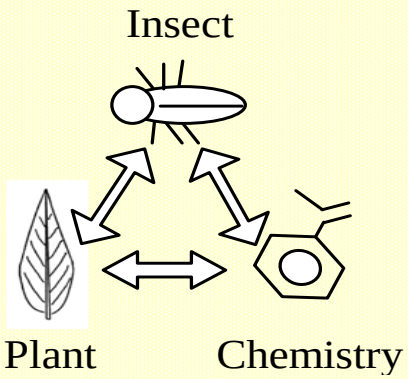
Introduction to Pesticides:

Understanding Performance Characteristics of Insecticides



John C. Wise, Ph.D.
MSU Department of Entomology
Trevor Nichols Research Center

Toxicology 101

- Toxicology: The science of dealing with the dose and antidotes of poisons

- Paracelsus (1492-1541) is the father of toxicology
  - Formulated revolutionary views on toxicology
  - Realized that poisons were chemicals, not “spirits”
    - Toxicon = toxic agent = chemical agent
    - Determined there were dose-response relationships

What makes something a poison?

"All substances are poisons; there is none which is not a poison. The right dose differentiates a poison...."

Paracelsus
(1493-1541)

Which is a true example of a poisoning?

Woman Dies from Drinking Water.

SACRAMENTO, California (AP) — A woman in a radio station's contest to see how much water she could drink without going to the bathroom died of water intoxication, the coroner's office said Saturday.

44 Toxic Chemicals Pollute Blood of Canadians

Ottawa , Ontario **-** A cocktail of harmful toxic chemicals has been found inside every person tested in a Canada-wide study, released today by Environmental Defense.

What is a Pesticide?

Historical definition:

"all inclusive word meaning killer of pests."

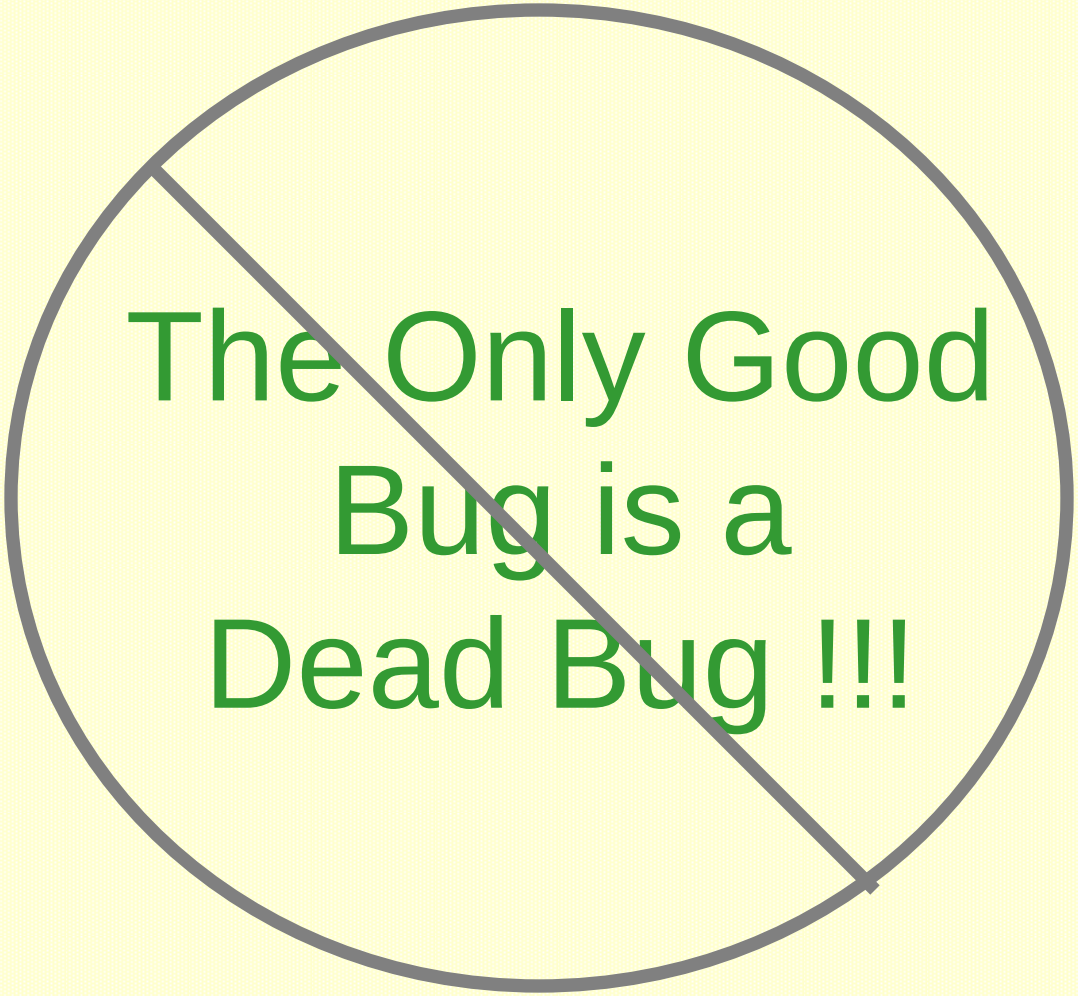
- The ending "*cide*" comes from the latin "*cida*" meaning killer.

Modern legal definition:

"any substance used for controlling, preventing, destroying, repelling, or mitigating any pest."

Pest Management

- To the degree that pest population management and crop protection goals are met, a compound's performance should be deemed acceptable.
- Crop protection does not necessitate pest mortality!


The Only Good
Bug is a
Dead Bug !!!

What is Effective Pest Management Performance?

"Any pest control tool (or combination of tools) employed in an IPM program must ultimately provide sufficient fruit protection to meet minimum grade standards for the targeted market."

Insecticides Registered in Fruit Crops - 1996

Conventional Insecticides

- Chlorinated Hydrocarbons (1)
- Organophosphates (6)
- Carbamates (2)
- Synthetic Pyrethroids (6)

New Insecticides

- Insect Growth Regulators (1)
- Avermectins (1)
- Neonicotinoids (1)

Insecticides Registered in Fruit Crops - 2014

20th Century Insecticides

- Chlorinated Hydrocarbons (1)
- Organophosphates (2)
- Carbamates (2)
- Synthetic Pyrethroids (6)

21st Century Insecticides

- Insect Growth Regulators (5)
- Spinosyns (2)
- Avermectins (2)
- Neonicotinoids (5)
- Oxadiazines (1)
- Diamides (3)
- Microbials/Botanicals (6+)
- Particle Film (1)
- Pyrizoles (1)
- Pyridine Carboxamides (1)
- Pre-mixes (4)

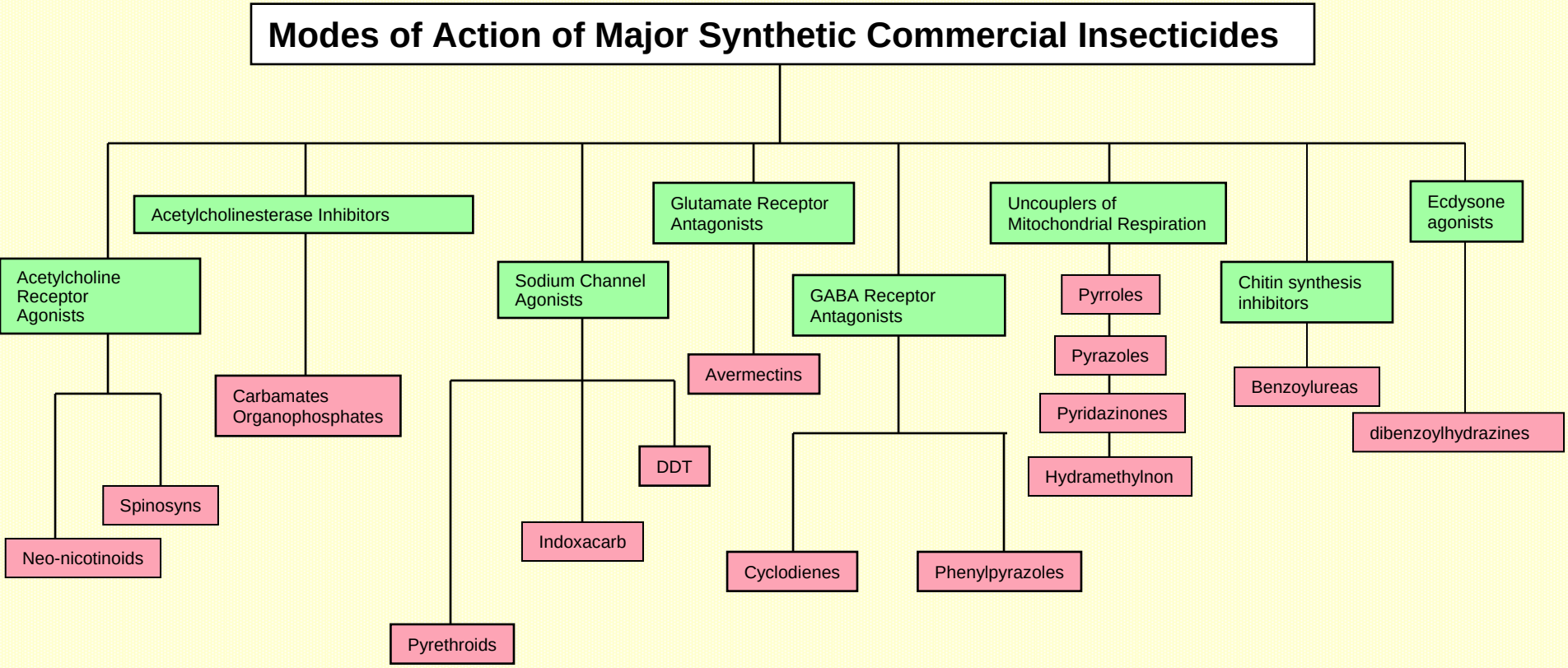
How are Pesticides Classified?

Pesticides are generally classified in 3 ways:

1. Based on chemical structures
2. According to their mode of action
3. According to their mode of entry

   i.e.; ingestion, inhalation, contact absorption

"*mode of action*" refers to the mechanism by which an insecticide controls the target organism.

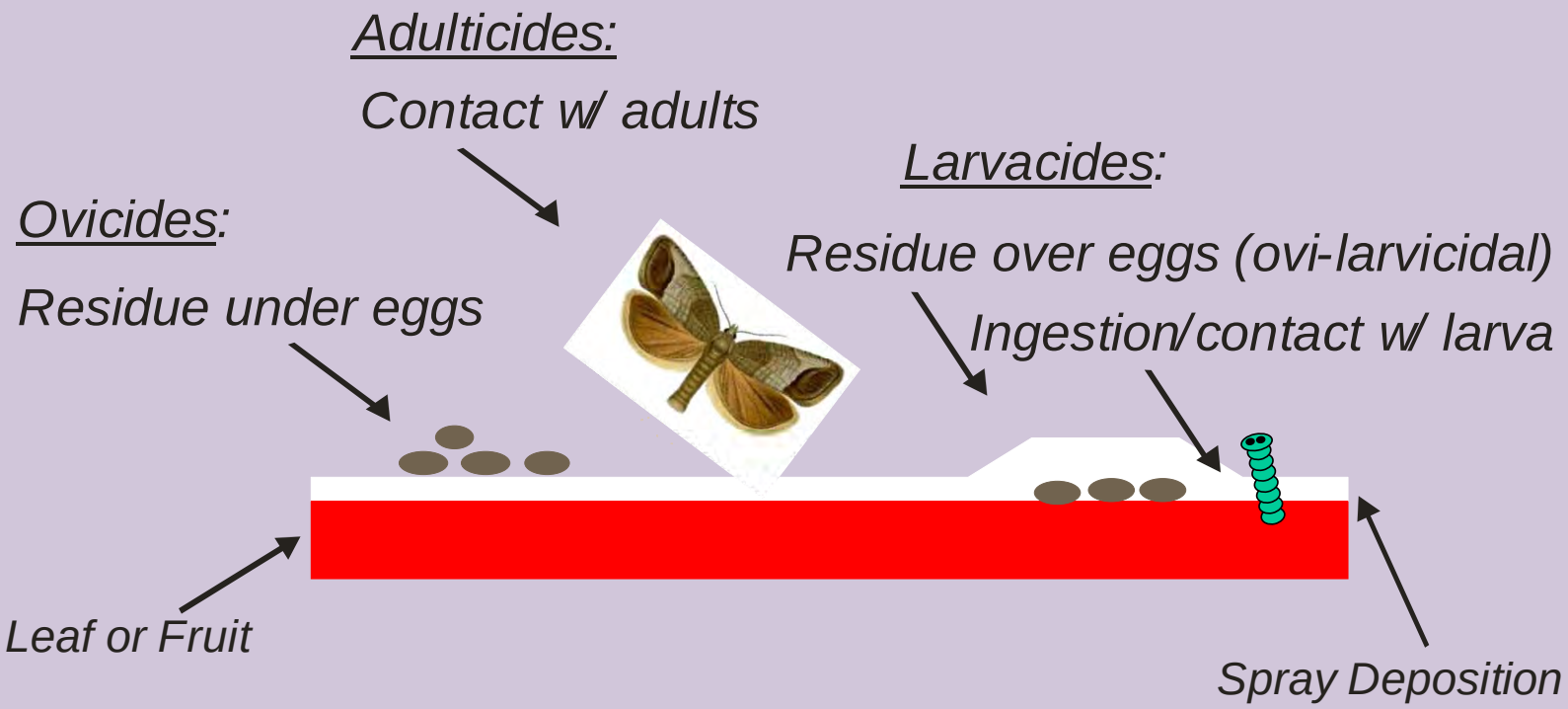


Mode of Activity

"*mode of activity*" is the field-assessable symptoms of an insecticide's action on an organism that are responsible for control.

- Insecticide Activity on Target Pest :
  - Lethal activity
  - Sub-lethal activity
  - Repellency
  - Anti-feedance and oviposition deterrence
  - Curative activity

Lethal activity results in direct mortality of the pest

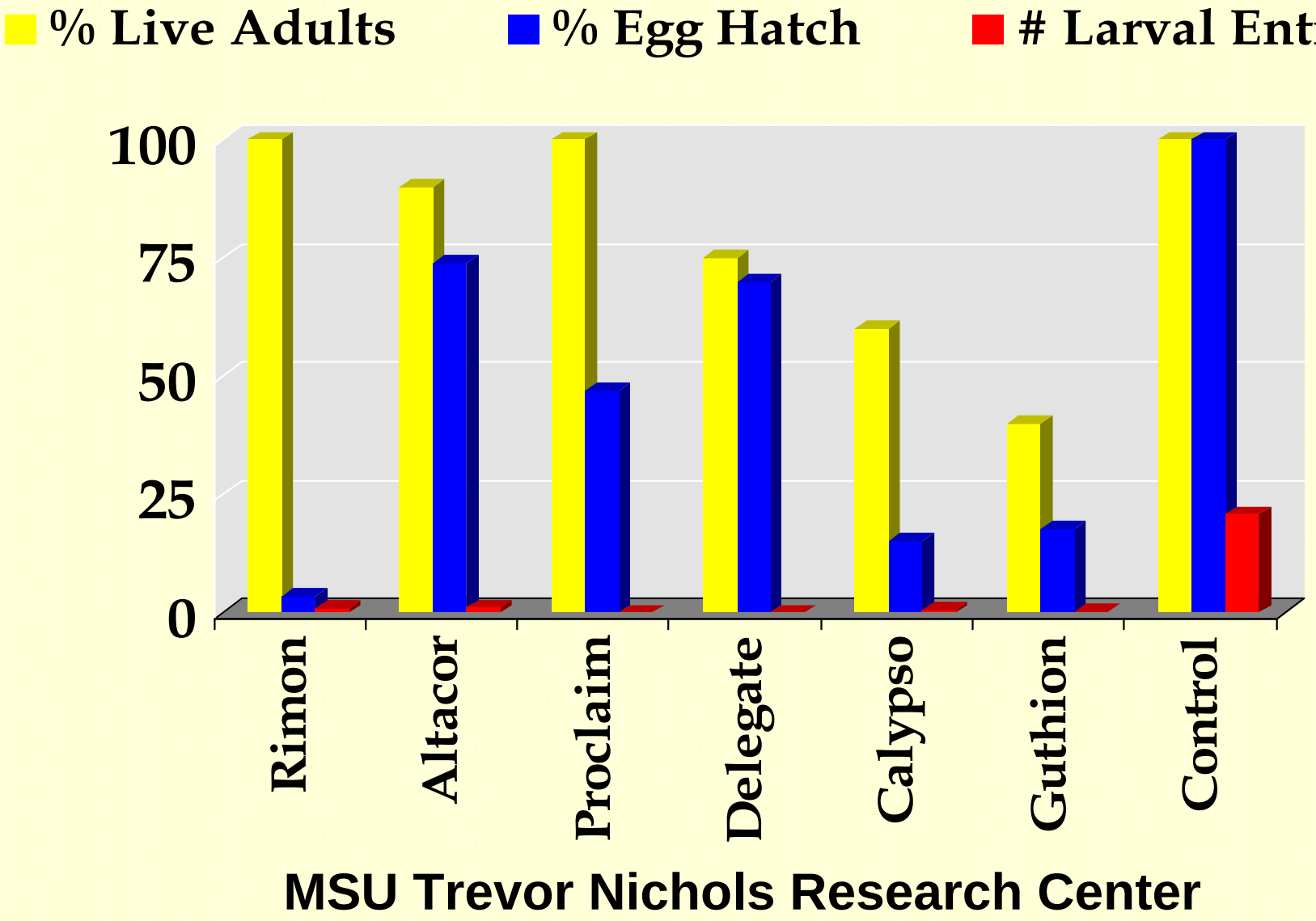


MICHIGAN STATE UNIVERSITY EXTENSION

CM Cumulative Life-Stage Activity Bioassays

Michigan State University AgBioResearch

Life Stage Activity of Insecticides on Codling Moth

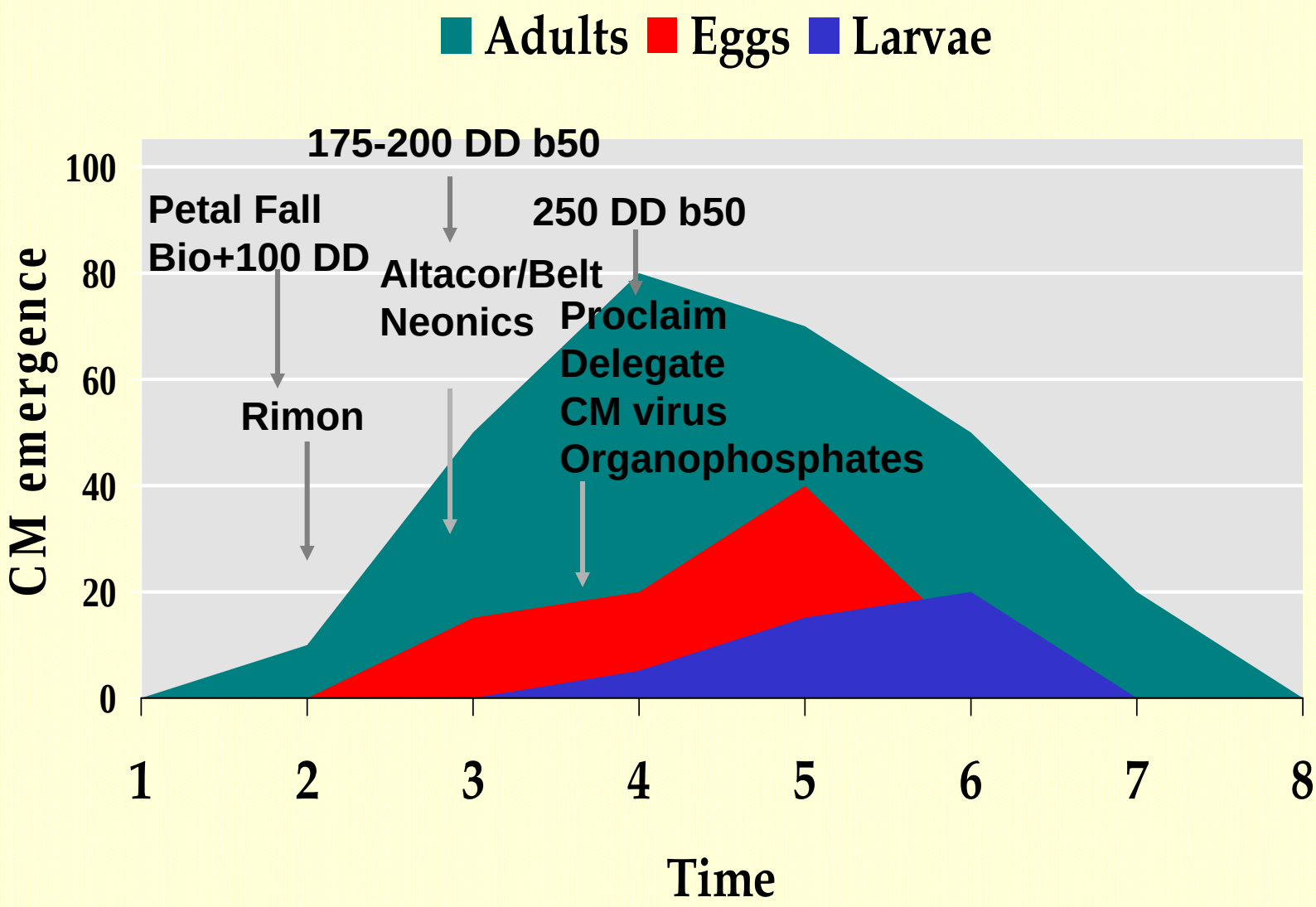


MSU Trevor Nichols Research Center

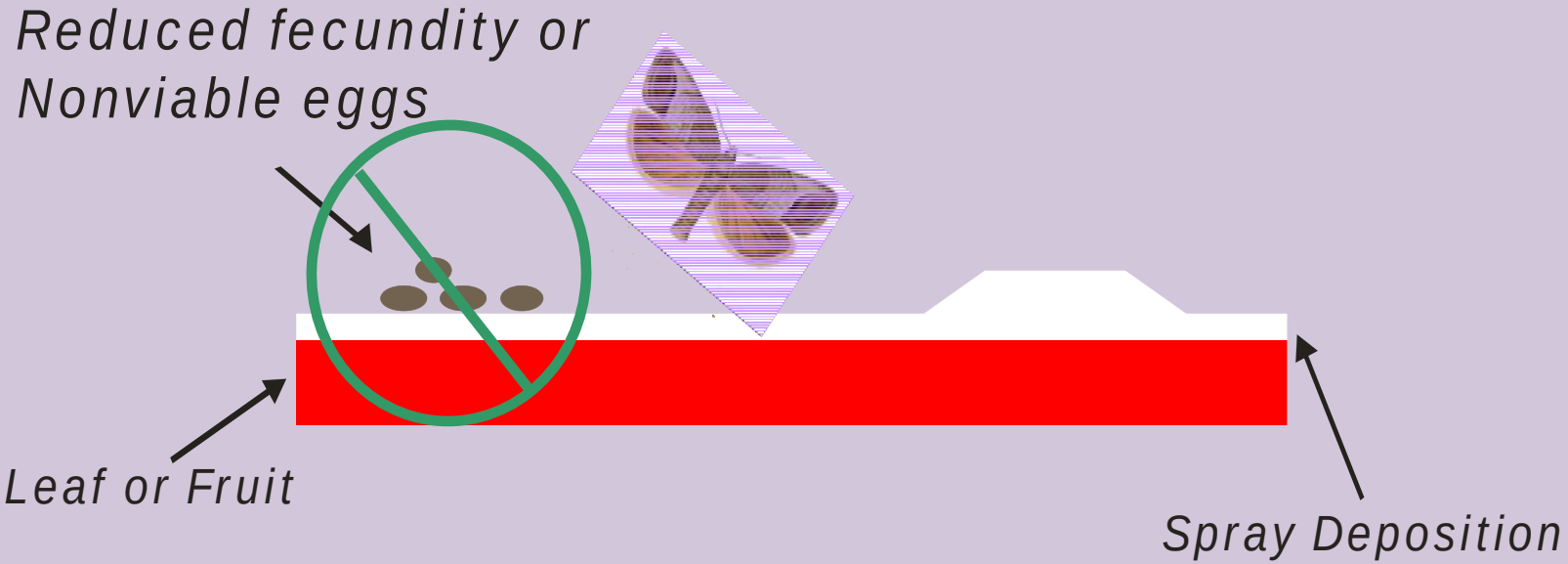
Insecticidal Activity on Codling Moth

Compound	Life-stage Activity	Mode of Exposure
Organophosphates	Eggs, Larvae, Adults	Contact / Ingestion
Pyrethroids	Eggs, Larvae, Adults	Contact / Ingestion
Rimon	Eggs Larvae Adult	Under / over egg contact Ingestion Contact – sublethal effects
Delegate	Eggs, Larvae	Ingestion / egg contact
CM Virus	Larvae	Ingestion
Neonicotinoids	Eggs, Larvae, Adults	Ingestion / contact
Proclaim	Eggs, Larvae	Ingestion / over egg contact
Altacor/Belt	Eggs, Larvae	Ingestion / over egg contact

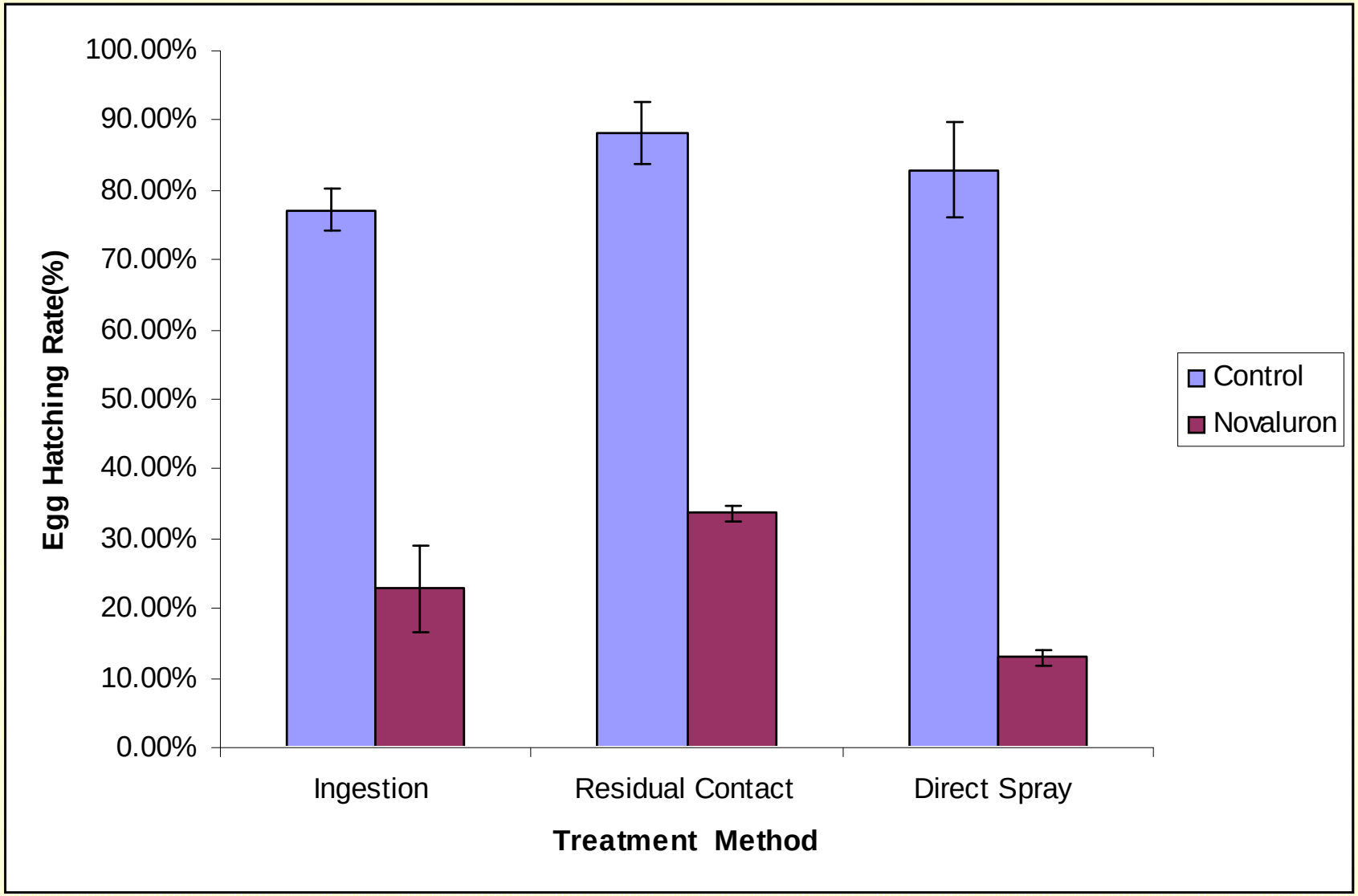
Optimal Timing for Codling Moth Control



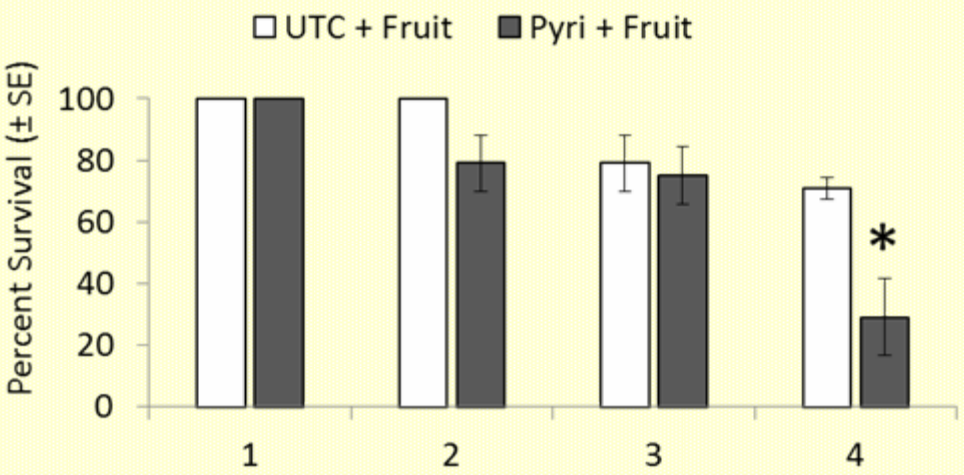
Sub-lethal activity affects the subsequent generation of the pest

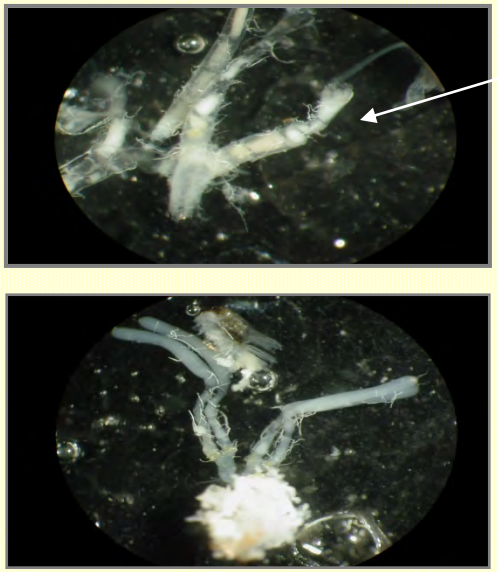


Sublethal Activity of Novaluron on Codling Moth

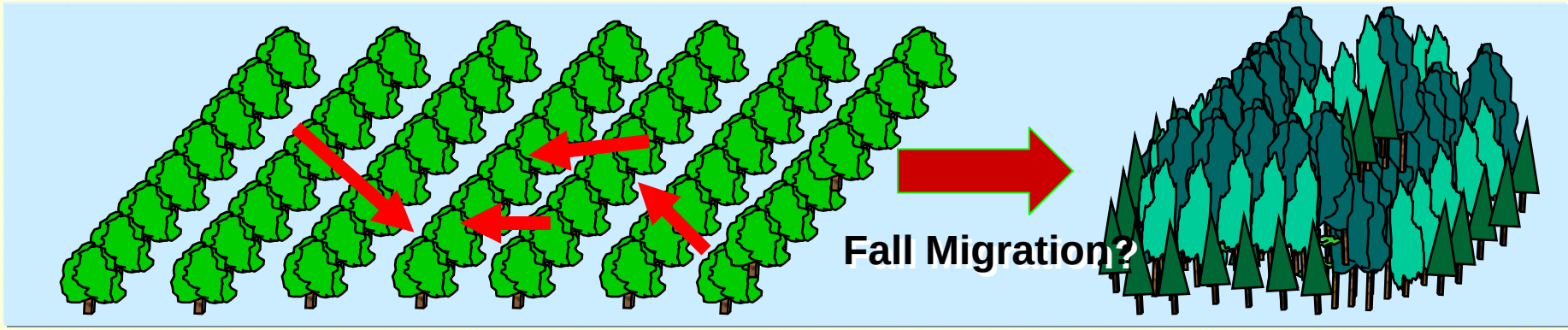


Esteem IGR Reduces Overwintering Survival in Plum Curculio (Whalon et al.)

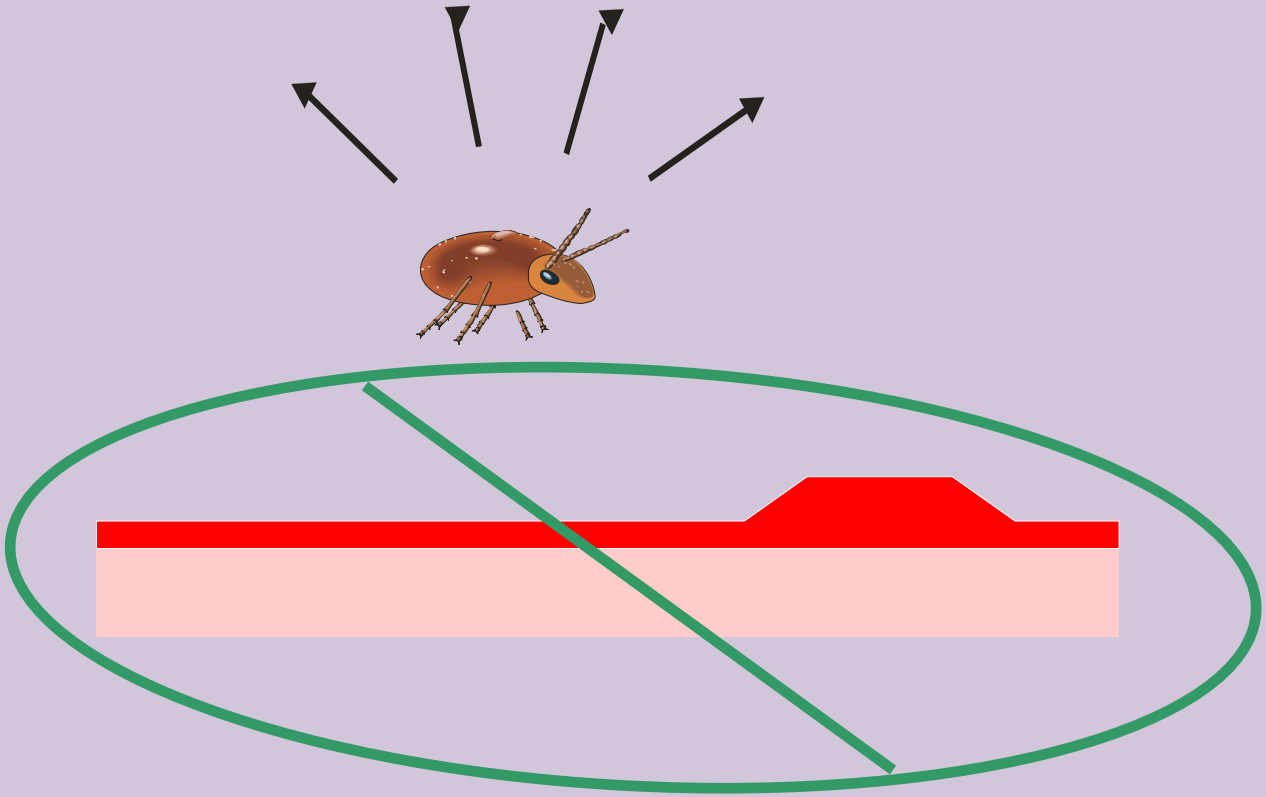




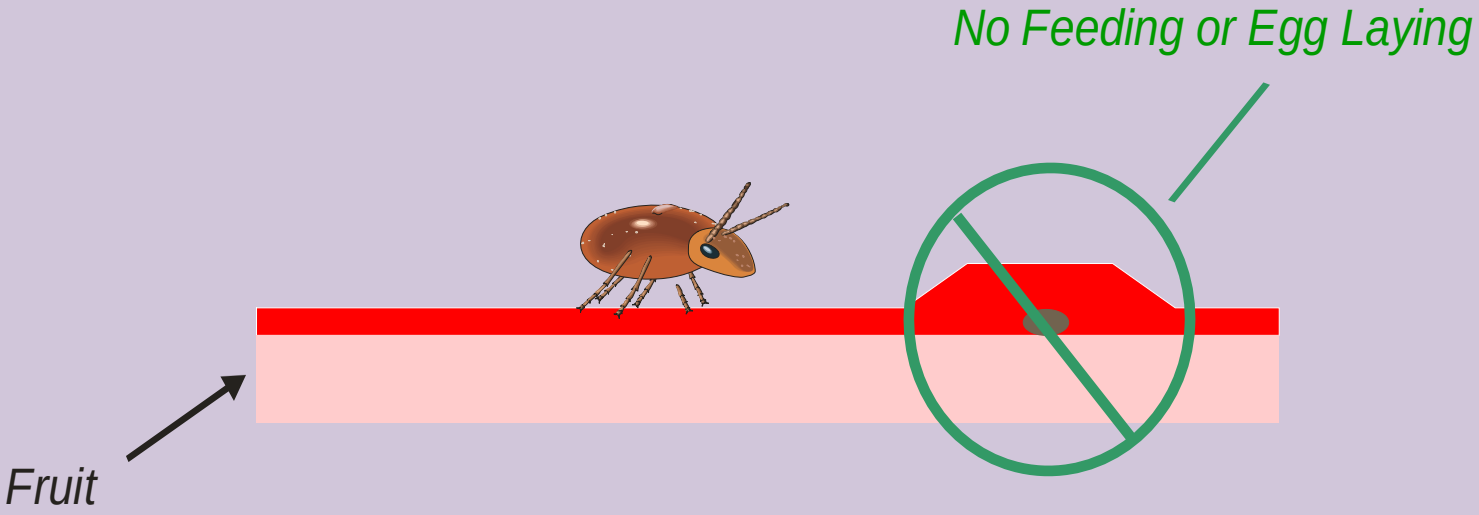
Eggs in Esteem Treated PC



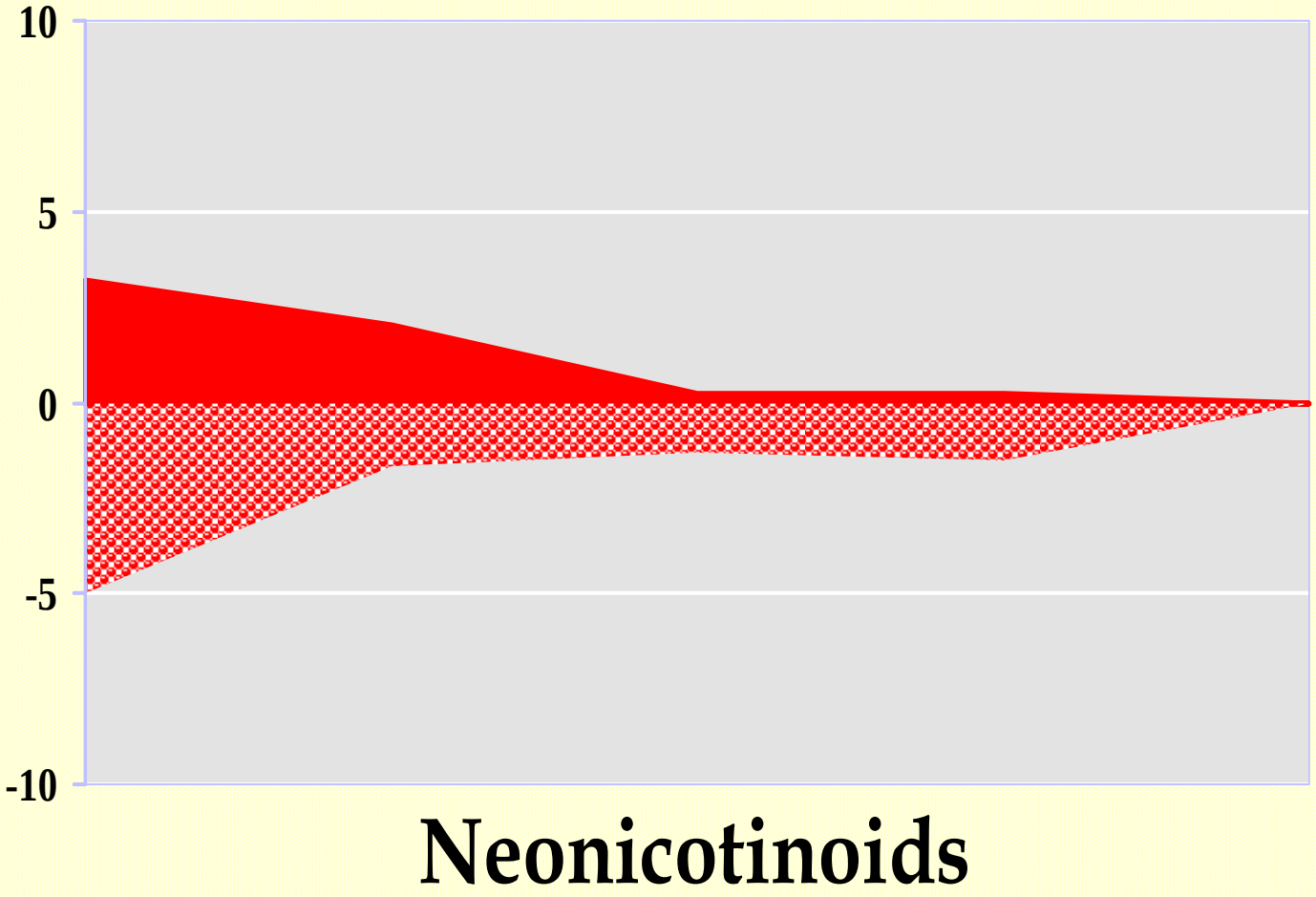
Repellents cause the pest to actively avoid the treated substrate



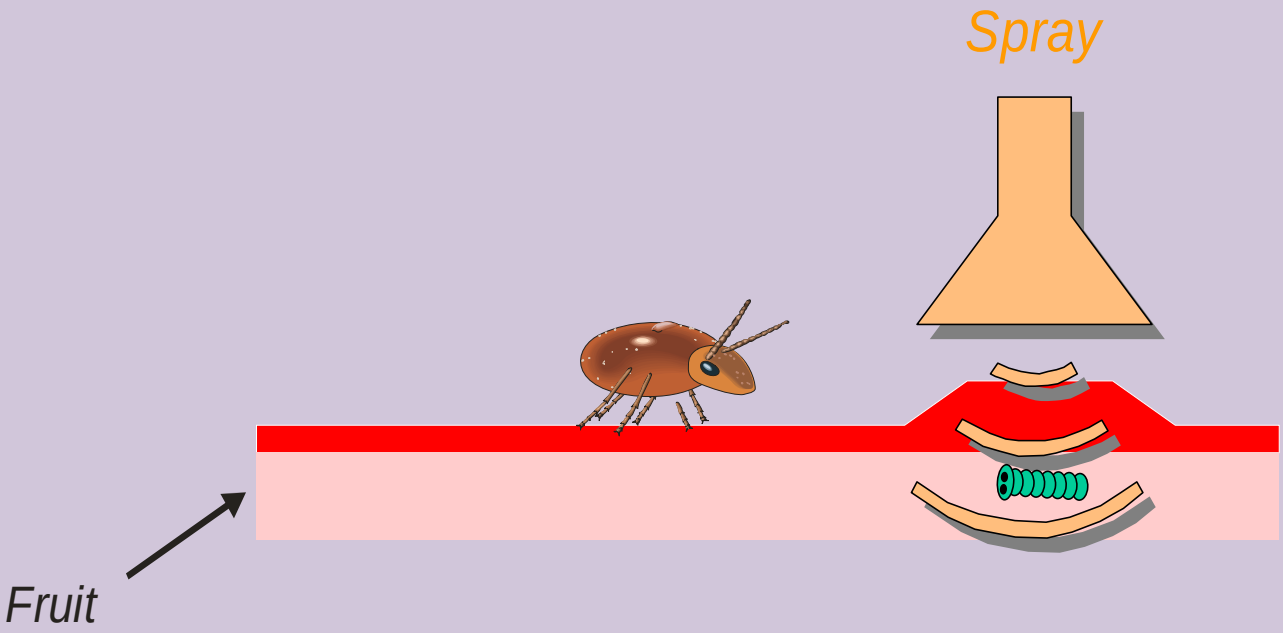
Antifeedants and Oviposition Deterrants reduce the desirability of the crop as a food source or egg laying host for the pest



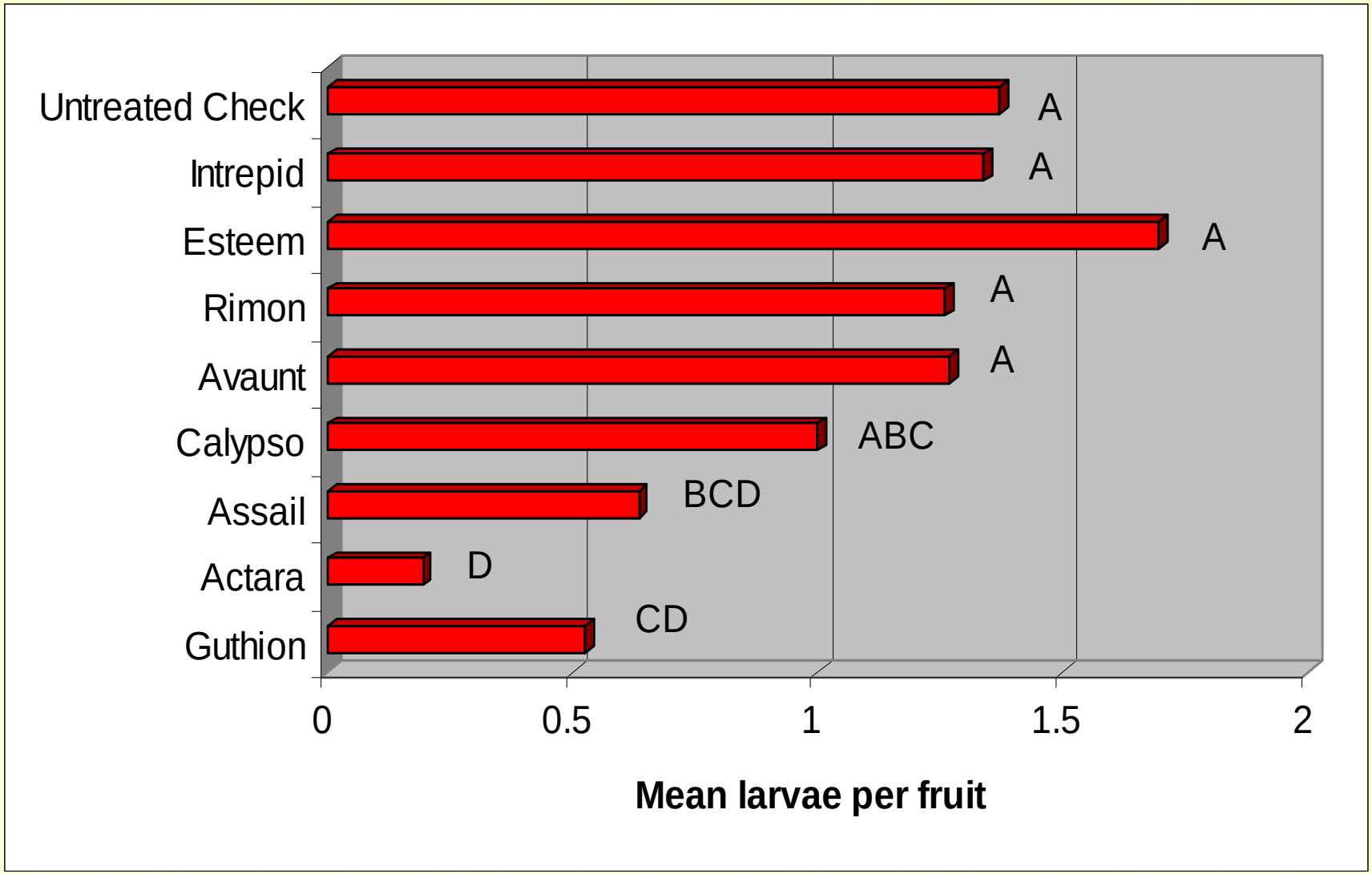
Residue Profile on Apple Leaves



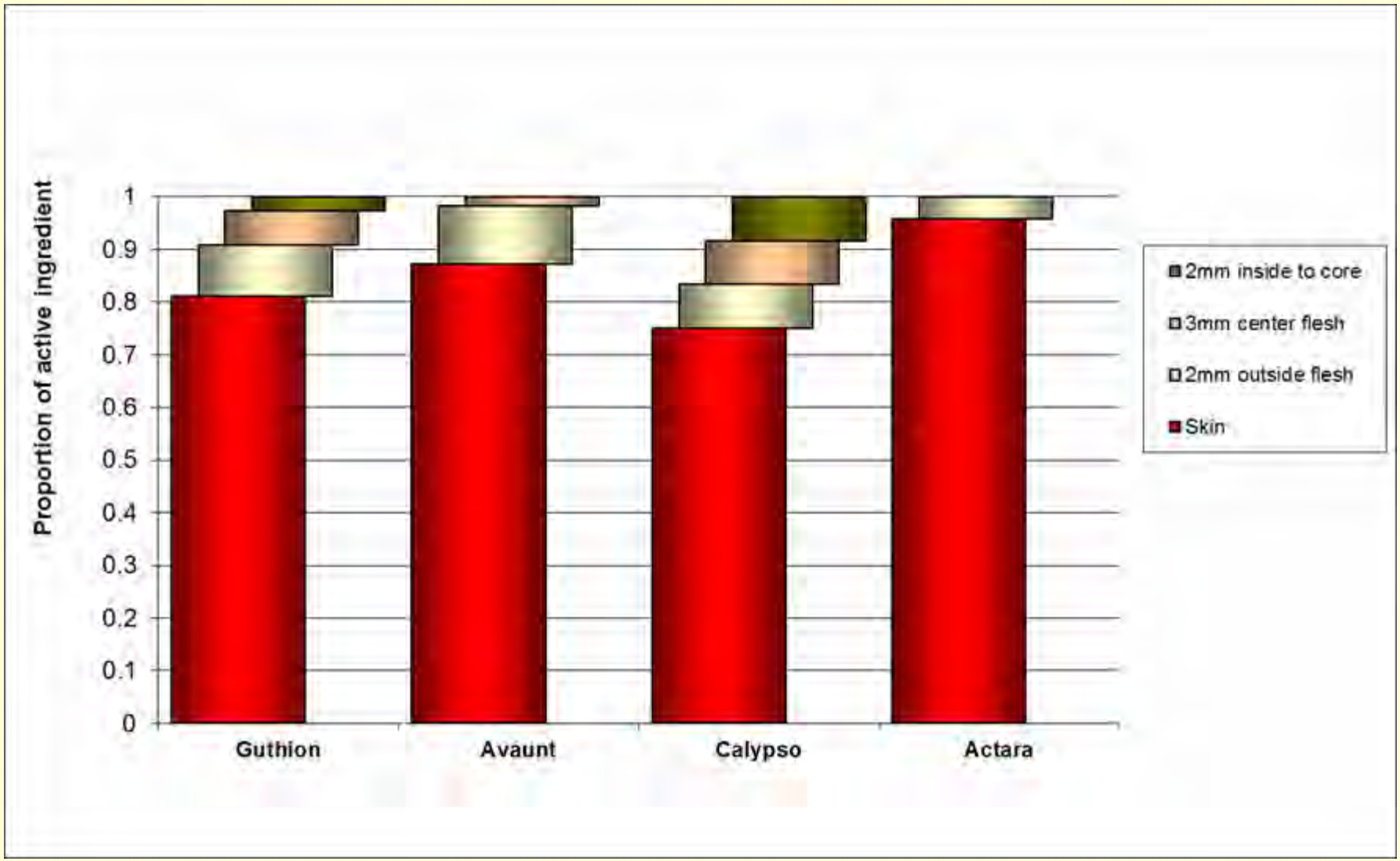
Curative activity is lethal action on a pest post-infestation resulting from the transitory penetration of the insecticide into plant tissue.



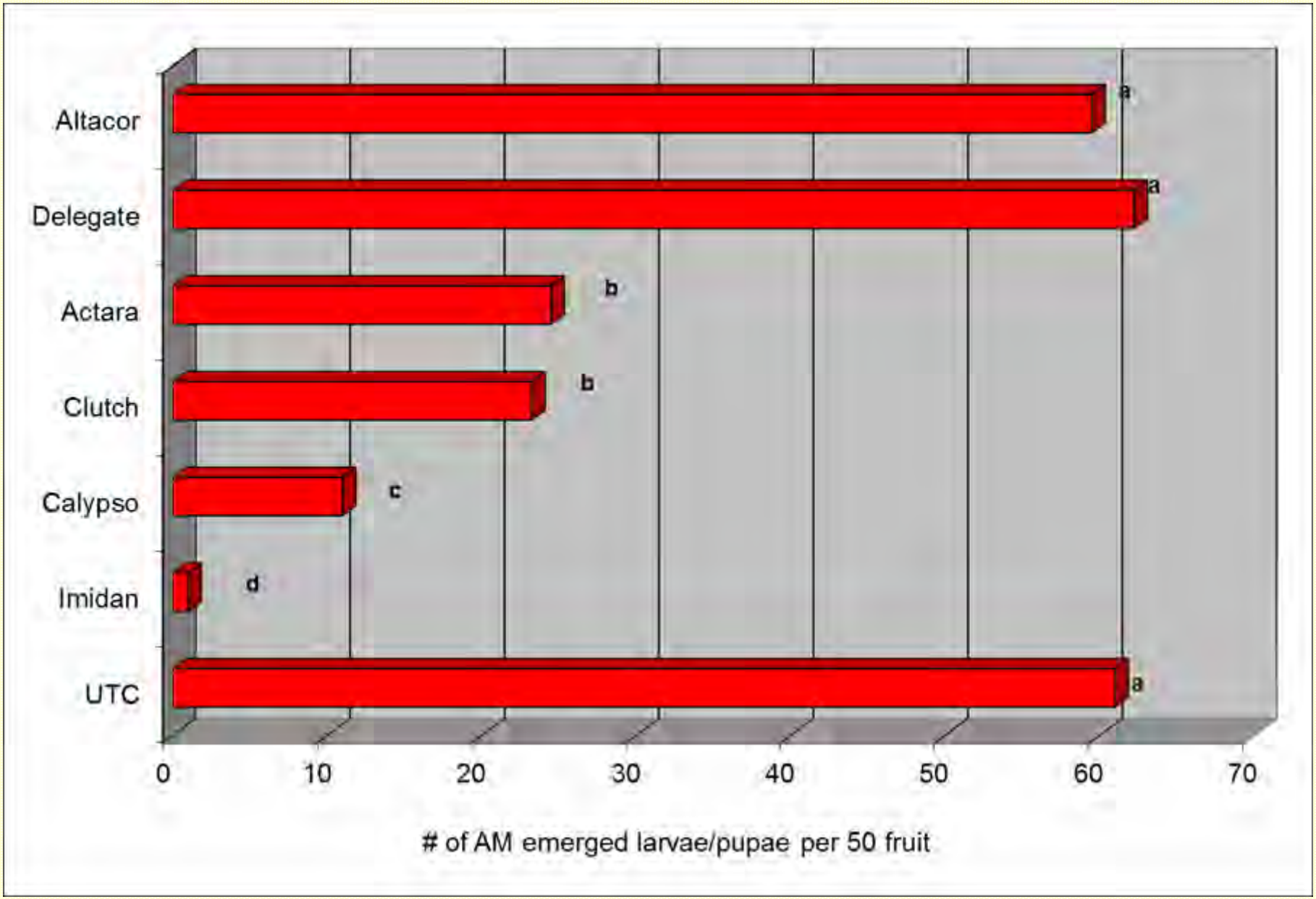
Curative Activity of Insecticides on Plum Curculio Larvae



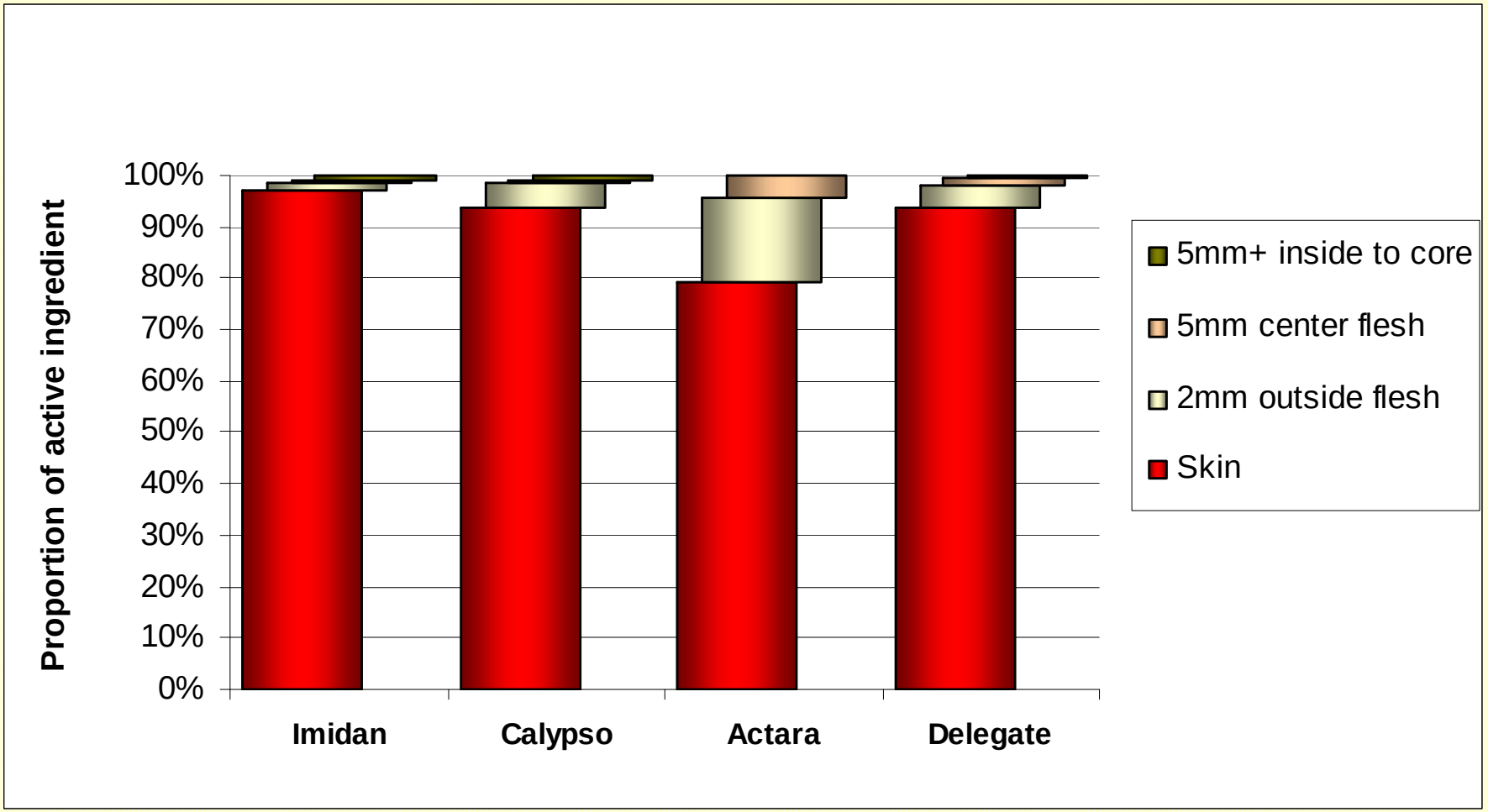
Insecticide Penetration Profiles in Early Season Apples



Curative Activity of Insecticides on Apple Maggot Larvae



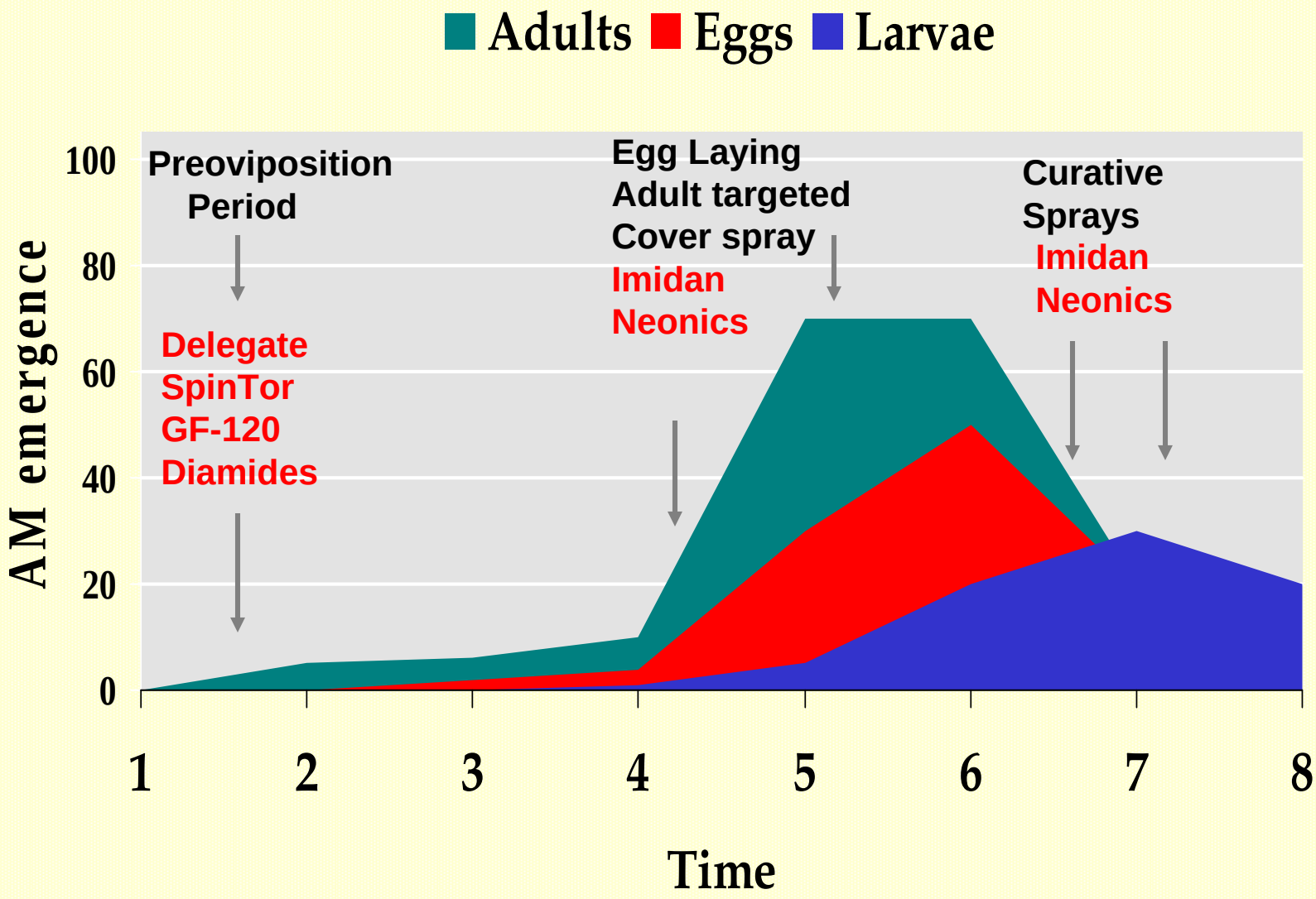
Insecticide Penetration Profiles in Apple Subsections



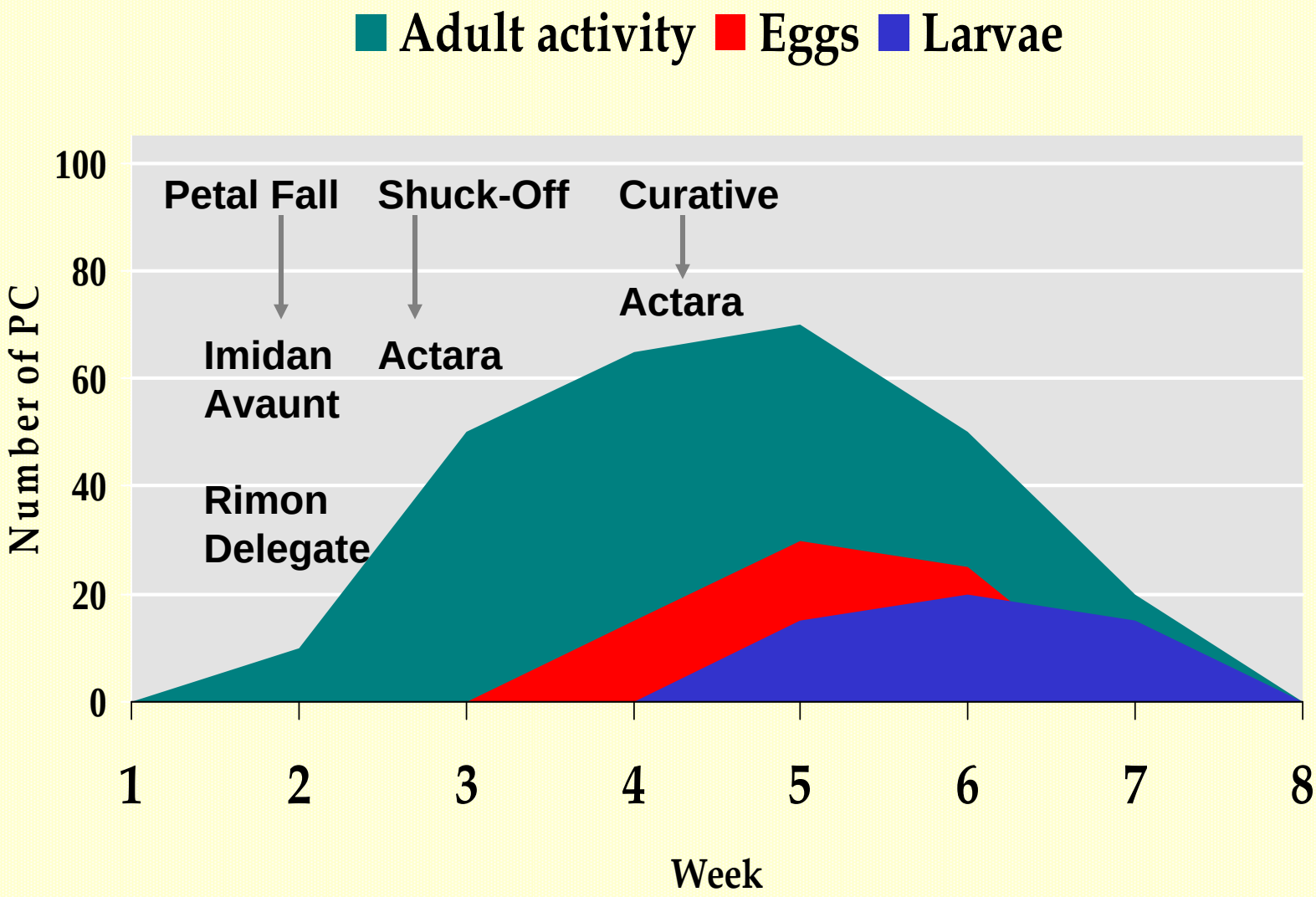
Chemical Activity Properties

Compound	Mode of Action	Mode of Entry	Insecticidal Activity	Speed of Activity
Organophosphates	Nerve Poison	Contact/Ingest	Lethal, Curative	Fast
Carbamates	Nerve Poison	Contact/Ingest	Lethal	Moderate
Pyrethroids	Nerve Poison	Contact/Ingest	Lethal / Repellent	Fast
Insect Growth Regulators	Hormonal	Ingestion / egg contact	Lethal / Sublethal	Slow
Spinosyns	Nerve Poison	Ingestion	Lethal	Fast
Oxadiazines	Nerve Poison	Ingest/contact	Lethal	Slow
Neonicotinoids	Nerve Poison	Contact/Ingest	Lethal / Antifeedant Ovipos deterrence Curative	Moderate
Diamides	Ryanodine Receptor Modulators	Ingestion	Lethal	Moderate

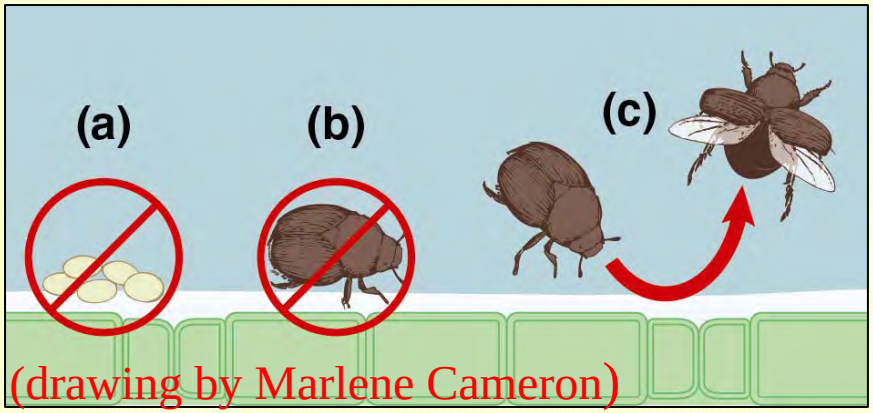
Optimal Timing for Apple Maggot Control



Optimal Timing for Plum Curculio in Stone Fruits

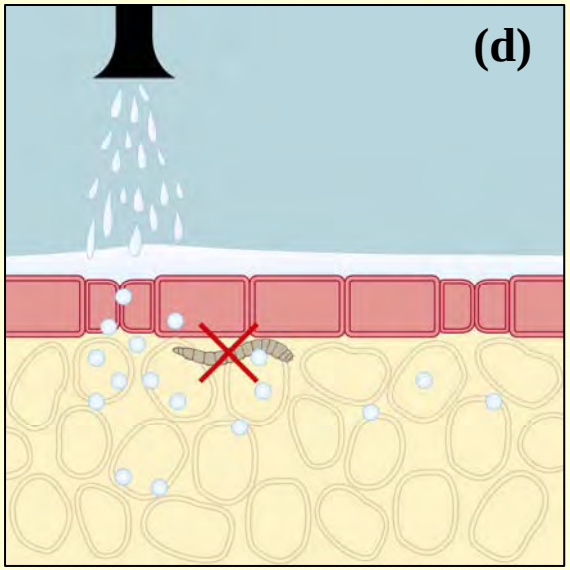


Identifying Modes of Insecticidal Activity



(drawing by Marlene Cameron)

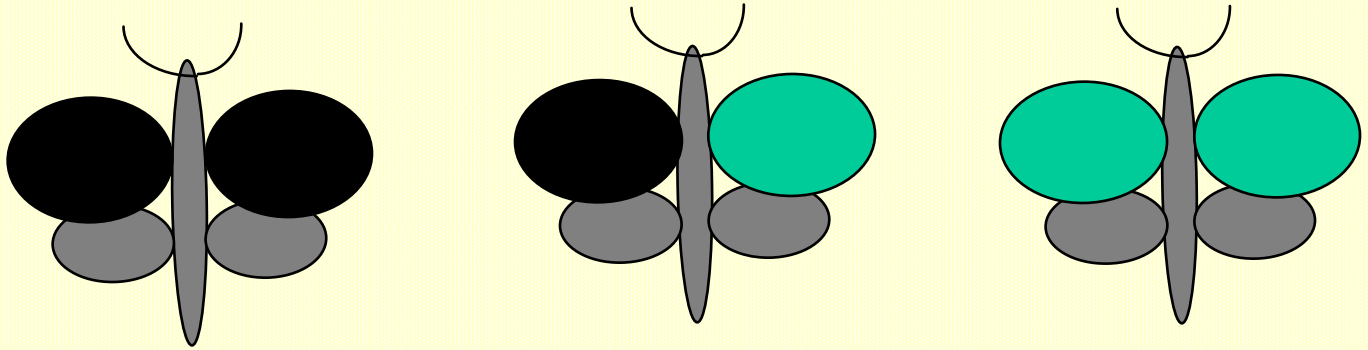
a) Oviposition deterence
b) Antifeedant
c) Repellency
d) Curative
e) Sub-lethal



For many of the RR insecticides “Lethal and non-lethal modes of insecticidal activity work in concert to achieve the overall crop protection seen in the field.”
(Wise and Whalon 2009; Biorational Control of Arthropod Pests: Application and Resistance Management. *In I. Ishaaya and A. Rami Horowitz (eds.), Biorational Control of Arthropod Pests: Application and Resistance Management*: Springer Pub. Ltd.)

How Insect Populations Develop Resistance

THREE GENOTYPES



RR

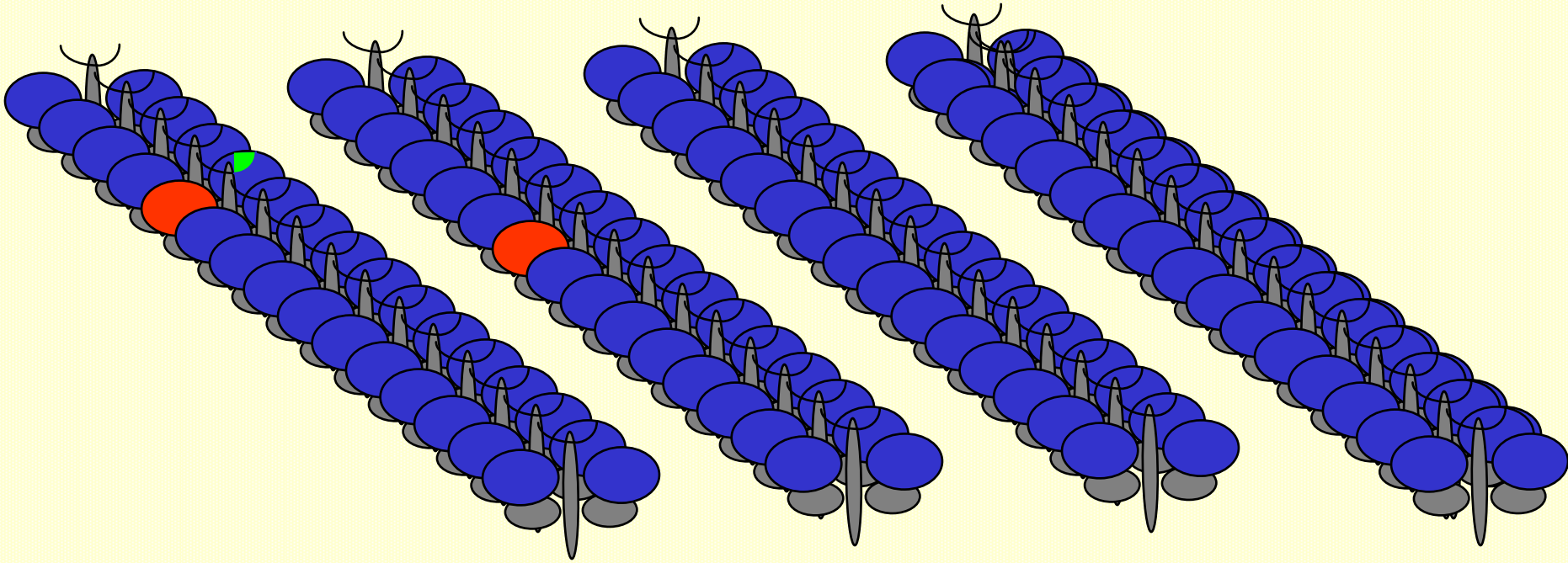
Homozygous Resistant

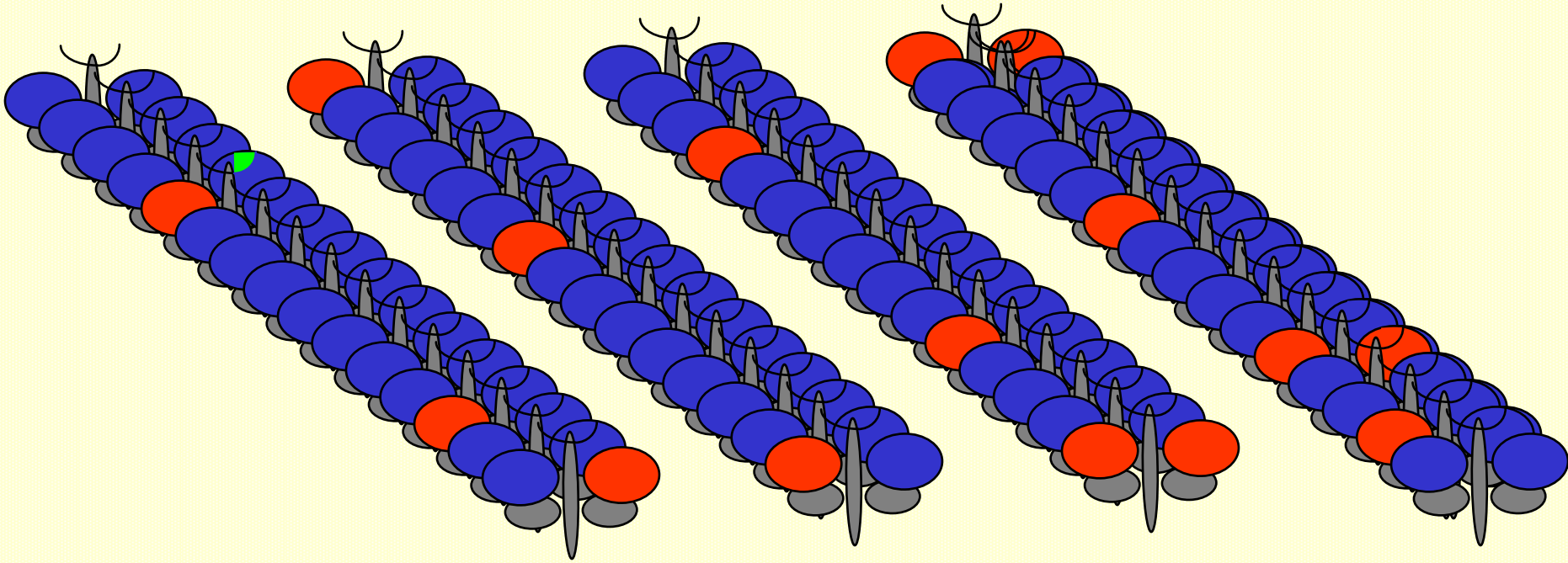
RS

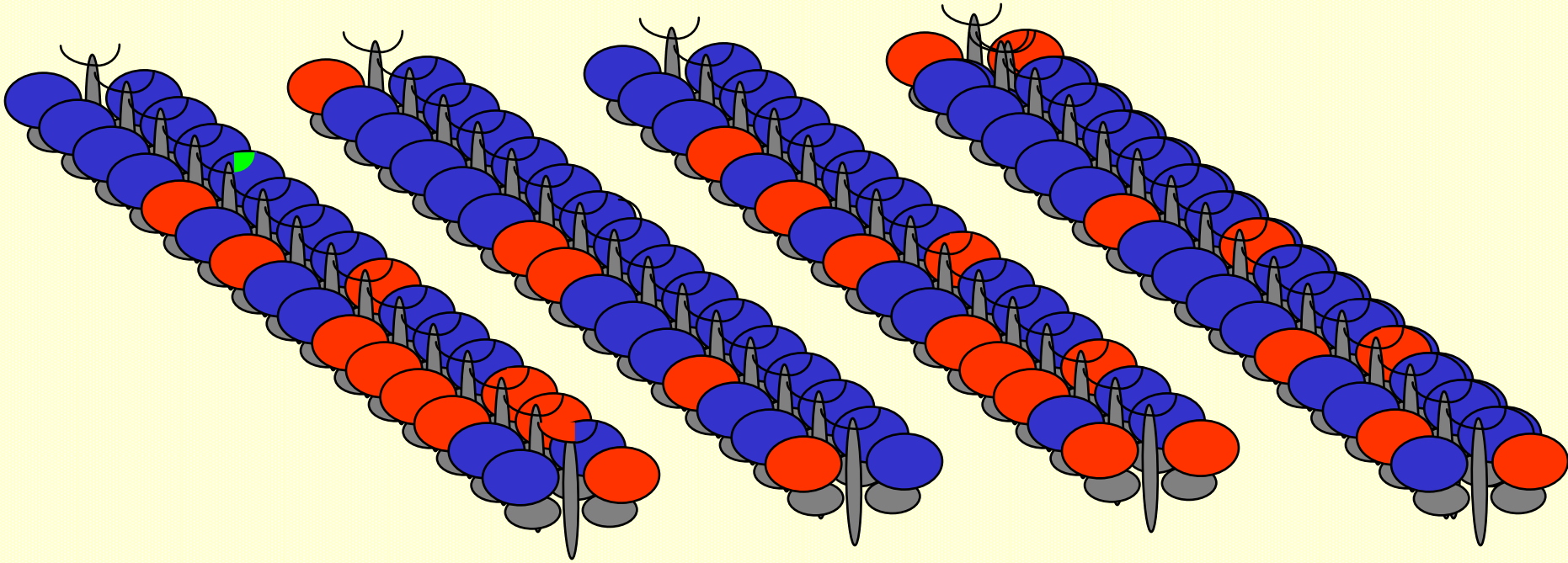
Heterozygous

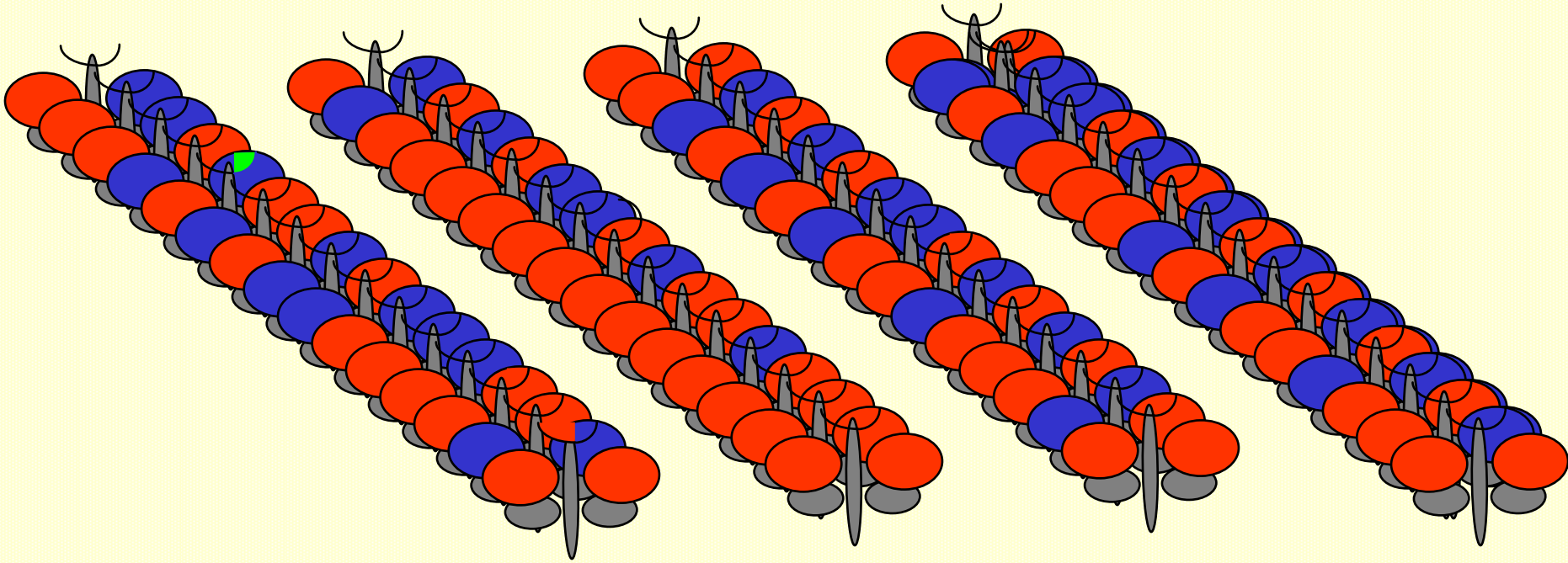
SS

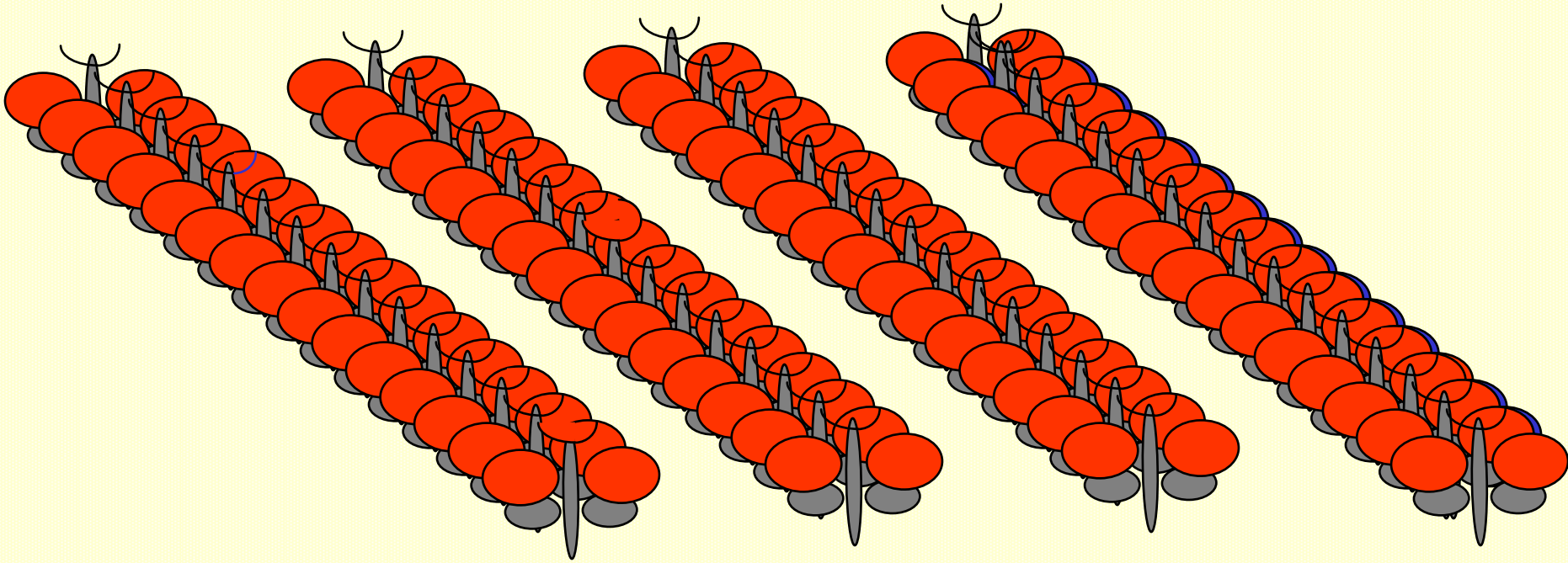
Homozygous Susceptible



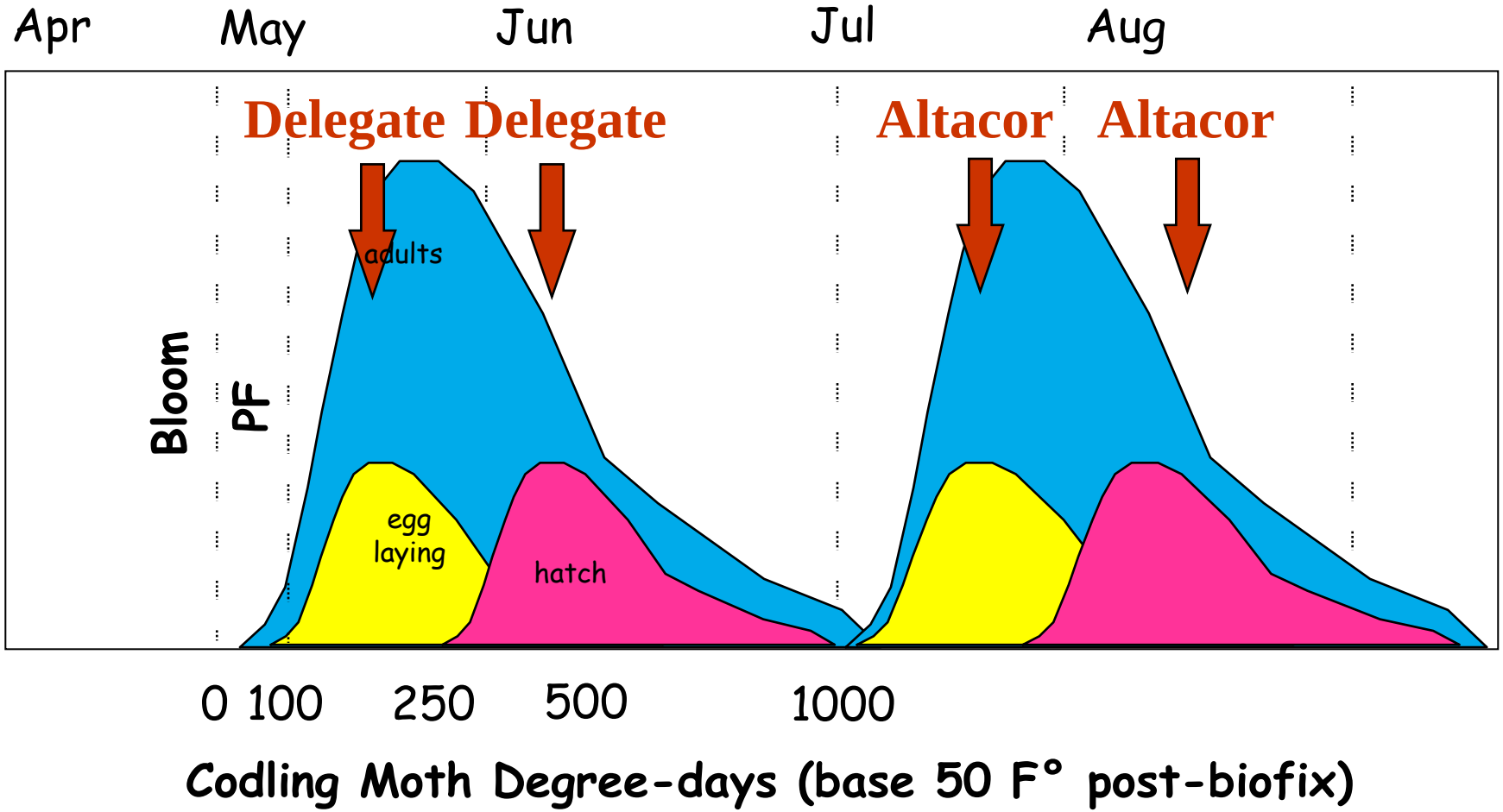




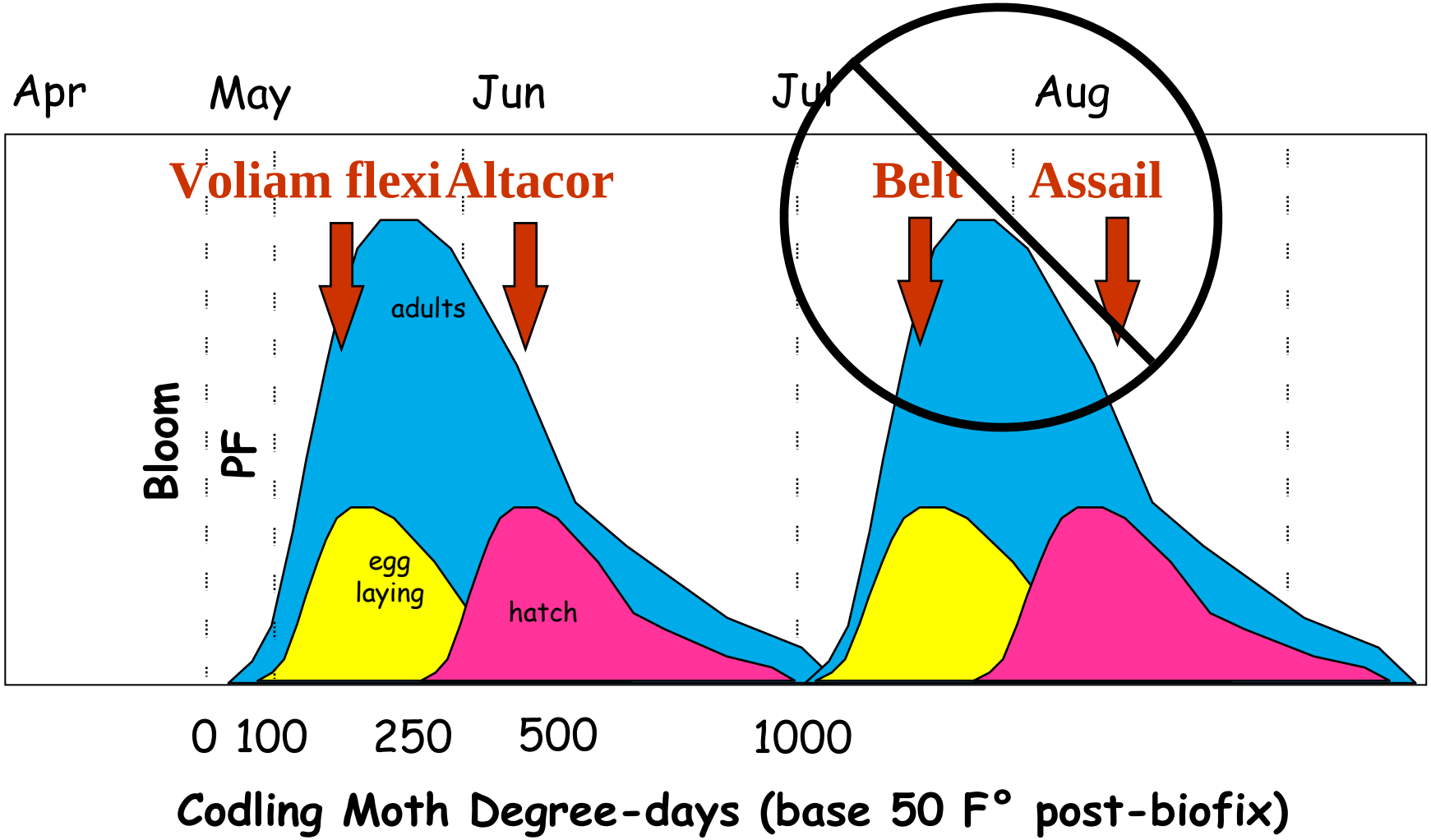




Seasonal Program Under Resistance Management

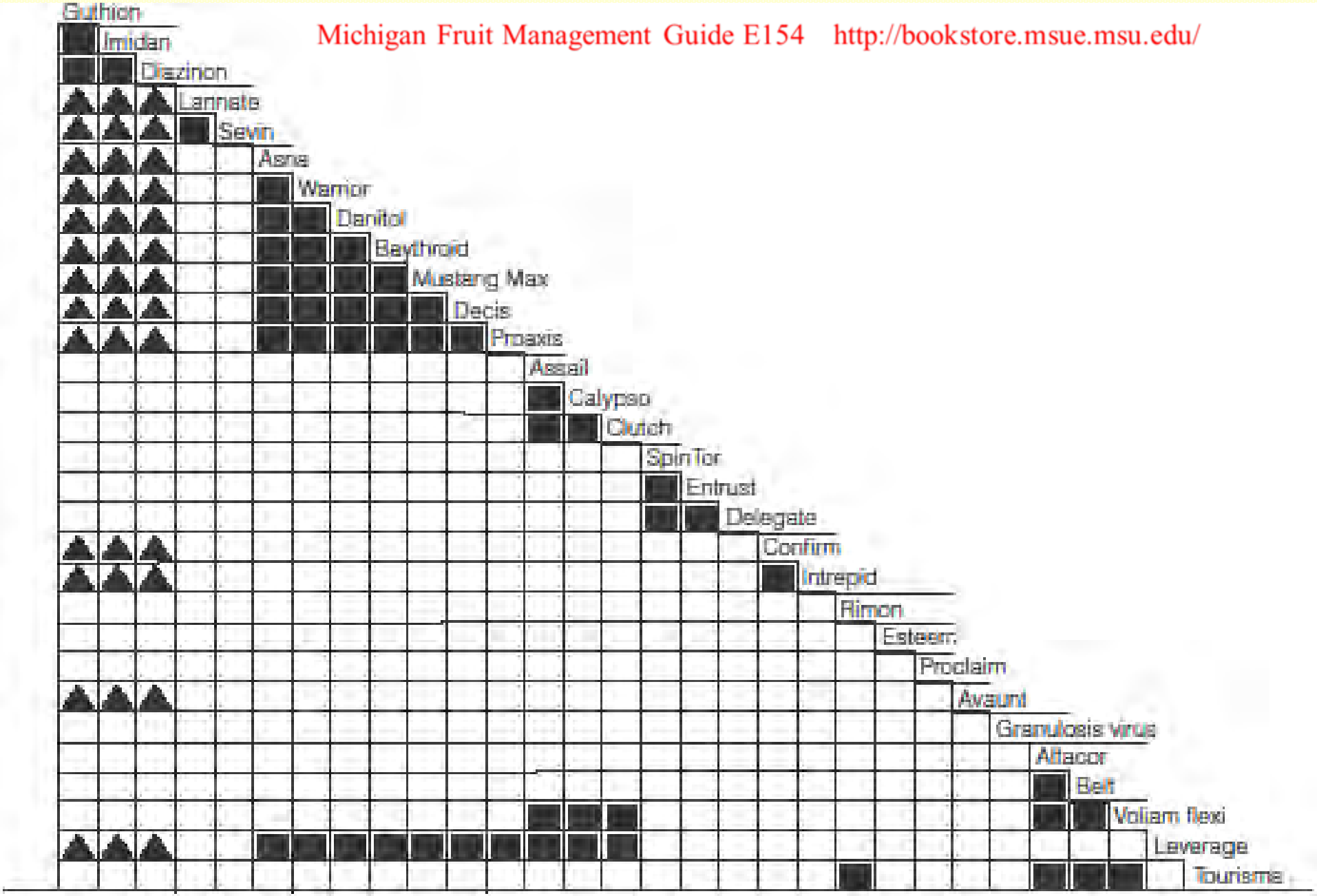


Seasonal Program Under Resistance Management

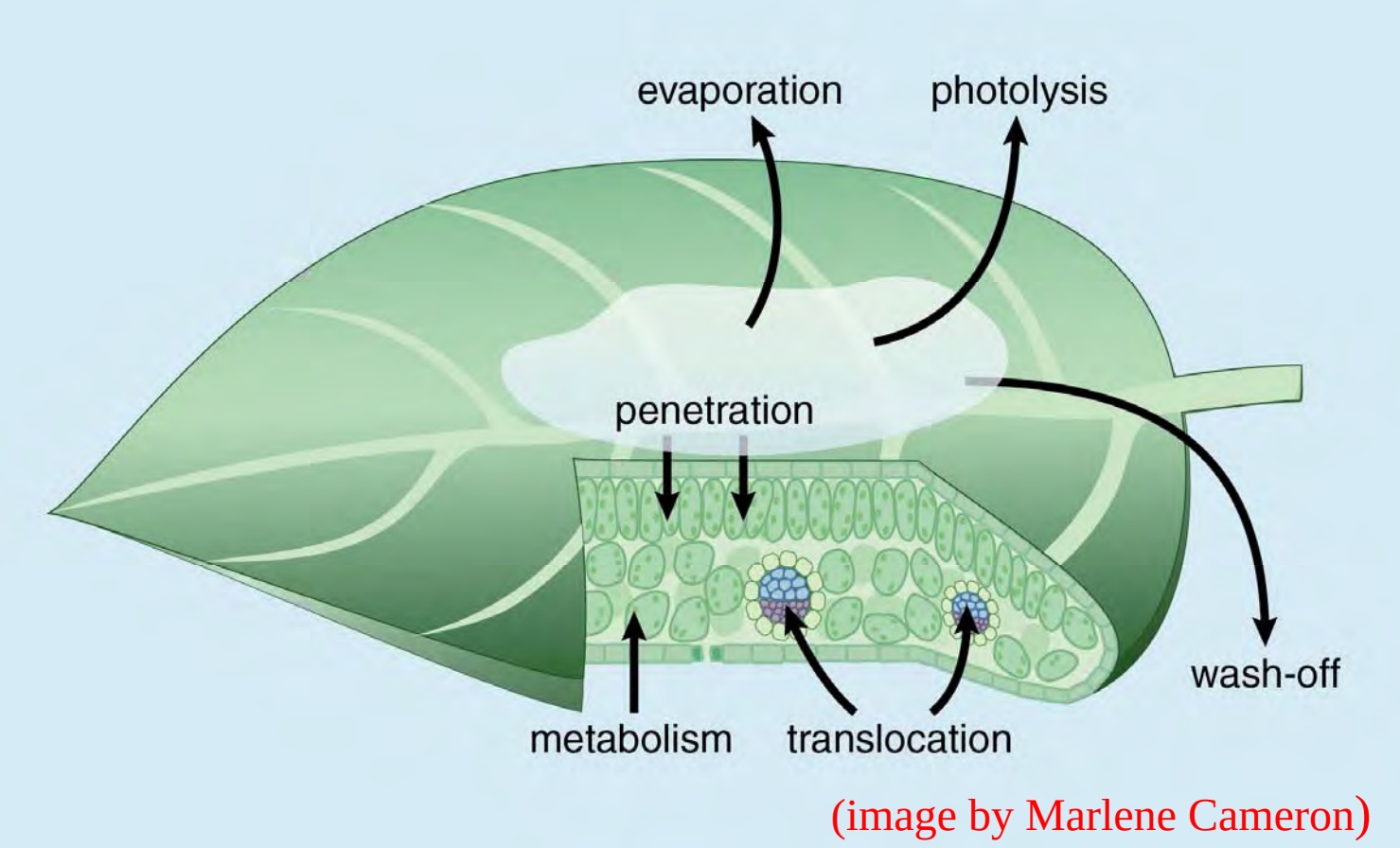


MSU Resistance Management Incompatibility Chart

Michigan Fruit Management Guide E154 http://bookstore.msue.msu.edu/



Factors that Influence Pesticide Wash-off

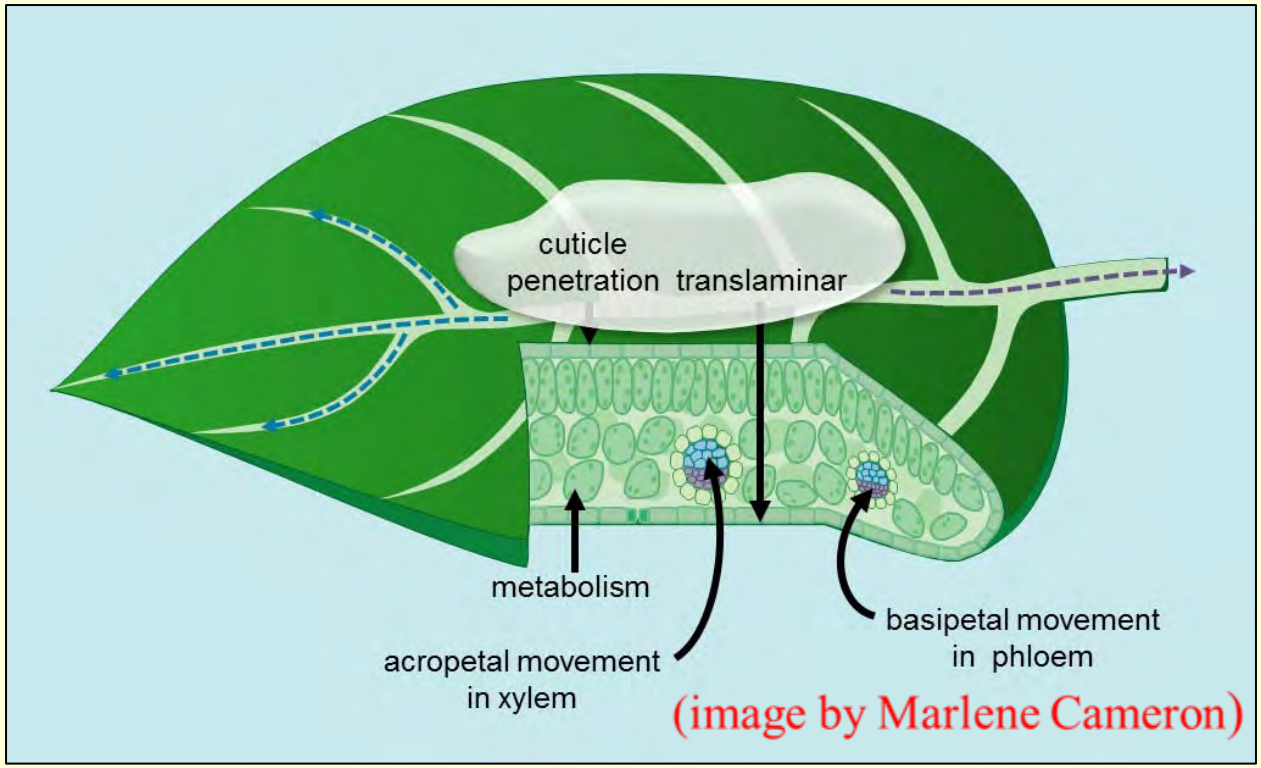


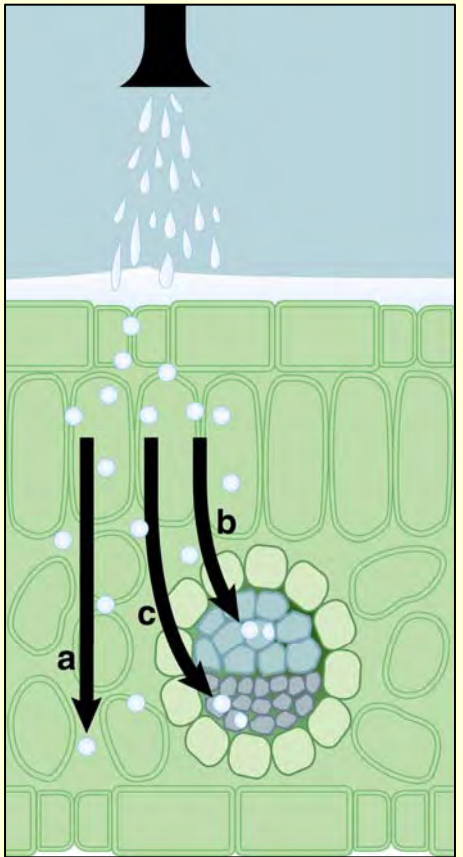
(image by Marlene Cameron)

- **Rainfall Characteristics**
- **Penetrative & Translocative Properties of the Compound**
- **Insecticide Inherent Toxicity and Application Rate**
- **Drying time, Persistence, and Additives**

Translocation and systemic mobility:

a. Translaminar -penetration of a foliar applied pesticide from the adaxial cuticular surface of the leaf, through the epidermis layer and distributing into the mesophyll on the abaxial side.
b. Acropetal - horizontal mobility in the plant xylem from central leaf tissue to the marginal ends.
c. Basipetal - movement of the insecticide within the phloem from the site of application in the downward direction.



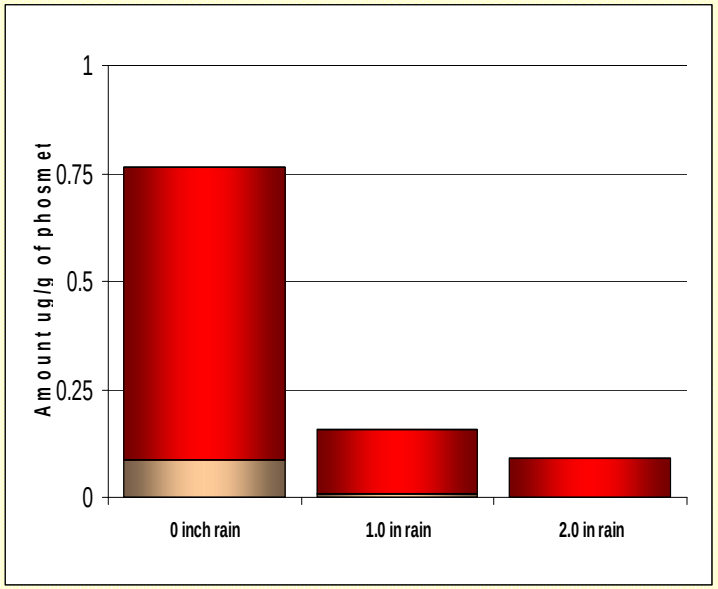


Physical and Chemical Properties

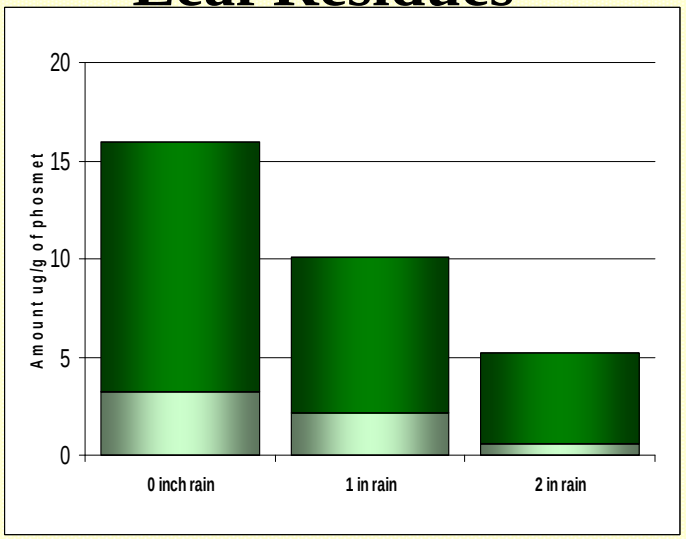
Compound Class	Residual (on plant)	Systemic Characteristics (foliar)	Systemic Characteristics (fruit)
Organophosphates	Long	Surface	Surface
Pyrethroids	Short	Cuticle Penetration	Cuticle Penetration
Neonicotinoids	Medium	Translaminar & Acropetal	Systemic
IGRs	Medium - Long	Translaminar	Cuticle Penetration
Spinosyns	Short - Medium	Translaminar	Cuticle Penetration
Diamides	Medium - Long	Translaminar	Cuticle Penetration

Imidan

Fruit Residues

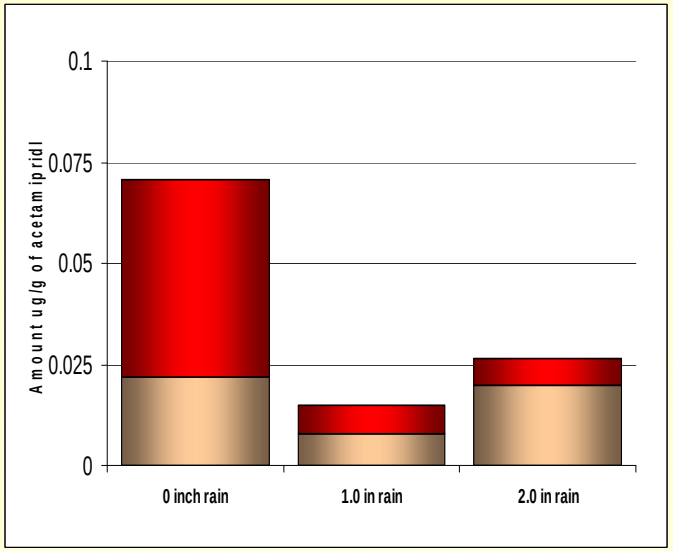


Leaf Residues

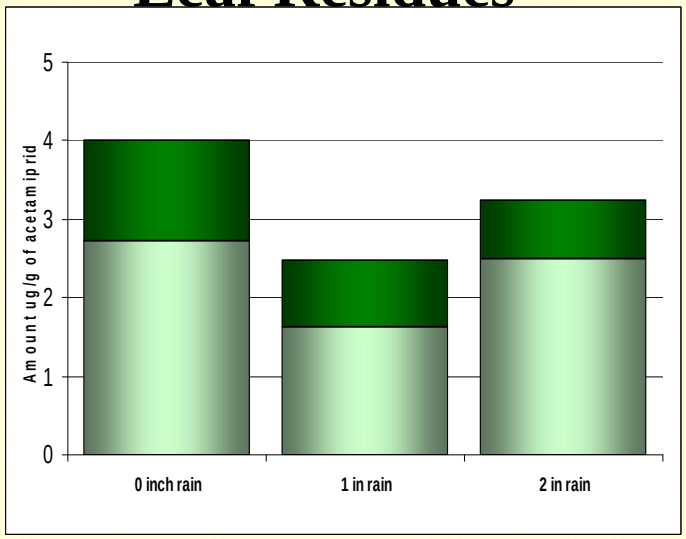


Assail

Fruit Residues

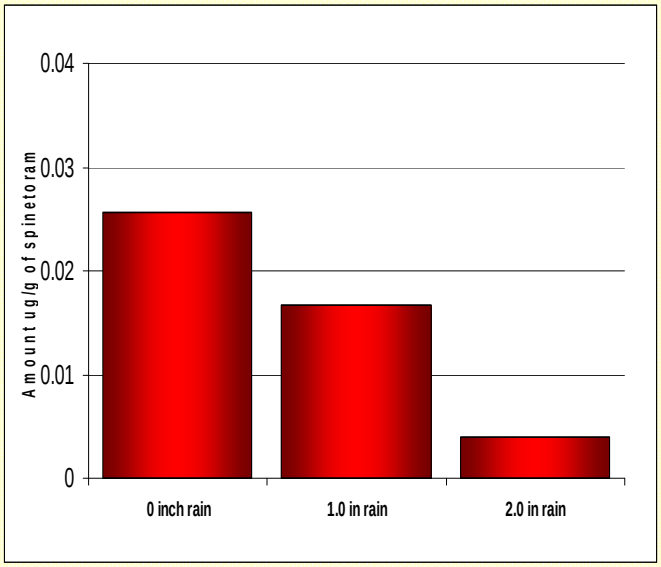


Leaf Residues

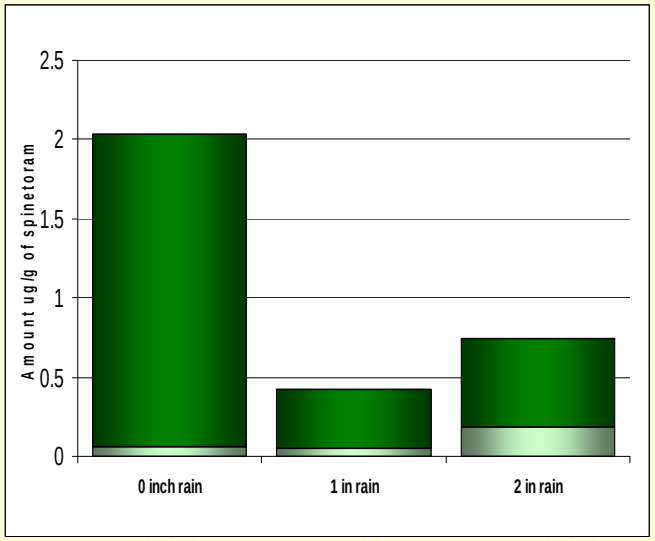


Delegate

Fruit Residues

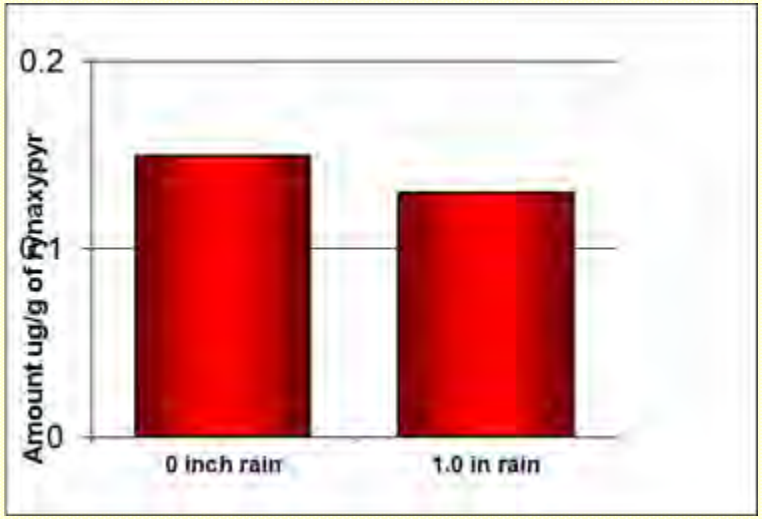


Leaf Residues

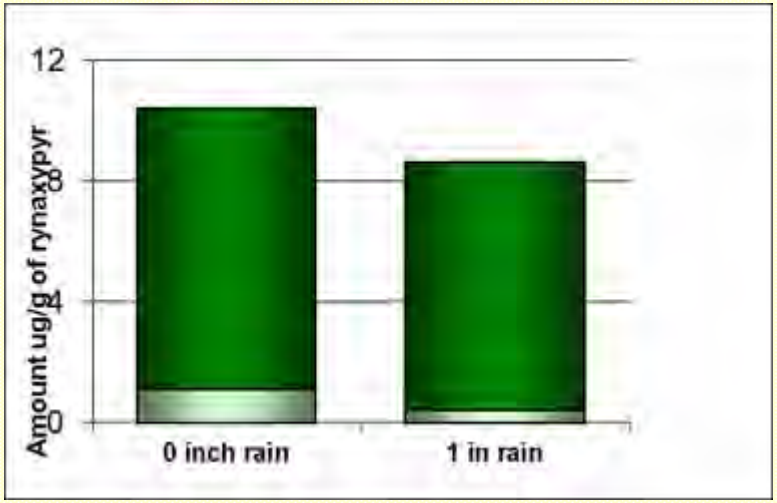


Altacor

Fruit Residues



Leaf Residues



Rainfastness Rating Chart

General Characteristics for Insecticide Chemical Classes

Insecticide Class	Rainfastness ≤ 0.5 inch		Rainfastness ≤ 1.0 inch		Rainfastness ≤ 2.0 inch	
	Fruit	Leaves	Fruit	Leaves	Fruit	Leaves
Organophosphates	L	M	L	M	L	L
Pyrethroids	M	M/H	L	M	L	L
Carbamates	M	M	L	M	L	L
IGRs	M	H				
Neonicotinoids	M,S	H,S	L,S	L,S	L,S	L,S
Spinosyns	H	H	H	M	M	L
Diamides	H	H	H	M	M	L
Avermectins	M,S	H,S	L,S	M,S	L	L

- H – highly rainfast (≤30% loss), M – moderate (≤50% loss), L – low (≤70% loss), S-systemic residues
- Michigan Fruit Management Guide E154 http://bookstore.msue.msu.edu/

Apple Insecticide Precipitation Wash-off Re-application Decision Chart:

Expected codling moth control in apples, based on each compound's inherent toxicity to CM larvae, maximum residual, and wash-off potential from rainfall.

Insecticides	Rainfall = 0.5 inch		Rainfall = 1.0 inch		Rainfall = 2.0 inches	
	*1 day	*7 days	*1 day	*7 days	*1 day	*7 days
Imidan		X		X	X	X
Asana		X	X	X	X	X
Calypso			X	X	X	X
Assail			X	X	X	X
Proclaim		X		X	X	X
Rimon			X	X	X	X
Delegate					X	X
Altacor					X	X
Belt					X	X

* Number of days after insecticide application that the precipitation event occurred.

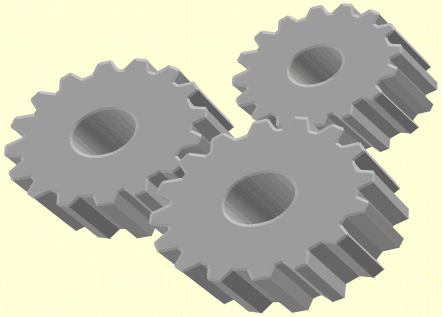
X – Insufficient insecticide residue remains, thus re-application is recommended.

MICHIGAN STATE UNIVERSITY EXTENSION

20th Century IPM

Industrial Age

"Time for another poison"



21st Century IPM

Information Age

"What optimal selection of IPM tools will best exploit the pest's weaknesses, reduce total inputs, minimize impacts on beneficials, while protecting human and environmental resources?"

Michigan State University AgBioResearch