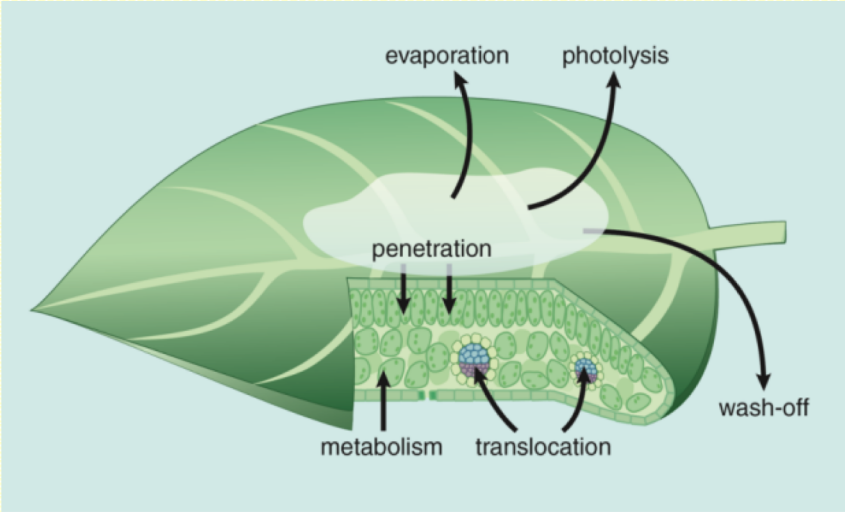
Rainfastness Attributes of Insecticides for Control of SWD in Cherries



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MSU Department of Entomology

Insecticides Registered in US Fruit Crops - 2019

20th Century Insecticides

- Chlorinated Hydrocarbons (1)
- Organophosphates (3)
- Carbamates (2)
- Synthetic Pyrethroids (6)

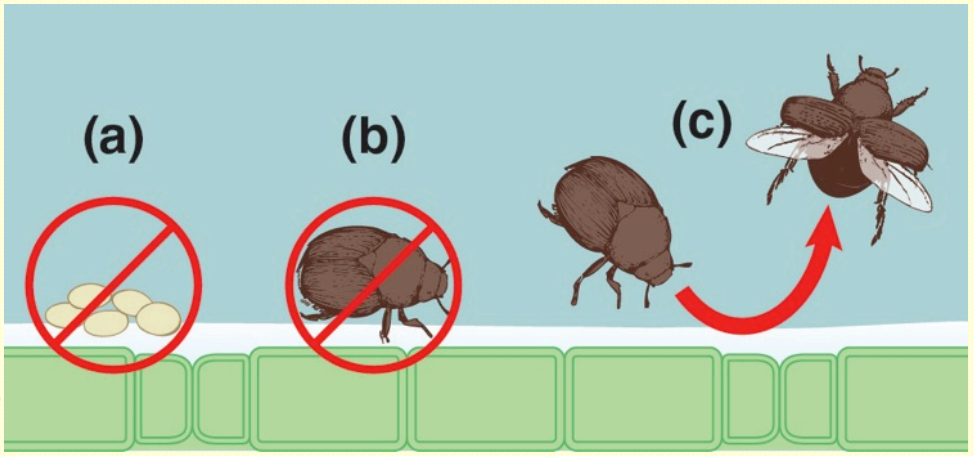
21st Century Insecticides

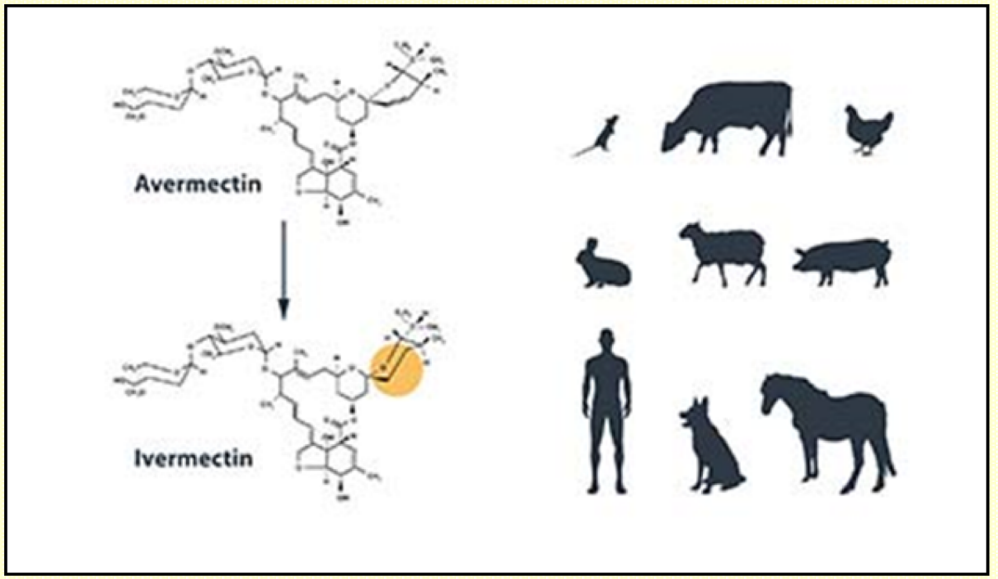
- Insect Growth Regulators (5)
- Spinosyns (2)
- Avermectins (2)
- Neonicotinoids (5)
- Oxadiazines (1)
- Diamides (4)
- Particle Film (1)
- Pyrizoles (1)
- Pyridine Carboxamides (1)
- Tetronic acid derivatives (1)

Expansion of Available Biopesticides in 21st Century

Biopesticides

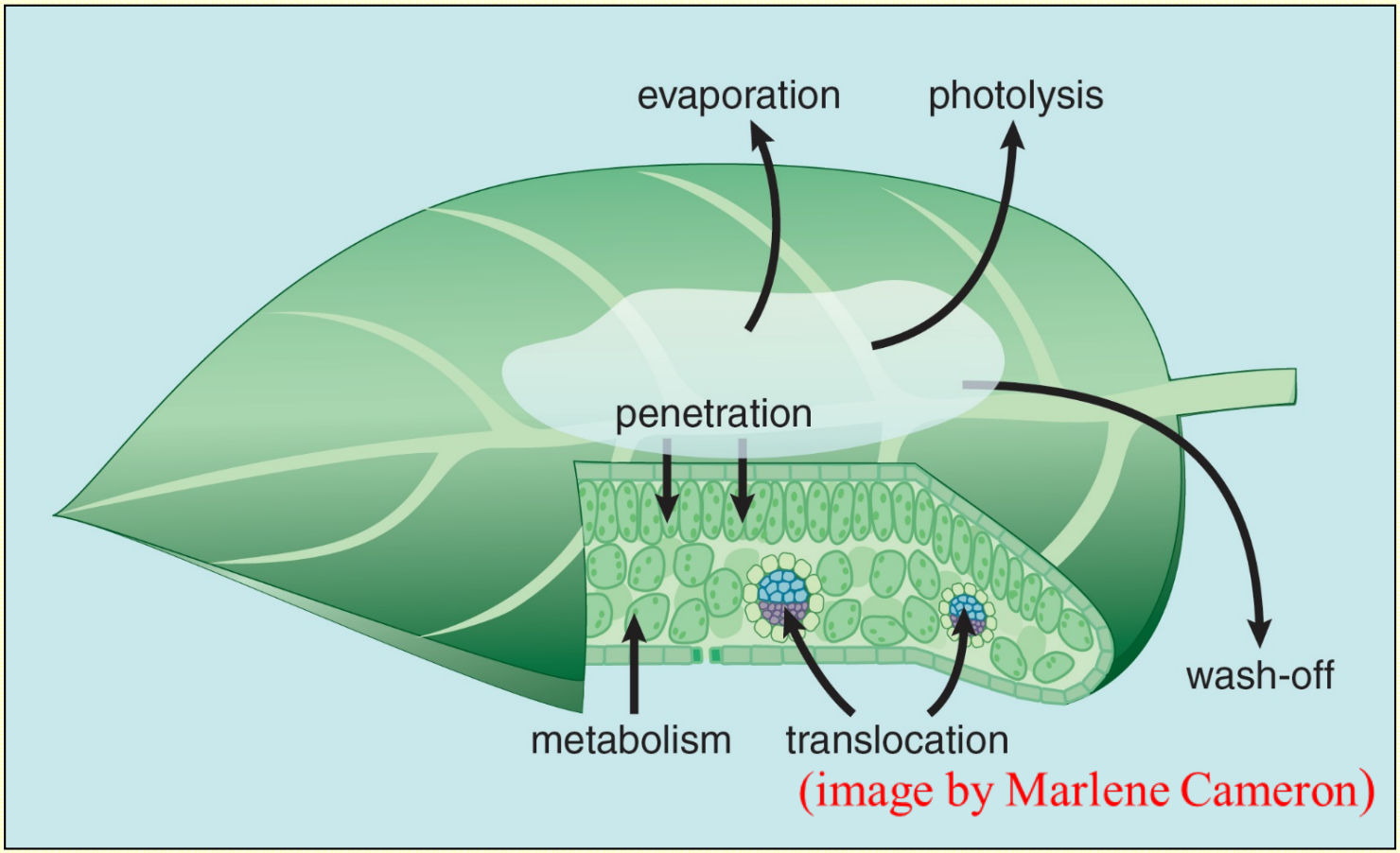
- Fermentation by-products
  - *Bts*
  - Spinosyns (Entrust, Delegate)
  - Grandevo & Venerate
- Botanical / Animal extracts
  - Azadirachtin (Neem)
  - Pyrethrins (Pyganic)
  - Sabadilla (Veratran)
  - Spider venom (Spear-T)
- Virus





Fate of insecticides on the plant surface:

1. Evaporation - The change of a liquid into a vapor at a temperature below the boiling point, leaving only the dry solid portion or deposit.
2. Photolysis - Chemical decomposition induced by light or other radiant energy.
3. Wash-off - Loss of surface residues from a wetting event.
4. Penetration – mobility into and throughout plant.

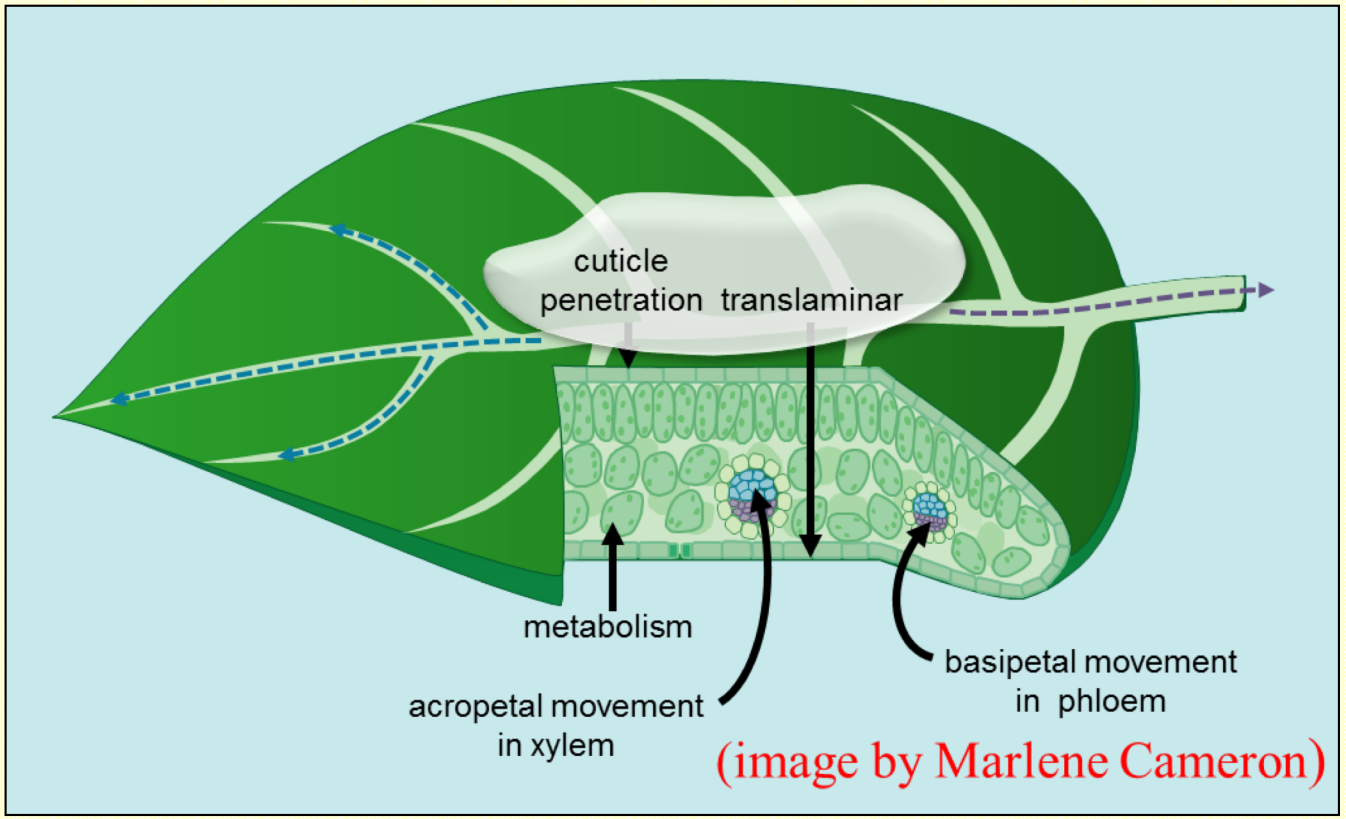


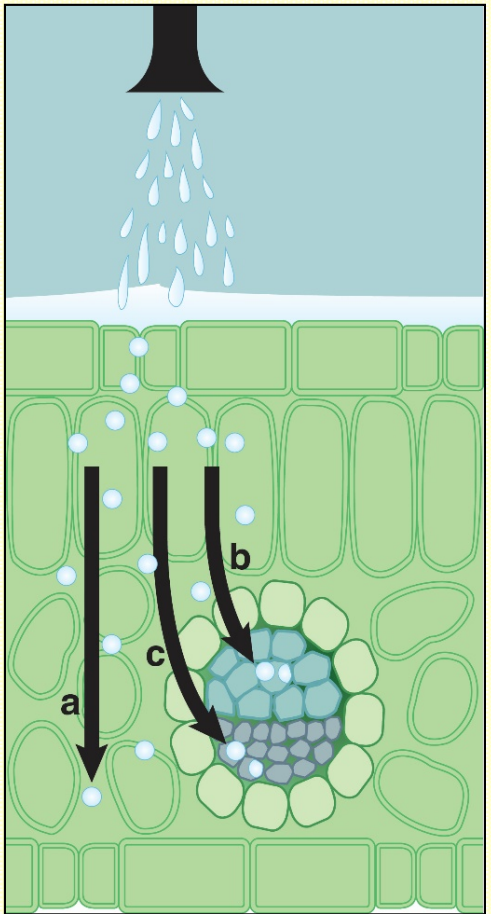
Translocation and systemic mobility:

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.

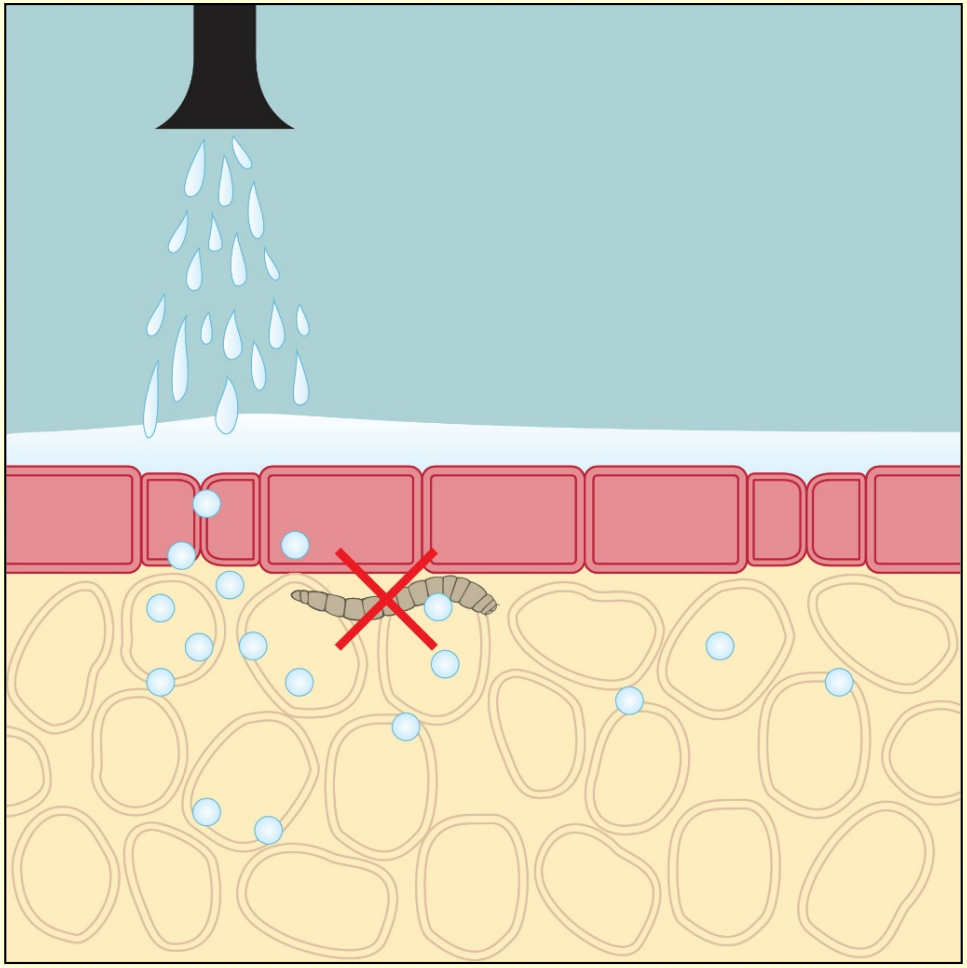
c. Basipetal - movement of the insecticide within the phloem from the site of application in the downward direction.





Insecticide Penetration in Fruits

a. Penetration of the fruit cuticle follows the same process as described for leaves, but desorption into the epidermal cells of the hypanthium follows a simple diffusion process.



Physical and Chemical Properties

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

Bioavailability of residues on plant surfaces:

a. dislodgeable residues represent residues that have not penetrated the plant cuticle sufficiently to resist physical removal from the plant surface.
b. Bioavailability will vary according to a compound's affinity to the plant cuticle, characteristics of leaf or fruit surface, temperature and humidity, plant penetration.
c. Behavior of insect; feeding vs grooming vs motile actions.

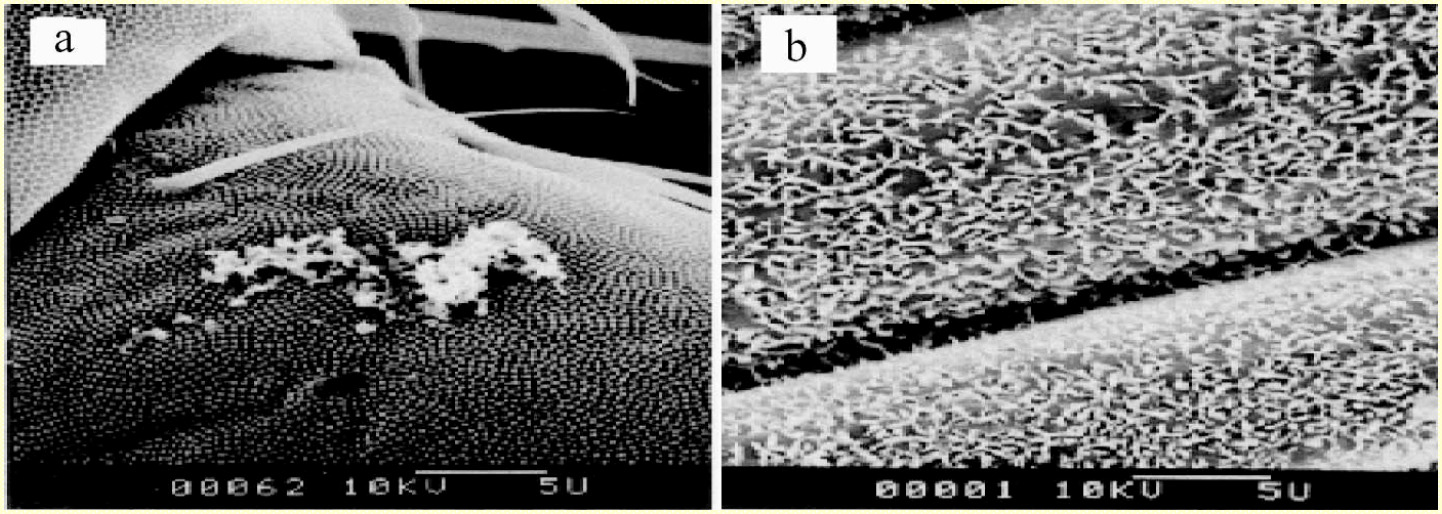
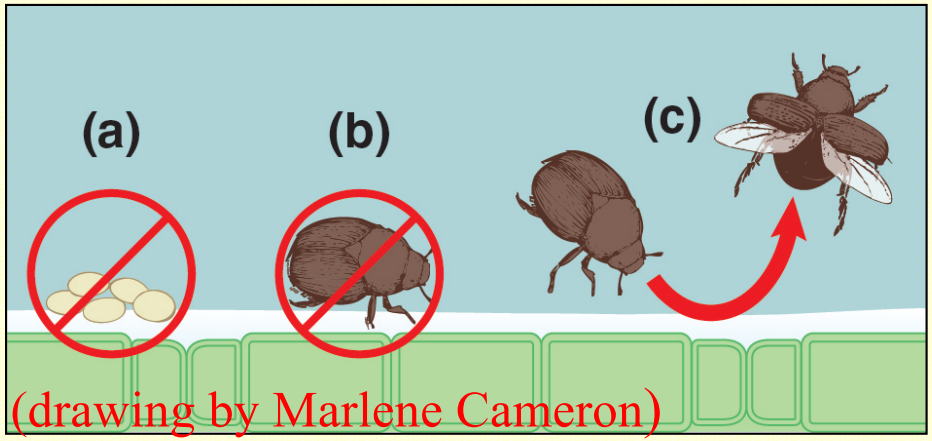


Figure 7. Scanning electron micrograph of (a) leg of F. candida and (b) adaxial surface of barley leaf showing prominent wax structures.

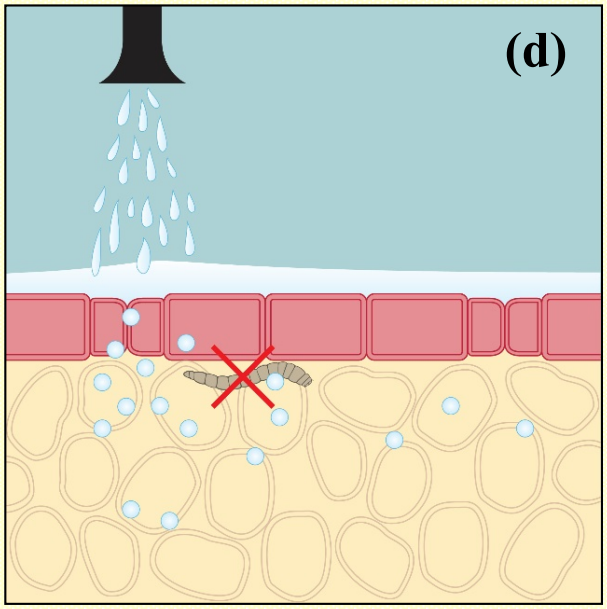
Image from: Chowdhury, et al. Leaf surfaces and the bioavailability of pesticide residues. *J. of Pest Manage Sci*. **2001**; *57*: 403-412.

Identifying Modes of Insecticidal Activity



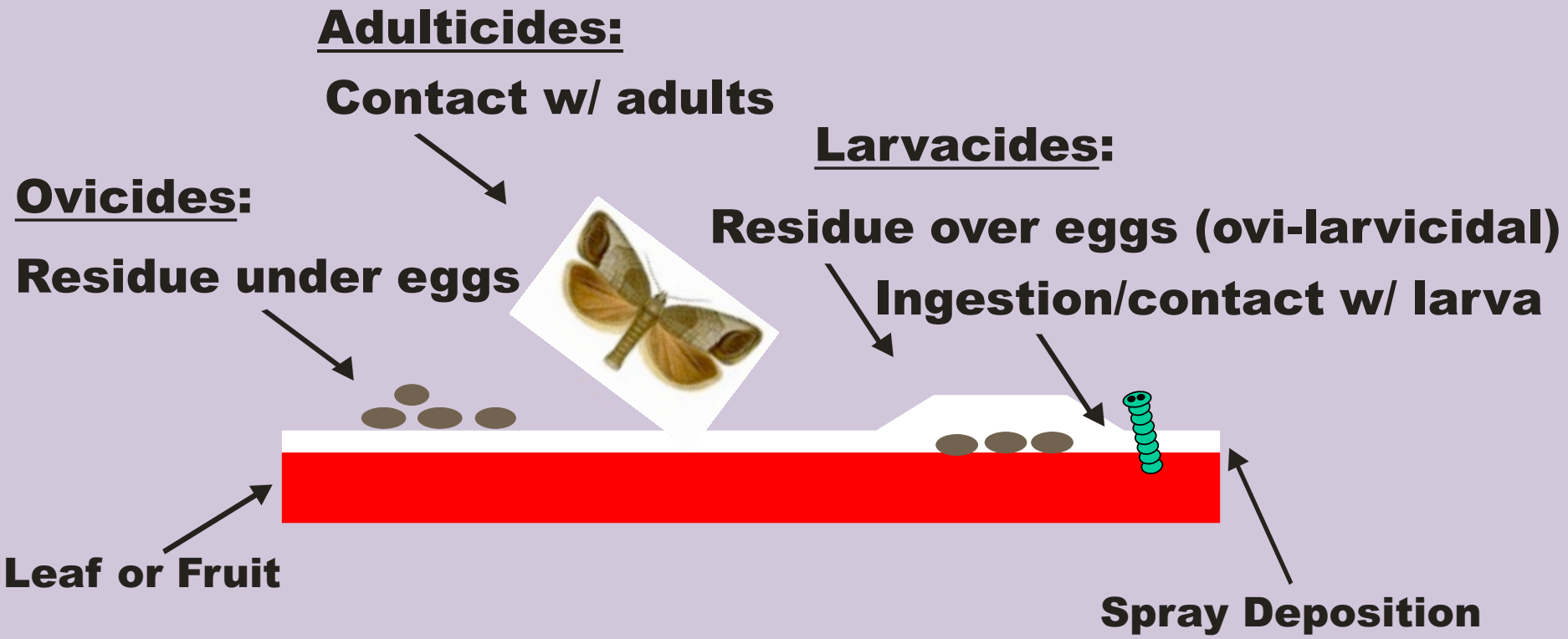
(drawing by Marlene Cameron)

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

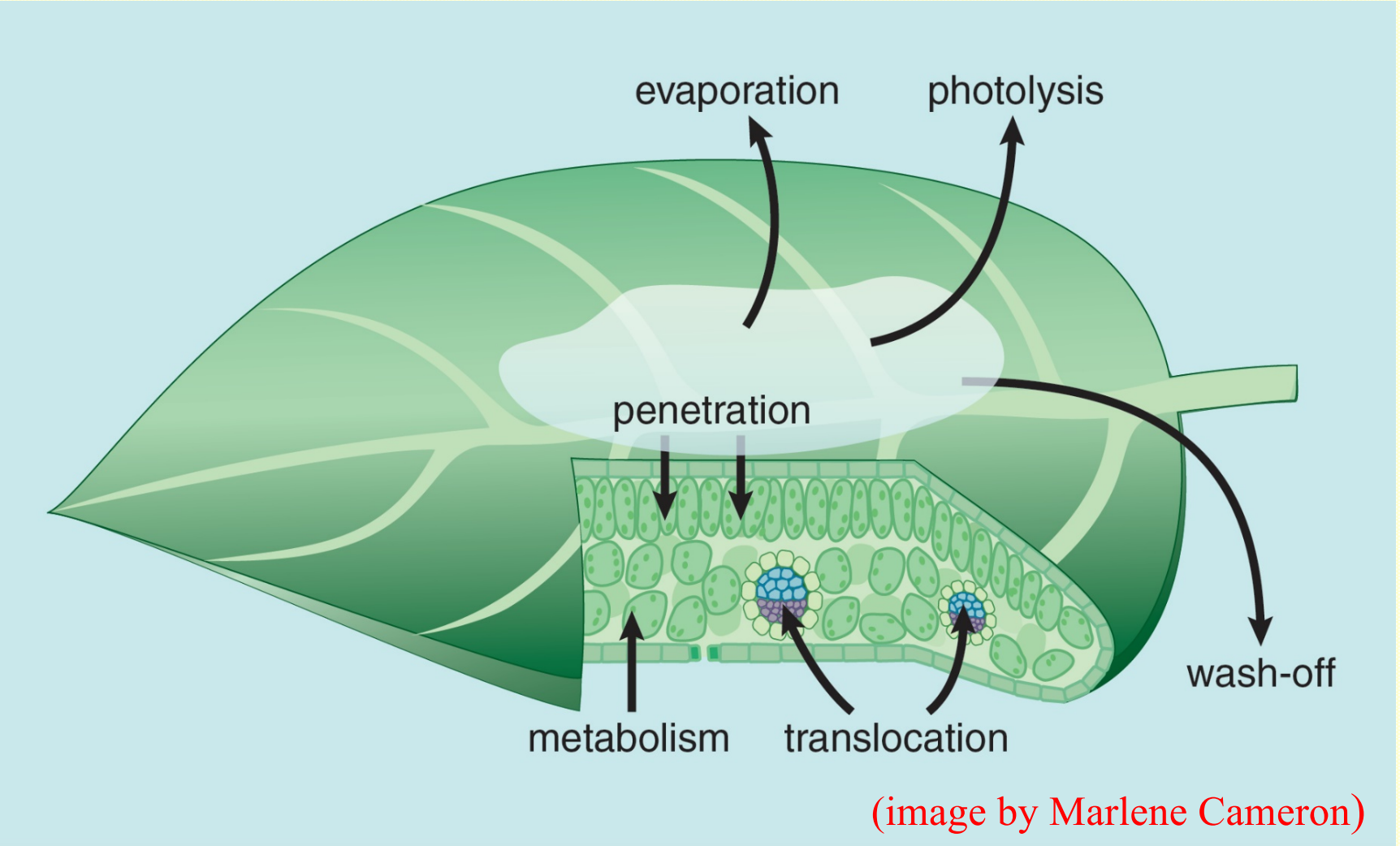


For many of the RR insecticides "Lethal and non-lethal modes of insecticidal activity work in concert to achieve the overall crop protection seen in the field."
(Wise and Whalon 2009; Biorational Control of Arthropod Pests: Application and Resistance Management. *In I. Ishaaya and A. Rami Horowitz (eds.),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

Lethal activity results in direct mortality of the pest



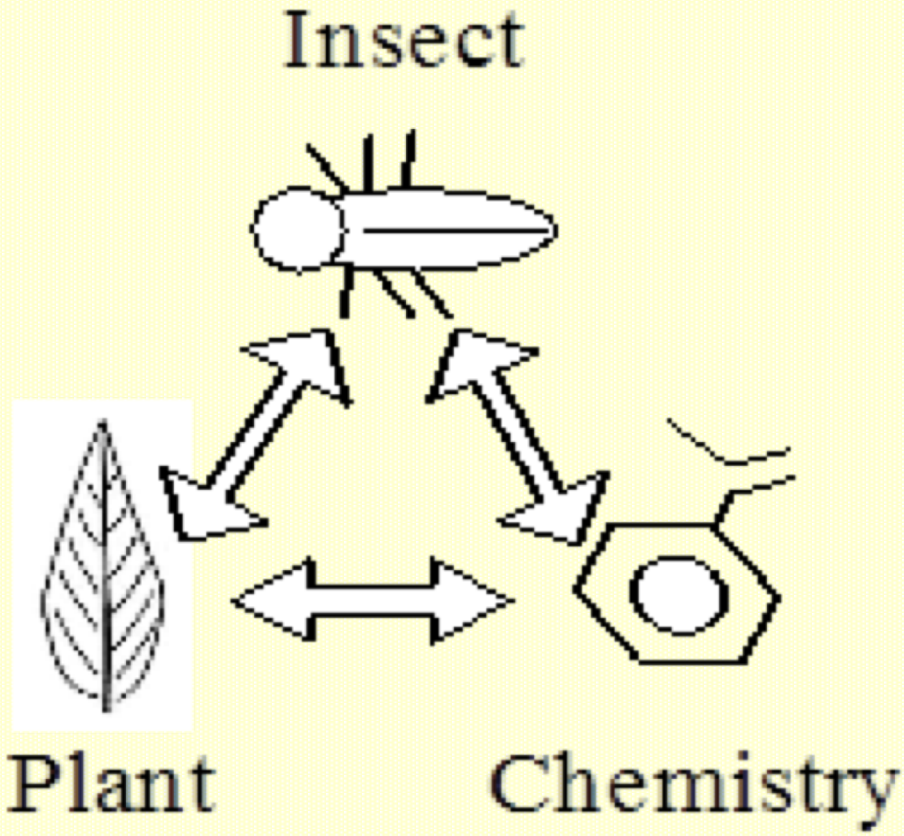
Factors that Influence Pesticide Wash-off



(image by Marlene Cameron)

- **Rainfall Characteristics**
- **Penetrative & Translocative Properties of the Compound**
- **Drying time, Persistence, and Additives**

Plant-Insect-Chemical TRIAD



Wise, J., and M. Whalon. **2009**. A Systems Approach to IPM Integration, Ecological Assessment and Resistance Management in Tree Fruit Orchards, pp. 325–346. *In* I. Ishaaya, A.R.H. (ed.), Biorational Control Arthropod Pests. Springer.

Spotted wing drosophila *(Drosophila suzukii)*

- Invasive species from East Asia
- Has spread to North and South America, and Europe
- Wide host range, includes raspberries, strawberries, blueberries, and cherries
- Oviposit in ripening

E. Beers, July 2010

Source: http://entnemdept.ufl.edu

Study Questions

- What are the effects of various rainfall amounts to insecticide control against SWD adults and infestation levels?
- What are the effects of various rainfall amounts to surface and sub-surface residue from tart cherry leaves and fruit?

Bioassay

Source: www.goodfruit.com

Bioassay

0, 12.7, 25.4 mm

5 leaves, 5 fruit,
12 flies (6 females & 6 males)

Analyzed REPEATED measure ANOVA
Tukey's test at α=0.05

Adult mortality was recorded

Brown sugar method.
Counted for small larvae, large larvae, and pupae

Day 1 Day 3 Day 5 Day 9

Flies were removed

Two-way ANOVA
Tukey's test at α=0.05

Residue Analysis

10 fruit and 20 leaves

Acetonitrile

Sonicated

DCM + 4 g $MgSO_4$ + 1 g NaCl

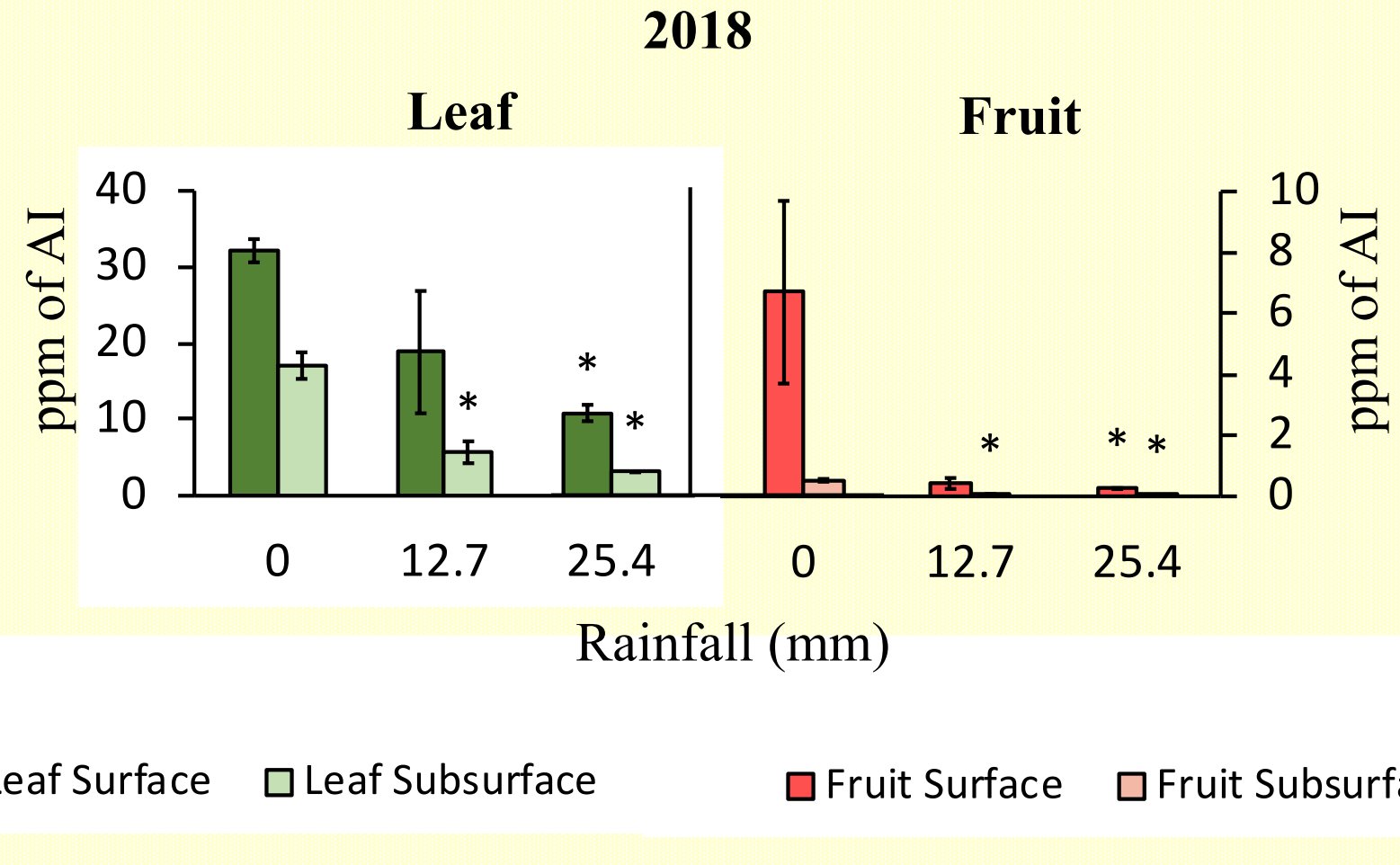
Filtered through 12 gr Na_2SO_4

One-way ANOVA

Dunett's test
α=0.05

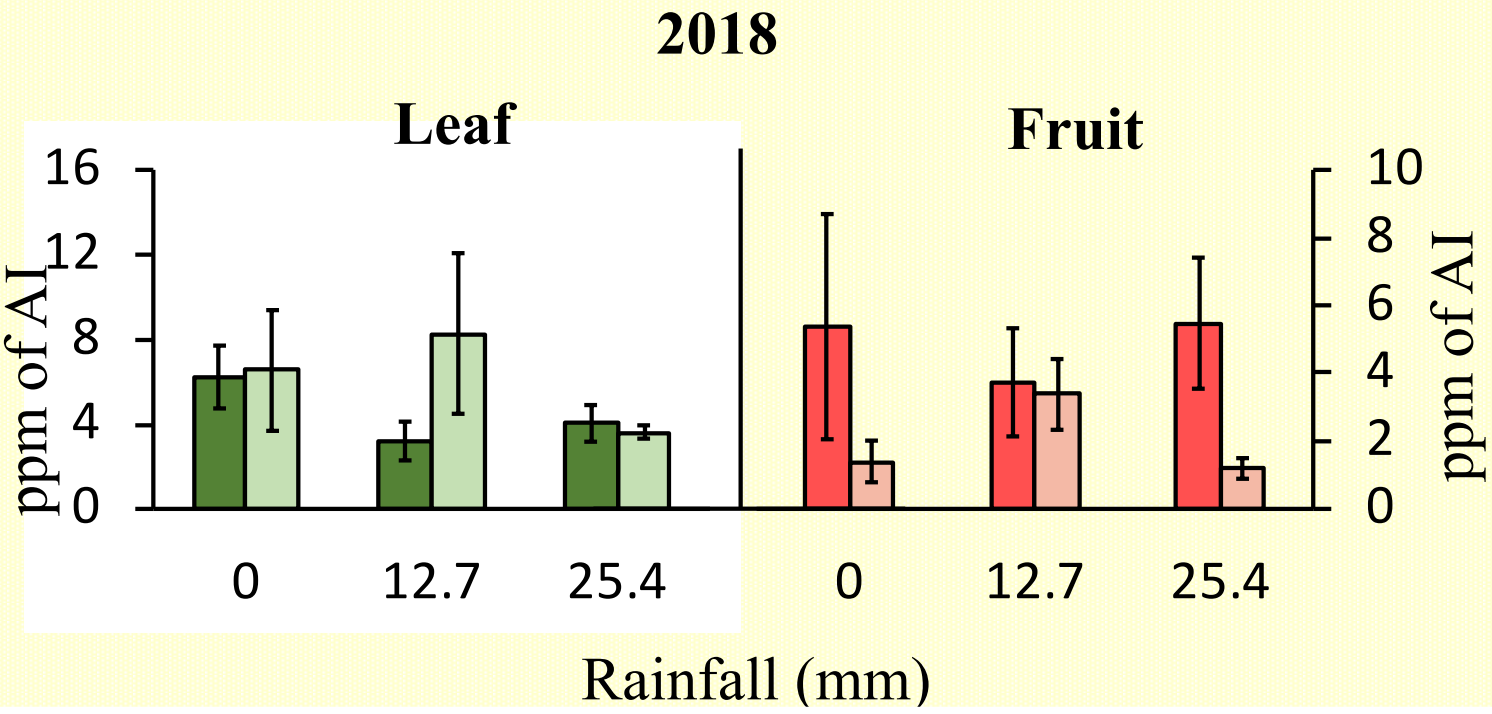
GCMS and HPLC

Phosmet



* Indicates significant differences compared to the 0 mm rainfall

Zeta-cypermethrin



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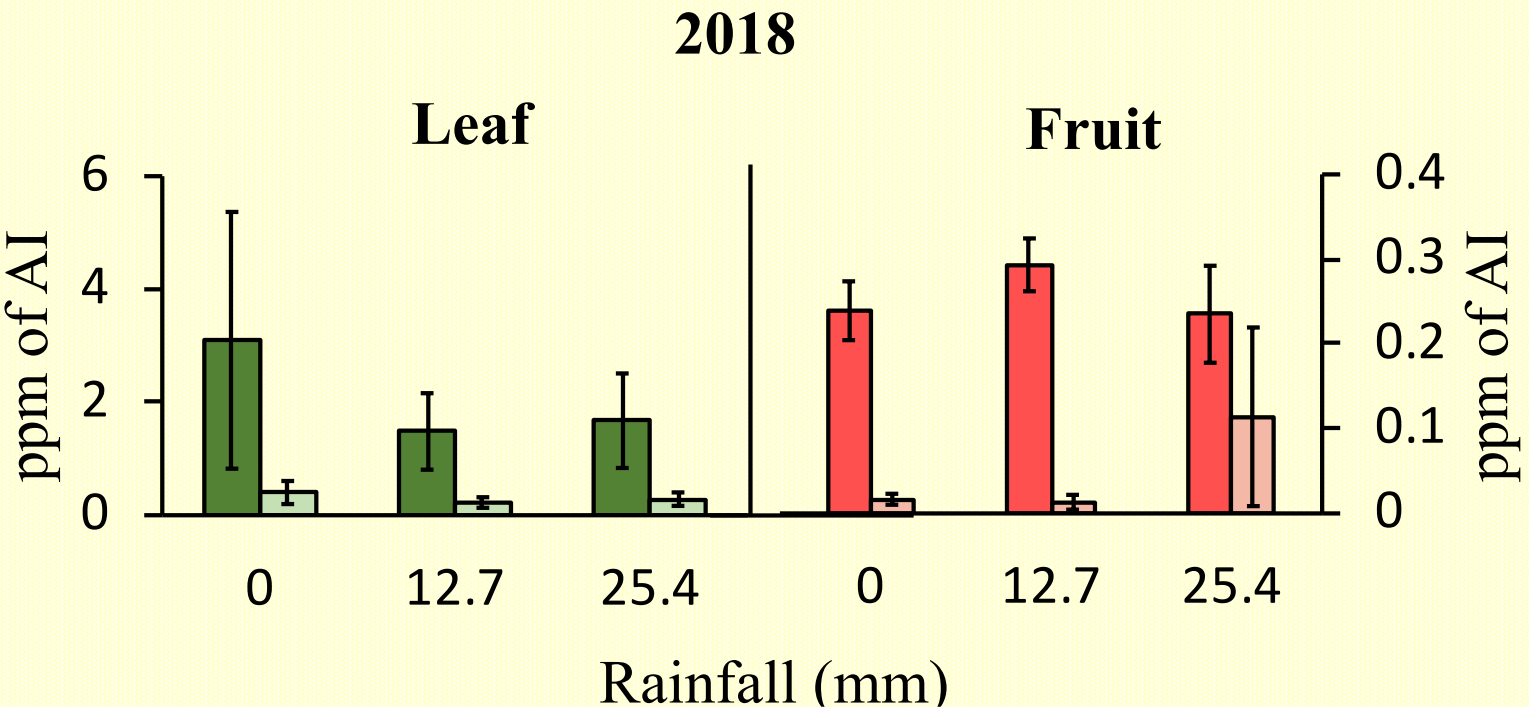
Acetamiprid



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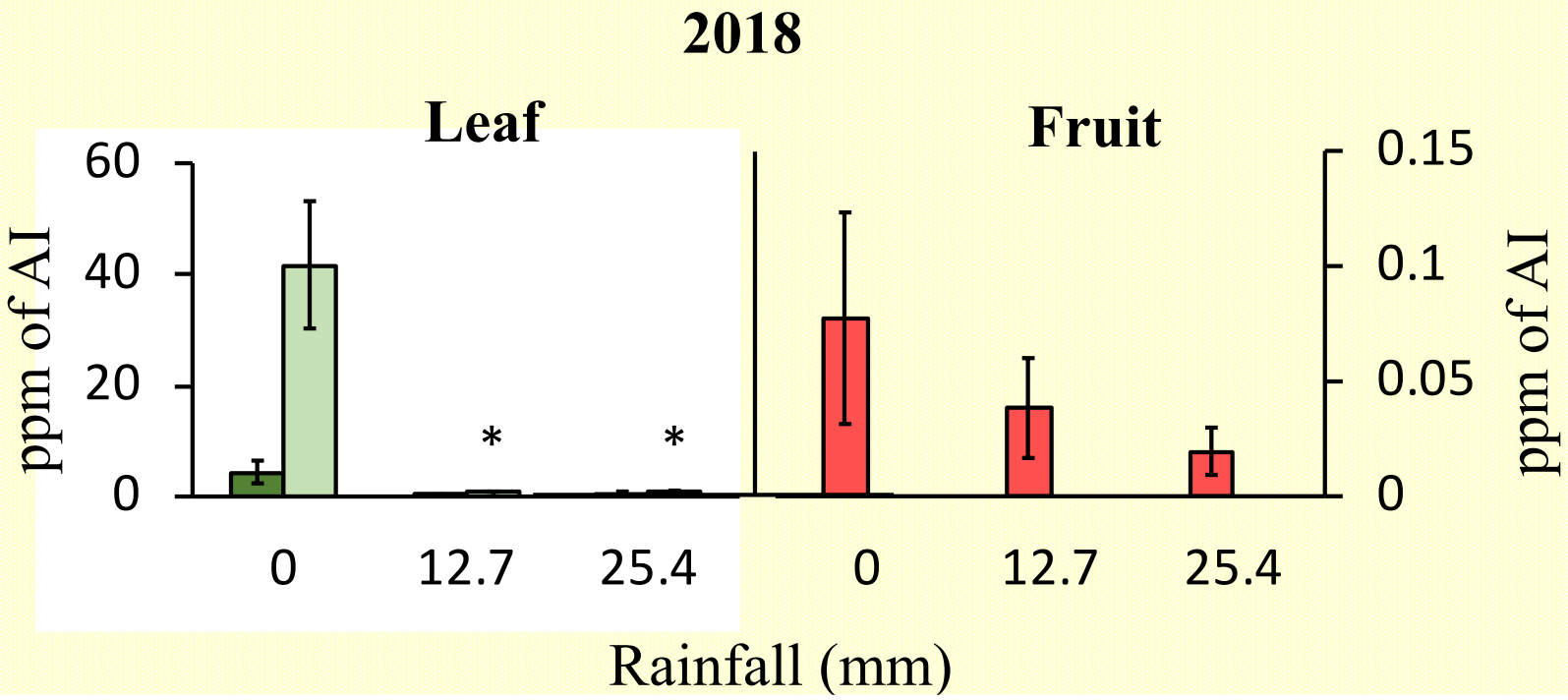
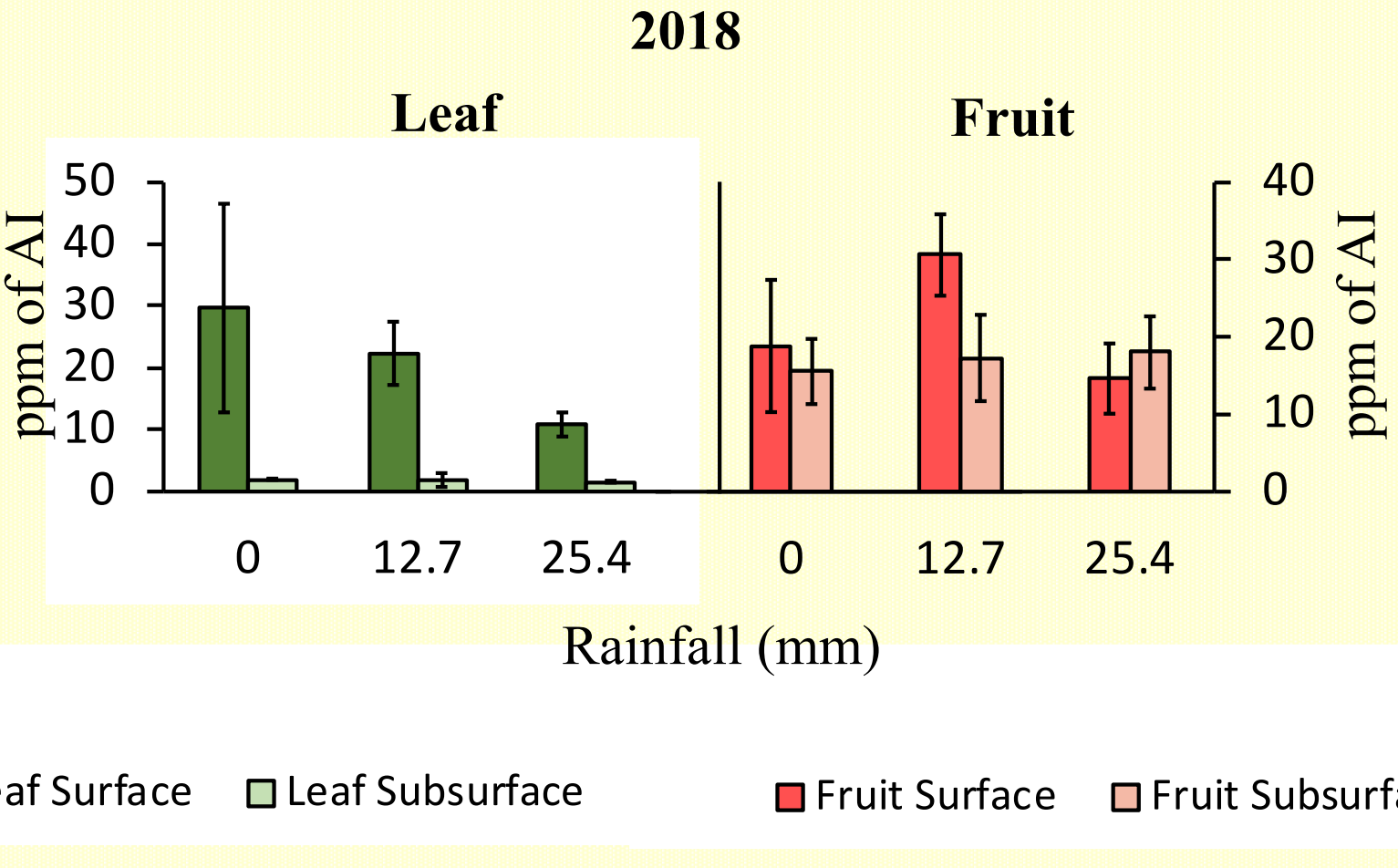
Spinetoram



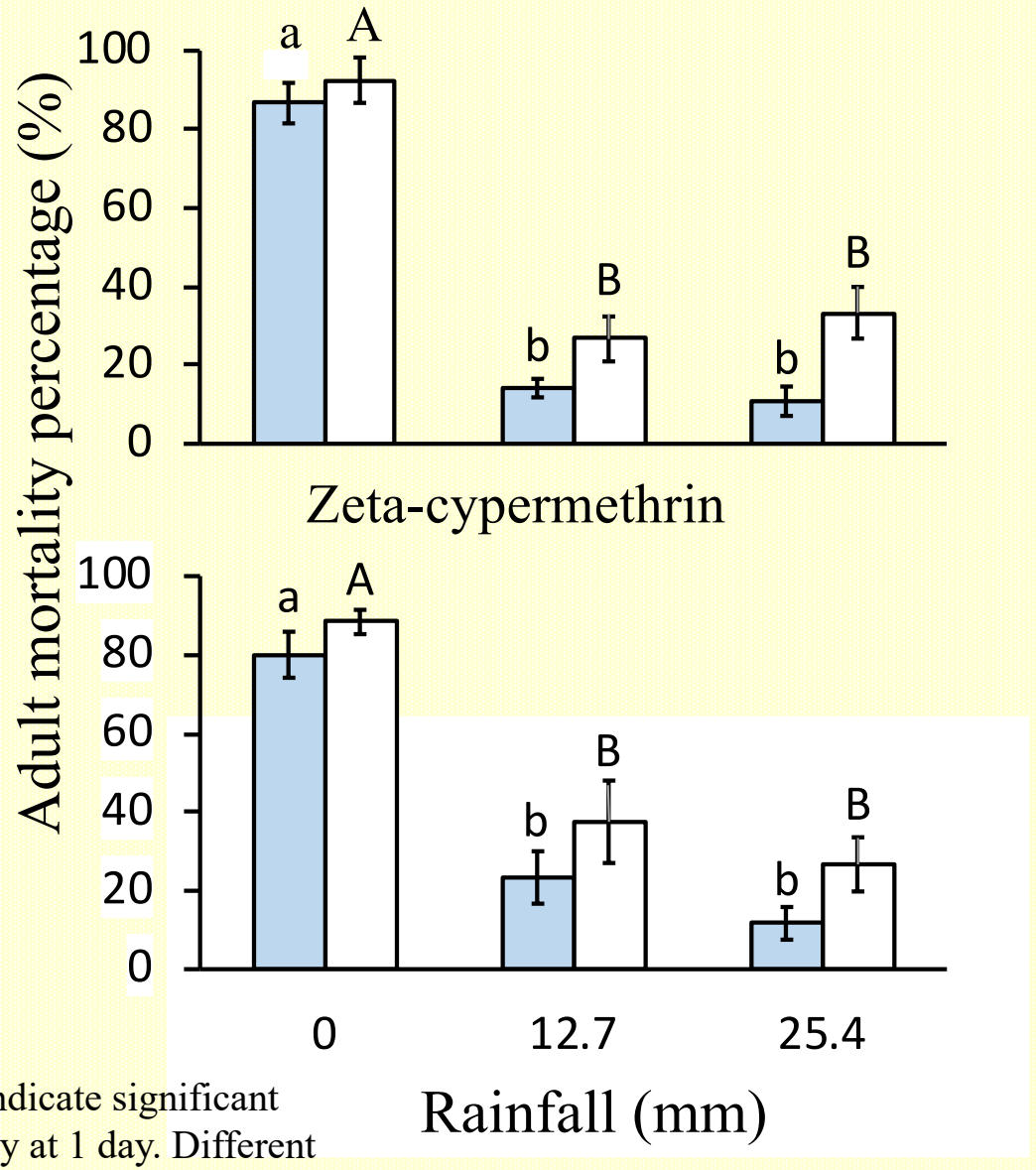
* Indicates significant differences compared to the 0 mm rainfall

Cyantraniliprole



* Indicates significant differences compared to the 0 mm rainfall

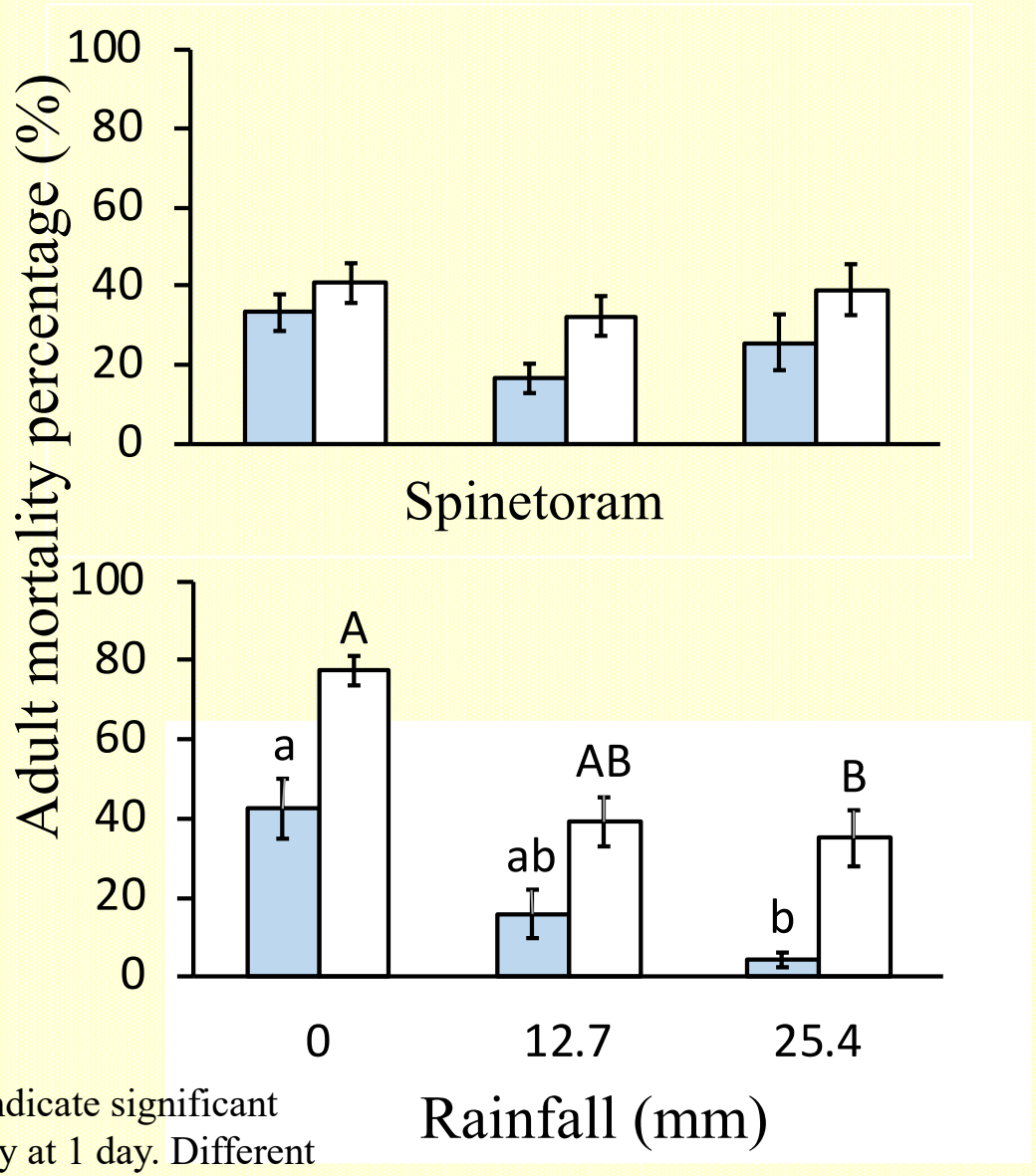
2018



Different lowercase letters indicate significant differences between mortality at 1 day. Different capital letters indicate significant differences between mortality at 3 day

2018

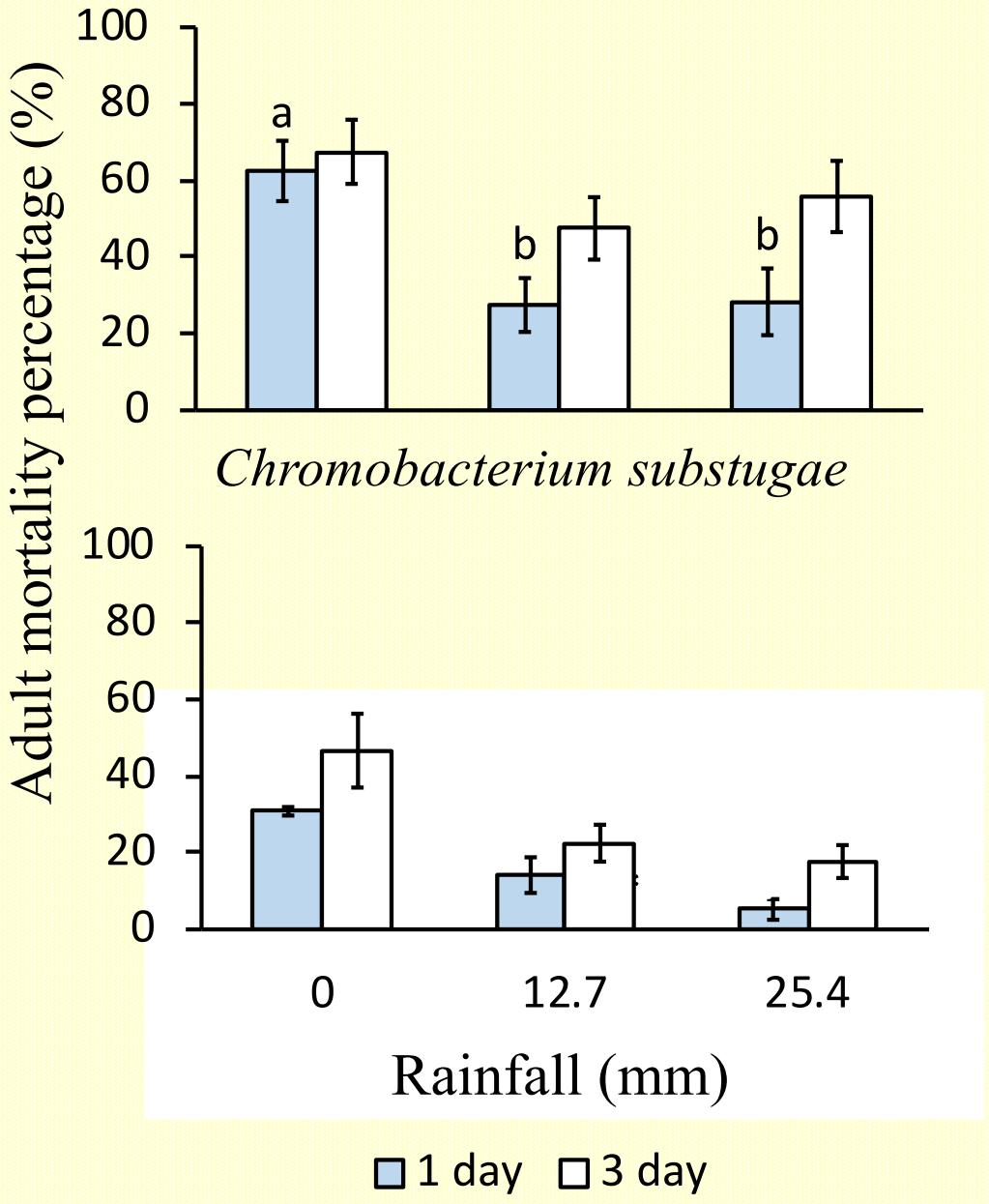
Acetamiprid



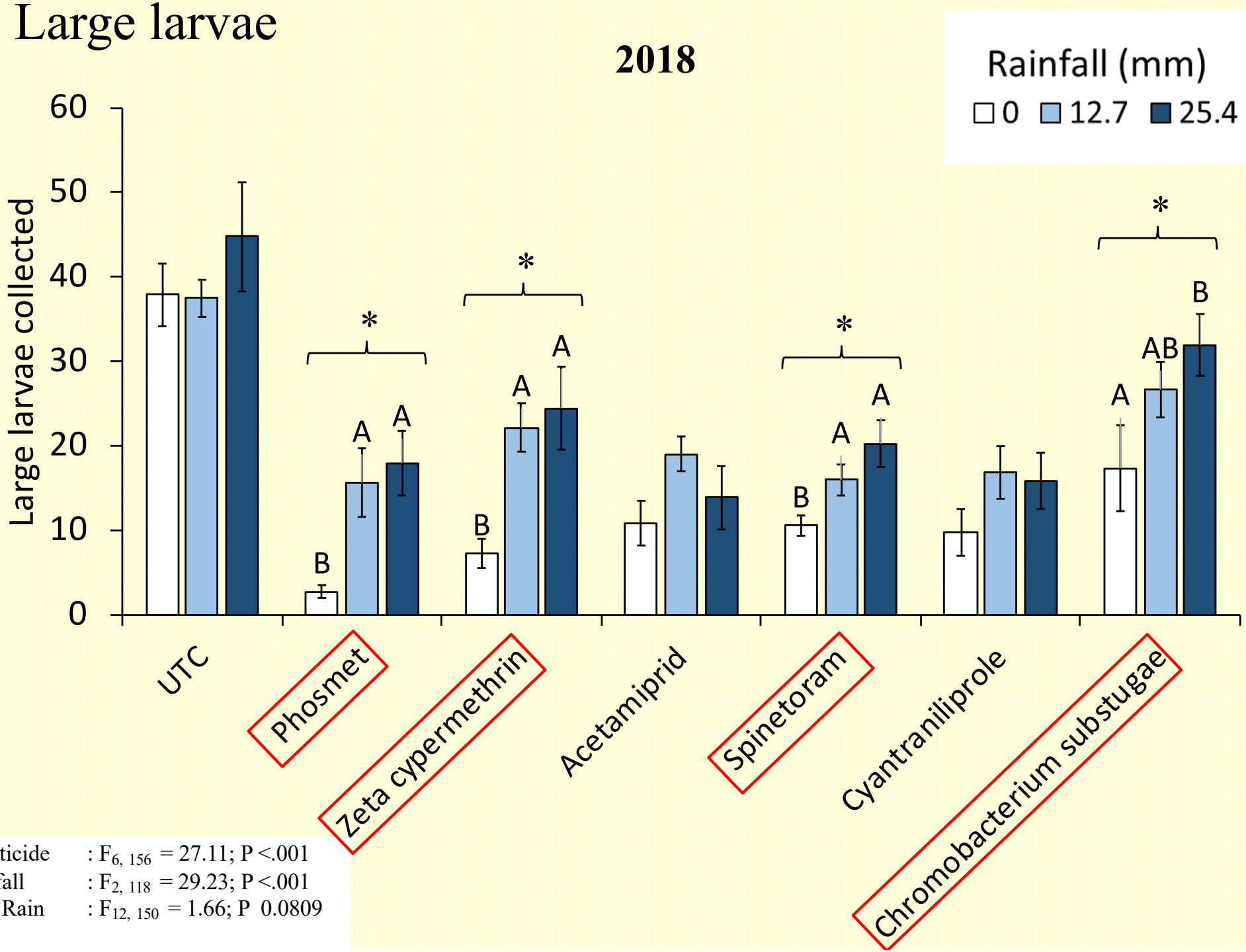
Different lowercase letters indicate significant differences between mortality at 1 day. Different capital letters indicate significant differences between mortality at 3 day

2018

Cyantraniliprole



Large larvae



Insecticide : $F_{6, 156} = 27.11$; $P < .001$
Rainfall : $F_{2, 118} = 29.23$; $P < .001$
Ins x Rain : $F_{12, 150} = 1.66$; P 0.0809

Conclusions

- Phosmet's adulticide action, infestation levels, and residues were sensitive to wash-off
- Spinetoram's adulticide action, infestation levels, and residues were sensitive to wash-off
- Zeta-cypermethrin's adulticide action and infestation was sensitive to wash-off by simulated rain. However, its residues were more resistant against wash-off
- *C. substugae* adulticide action and infestation level were affected by simulated rainfall.
- Adulticide action, infestation level, and residues of acetamiprid were not sensitive to rainfall
- Cyantraniliprole adulticide action was affected by rainfall; however, its effect to immature stages and residues more resistant to wash-off

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/

Rainfastness Rating Chart (E154)

Cherry Insecticide Precipitation Wash-off Re-application Decision Chart: Expected spotted wing Drosophila control in tart cherries, based on each compound's inherent toxicity to SWD, maximum residual, and wash-off potential from rainfall.

Insecticides	Rainfall = 0.5 inch		Rainfall = 1.0 inch		Rainfall = 2.0 inches	
	*1 day	*3 days	*1 day	*3 days	*1 day	*3 days
Imidan	X	X	X	X	X	X
Mustang Max	X	X	X	X	X	X
Exirel		X		X	X	X
Grandevo	X	X	X	X	X	X
Delegate		X	X	X	X	X
Assail				X	X	X

* Number of days after precipitation event and presence of SWD adults (assuming rainfall no more than 24 hr after insecticide spray).

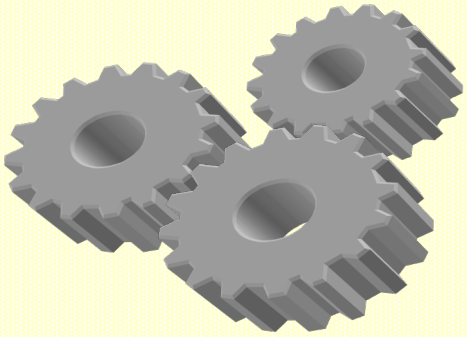
X – Insufficient insecticide residue remains to provide significant activity on the target pest, and thus an immediate re-application is recommended.

- An un-marked cell suggests that there is sufficient insecticide residue remaining to provide significant activity on the target pest, although residual activity may be reduced.

MICHIGAN STATE UNIVERSITY EXTENSION

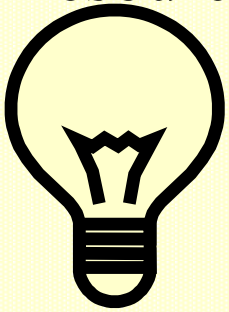
20th Century IPM
Industrial Age

"Time for another poison"



21st Century IPM
Information Age

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



Michigan State University AgBioResearch

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