

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
 - 3rd 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)

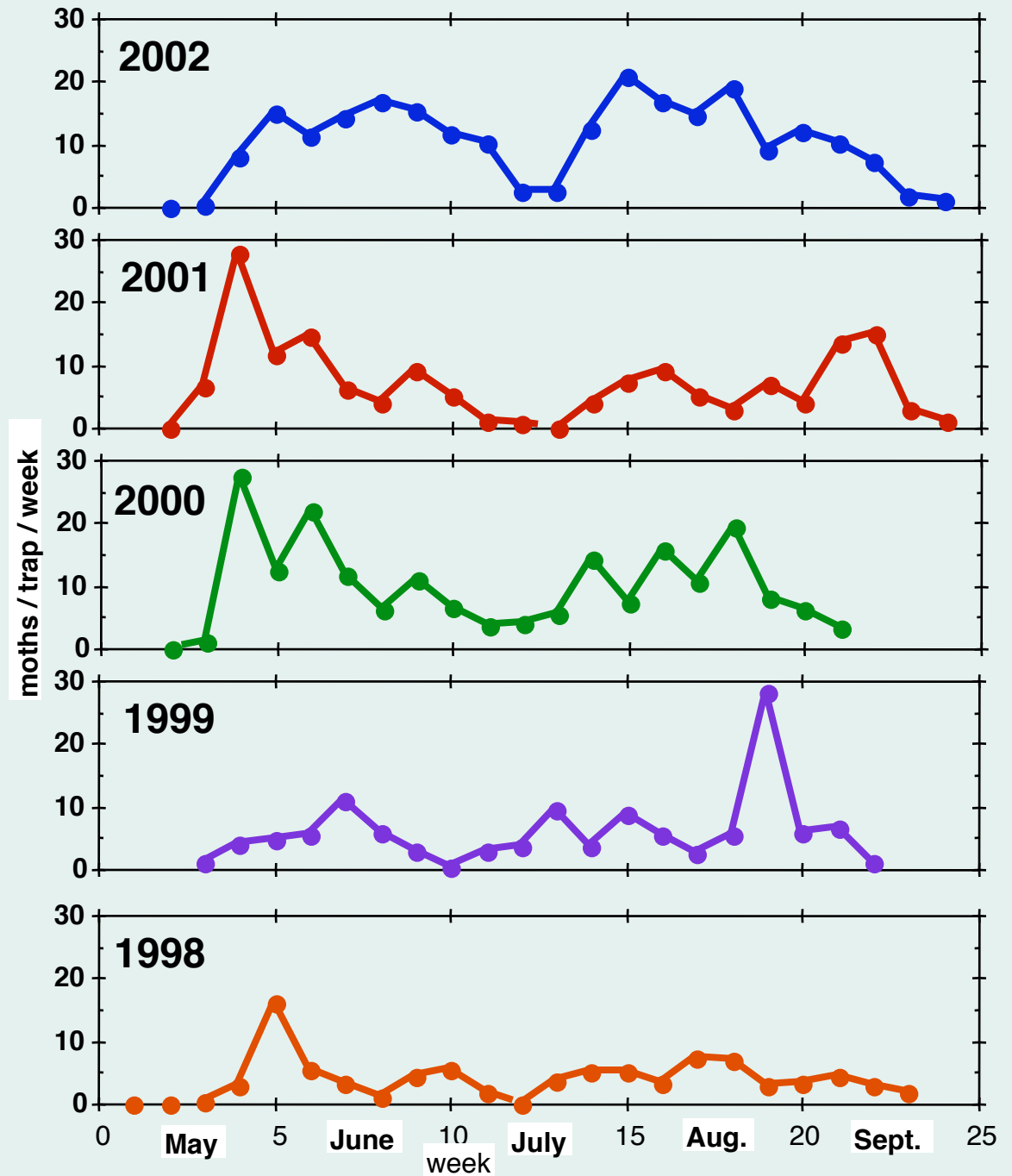


Codling moth: example of suspected resistance problem

- 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



- 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)

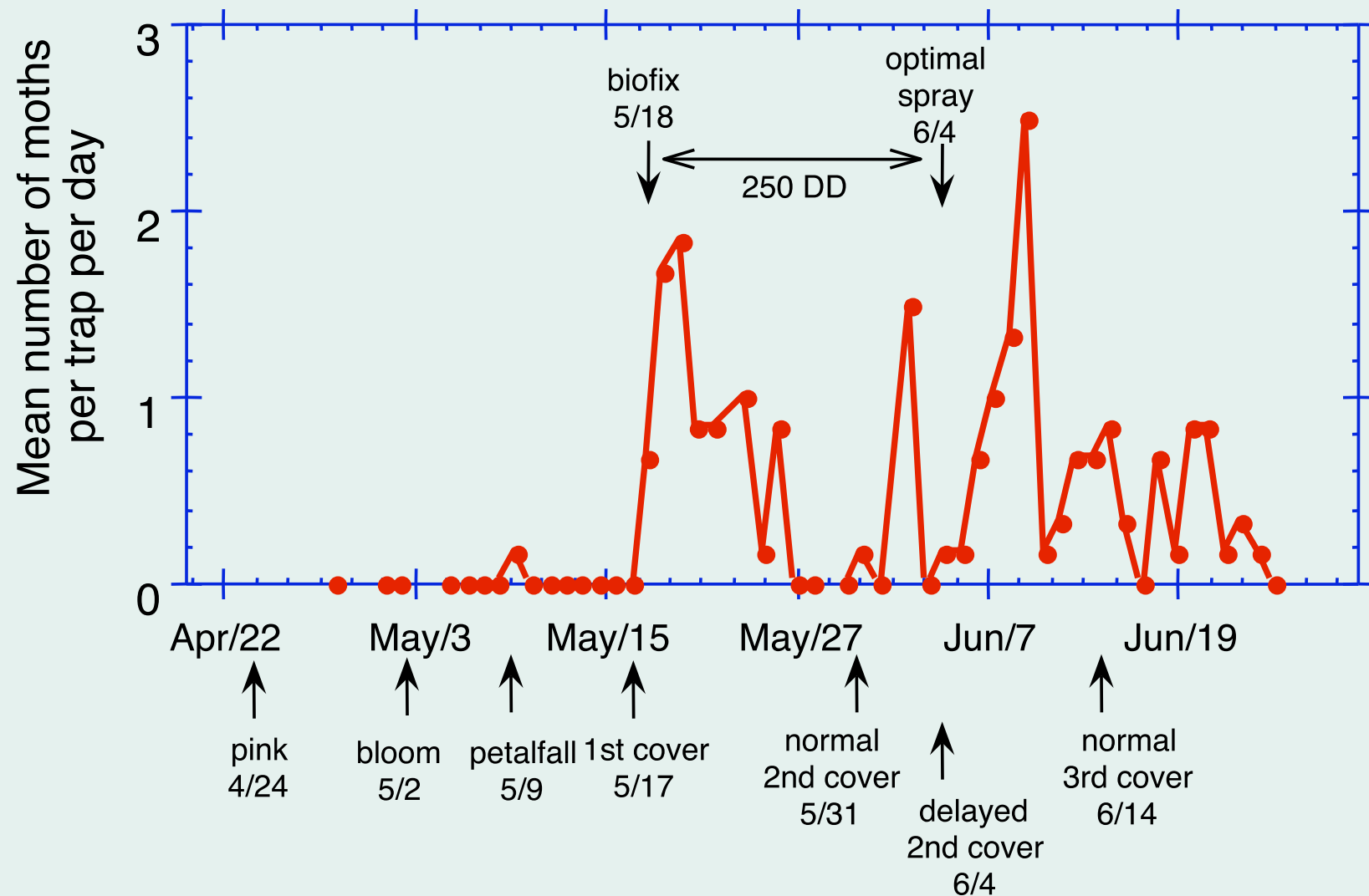
<i>Day</i>	<i>T max</i>	<i>T min</i>	<i>T avg</i>	<i>DD 50</i>	<i>DD Cumulative</i>
1	62	52	57	7	7
2	66	50	58	8	15
3	58	54	56	6	21
4	70	56	63	13	34

Timing for codling moth

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

Codling Moth, 1996

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



Timing for 1st spray for codling moth

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

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

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

Keep limitations in mind

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

* 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 (1st moth: petalfall)
 - OFM earlier (1st moth: early pink)
- Susceptibility to insecticides
 - Differs for some chemicals

Waterman Orchard, Columbus Ohio, 2004



Moth I.D.



Oriental fruit moth

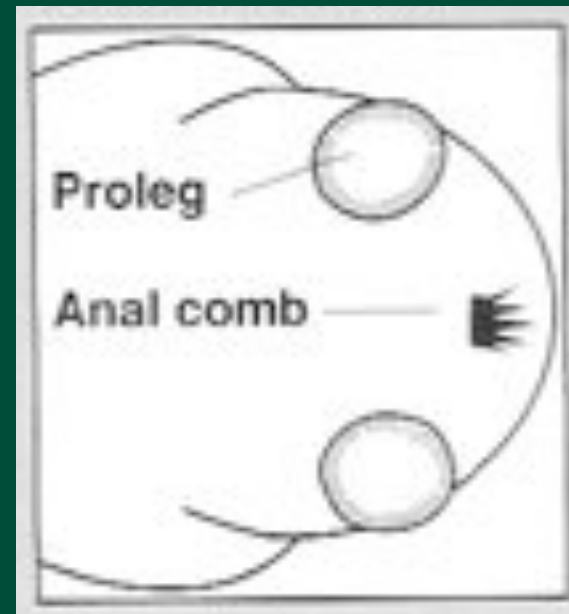
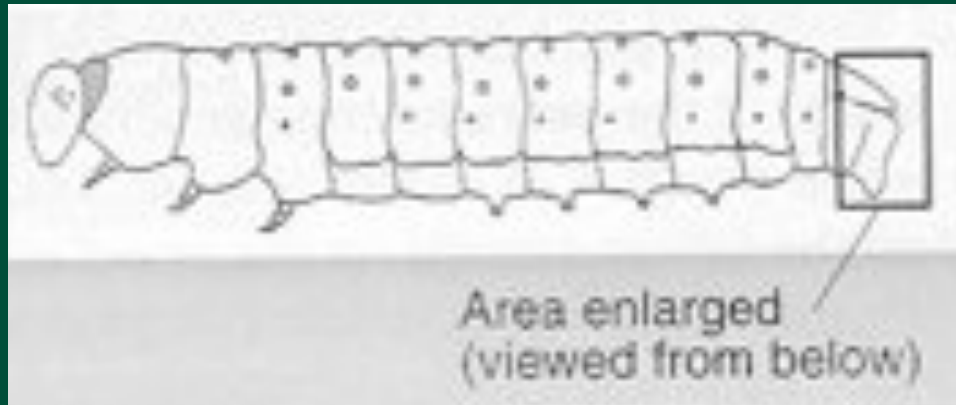


Lesser appleworm

- **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

- 1st brood larvae in terminal shoots (causes 'flagging')

Insecticides on apple (PA, NJ, MI)

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

**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 1st gen.

- Spray at 1125 degree-days for 2nd gen.

- Spray at 2250 degree-days for 3rd 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

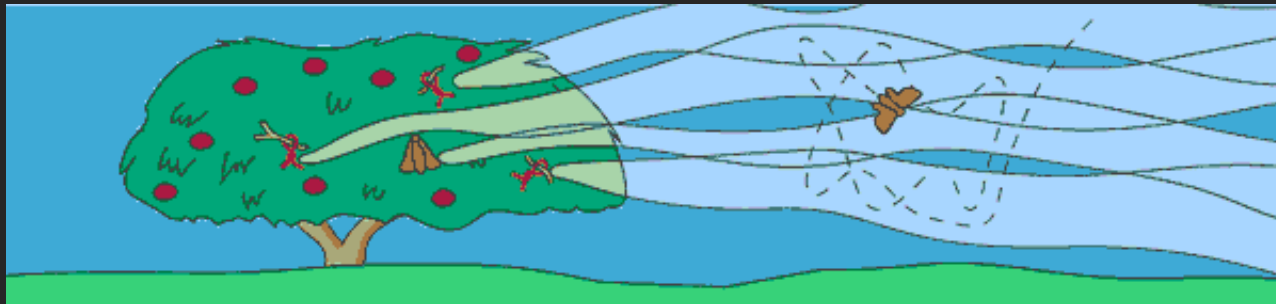


Codling Moth: Cultural Control

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

**Alternative management
strategy:**

Mating Disruption



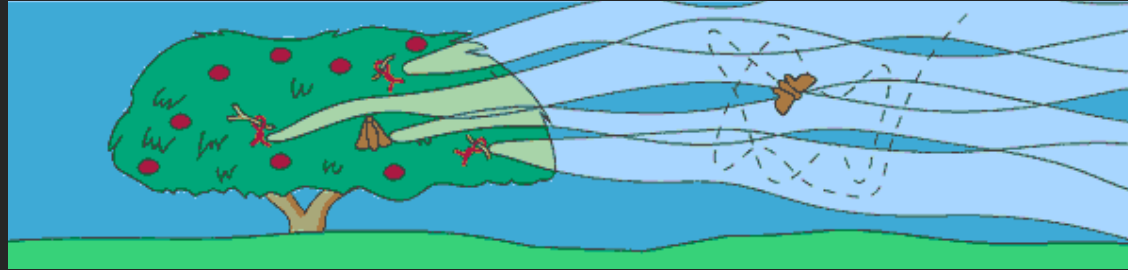
Insect Pheromones

- 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

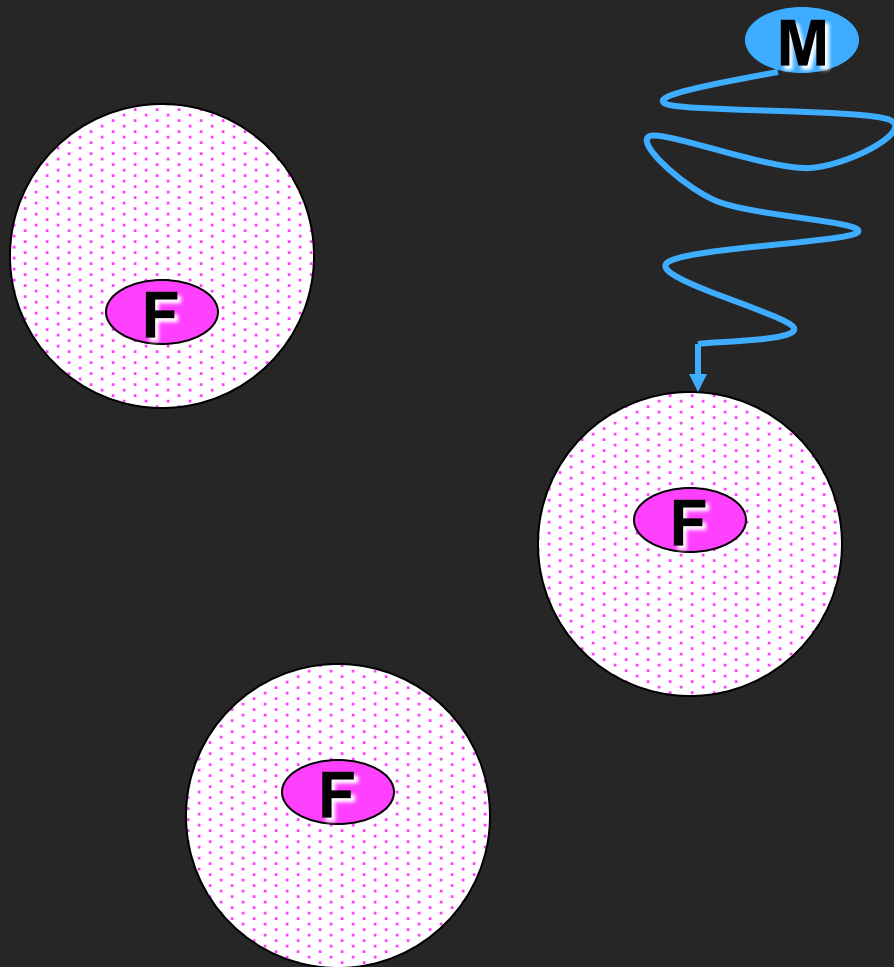
- Goal: control the pest population by preventing mating, thus no fertile eggs to start the next generation
- **Two techniques:**
 - **Male confusion technique**
 - **Attract-and-kill technique**

Male confusion technique

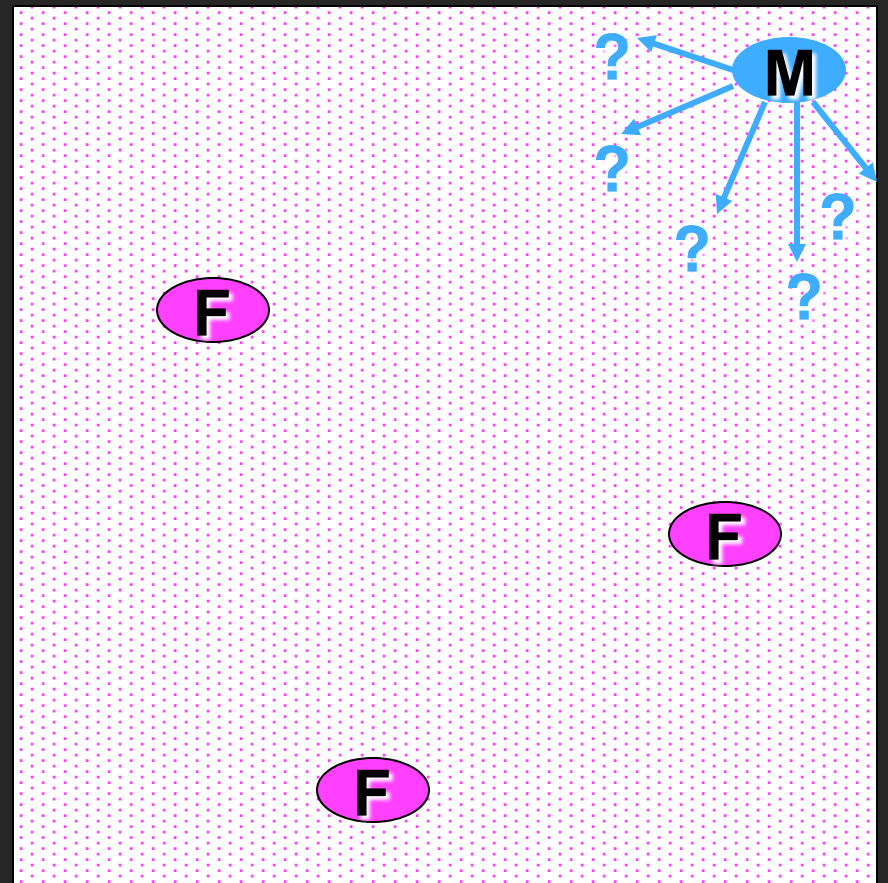


- Saturate the area with scent of female moth's sex pheromone
- Male moths become **confused**, unable to locate real females
- Females do not mate
- No fertile eggs laid

Normal mating



Mating disruption by male confusion



Moth behavior

NORMAL:

Mate finding



Mating



Egg fertilization



**Development of
egg then larva**

DISRUPTED:

Mate ~~X~~ finding

Mat~~X~~ing

Egg fert~~X~~ilization

**Develop~~X~~ment of
egg then larva**

Types of Products for Mating Disruption

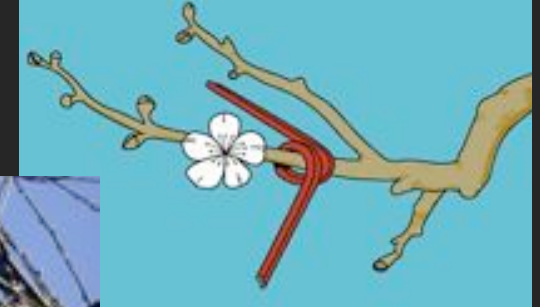
- Manual dispensers

- 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>
Codling moth	Fair (best to combine with insecticides)	-
Oriental fruit moth	Excellent (can be used without insecticides)	Excellent (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>
Isomate	Pacific Biocontrol	*	
CheckMate	Suterra	*	*
NoMate	Scentry	*	

Mating disruption for Oriental fruit moth

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

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

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

Size of Target Area

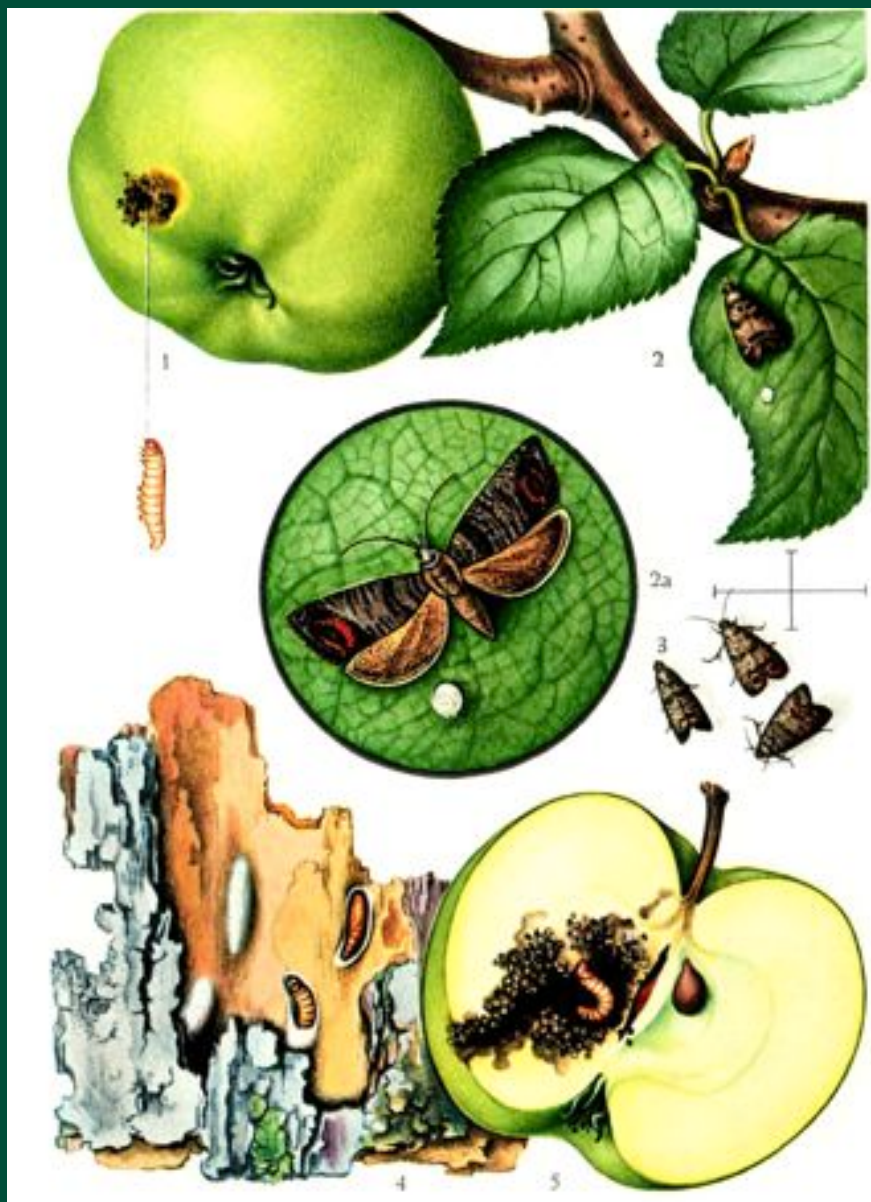
- General rule: 5 acre minimum
- Assumes resident population; no immigration
- Beware of immigrating female moths already mated, especially near border of area
- Border treatment with insecticides can be needed

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