Managing Worms on Vegetable Crops



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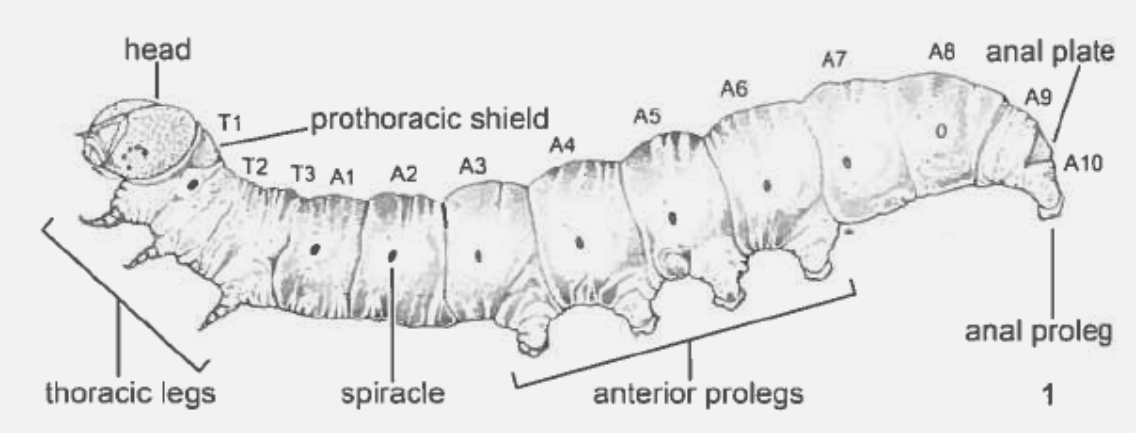
THE OHIO STATE UNIVERSITY

‘Worms’ = caterpillars



- **Identification**
- **Insecticides**
- **Non-chemical controls**

18 important caterpillar pests on veg crops

Crop	Pest
Sweet corn	Corn earworm + European corn borer + Fall armyworm + Western bean cutworm Armyworm Black cutworm +
Pepper, tomato	Tobacco hornworm Variegated cutworm Yellow-striped armyworm Stalk borer + Beet armyworm
Cole crops & greens	Imported cabbageworm Diamondback moth Cabbage looper + Cross-striped cabbageworm Zebra caterpillar +
Squash & pumpkins	Squash vine borer
Parsley	Parsleyworm

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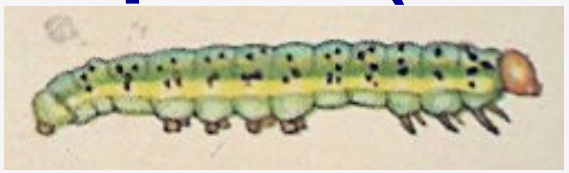
Caterpillars: generalities?

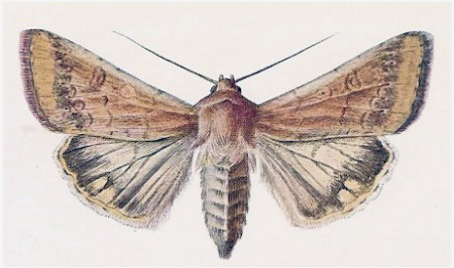
- External feeders: easier
- Internal feeders: harder
- Monitor
  - Scouting
  - Trapping
- Control
  - Chemical: beware species not equal
  - Microbial: B.t. spray
  - Biocontrol: can be encouraged
  - Mechanical: row covers

Life Cycle

Caterpillar (Larva)



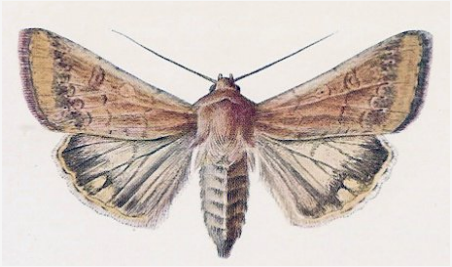
Pupa



Moth (Adult)

Egg

Do moths matter?

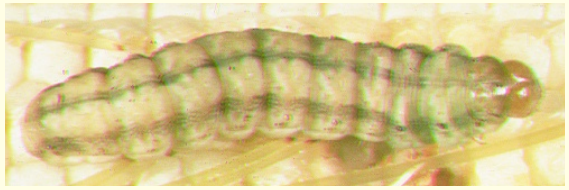


- Can be easier to monitor than caterpillars
- Give advance warning of caterpillars

Worms in sweet corn

- Caterpillar i.d.
- Monitoring
- Insecticides
  - Before silking
  - During silking
  - Conclusions from trials, 2007-2015
- Alert: new species

Caterpillars in Sweet Corn

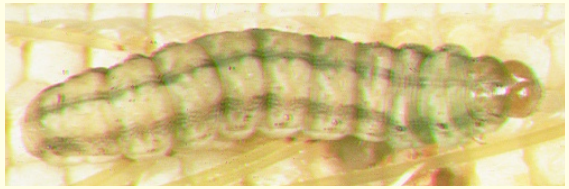


Corn Earworm

European Corn Borer

Fall Armyworm

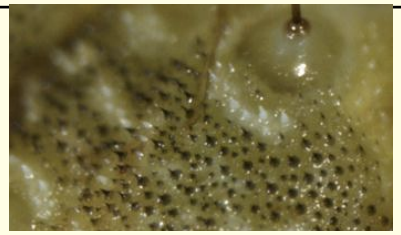
Caterpillars in Sweet Corn



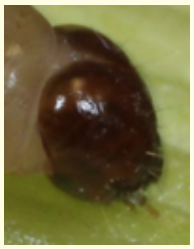
- **Key pests; can ruin the crop**
- **Pest management is complex**
  - **Several insect species**
  - **Sequential plantings**
- **The need to control them varies through the season**
  - **No control**
  - **Low intensity control**
  - **High intensity control**

Caterpillar i.d.

	Corn earworm	European corn borer	Fall armyworm
			
Body color	Variable: yellow, green, brown, or pink	Cream to light brown	Light brown top, dark brown sides
Body marks	Distinct stripes	Subtle stripes, round dots	Stripes
Texture	Dense microspines	Smooth; few sparse hairs	Smooth



Caterpillar i.d.

	Corn earworm	Eur. corn borer	Fall armyworm
			
Head size	Large	Small	Large
Head color	Light orange/ brown 	Dark brown 	Dark sides, light in middle 

Sweet Corn Development

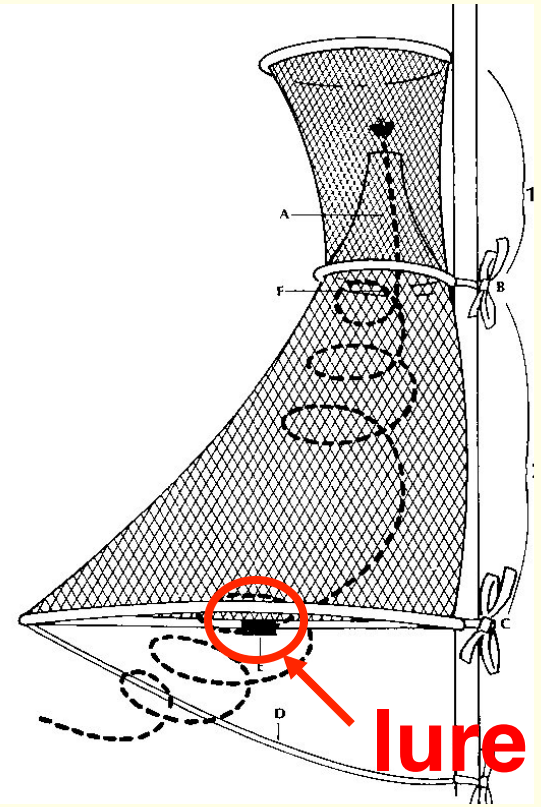
- Seedling
- Whorl stage
- Emerging tassel stage **
- Fresh silk ***
- Dry silk

1. Corn Earworm

- Moths migratory from South
- Arrival time varies
- Eggs laid on silk
- Eggs hatch in 48 hrs

Trap to Monitor Corn Earworm

- Pheromone lure
- Attracts male moths
- Highly effective



2. European Corn Borer

- **Moths active:**
  - –1st flight:
    - Late May to late June
    - Most eggs on whorls
    - Move to tassel to ear
    - Control before silking
  - –2nd flight:
    - Late July to late August
    - Most eggs near ear
    - Control during silking
- **Monitor moths with pheromone traps**

European corn borer: generations per year

- 2 generations
  - –when summer has average temperatures (60% of years in Ohio)
- 3 generations
  - –when summer has high temperatures (40% of years)

3. Fall Armyworm

- Also migratory from South
- Arrival time varies
- Harder to kill

Fall Armyworm During Silking

- **Pheromone trap**
  - –All-green unitrap
- **Spray every 5-7 days during silking if more than 3 moths per week in trap**

fall armyworm moth

Emerging-Tassel Stage

- **Scout (examine plants)**
  - 50 plants in small plantings (<2A)
  - 100 plants in large plantings (>2A)
  - **Record # with fresh feeding damage**
- **Action threshold**
  - Spray if fall armyworm and/or European corn borer on >10% of plants

During silking: control worms by insecticide

- For 3 week period before harvest
- Start spray schedule when fresh silk begins to show, IF moths active
- Use traps to monitor moths

Difference in ‘Worm’ Invasion

	Corn earworm	European corn borer
Egg location	silks	ear leaf
Egg hatch	2-3 days	3-5 days
Moth source	migratory	local

How often to spray during silking?

Moths active?		*Insecticide need to control larvae*
Corn earworm	*Eur. corn borer*	
+	+ or -	More intensive
-	+	Less intensive
-	-	None

Relative importance of pests during silking

Rank	Pest	Spray Interval
1	Corn earworm	2-6 d
2	Eur. corn borer	5-7 d
3	Fall armyworm	5-7 d

Most critical time for earworm invasion: silking

- For 3 week period before harvest
- Stages: fresh, wilting, dry & brown
- Pests attracted to fresh silk
- Silk grows rapidly (up to 1.5” per day)
- If sprayed, next day new silk unprotected

Insecticide Issues During Silking in Main Season & Late Season Corn

*** Spray interval

** Coverage of ear zone

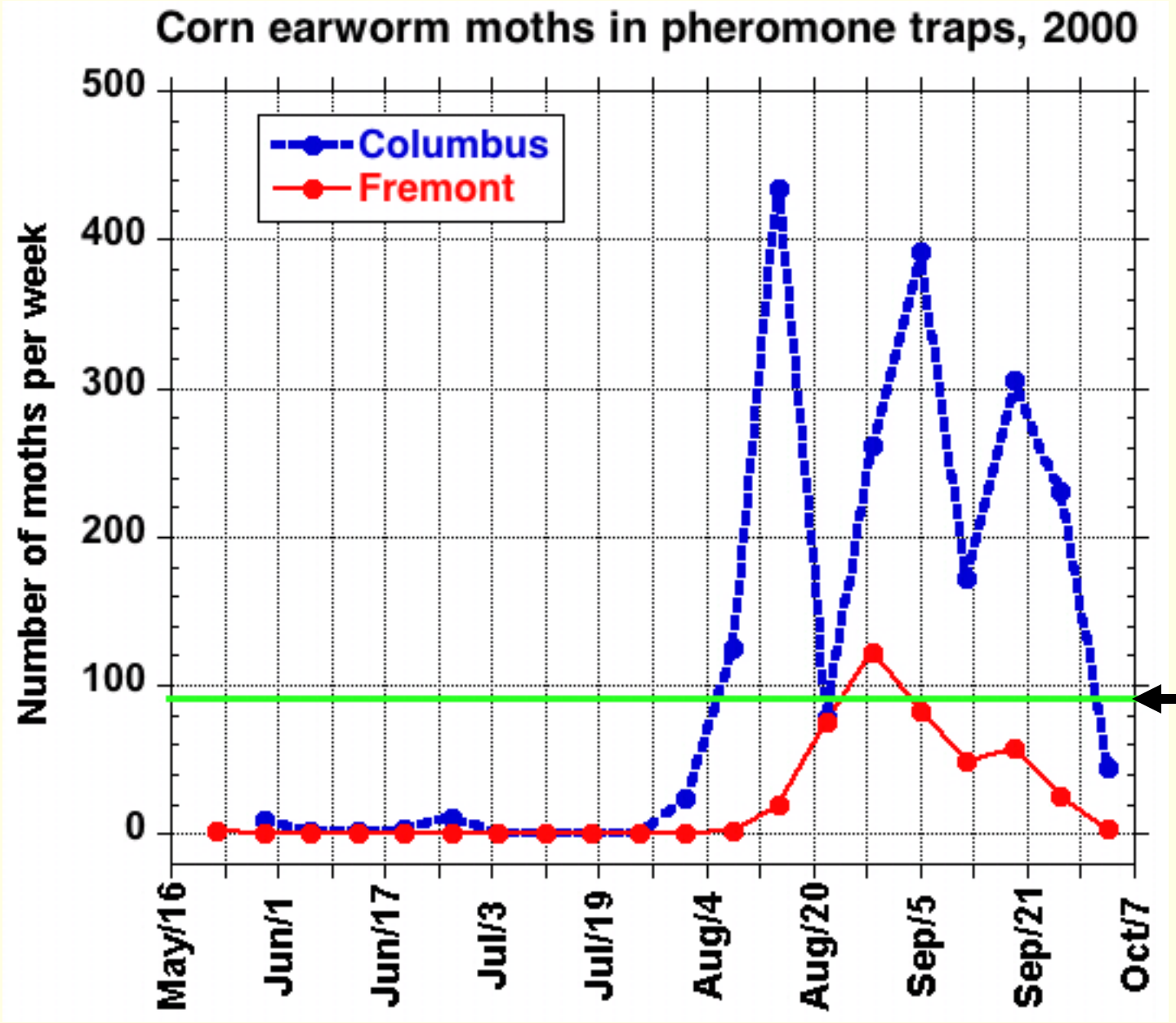
* Choice of insecticide

Corn Earworm Insecticide Spray Schedule

(based on Maryland & Massachusetts)

Number moths per pheromone trap per day	*Spray interval*	
	Maximum daily temp. <80°F	*Maximum daily temp. >80°F*
< 0.2	No spray	No spray
0.2 - 0.5	Every 6 days	Every 5 days
0.5 - 1	Every 5 days	Every 4 days
1 - 13	Every 4 days	Every 3 days
> 13	Every 3 days	Every 2 days

Note, in Georgia and Florida,
sweet corn is sprayed every day!

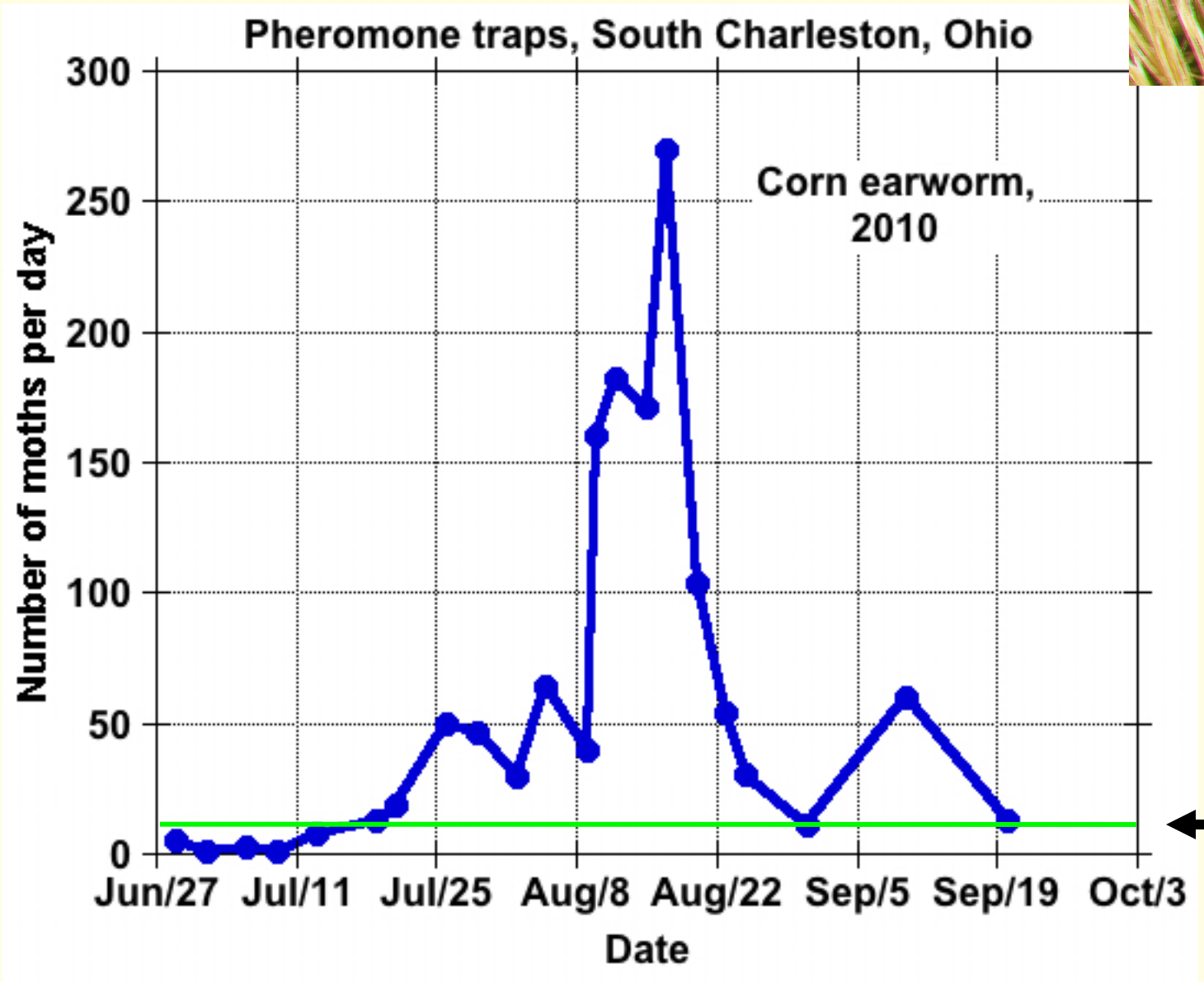


intensive schedule when >13 moths per day (>90 moths per week)

Field trial to compare spray schedule intensity, 2010

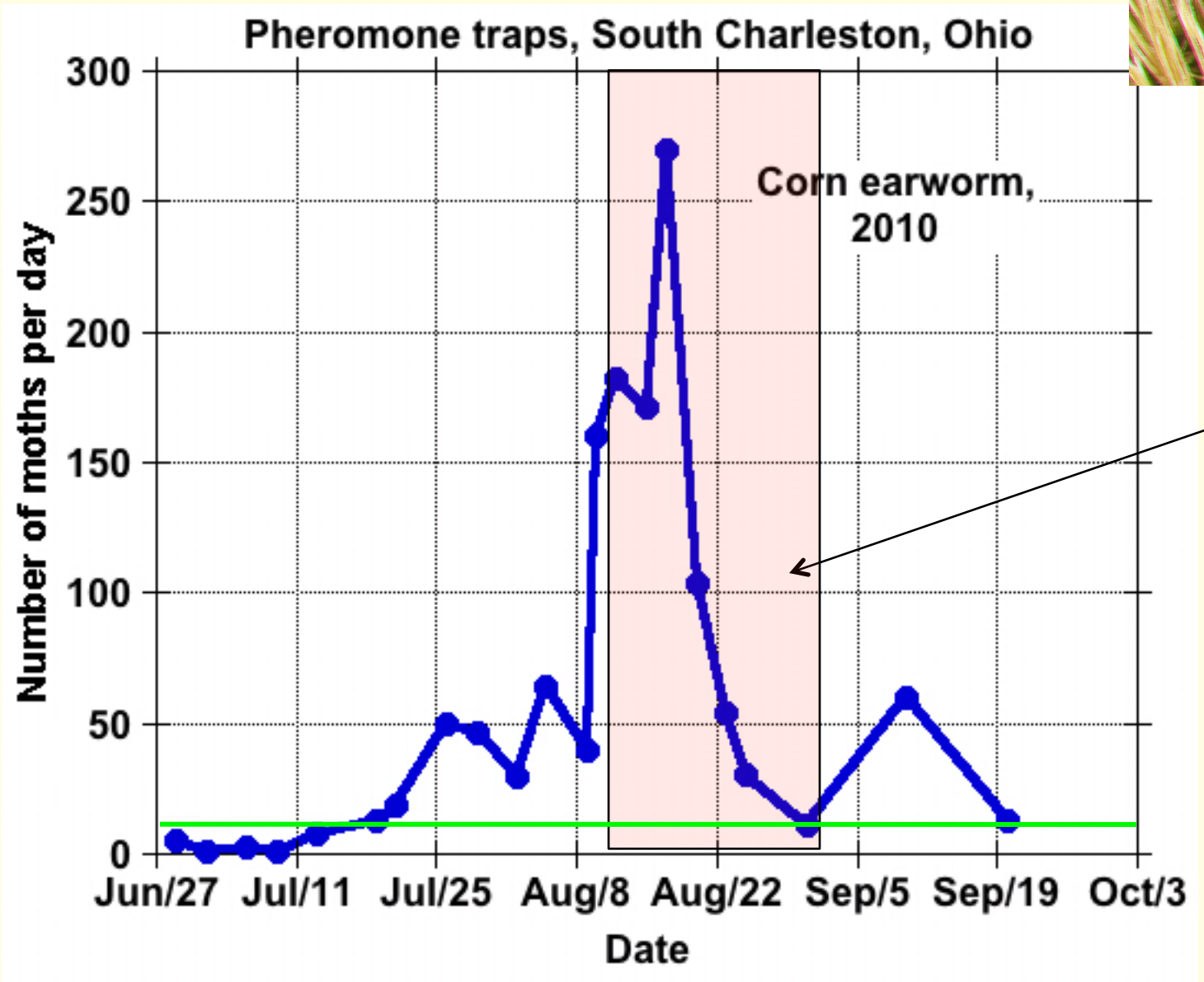
- One product: Warrior, at max rate
- Treatments (during silking):
  - Spray every 2 days (11 times)
  - Spray every 3 days (7 times)
  - Spray every 4 days (6 times)
  - Spray every 5 days (5 times)
  - Start 3-day, then 4-day (6 times)
  - No spray

Pest pressure at field trial site

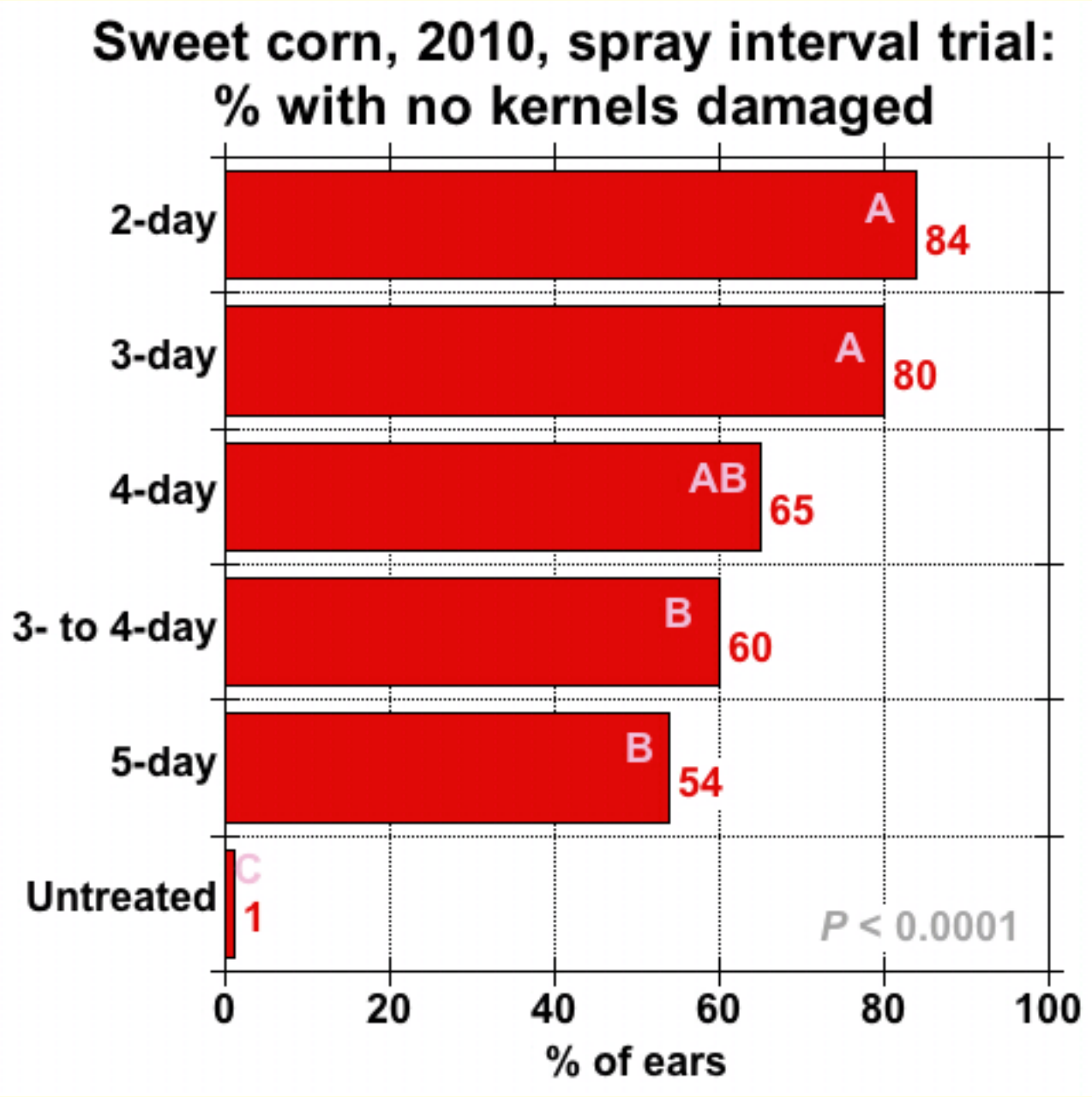


>13 moths per day

Pest pressure at field trial site



Silking began 8/10; sprays 8/10-8/30


Sweet corn, 2010, spray interval trial:
% with no kernels damaged
2-day
A
84
3-day
A
80
4-day
AB
65
3- to 4-day
B
60
5-day
B
54
Untreated
C
1
P < 0.0001
0
20
40
60
80
100
% of ears

European Corn Borer on Sweet Corn: spray during silking if moths active (> 1 moth per night = 7 moths per week in pheromone trap)

- 1st spray when 10-20% of plants silking
- Spray every 5 - 7 days
  - 5-day during peak egg hatch
  - 5-day when temperatures hot (>80 F)

Transgenic option: B.t. sweet corn

- Less developed than field corn
- Rejected by some consumers
- Lower residue of insecticides

B.t. sweet corn

- **'Attribute' from Rogers, since 2003:**
  - BC 0805
  - BC 0822
  - GH 0851
  - WH 0809
  - GSS 0966
  - WSS 0987
  - BSS 0977
  - BSS 0982
- **From Seminis (Monsanto), since 2012:**
  - **'Obsession II' (bicolor shQ)**
  - **'Passion II' (yellow sh2)**
  - **'Temptation II' (bicolor se)**

B.T. sweet corn

- **'Attribute':**
  - European corn borer:
    - Excellent control
  - Corn earworm:
    - Adequate protection if population low
    - Supplement with 2 sprays of insecticide if population high
- **Seminis/Monsanto**
  - Insect protection
    - Above ground (all worms, including earworm)
    - Below ground (rootworms)
  - Weed control
    - Round-up tolerant

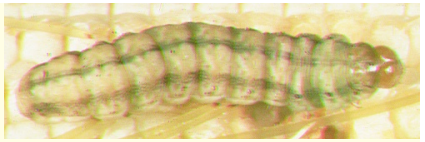
Worm management with B.t. sweet corn

- If corn earworm pressure low
  - No insecticide sprays needed during silking
- If corn earworm pressure moderate or high
  - Use 2 sprays
  - First spray: 75% fresh silk
  - Second spray: 4 days later

Spraying for organic production

- Use same spray schedule rule
- 'Entrust' allowed
  - A.I.: spinosad
  - On OMRI list
  - Rate: 0.5 - 2 oz/acre
  - Cost: $571 - $649/lb

Organic alternative for worms in sweet corn: B.t. + Oil



(Ruth Hazzard, Univ. Mass.)

- **'Zea-later II' applicator**
  - **Hand-held**
  - **$109 (Johnny's Selected Seeds)**
- **Mix:**
  - **900 ml food-grade corn oil**
  - **Lecithin 5% (emulsifier)**
  - **28.6 grams DiPel DF (a B.t.)**
  - **100 ml water**
- **Treat:**
  - **Once, 5 days after silking begins**
  - **Squirt 0.5 ml of oil mix into each ear tip**

Corn earworm control, sweet corn field trials 2007-2015

Jim Jasinski & Celeste Welty

- Concern about pyrethroid resistance
- Start spray program at 1st silk
- 6 sprays at 3- to 4-day intervals

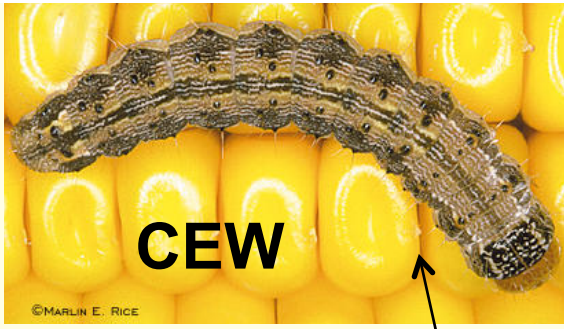
Conclusions from 9 years of Ohio field trial data

- Relief that pyrethoids still ok
  - When CEW low
  - Max rates needed
- Relief that new a.i.s now available
  - diamides
  - spinosyns
- Worry about whether efficacy of pyrethroids will suddenly drop

New Pest Alert for Sweet Corn:

Western Bean Cutworm

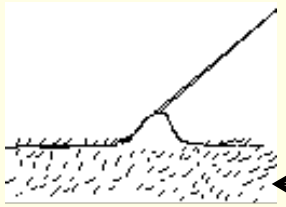
How to identify it?



	Western bean cutworm	Corn earworm

How to identify it?

	Western bean cutworm	Corn earworm
Number of worms per ear	Many	One
Prothorax (segment behind head)	Broad dark stripes	No stripes
Micro-spines on body	None	Many
Net-like marks on head	No	Yes



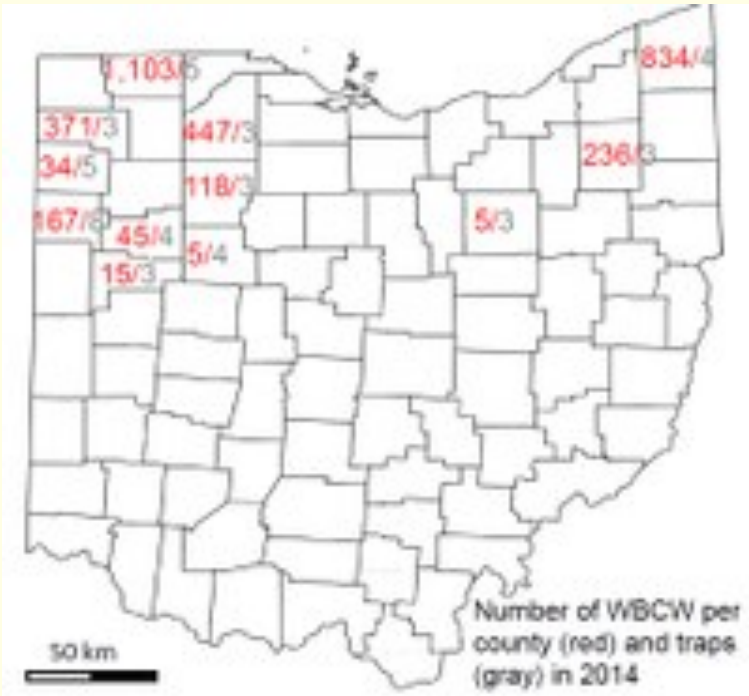
How to monitor it?

- **Pheromone lure in trap**
  - **Milk jug or unitrap**
  - **One generation per year**
  - **Adults active in July**
  - **Trap June to August**

How to monitor it?

Where is it?

- **Confirmed catches**
  - **NW Ohio since 2007**
  - **Central Ohio since 2009**
  - **But numbers very low compared to West**



How to monitor?, part 2

- **If any moths trapped, then scout:**
  - **Late July & early August**
  - **In plantings with tassels emerging**
  - **Upper 4 leaves of 100 plants/planting**
  - **Look for eggs**
  - **Look for young larvae**

How to decide on control?

- **Thresholds (sweet corn):**
  - **4% of plants infested (processing)**
  - **Tentative: 1% of plants (fresh-market)**

What are control options?

- **Insecticide:**
  - **When eggs are hatching →**

  - **When ~90% of tassels have emerged**
  - **A pyrethroid or Sevin**

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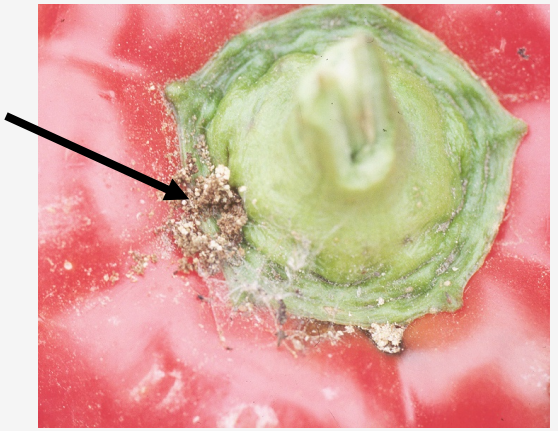
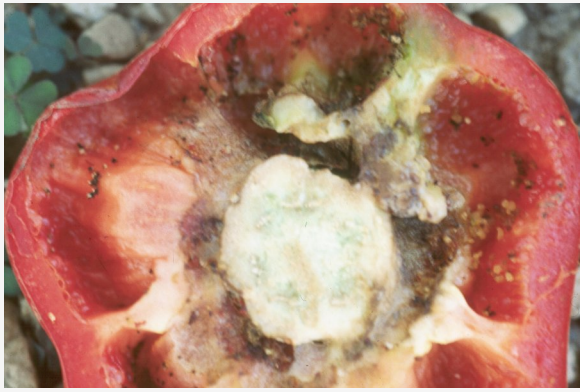
- **Transgenic BT hybrid varieties:**
  - 'Attribute' sweet corn and 'YieldGard' field corn are not effective
  - 'Herculex' field corn is effective

Worms in Peppers

European Corn Borer

- **Key pest of bell peppers**
  - **Bore into fruit**
  - **Quality loss**
  - **Yield loss**

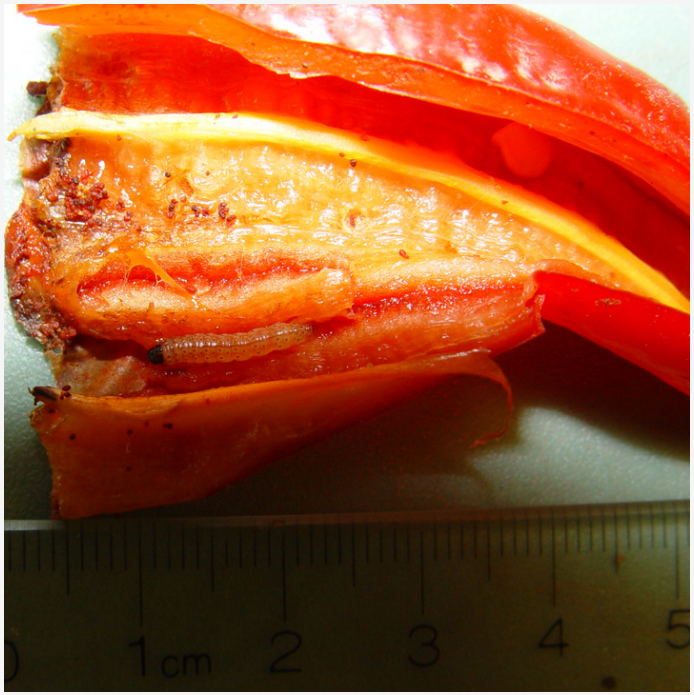




European Corn Borer

- **Also infests non-bell peppers**

jalapeño

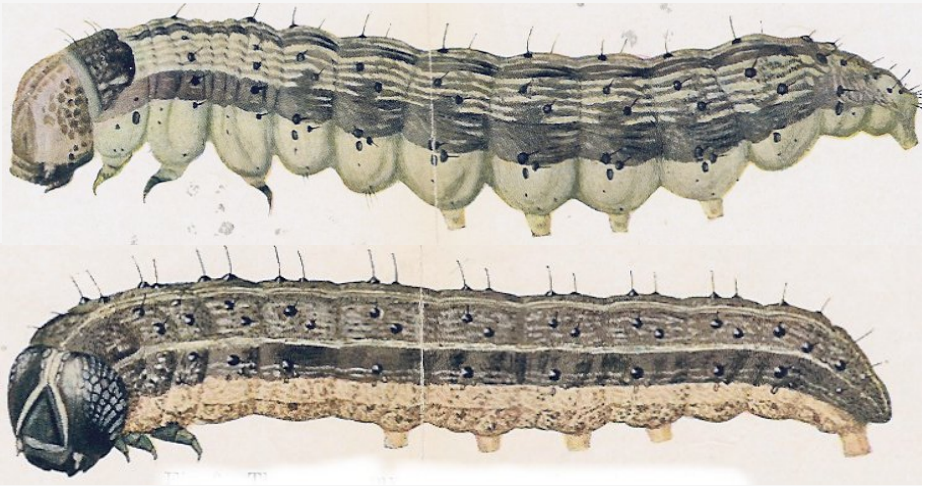


cayenne

cherry

Occasional pests in peppers

- Corn earworm
- Fall armyworm
- Beet armyworm
- Hornworms



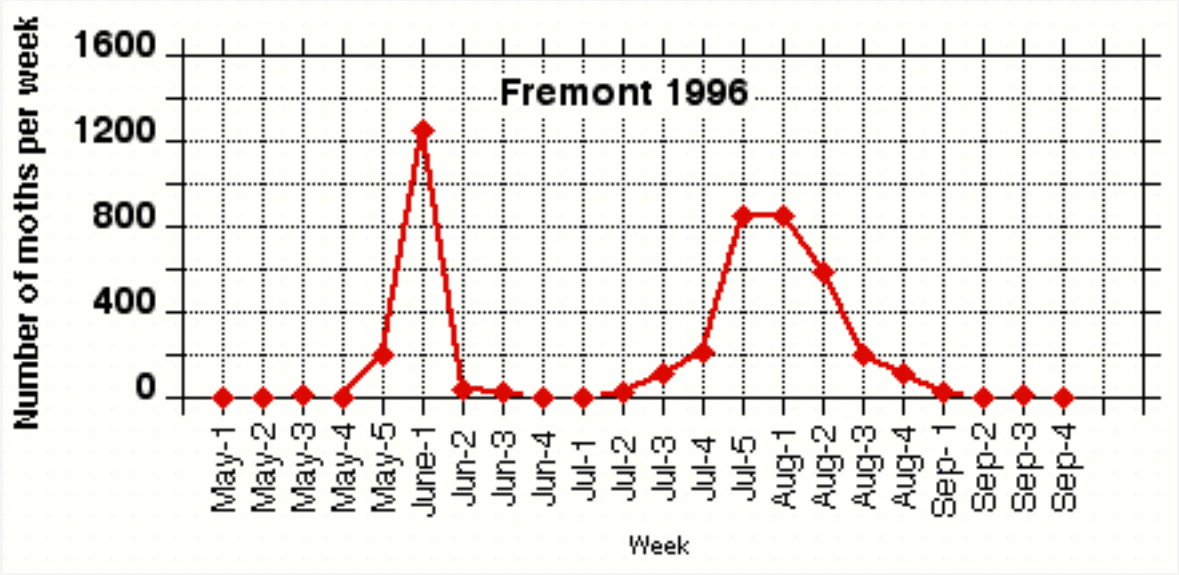
Controlling borers in peppers

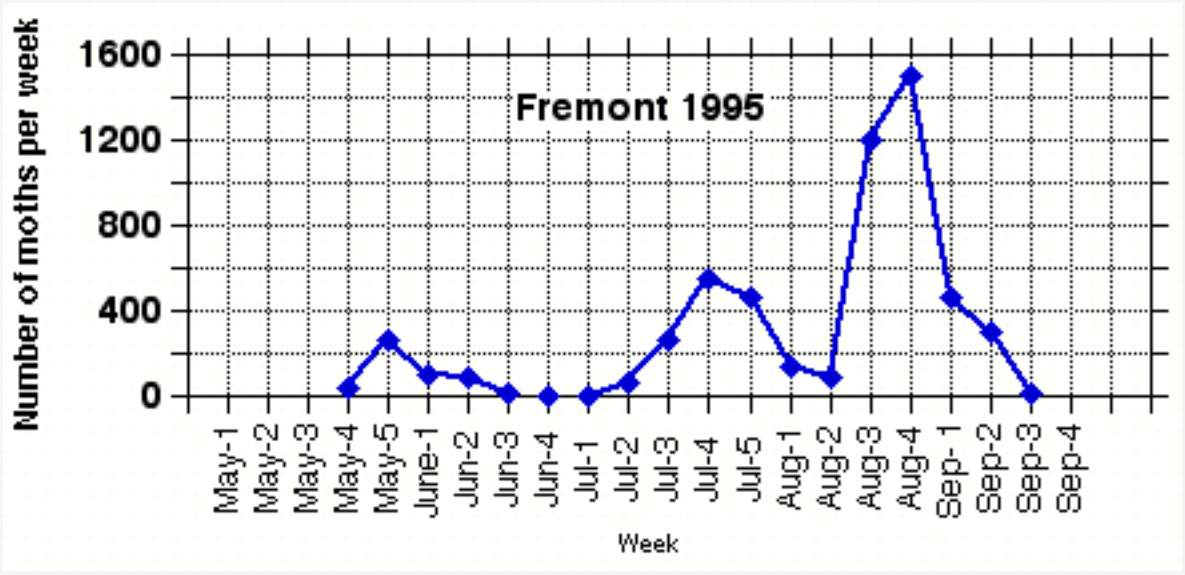
- Target of insecticide:
  - young larvae
  - cap end of fruit
- Insecticide efficacy affected by:
  - timing
  - coverage
  - choice of material

When does European corn borer damage peppers?

Month	Fruit present?	Moths present?
May	no	no
June	no	yes (1st gen.)
July	yes	no
August	yes	yes (2nd gen.)
September	yes	no/yes (if 3rd gen.)

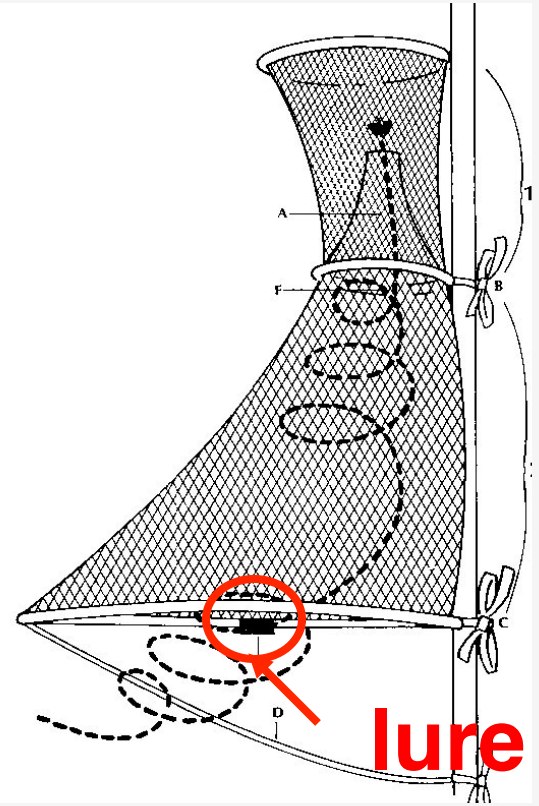
ECB: 2 vs 3 generations





Trap to Monitor European Corn Borer

- Pheromone lure
- Attracts male moths



Challenge: good control

- 100% control of ECB is rare
- Due to canopy:
  - Dense
  - Hard to cover thoroughly

- Due to borer location:
  - Entry on stem often oriented down
  - Protected inside fruit
- Processors demand <3% damage

Insecticide timing for borer control in pepper

- **First spray:**
  - within 1 week of surge in trap catch
  - when >1 moth/night in trap
  - usually late July
- **Spray schedule:**
  - spray every 7 days (range 5 - 14 days)
  - during time moths active, 4 - 6 weeks
- **Stop spraying:**
  - once trap catch falls (usually early Sept.)
  - or until harvest if other pests active

Insecticides for borer on peppers

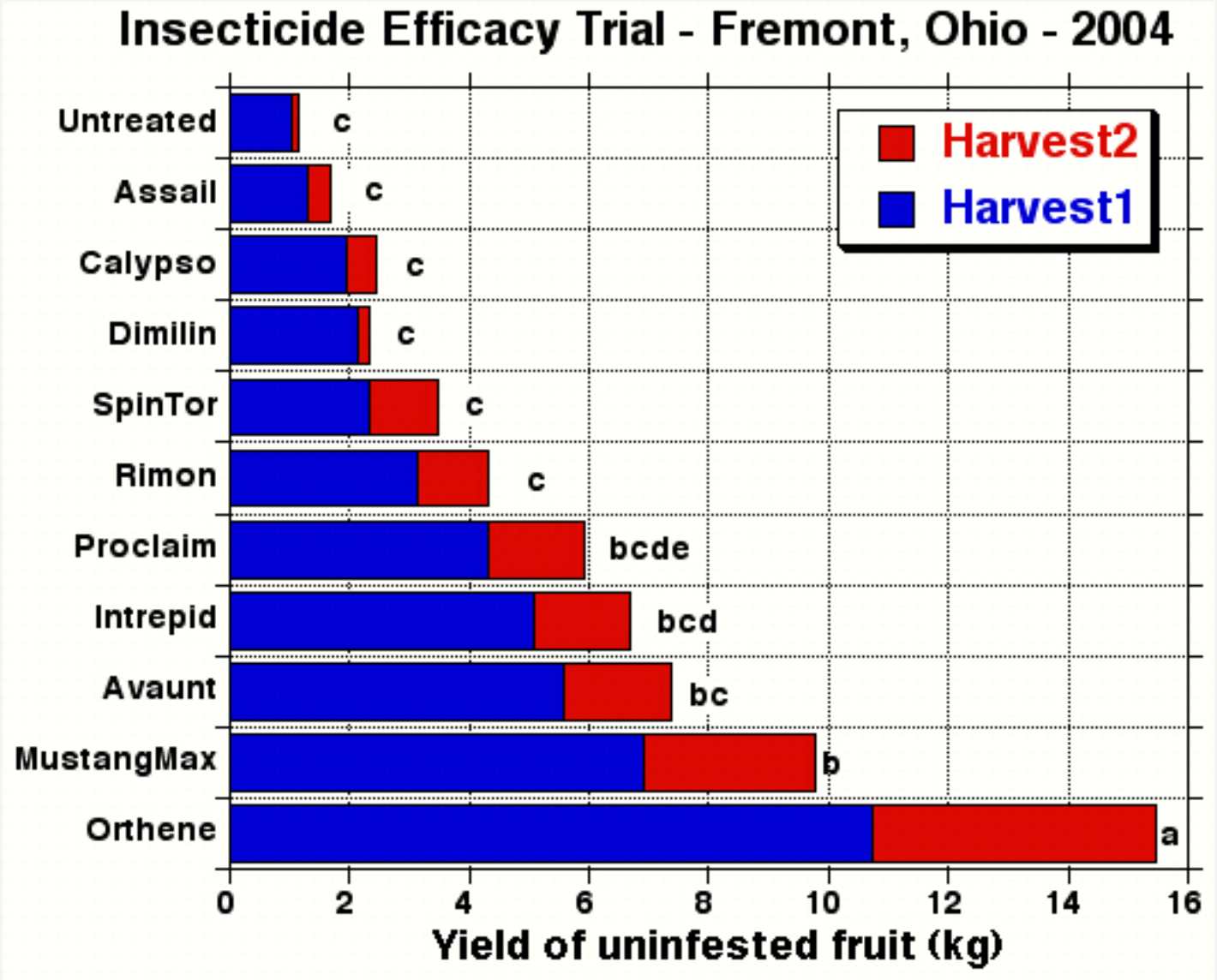
Insecticide	*PHI*	*efficacy*
Coragen	1	E
Orthene	7	E
Mustang	1	G
Pounce/Ambush	3	G
Warrior	5	G
Baythroid	7	G
Brigade	7	G
Radiant	1	G
Intrepid	1	G
Confirm	7	G
Asana	7	F
Sevin	3	F
Lannate	3	F
B.t.	0	F

European Corn Borer on Peppers

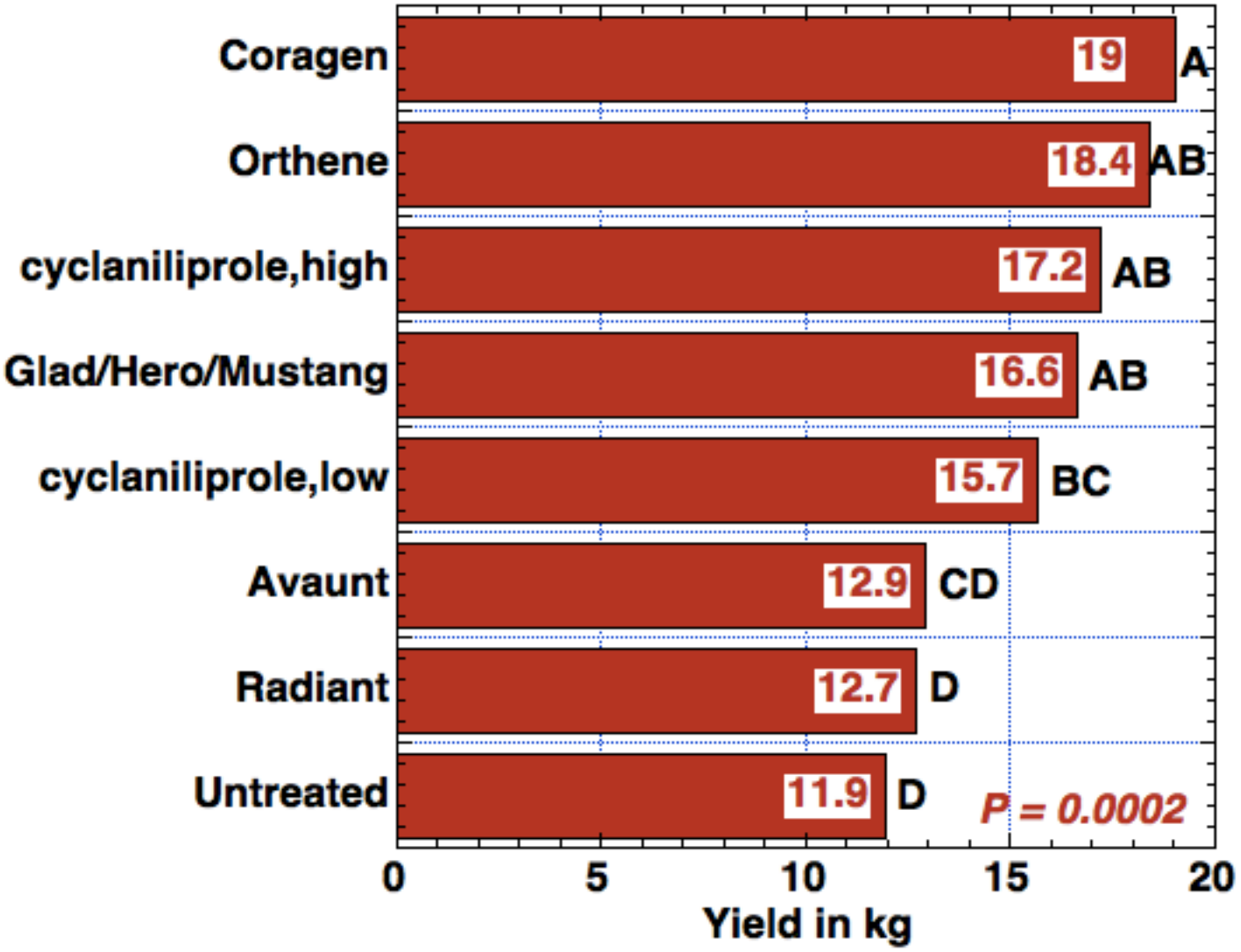
- When temperature average:
  - –Only 2 generations likely
  - –Need 4 to 6 sprays total
- When very hot:
  - –3 generations likely
  - –Need 8 to 10 sprays total

Spray B.t. on peppers

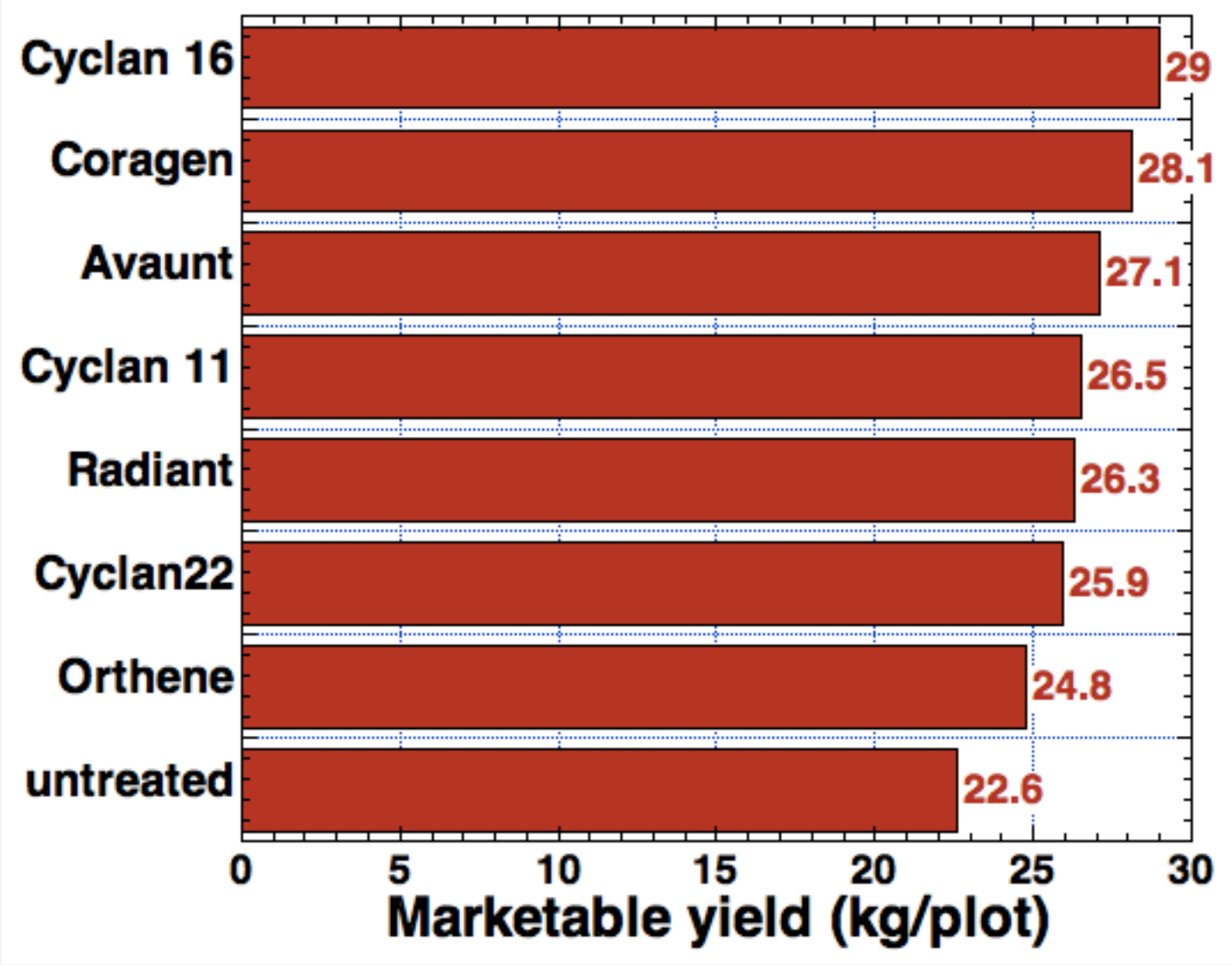
- ***Bacillus thuringiensis* products:**
  - **Javelin, CryMax, Agree, Deliver (Certis)**
  - **DiPel, XenTari (Valent)**
- **Controls caterpillars:**
  - **European corn borer**
  - **Hornworms**
- **Apply twice per week**

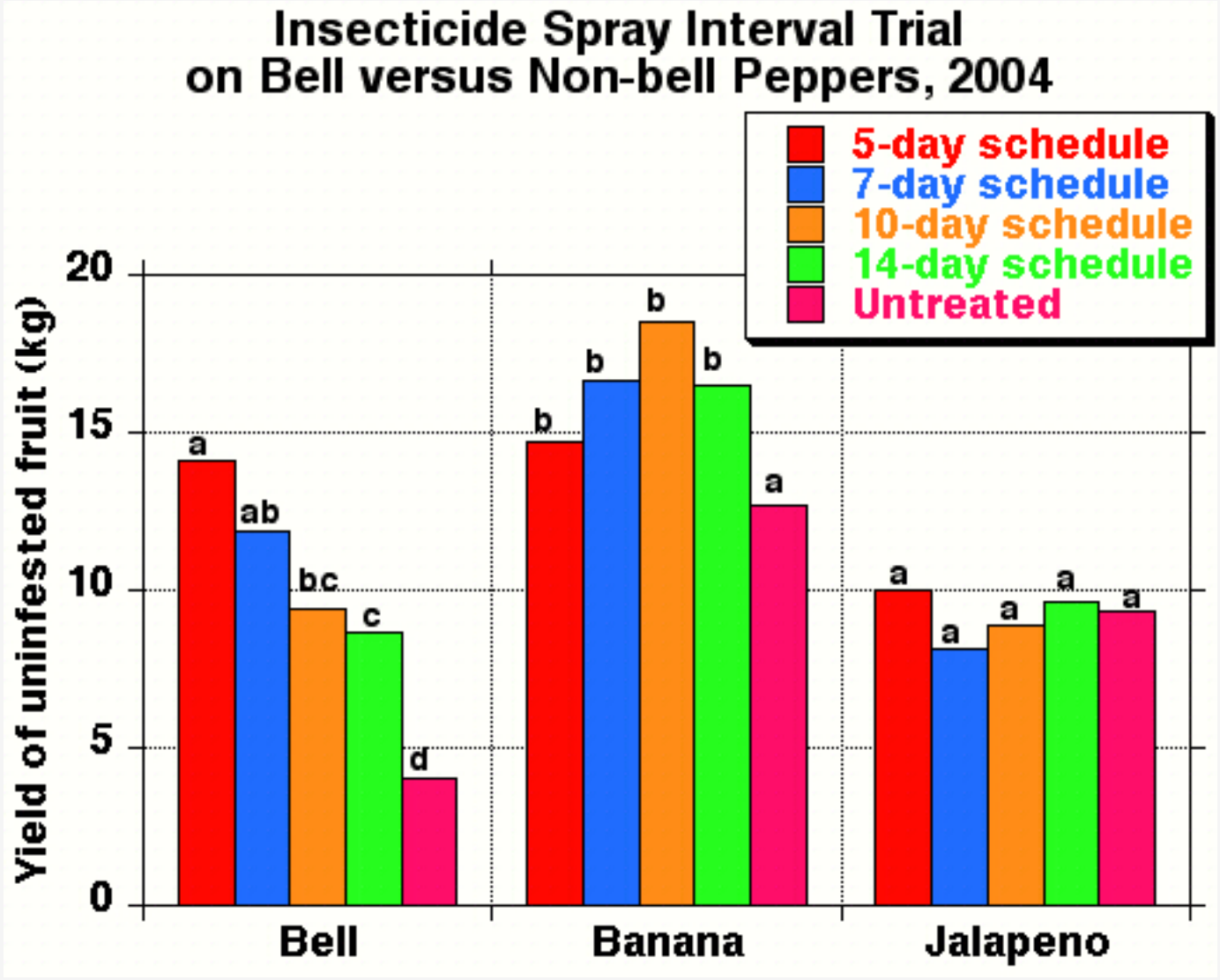

Insecticide Efficacy Trial - Fremont, Ohio - 2004
Harvest2
Harvest1
Untreated
Assail
Calypso
Dimilin
SpinTor
Rimon
Proclaim
Intrepid
Avaunt
MustangMax
Orthene
c
c
c
c
c
c
bcde
bcd
bc
b
a
0
2
4
6
8
10
12
14
16
Yield of uninfested fruit (kg)

Marketable yield of red bell peppers in 4 harvests (cumulative) after 5 insecticide applications at 10-day spray interval, Fremont, Ohio, 2013



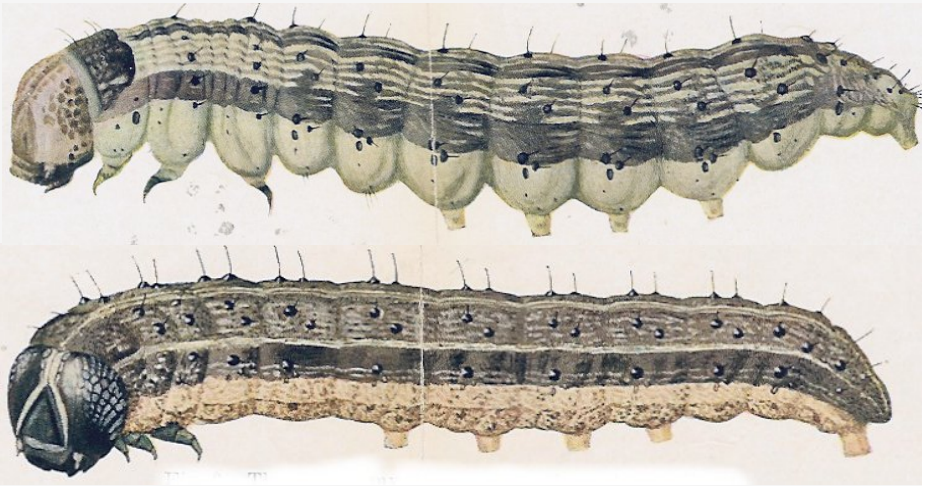
Marketable yield of red bell peppers after insecticides at 7-day interval, 2014




Insecticide Spray Interval Trial
on Bell versus Non-bell Peppers, 2004
5-day schedule
7-day schedule
10-day schedule
14-day schedule
Untreated
Yield of uninfested fruit (kg)
20
15
10
5
0
a
ab
bc
c
d
b
b
b
b
a
a
a
a
a
a
Bell
Banana
Jalapeno

Occasional pests in peppers

- Corn earworm
- Fall armyworm
- Beet armyworm
- Hornworms



Beet Armyworm

- Pepper & tomato
- Leaves & fruit

- Scout for window-paning on upper youngest leaves
- Green, usually striped, 1 1/4”
- Not susceptible to pyrethroids

Beet Armyworm

- Monitor moths with pheromone trap
- Scout field if any moths caught
- Abundant at some sites in Ohio 2004:
  - June: most with 1-10 moths per trap per week
  - July: most with 3-60; up to 223
  - August: most with 25-100; up to 330

Beet Armyworm

- **Insecticide choices:**
  - Confirm/Intrepid excellent
  - Avaunt excellent
  - Proclaim excellent
  - Radiant excellent (young worms)
  - Radiant good (older worms)
  - B.t. aizawai* fair
  - Orthene poor
  - Baythroid poor
  - Warrior poor
  - Asana poor
  - Lannate poor

*aizawai strain in Agree, XenTari

Worms in Cole Crops:

cabbage, broccoli, collards, kale, turnip

- pests & natural enemies
- scouting & thresholds
- using BT & insecticides

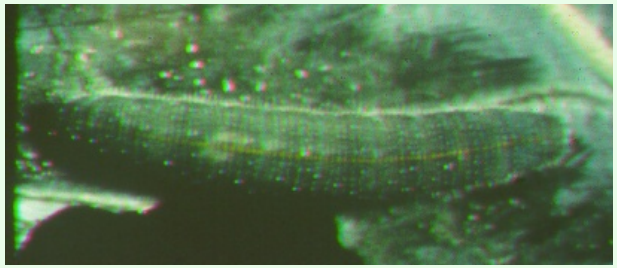
Caterpillars on cole crops

- Diamondback moth

- Imported cabbageworm

- Cabbage looper

Parasitoid wasps attack caterpillars

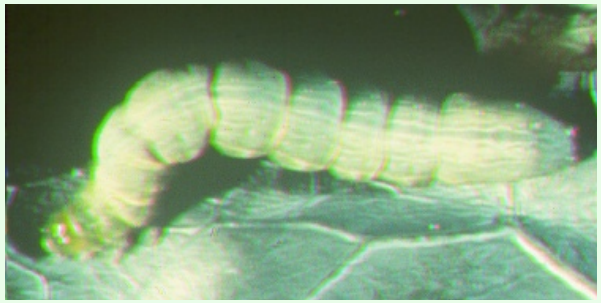


Imported cabbageworm

Cotesia larvae

Cotesia adults emerging

Cotesia adult wasp



Cabbage looper

Copidosoma floridanum wasps emerging from one cocoon

Diamondback moth

Diadegma insulare oviposits on larvae

Diadegma insulare, Parasitoid of Diamondback Moth Larvae

- small wasp, 1/4” long
- black body, red/brown marks
- adult wasp lays egg in older caterpillar
- new adult wasp emerges from pupa

Diamondback & Biocontrol

- **% of diamondback larvae attacked:**
  - **53 to 88% in Wisconsin study**
  - **46 to 69% in Virginia study**
  - **24 to 36% in Ohio study**

Diamondback pupae

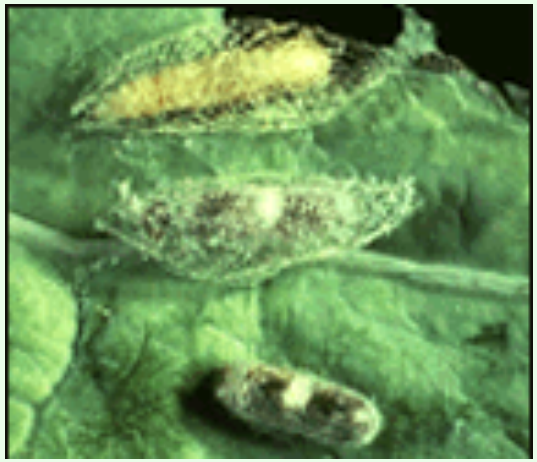


Photo by J. Ogrodnick

Healthy pupa

Parasitized pupae

Floral resources help biocontrol

- Provide nectar: food for adult parasitoids
  - wasps live longer
  - lay more eggs
  - sting host faster

- Attracts some biocontrol agents
- Can be scarce in conventional fields
- Wild: yellow rocket, wild mustard
- Cultivated: sweet alyssum
- Trials with alyssum, 2011 & 2012

Does cabbage need insecticide treatment for caterpillars?

- If few worms: no
- If many worms: yes
- If some worms: need help

Caterpillar management

- Decisions (weekly)
  - Need to apply insecticide?
  - Which insecticide?
- Constraints
  - Resistance to insecticides
- Tools
  - Scouting
  - Thresholds

Management Decisions

- **Scouting** = how many worms are in field?
- **Thresholds** = is the number of worms more or less than what the plant can tolerate?

Management decisions using scouting & thresholds

- Formal: at start
- Casual: after experience

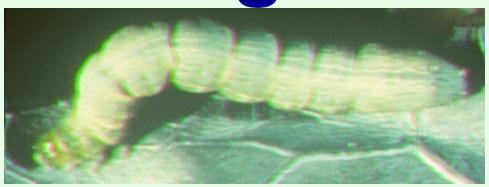
Basis for cabbage thresholds

- Number of worms tolerated by crop depends on plant size
- Different worm species eat at different rates
- Air temperature affects feeding rate of worms

Larval Units (LU)

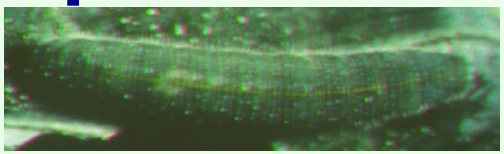
1 LU = 1 large cabbage looper

1 LU = 1.4 small cabbage loopers



1 LU = 1.4 large imported cabbageworms

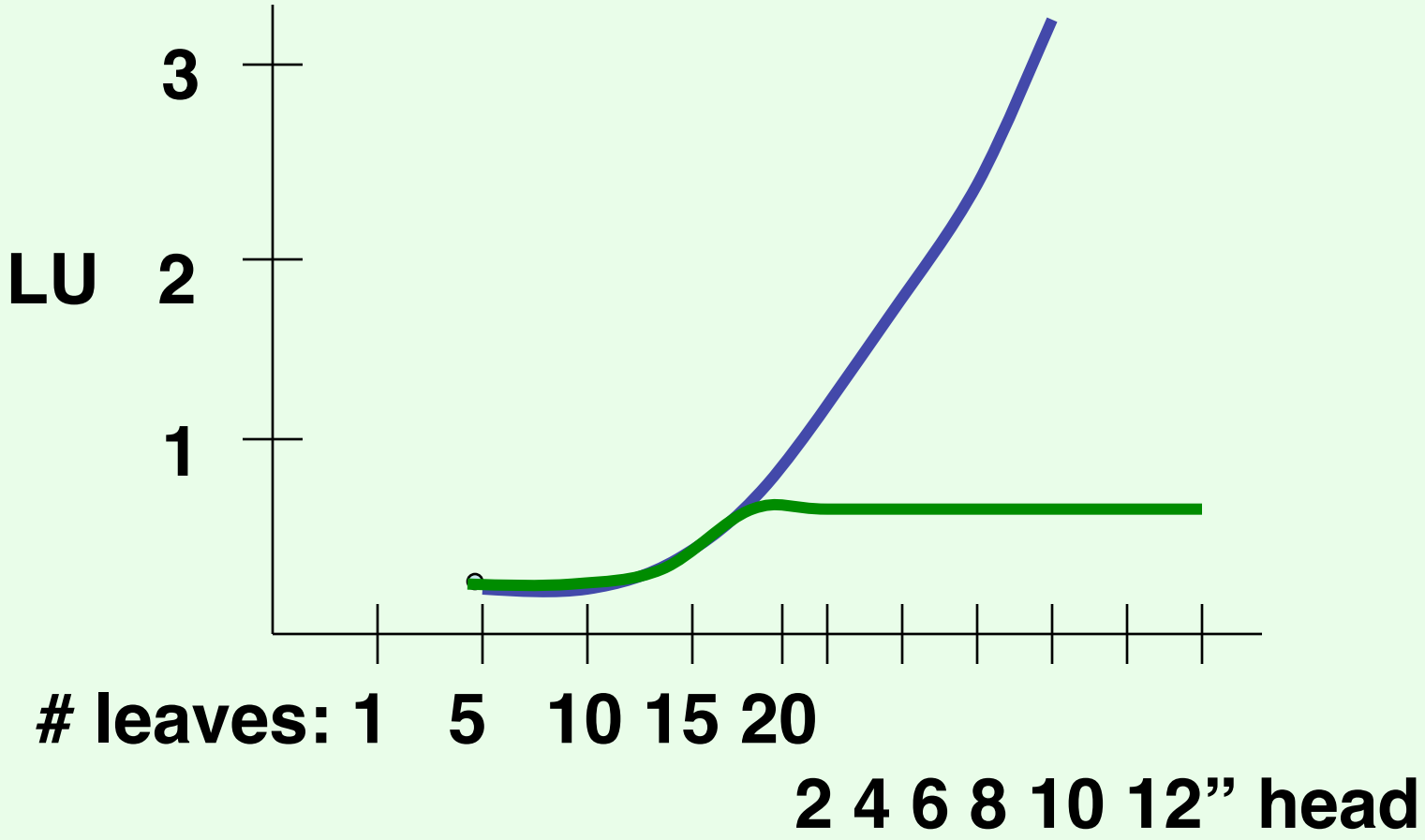
1 LU = 10 small imported cabbageworms



1 LU = 10 diamondback larvae

Caterpillar thresholds

- Processing cabbage
- Fresh-market cabbage



Thresholds, Processing Cabbage

Avg temp	Threshold (Avg Larval Units per plant)		
	4-leaf	16-leaf	6”head
60°F	0.08	1.46	6.25
70°F	0.04	0.69	2.94
80°F	0.03	0.48	2.04

See handout for complete list of temperatures and plant stages

Cabbage weekly scouting steps

1. Determine crop stage
2. Determine sample size
   - Fixed:
     - young (<8 leaf): 4 plants @ 10 segments
     - older (>8 leaf): 2 plants @ 10 segments
   - Variable: 1 - 4 plants @ 10 segments
3. Randomly choose plants to inspect
4. Inspect plants for target pests
5. Record # of pests per category

Decision-making steps

1. Determine average number of caterpillars per plant for 3 species
2. Convert to total Larval Units
3. Find action threshold (for crop growth stage & temperature)
4. Compare current LU with threshold LU

Caterpillar Response to Insecticides

- **Imported cabbageworm:**
  - **Easiest to kill**
- **Cabbage looper:**
  - **Most difficult to kill**
- **Diamondback:**
  - **Usually difficult but varies with population's history of resistance**

Cabbage Insecticide Efficacy

Product	Caterpillar species		
	Imported cab'wm	Diamond back	Cabbage looper
Avaunt	good	excel.	excel.
B.t. (DiPel)	good	good	fair
Confirm, Intrepid	good	fair	good/excel
Proclaim	good	excel.	fair/good
SpinTor, Radiant	good	excel.	good
pyrethroids	good	good	good
Lannate			
Sevin			

Integration of chemical control & biological control

- **Depends on choosing a selective insecticide**
  - **Kills caterpillars**
  - **Does not kill parasitoids**
  - **Use microbial insecticide, BT**
    - **‘DiPel’, ‘Javelin’, ‘XenTari’ etc.**

Insecticides for caterpillar management on cole crops

Insecticide	*Imported cabbage-worm*	*Diamond-back moth*	*Cabbage looper*	*Natural enemies*
Conventional	Excellent control	Fair control	Good control	Poor survival
B.t.	Good control	Good control	Fair control	Excellent survival

Thus B.t. works best when diamondback moth or imported cabbageworm is dominant pest

Caterpillar Calendar

Calendar for integrated bio & chemical control in cabbage

- **Early & mid-season (April to July)**
  - if imported cabbageworm &/or diamondback dominant
  - **use only B.t.**
- **Mid- to late-season (August)**
  - if cabbage looper dominant pest
  - use Confirm, SpinTor, or Proclaim
- **Late season (Sept.-October)**
  - if cabbage looper dominant pest
  - use pyrethroids

B.t. for control of caterpillars

What is B.t.?

- A natural soil-borne bacterium
- Species: *Bacillus thuringiensis*
- This bacterium produces crystal-like proteins that kill certain insects
- Found world-wide
- Produced by fermentation methods
- Discovered 1915; used since 1957

How does B.t. work?

- B.t. must be eaten by target insect
- B.t. contains toxins that are activated by insect's gut enzymes
- toxins paralyze digestive tract
- feeding stops within 2 hours
- death takes 1 - 5 days

B.t. products

- For caterpillar control:
  - DiPel, XenTari, Biobit (Valent)
  - Javelin, Agree, CryMax, Deliver (Certis)
- For Colorado potato beetle:
  - Novodor (Valent)

B.t. performance

- **Sometimes erratic:**
  - **Breakdown in U.V. light**
  - **Reduced toxicity against older larvae**
  - **Incomplete spray coverage**
  - **Too long a spray interval**
- **Best if:**
  - **Target young larvae**
  - **Apply at frequent intervals**
  - **Get thorough coverage**
    - **Lot of water (>35 gal/A)**
    - **Good pressure (60 psi)**

How are B.t. sprays most effective?

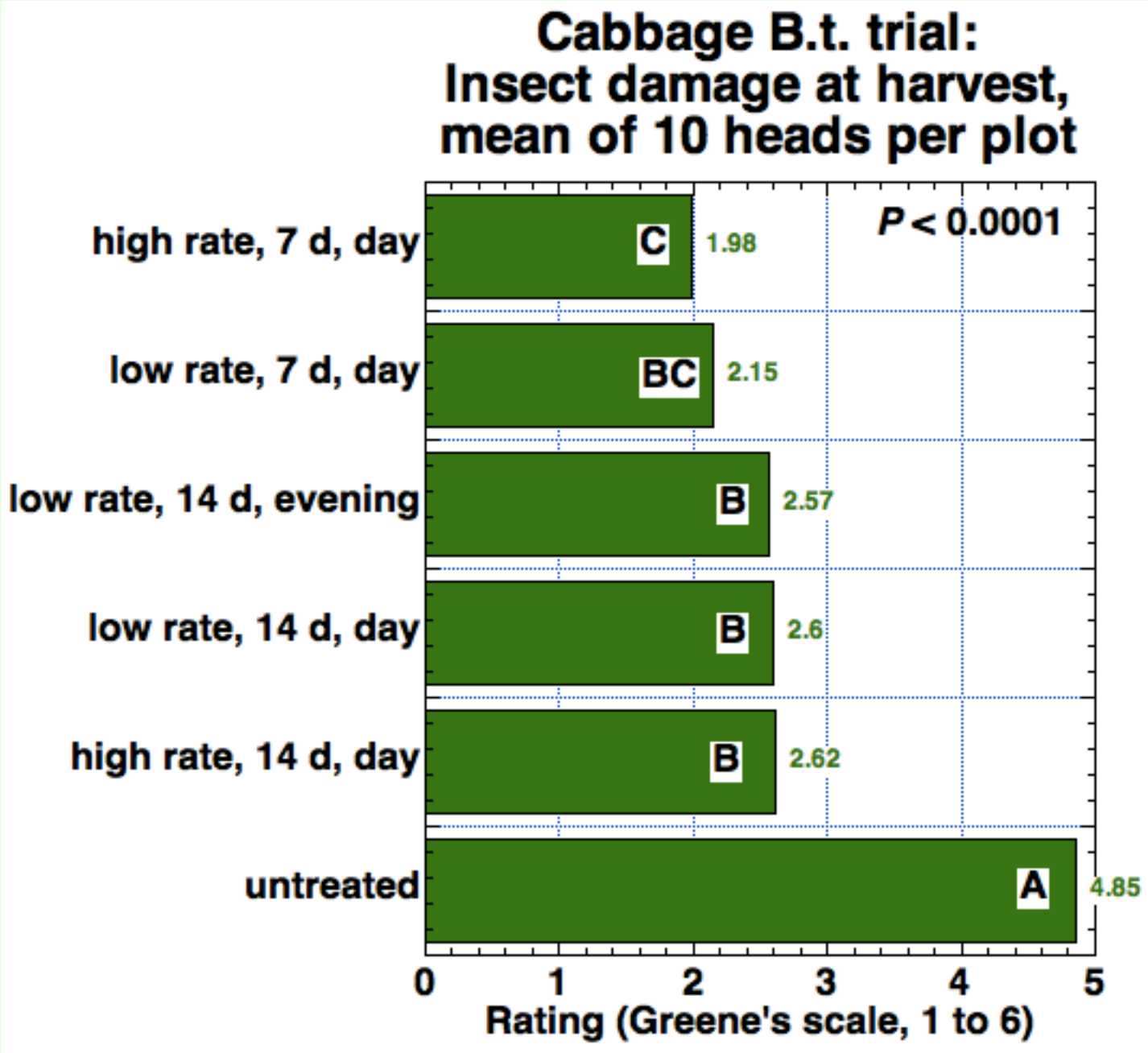
- Rate?
- Frequency?
- Time of day?

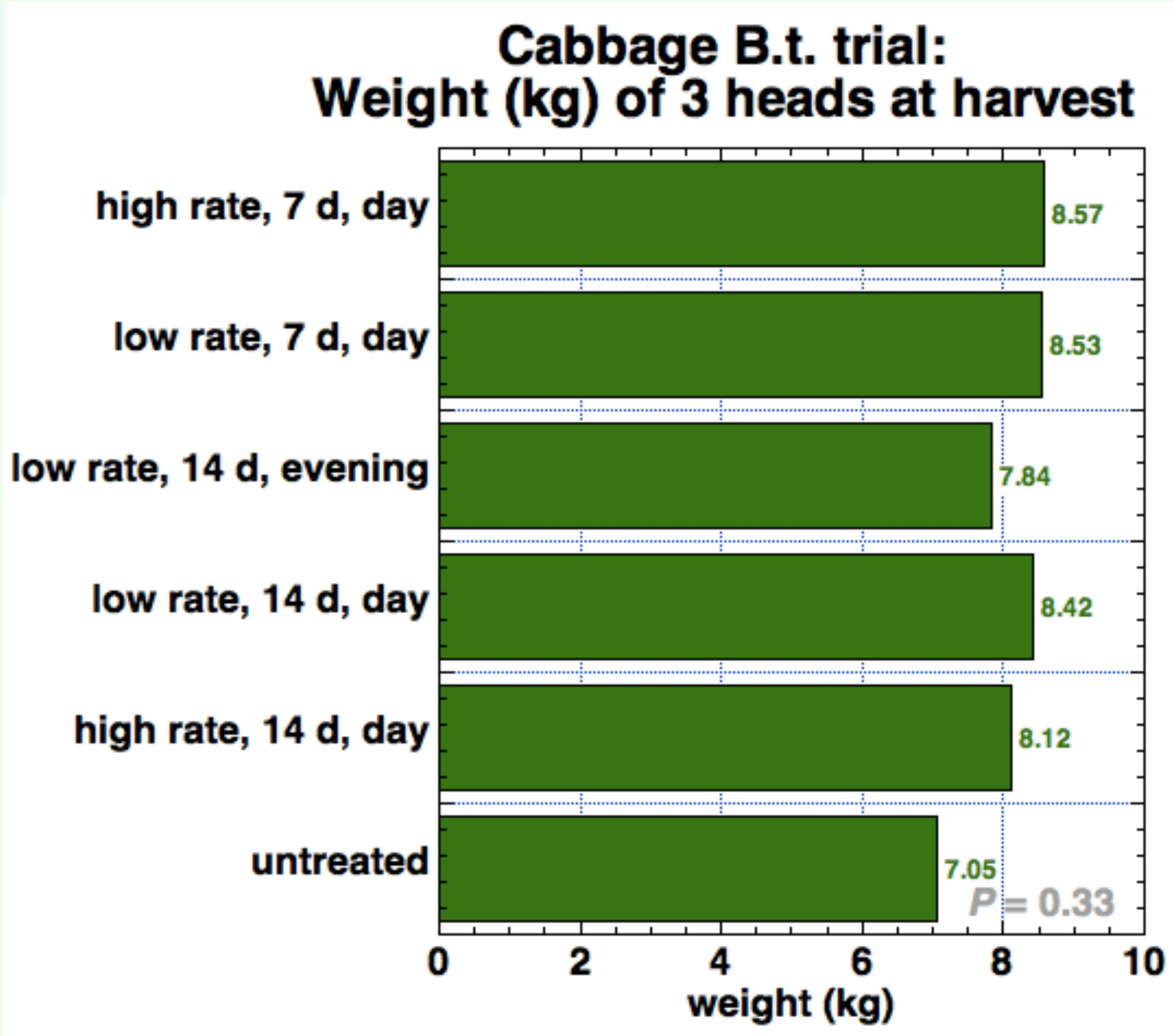
Field trial on B.t. in cabbage, 2012

- cv ‘Bravo’
- Transplanted 18 May
- Scouted weekly for insects
- 1st spray 18 days after planting
- Sprays for 11 weeks
- Harvest 20 August

B.t. trial: Treatments

Treat-ment	Rate of Dipel DF	Frequency	Time
1	-	-	-
2	Low (0.5 lb/A	Every 7 days	daytime
3	Low (0.5 lb/A)	Every 14 days	daytime
4	High (1.0 lb/A)	Every 7 days	daytime
5	High (1.0 lb/A)	Every 14 days	daytime
6	Low (0.5 lb/A)	Every 14 days	evening

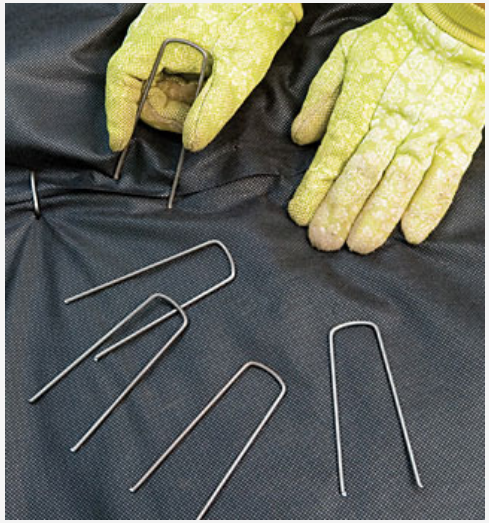

Cabbage B.t. trial:
Insect damage at harvest,
mean of 10 heads per plot
P < 0.0001
high rate, 7 d, day
C
1.98
low rate, 7 d, day
BC
2.15
low rate, 14 d, evening
B
2.57
low rate, 14 d, day
B
2.6
high rate, 14 d, day
B
2.62
untreated
A
4.85
0
1
2
3
4
5
Rating (Greene's scale, 1 to 6)


Cabbage B.t. trial:
Weight (kg) of 3 heads at harvest
high rate, 7 d, day
low rate, 7 d, day
low rate, 14 d, evening
low rate, 14 d, day
high rate, 14 d, day
untreated
8.57
8.53
7.84
8.42
8.12
7.05
P = 0.33
0
2
4
6
8
10
weight (kg)

B.t. trial: Conclusions

- Frequency more important than rate
  - Every 7 days better than every 14 days
  - Low rate as effective as high rate
- Daytime spray as effective as evening spray

Cole crop pests: mechanical control by row covers



18 important caterpillar pests on veg crops

Crop	Pest
Sweet corn	Corn earworm + European corn borer + Fall armyworm + Western bean cutworm Armyworm Black cutworm +
Pepper, tomato	Tobacco hornworm Variegated cutworm Yellow-striped armyworm Stalk borer + Beet armyworm
Cole crops & greens	Imported cabbageworm Diamondback moth Cabbage looper + Cross-striped cabbageworm Zebra caterpillar +
Squash & pumpkins	Squash vine borer
Parsley	Parsleyworm

the end

Info on fruit & veg. pests
u.osu.edu/pestmanagement/

Questions?

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