mating disruption for internal leps

<i>Pest</i>	<i>Crop</i>	
	<i>Apple</i>	<i>Peach</i>
<b>Codling moth</b>	<b>Fair</b> (best to combine with insecticides)	-
<b>Oriental fruit moth</b>	<b>Excellent</b> (can be used without insecticides)	<b>Excellent</b> (can be used without insecticides)

# Mating disruption products for Oriental fruit moth & codling moth

<i>Brand</i>	<i>Company</i>	<i>Manual</i>	<i>Sprayable</i>
<b>Isomate</b>	<b>Pacific Biocontrol</b>	*	
<b>CheckMate</b>	<b>Suterra</b>	*	*
<b>NoMate</b>	<b>Scentry</b>	*	

# Mating disruption for Oriental fruit moth

<i>Product</i>	<i>Duration</i>	<i>Rate/A</i>	<i>Cost</i>
<b>Isomate-M</b>	<b>90 days</b>	<b>400</b>	
<b>Isomate-M 100</b>	<b>90 days</b>	<b>100</b>	<b>\$39/A</b>
<b>Isomate-M Rosso</b>	<b>120 days</b>	<b>200</b>	<b>\$80/A</b>
<b>Sprayable</b>	<b>2 weeks</b>	<b>1.7 oz</b>	<b>\$18/A</b>

## Combination of insecticides & mating disruption as used in peaches in New Jersey

<i>Target</i>	<i>Early varieties (harvest &lt; late Aug.)</i>	<i>Late varieties (harvest &gt; late Aug.)</i>
<b>1<sup>st</sup> gen. OFM + plum curc. + plant bugs (April &amp; May)</b>	<b>insecticide</b>	<b>insecticide</b>
<b>2<sup>nd</sup> &amp; 3<sup>rd</sup> gen. OFM (starting late May)</b>	<b>Isomate-M 100</b>	<b>Isomate-M Rosso OR Isomate-M 100 then sprayable in late Aug./Sept.</b>

# Size of Target Area

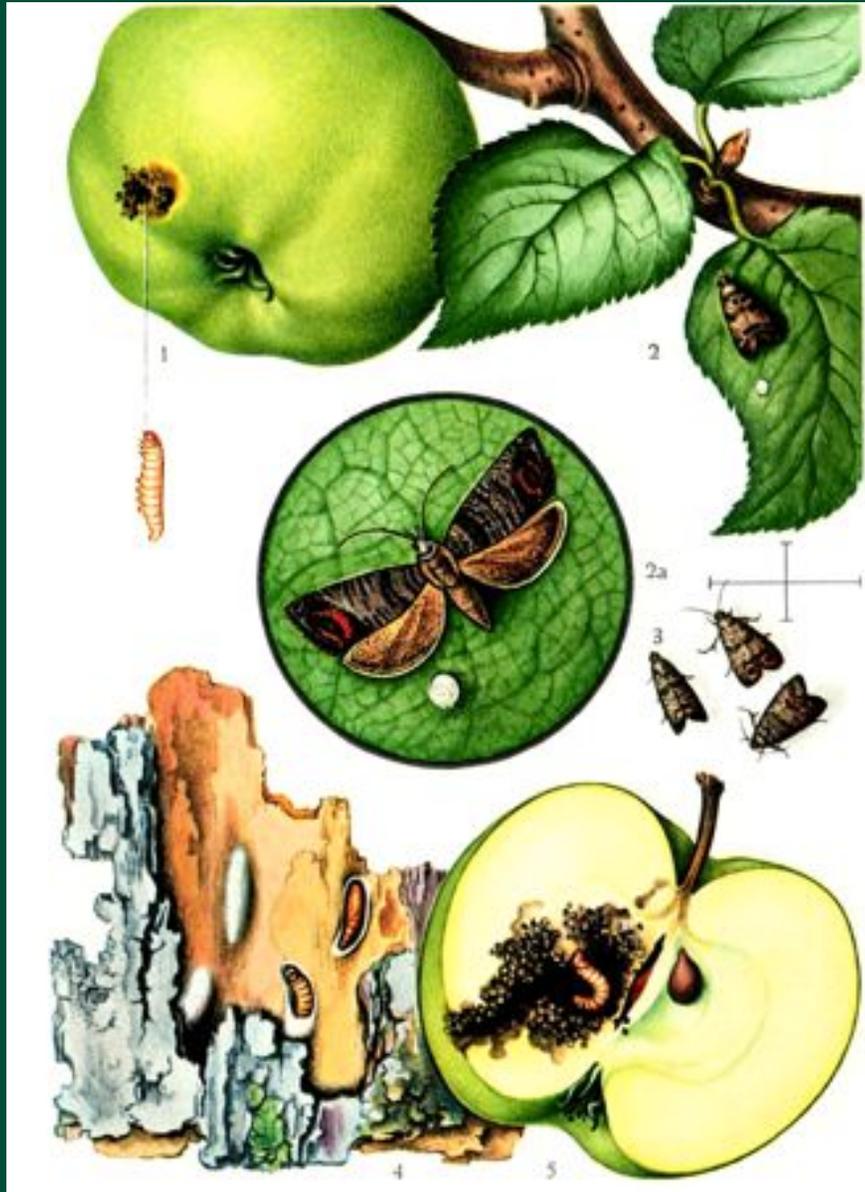
- General rule: 5 acre minimum
- Assumes resident population; no immigration
- Beware of immigrating female moths already mated, especially near border of area
- Border treatment with insecticides can be needed

# Trap Shut-down

- Pheromone trap in orchard without mating disruption
  - Moths find the trap
  - Moths are caught
  - Trends are seen
- Pheromone trap in orchard with mating disruption
  - Moths can not find the trap
  - Moths are not caught
  - Called 'trap shutdown'
  - **Good indicator** that disruption working

# Worm Management Summary

- **Chemical tactics**
  - **Insecticides (old or new)**
- **Microbial tactics**
  - **Granulosis virus**
- **Behavioral tactics**
  - **Pheromone mating disruption**
- **Cultural tactics**
  - **Sanitation**
  - **Remove abandoned trees**



The end