

Integrated Pest Management of Vegetables in Protected Culture

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TEXAS A&M
AGRILIFE
EXTENSION

Agricultural History

The Green Revolution

- Between 1940's - 1960's
- “saved over a billion people from starvation”
- high-yielding varieties of cereal grains
- Expansion of irrigation infrastructure
- Modernization of management techniques
- Distribution of hybridized seeds, synthetic fertilizers, and pesticides to farmers



Norman Borlaug

Agricultural History



Agricultural History | Invasive species

502 Records
\$ billions in economic impact

Spotted Wing Drosophila
Estimated revenue loss in 2008
\$511.3 million

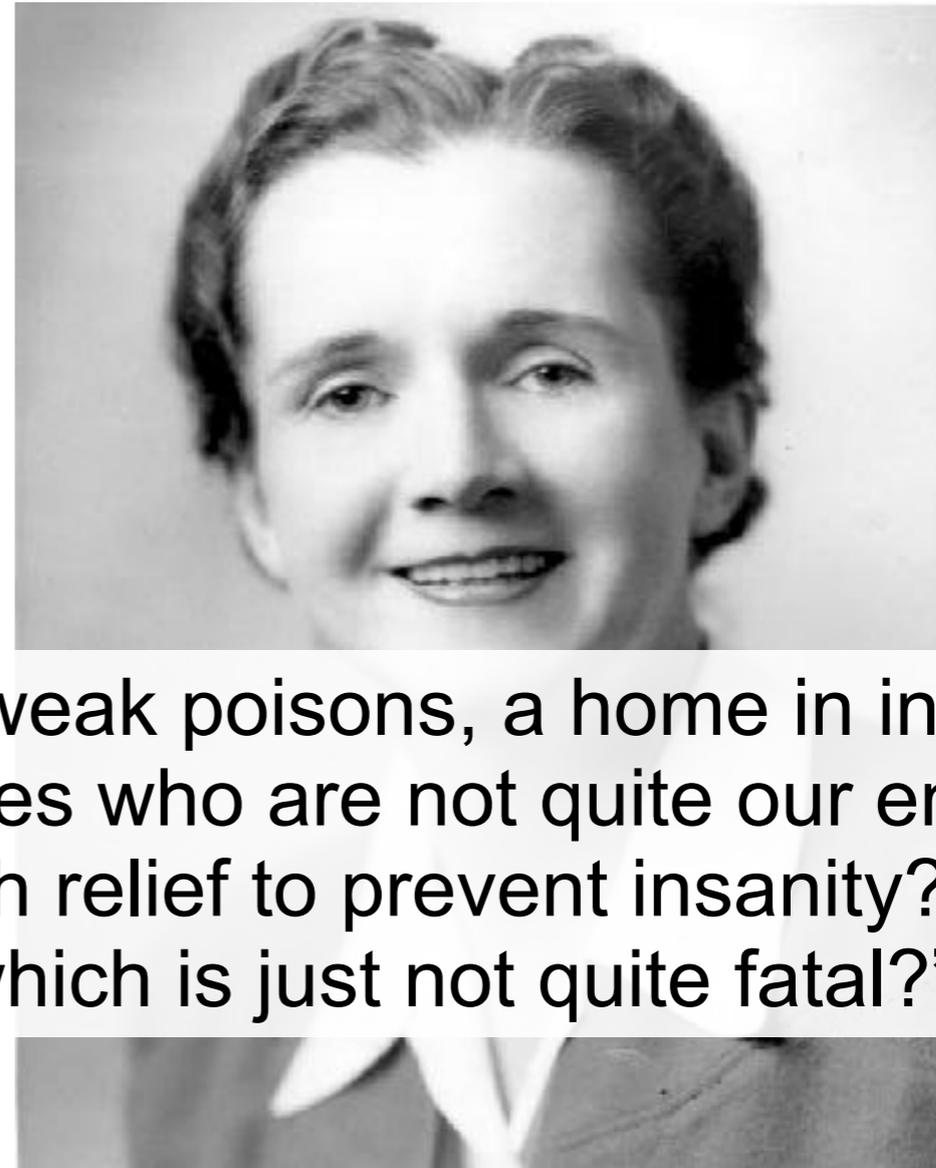
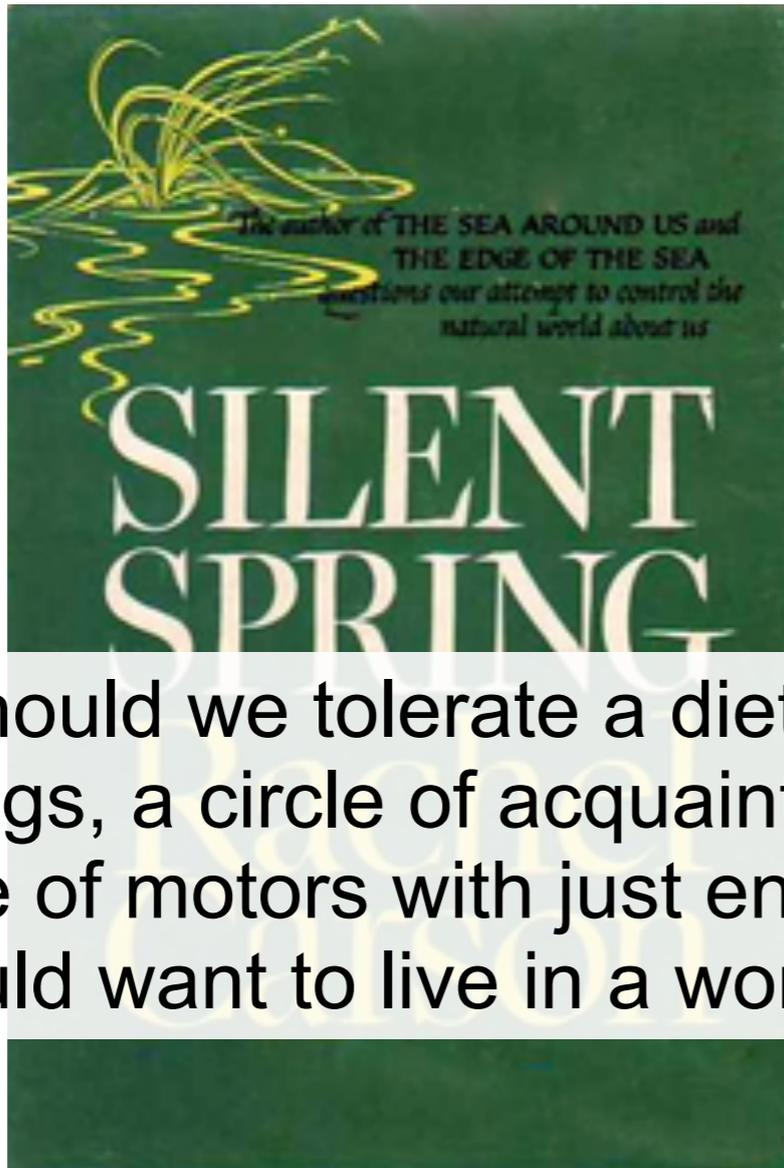
Agricultural History



Agricultural History



Integrated Pest Management



“Why should we tolerate a diet of weak poisons, a home in insipid surroundings, a circle of acquaintances who are not quite our enemies, the noise of motors with just enough relief to prevent insanity? Who would want to live in a world which is just not quite fatal?”

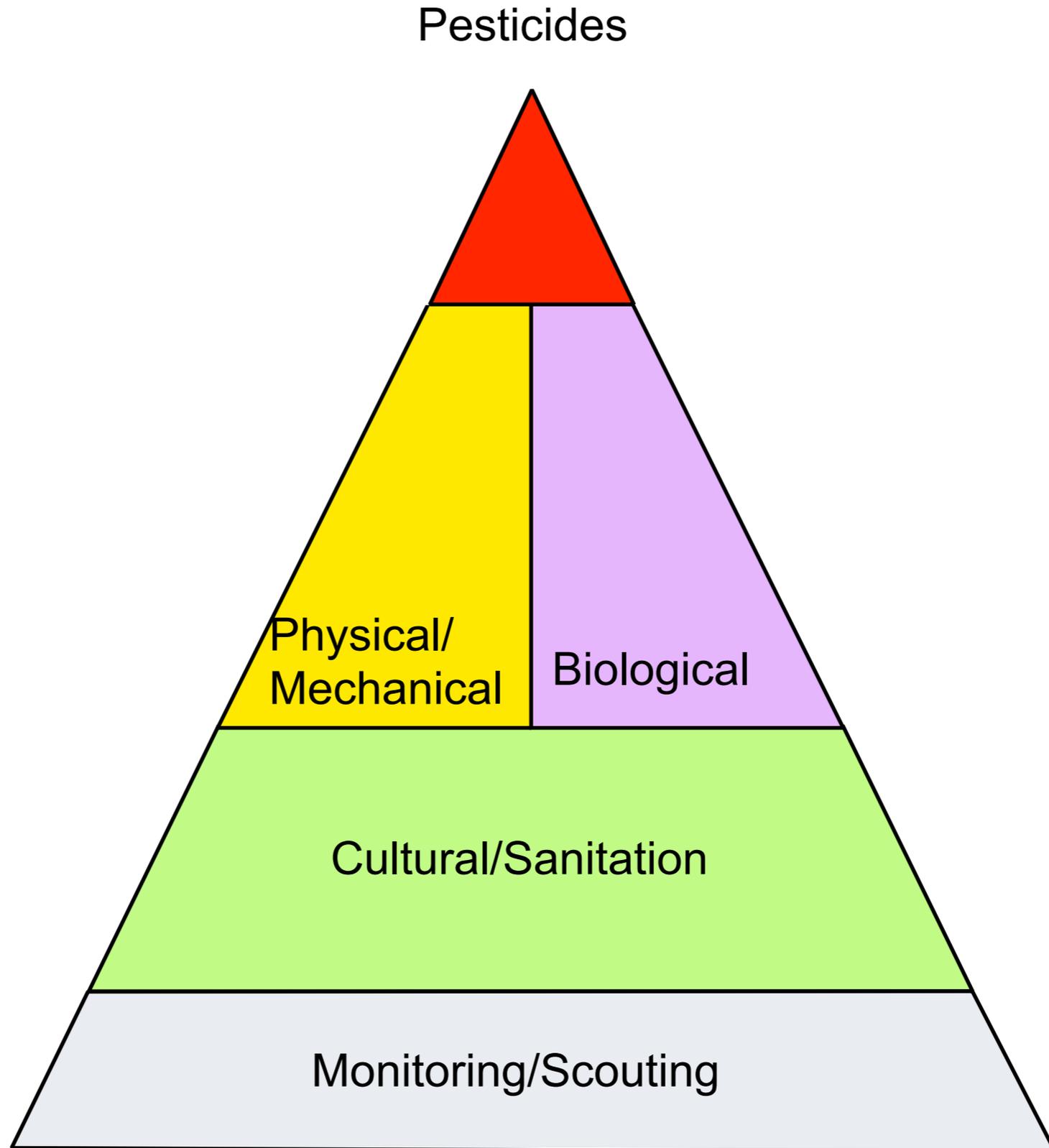
1970's

USDA creates nationwide IPM program in Land Grant Universities

Integrated Pest Management

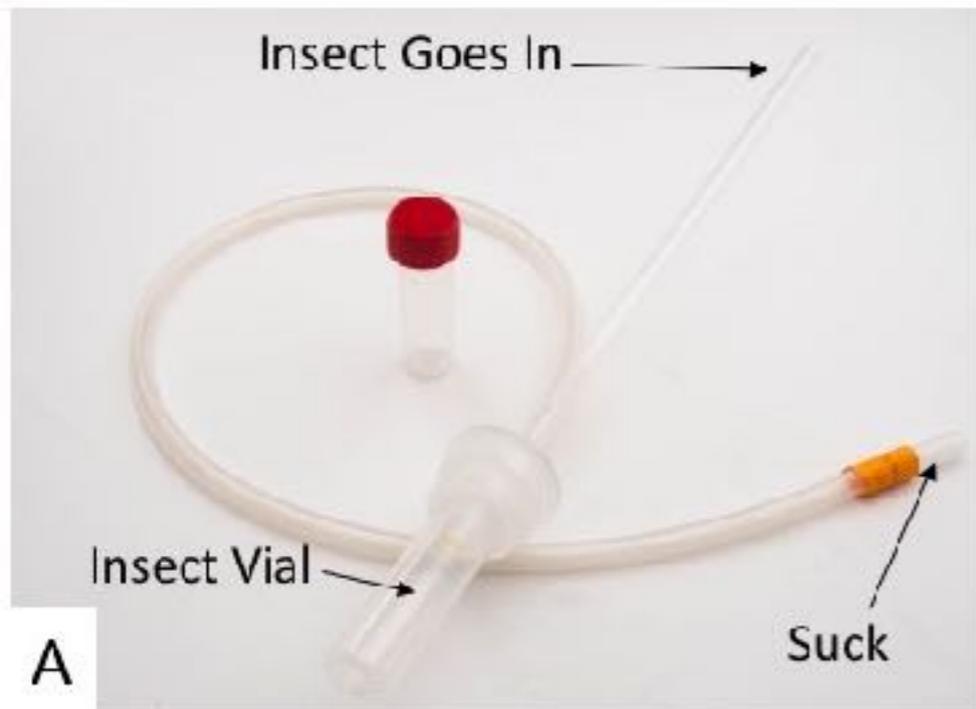
- Minimize impact on the environment
- Minimize impact on human health
- Maintain or increase soil fertility
- Long-term pest management
- Prevent pesticide-resistant pests
- Strives to maximize long-term returns/savings

IPM Pyramid



Monitor

Tools of the Trade



Monitor

Tools of the Trade



Monitor

Tools of the Trade



Koppert iPM

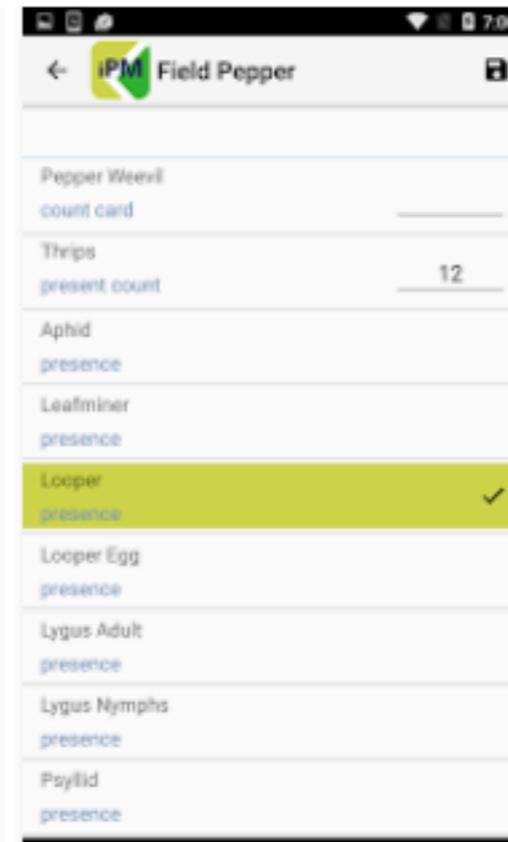
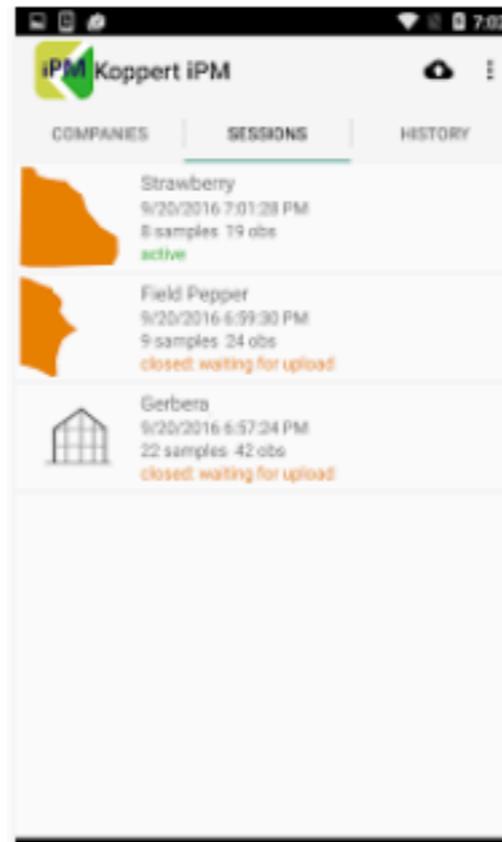
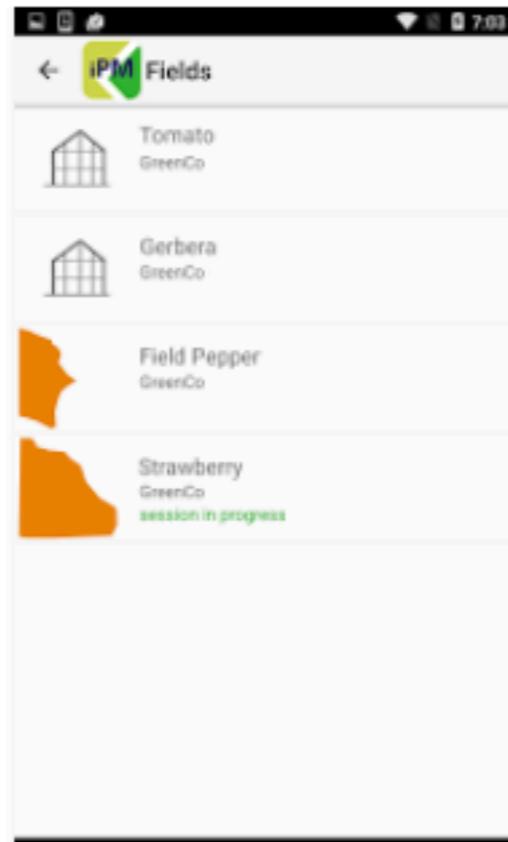
Koppert iPM Tools

★★★★★ 6

Everyone

This app is compatible with some of your devices.

Installed



Monitor

Tools of the Trade



Farm Scout Pro

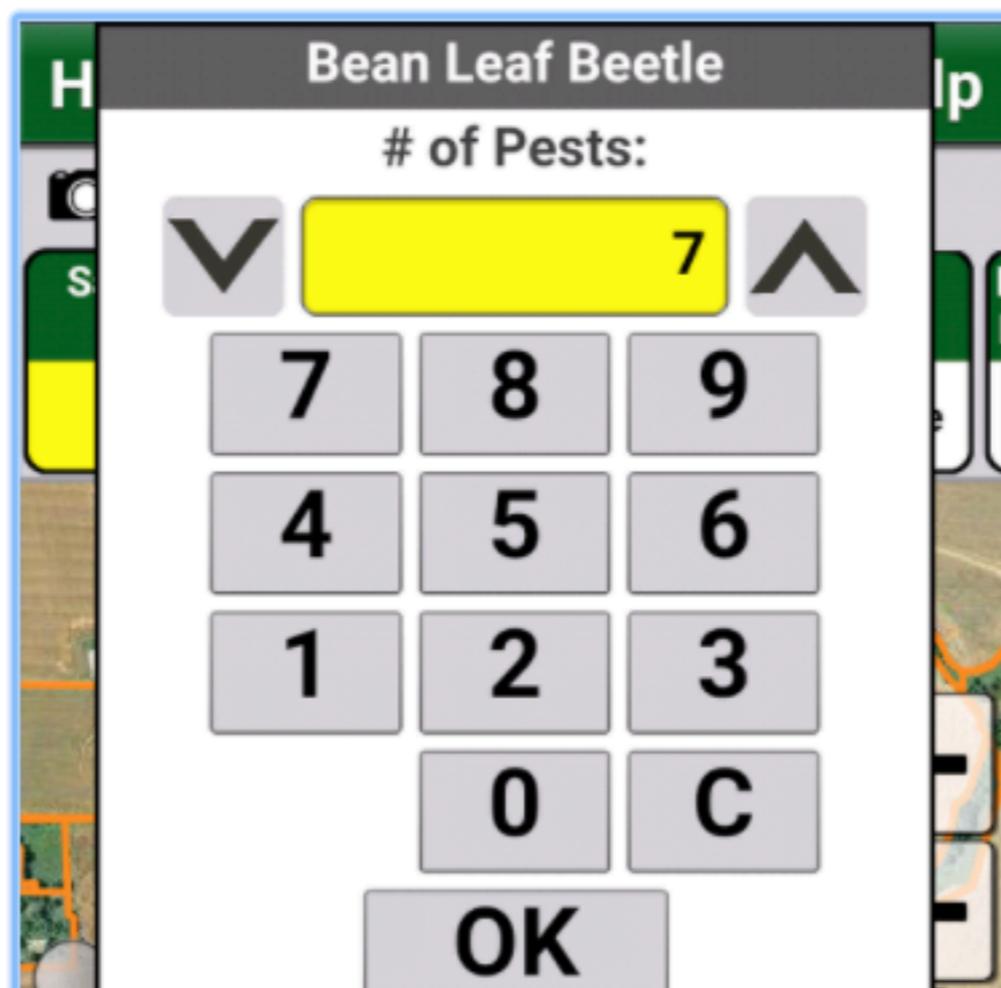
TapLogic, LLC Tools

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Monitor

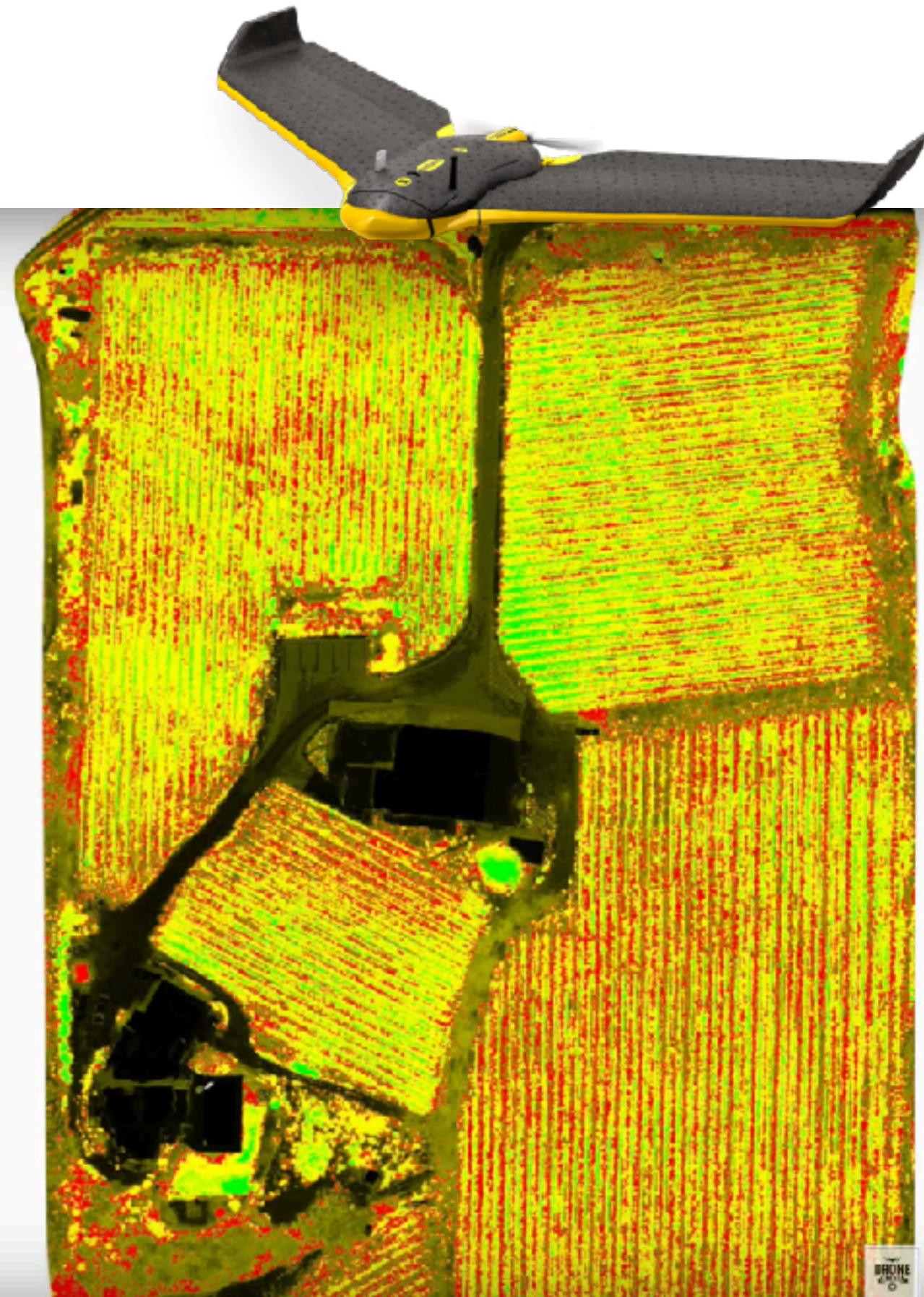
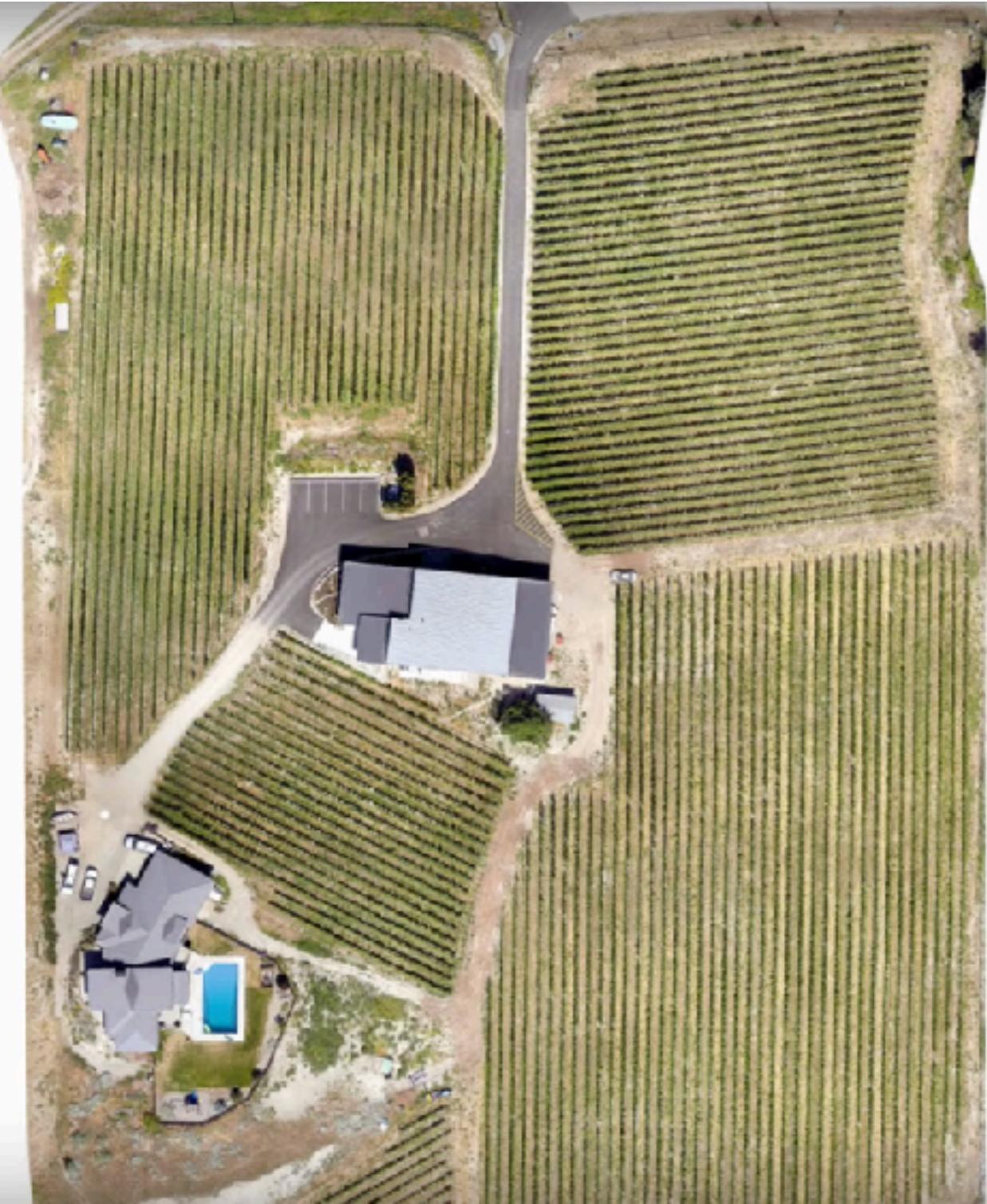
Tools of the Trade

NatureFresh Farms. “Meet Chili: The Pepper Weevil Scent Detection Dog”

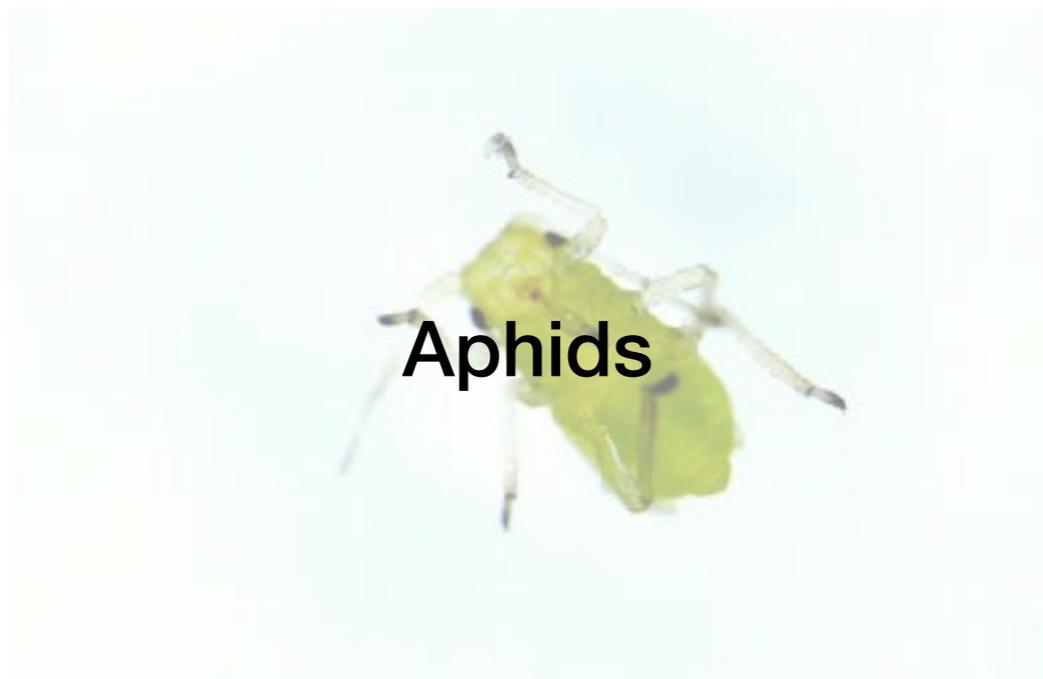


Monitor

Tools of the Trade



Monitoring



Twospotted spider mites



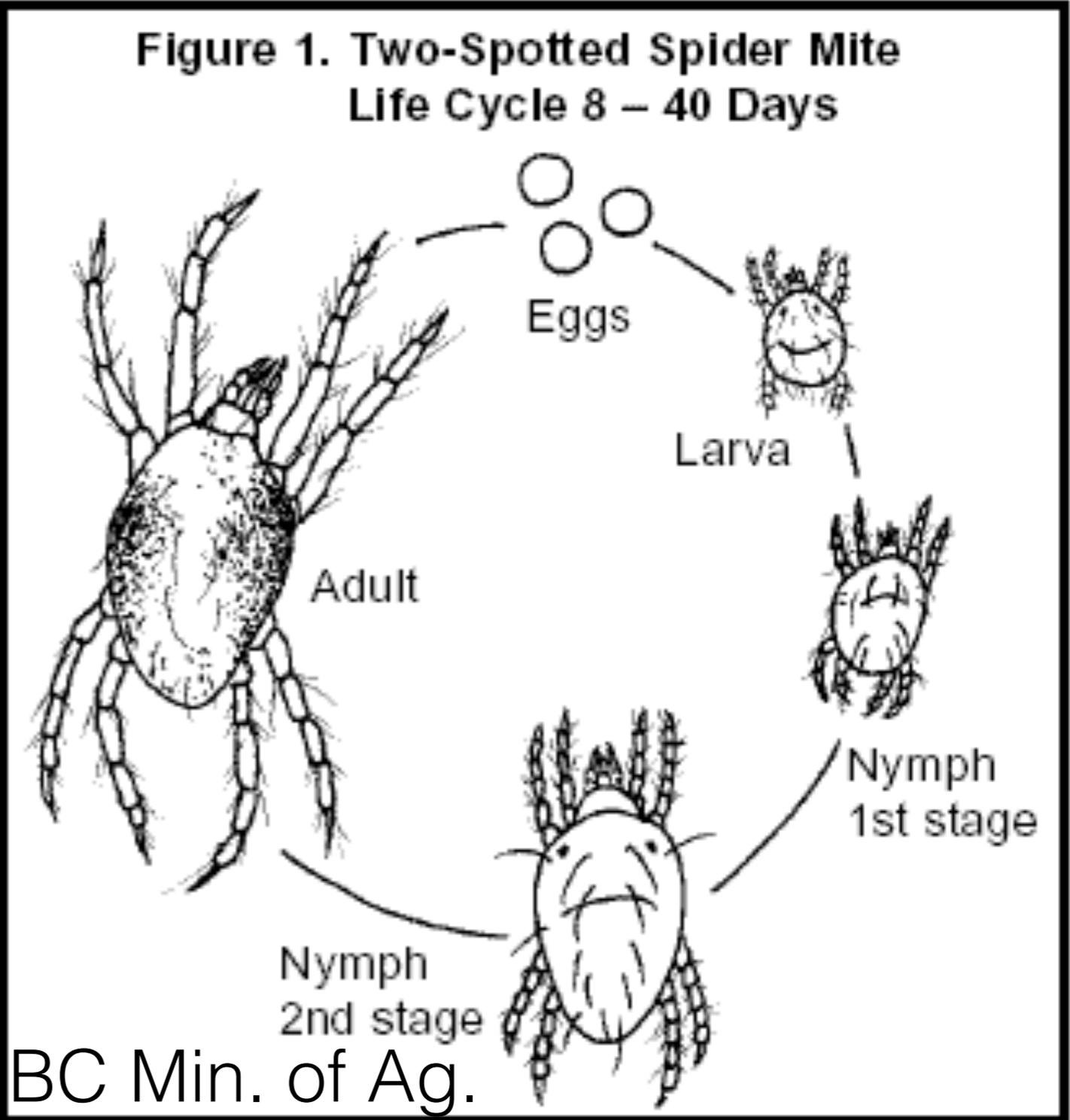
Twospotted spider mites



Twospotted spider mites



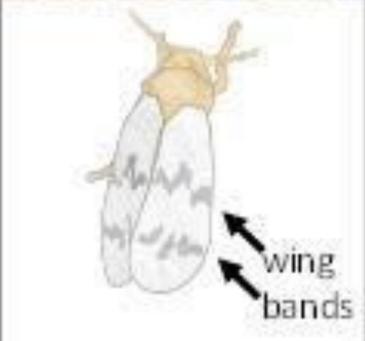
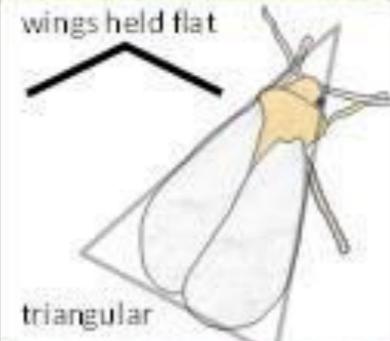
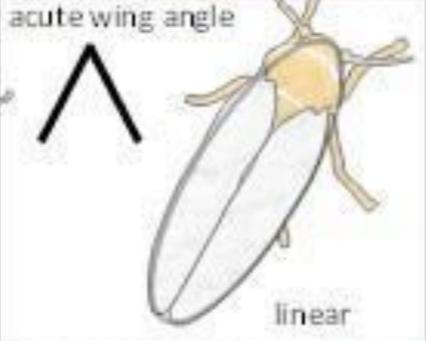
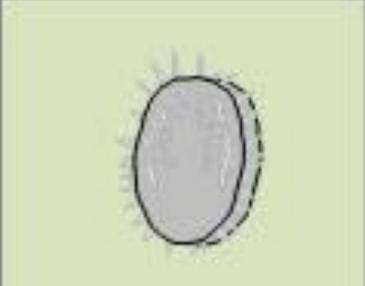
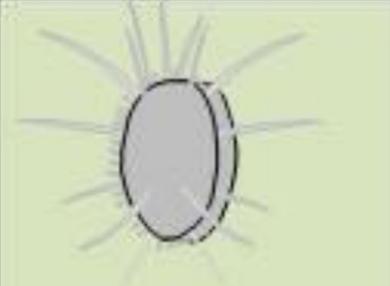
Twospotted spider mites



Whiteflies



Whiteflies

Bandedwinged Whitefly	Greenhouse Whitefly	Sweetpotato Whitefly
 <p>R. Smith UGA857007</p>		
 <p>wing bands</p>	 <p>wings held flat triangular</p>	 <p>acute wing angle linear</p>
 <p>exuviae</p>	 <p>triangular</p>	
		

Greenhouse whitefly =
Trialeurodes vaporariorum

Sweetpotato whitefly =
Bemisia tabaci

Whiteflies

Scott Bauer, USDA Agricultural Research Service, Bugwood.org

Sweetpotato Whitefly



UGA1316008

Greenhouse Whitefly



DGA5351016

David Cappaert, bugwood.org

Whiteflies



Q-type

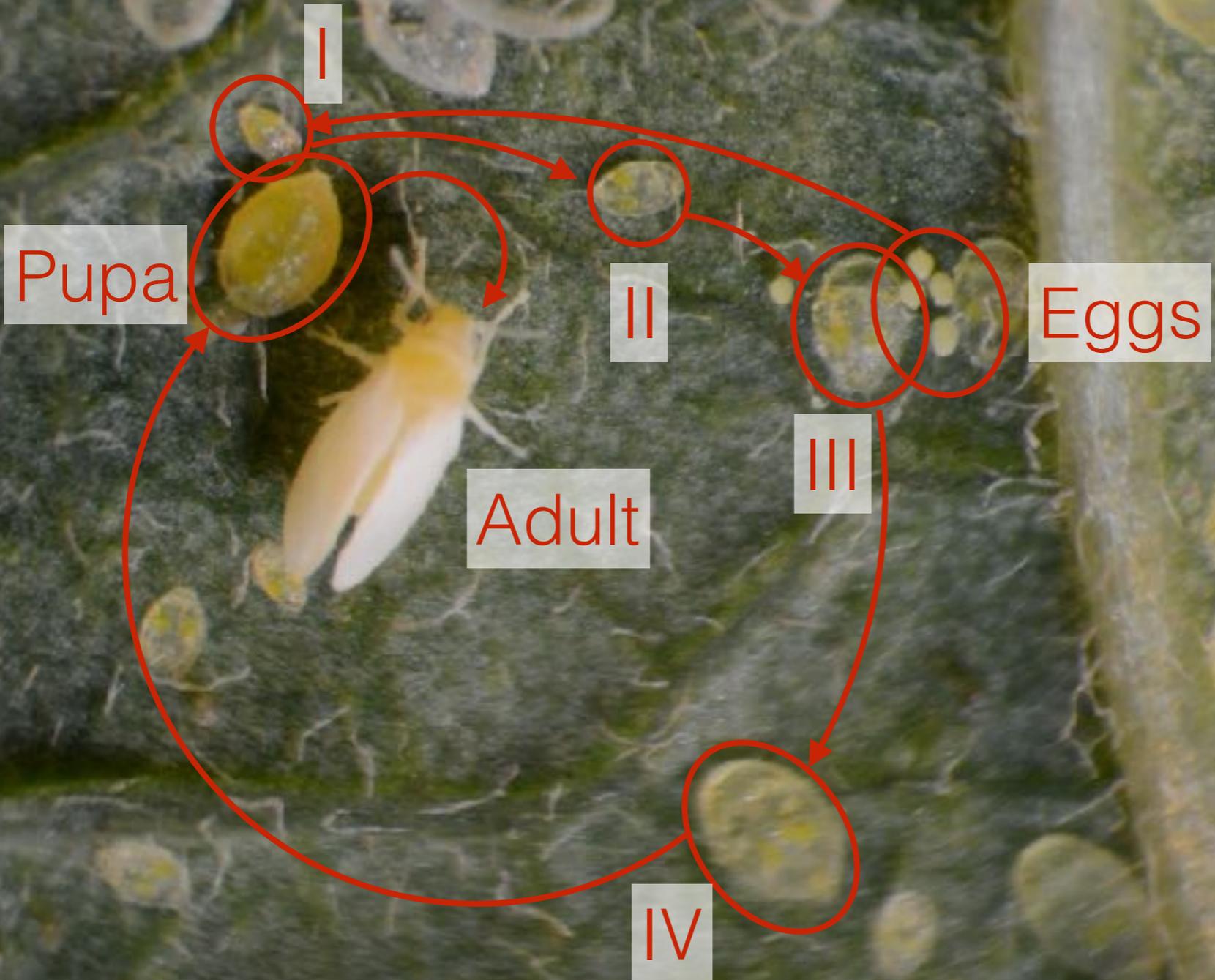
Bemisia tabaci

- Identified in US for the first time in 2004
- Higher resistance to pyriproxyfen and imidacloprid than B-type

B-type

Bemisia argentifolii

- More common
- Less pesticide resistance



Whiteflies & Aphids



Aphids



I know. I suck.

Aphids

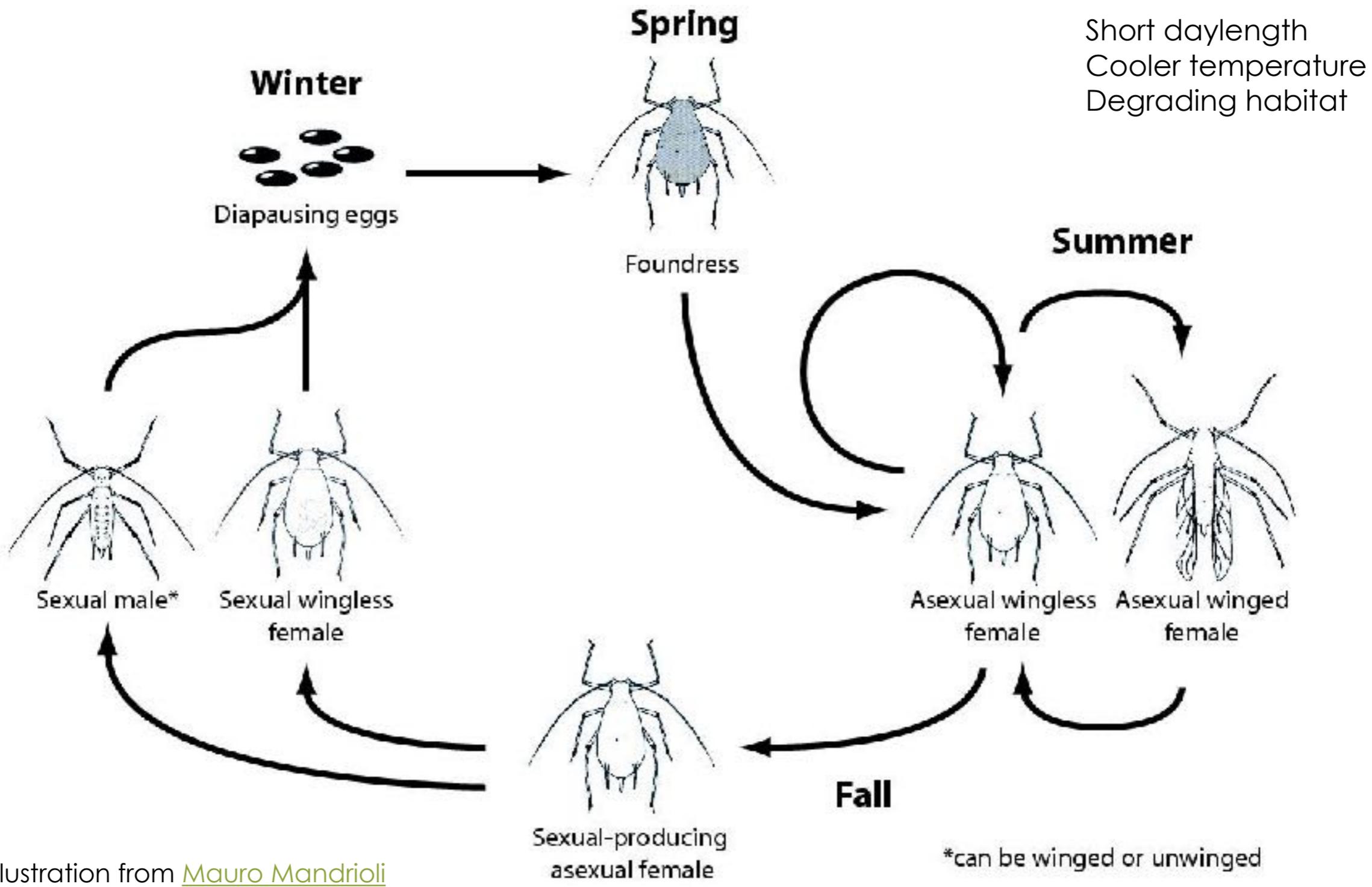


Illustration from [Mauro Mandrioli](#)

Cornicles



Spotted Wing Drosophila



Photo Credit: Whitney Olsen, Calif, Ohio Dept of Forests and Agriculture

Spotted Wing Drosophila

Potential Hosts

Apples
Apricots
Blueberries
Cherries (sour)
Cherries (sweet)
Cranberries

Grapes
Nectarines
Peaches
Pears
Plums and prunes
Raspberries
Strawberries

Spotted Wing Drosophila

CREATING SWD TRAP

LIVE DEMONSTRATION!



Spotted Wing Drosophila



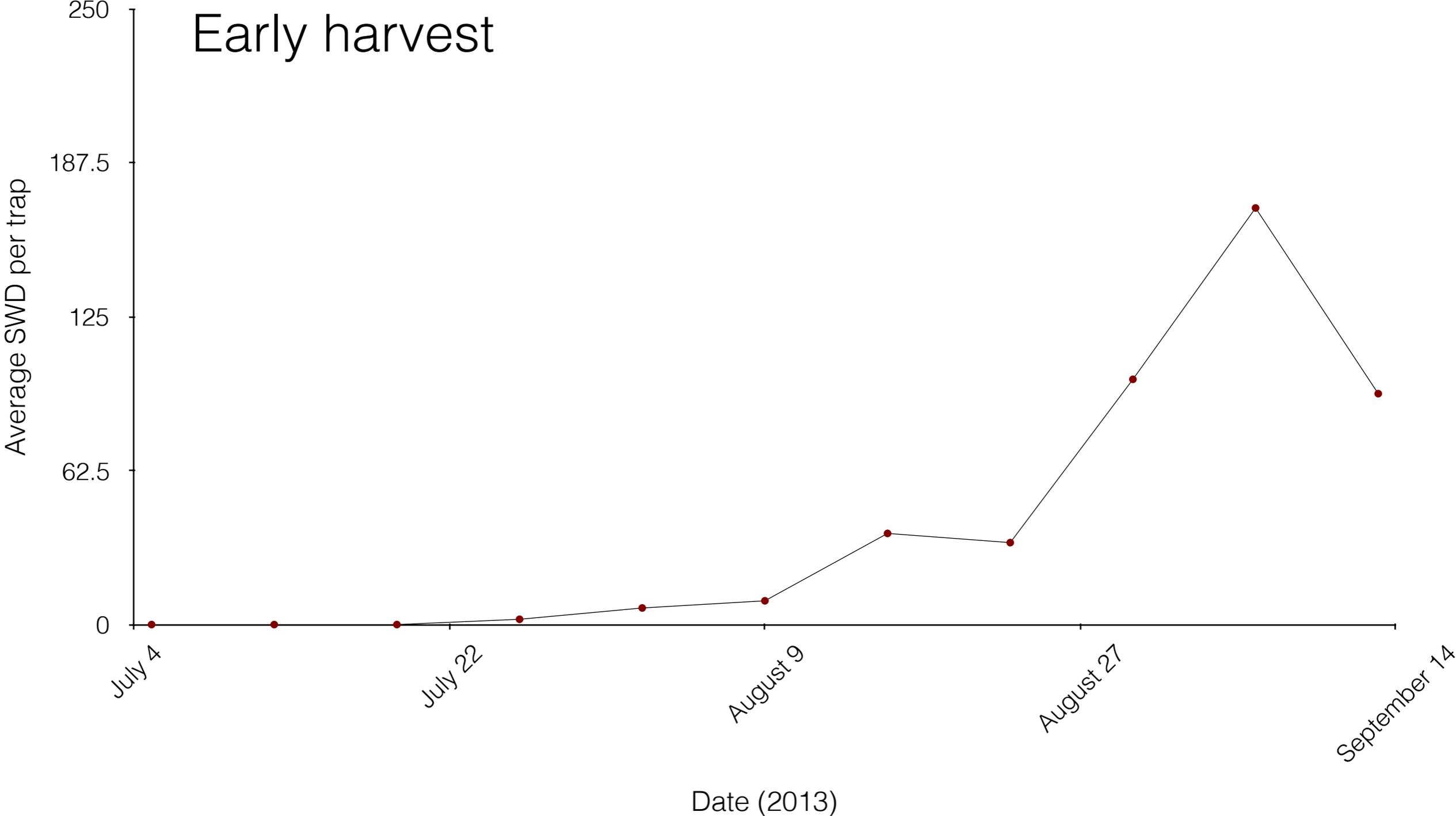
Spotted Wing Drosophila



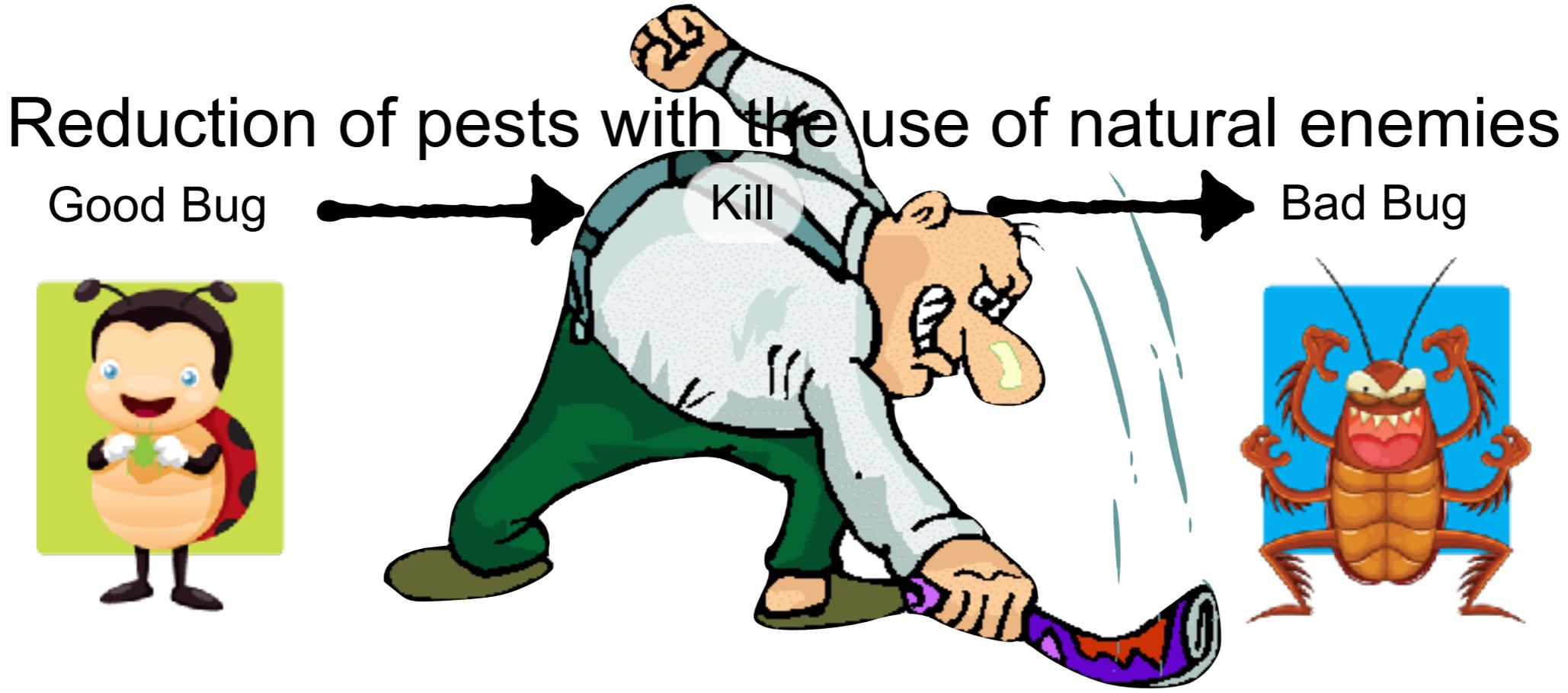
Spotted Wing Drosophila



Spotted Wing Drosophila



Biological Control



Multicolored Asian Lady Beetle



Larva

185 aphids over 11 days

Adults

35 - 45 aphids/day

~240 viable offspring

Can live longer than a year

Generalist

Tend to disperse shortly after introduction



Twospotted
spider mites

Whiteflies

Aphids

Delphastus spp.



Hosts:

- Whiteflies (*Bemisia* and *Trialeurodes*)
- Aphids (i.e. *Myzus persicae*)
- Twospotted spider mites

Population doubling time (DT) of 4.8 days
(Liu 2005)

Voracious predators

Feed on aphids and twospotted spider mites when whiteflies are sparse

Potential on tomatoes

Aphidius colemani

greenmethods.com



Hosts:

- Cotton aphid or melon aphid | *A. gossypii*
- Cabbage aphid | *B. brassicae*
- Green peach aphid | *M. persicae*
- Corn leaf aphid | *R. maidis*
- Greenbug or wheat aphid | *S. graminum*
- Over 40 aphid species

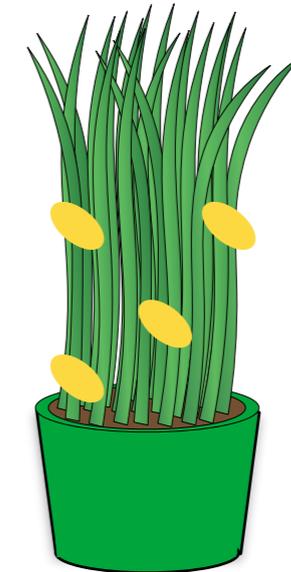
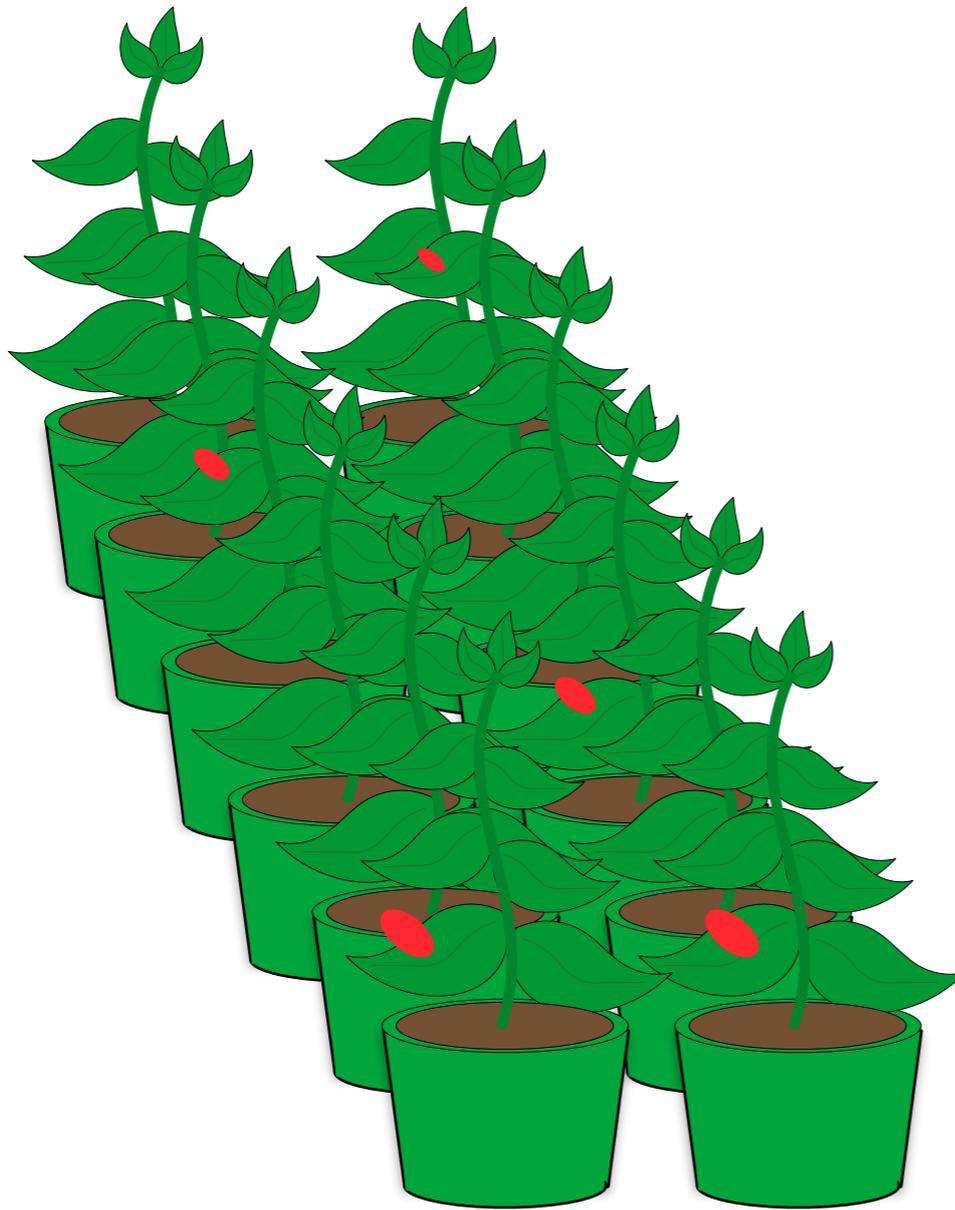
(Reed et al. 1994; De Conti et al. 2008)

Life-history:

- Female can produce 71 - 105 mummies (Wee Han et al. 2001)
- No mummies formed below 15°C (59F) or above 30°C (86F) (Wee Han et al. 2001; Baniameri et al. 2006)

Biological Control | Predators

Banker plants



Twospotted
spider mites

Whiteflies

Aphids

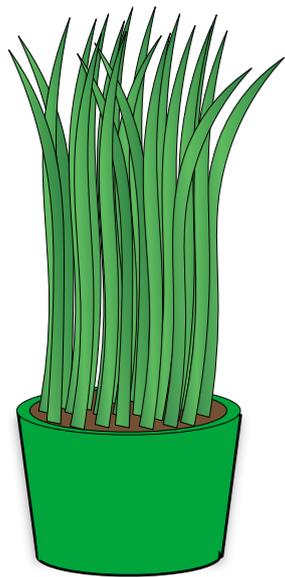


Biological Control | Predators

Banker plants



Cereal aphids¹, bird cherry oat aphids^{2,3}, greenbug⁵



Cereal plants: rye⁴, wheat⁵, barley⁵, maize⁵, sorghum⁵



Parasitic wasps: *Aphidius ervi*^{1,4}, *A. matricariae*², *A. colemani*^{2,3,4,5}

Twospotted
spider mites

Whiteflies

Aphids

Aphidius ervi

Nikk, Flickr



Hosts:

- Green Peach aphid | *M. persicae*
- Tobacco aphid | *M. persicae*
- Foxglove aphid | *A. solani*
- Pea aphid | *A. pisum*
- Over 40 species of aphids

Lay 50 - 150 eggs

Produce males and females

Twospotted
spider mites

Whiteflies

Aphids

Aphidius matricariae

biobest.com



Hosts:

- Over 40 aphid hosts (Schlinger et al. 1963)
- Green peach aphid (*Myzus persicae*)

Optimal temperatures 18-25°C (64-77°F)

Lay ~100 eggs in their lifetime, and attack 200 - 300 aphids in the process

Encarsia formosa



Hosts:

- **Greenhouse whitefly (*Trialeurodes vaporariorum*)**
- Sweet potato/silverleaf whitefly (*Bemisia tabaci*)
- 15 species of whiteflies

Produce only female offspring (thelytokous)

Above 31°C (88F), start producing males

(Kajita, 1989; Zchori-Fein et al. 1992)

Cause significant mortality due to “host feeding”

Adult survival: 36.8 days

Lays about 442 eggs in her lifetime

Kills about 101 hosts by “host-feeding”

(Arakawa 1982)

Twospotted
spider mites

Whiteflies

Aphids

Encarsia formosa

“*E. formosa* develops slower, shows a higher mortality and is less fecund when *B. tabaci* is offered as host.”

Szabo et al. (1993)

Kills about 101 hosts by “host-feeding”

(Arakawa 1982)

Twospotted
spider mites

Whiteflies

Aphids

Eretmocerus eremicus



Hosts:

- **Sweet potato/silverleaf whitefly** (*Bemisia tabaci*)
- Greenhouse whitefly (*Trialeurodes vaporariorum*)
- Bandedwinged whitefly (*T. abutlonea*)

Native to America's desert region

Optimal temperature between 25 - 29°C

Does not host feed

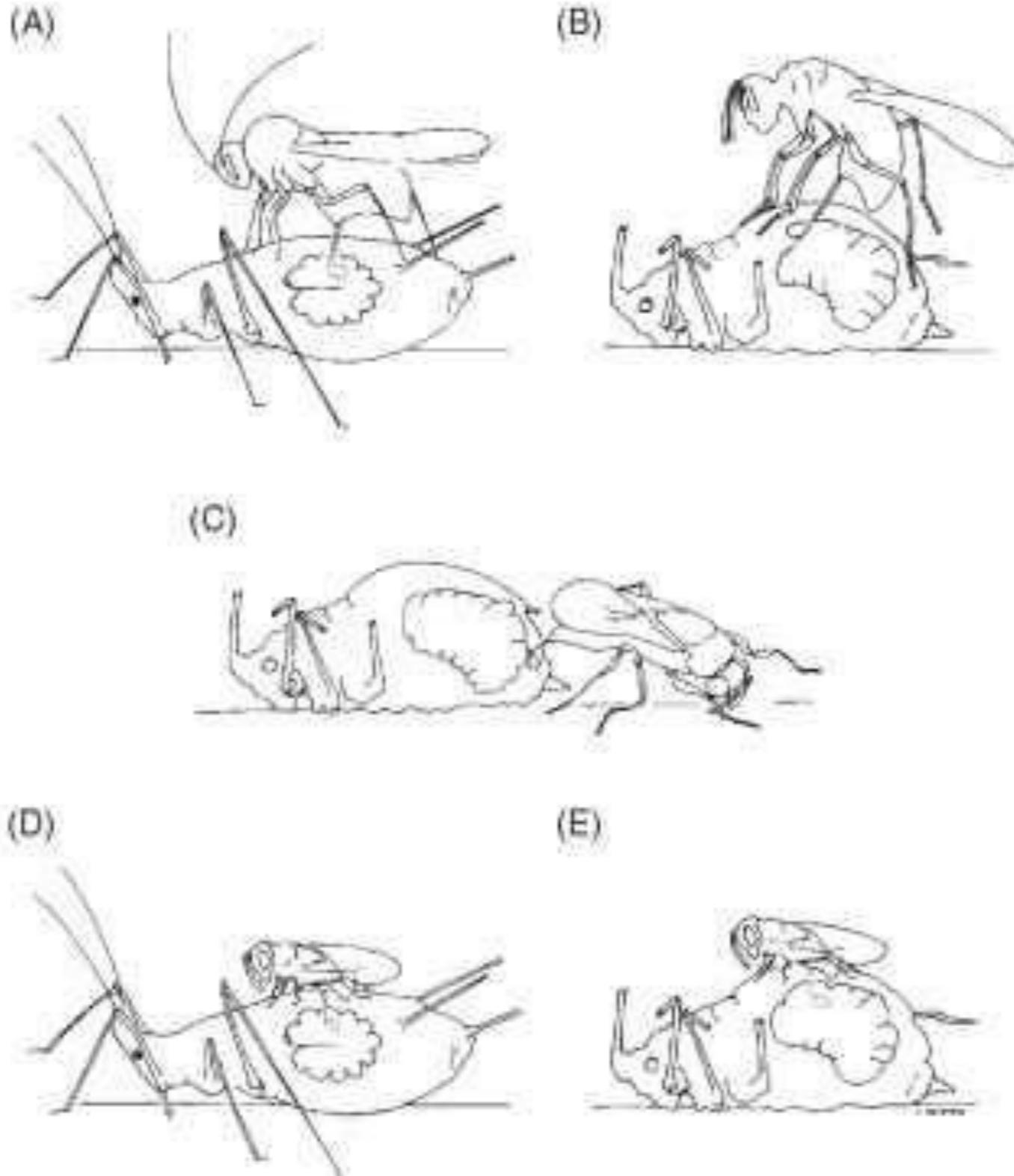
Produces males and females (~1:1 ratio)

Twospotted
spider mites

Whiteflies

Aphids

Hyperparasitoids



Sullivan, D. J. (1988)

Twospotted
spider mites

Whiteflies

Aphids

A. swirskii

Steven Arthurs, University of Florida



Hosts:

- Thrips
- Whiteflies
- Broad mite

First discovered as a predator while investigating the cause of continuous disappearance of *B. tabaci* eggs and larvae in a lab culture (Teich 1966)

Performs in environments where maximum daily temperatures are between 28 – 30°C (82 - 86F), with peaks up to 40°C (104F) (Bolkmans et al. 2005)

Can survive on pollen



Bill Lewis, Delray Plants

Twospotted
spider mites

Whiteflies

Aphids

Macrolophus pygmaeus

Hosts:

- Aphids (i.e. *Myzus persicae*)
- Whiteflies (*Bemisia* and *Trialeurodes*)
- Caterpillars (*Tuta absoluta*)
- Generalist

Can work on hair plants (has stilts!)

Performs well at 27.5°C (81.5°F)
and potentially higher
(Perdikis et al. 2002)

Disclaimer: Can cause damage to plant or fruit
set if predator populations get too high



Twospotted
spider mites

Whiteflies

Aphids

Amblyseius californicus



Hosts:

- Two-spotted spider mite
- Tomato russet mite
- Carmine mite

Performs better on less hairy plants
(Cédola et al. 2001).

Can survive on pollen and other arthropods

Active in high temperature and low humidity conditions (Weintraub & Palevsky 2008).

Upper temperature threshold approximately 37.5°C (99.5°F) (Gotoh et al. 2004)

Twospotted
spider mites

Whiteflies

Aphids

Phytoseiulus persimilis

Hosts:

- Two-spotted spider mite
- Voracious feeders of two spotted spider mite eggs and adults
- Effective at temperatures 14 - 30°C (57 - 86 °F). Above the upper temperature range, two-spotted spidermites will reproduce faster than *P. persimilis* can eat
- Works in tomatoes (French et al. 1976).



Twospotted
spider mites

Whiteflies

Aphids

Phytoseiulus persimilis



Twospotted spider mite
Tetranychus urticae



Tomato mite
Tetranychus evansi

Sato et al. (2014).

Twospotted
spider mites

Whiteflies

Aphids

Aphidoletes aphidimyza



Hosts:

- Aphids

Feed on over 60 aphid species

Each female can lay about 70 eggs on leaves among aphids

Eggs hatch (2-4 days) and midge larva paralyses each aphid and then sucks it dry

Larvae pupate in the soil below the plant

Economic mass production

Most effective between 20 - 26°C (68 - 78.8 F)



Twospotted
spider mites

Whiteflies

Aphids

Chrysoperla spp. | Green lacewings



- AKA Aphidlion
- Consumes ~200 aphids/ week
- Female lays up to 300 eggs over 3 - 4 weeks
- Generalist: insect eggs, aphids, thrips, mealybugs, immature whiteflies, and small caterpillars.
- Released aphid lions can move 80 - 100 feet in search of prey.



Beneficial Insectary
PROVIDING A NATURAL BALANCE IN PEST MANAGEMENT

Main Suppliers to Consider



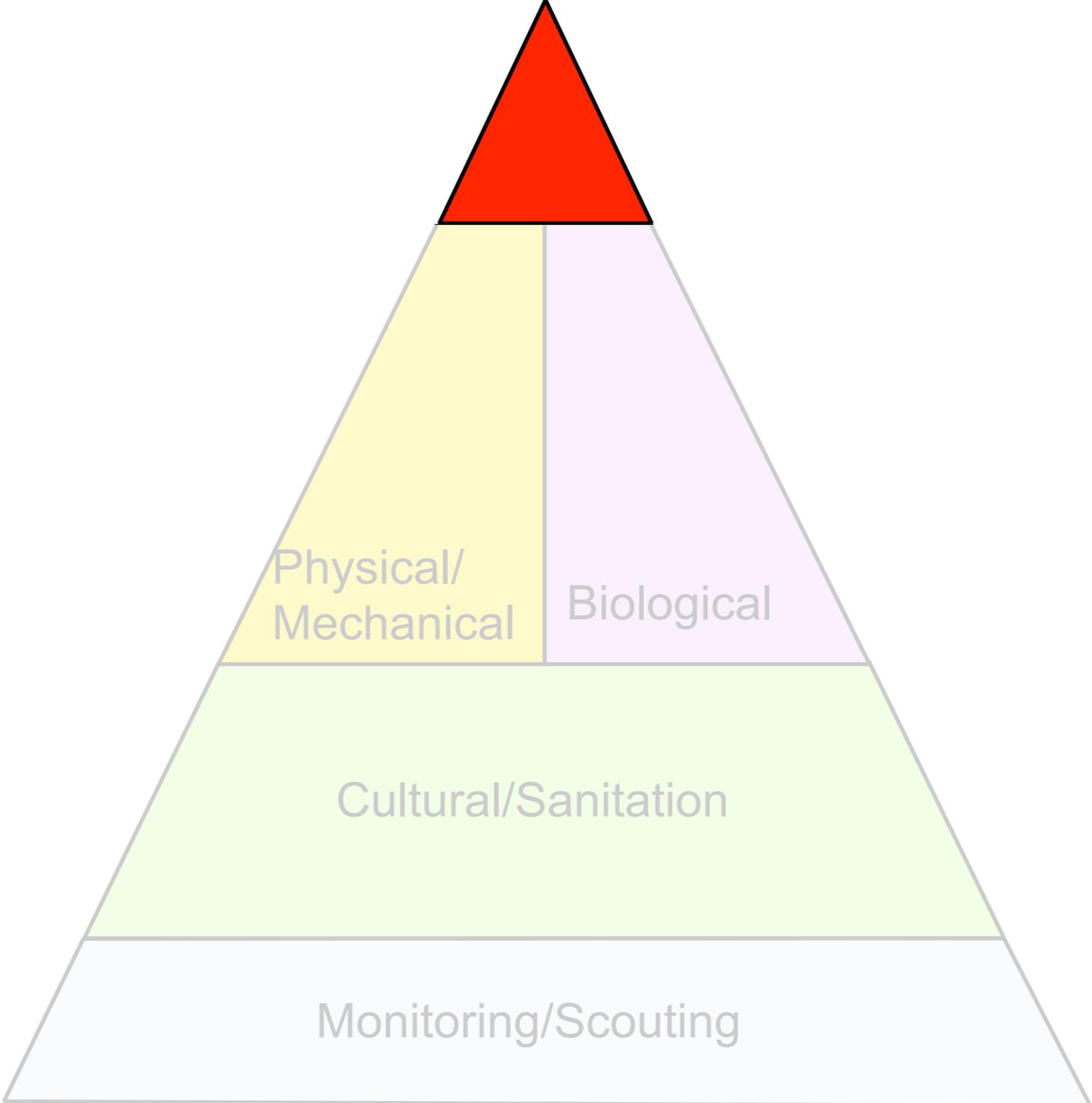
KOPPERT
BIOLOGICAL SYSTEMS



bioBEST[®]
SUSTAINABLE CROP MANAGEMENT

IPM Pyramid

Pesticides





Biobest Side Effects

Wax BVBA Productivity

★★★★★ 3

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Side Effects Next

Active ingredient | Commercial product

Filter | Clear Selection

- 2,4.D
- abamectin
- acephate
- acequinocyl
- acetamiprid
- acrinathrin
- Adoxophyes orana Granulose Virus
- alachlor
- aldicarb
- alphacypermethrin
- amitraz
- atrazine
- azadirachtin

Side Effects

Active ingredient | Commercial product | Beneficial organism

Filter | Clear Selection

- 2,4.D
- abamectin
- acephate
- acequinocyl
- acetamiprid
- acrinathrin
- Adoxophyes orana Granulose Virus
- alachlor
- aldicarb
- alphacypermethrin
- amitraz
- atrazine

No results found

Generate PDF

Beneficial organism

- Amblyseius californicus
- Amblyseius cucumeris
- Amblyseius degenerans
- Amblyseius swirskii
- Anthrenus nemoralis
- Aphidius spp.
- Aphidoletes aphidimyza
- Bombus spp.
- Chrysopa carnea
- Coleoptera
- Dacnusa sibirica
- Diglyphus isaea

Toxicity on natural enemies

Class	Toxicity
	Non-toxic
	Values ranging between class
	Slightly toxic
	Values ranging between class
	Mod. Toxic
	Values ranging between class
	Toxic

Toxicity on bumblebees

Method of application

Persistent code

Greenlab



Side Effects Guide

Koppert Biological Systems Business

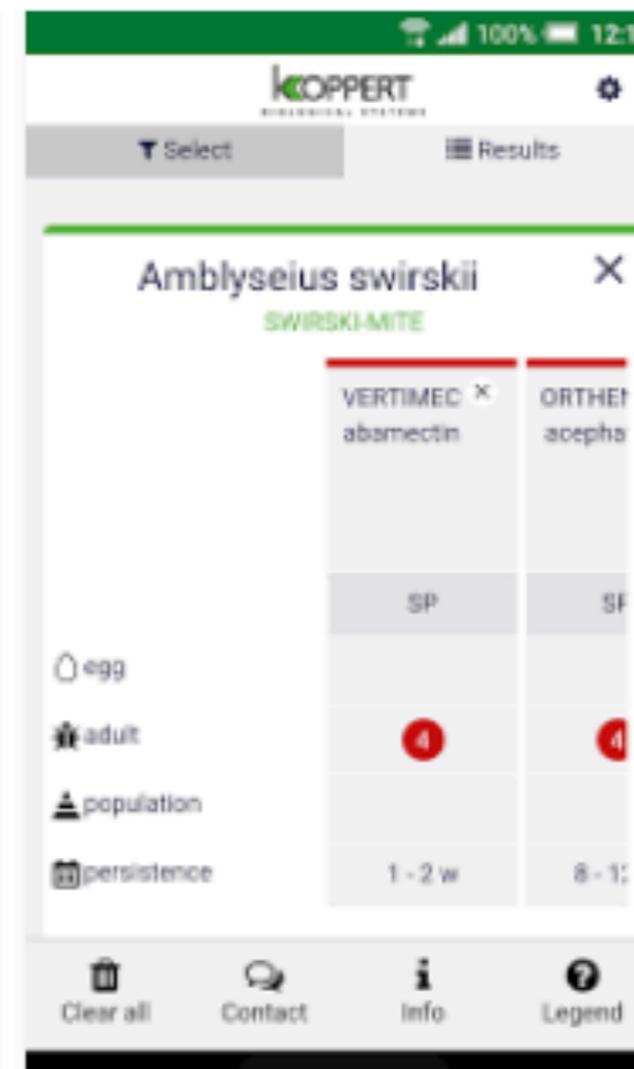
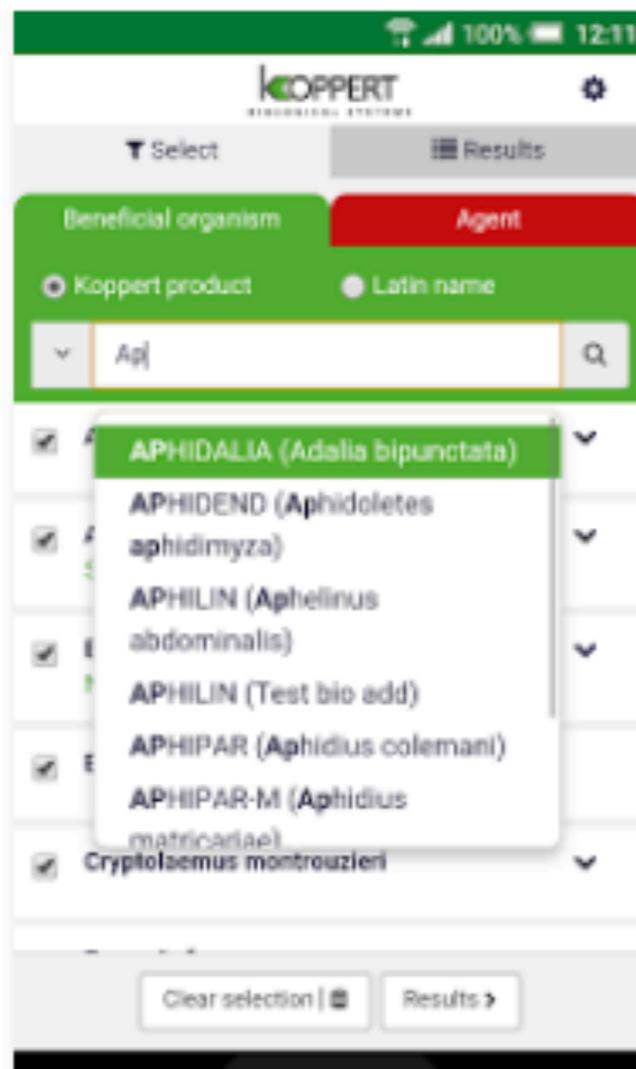
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The Bioline App

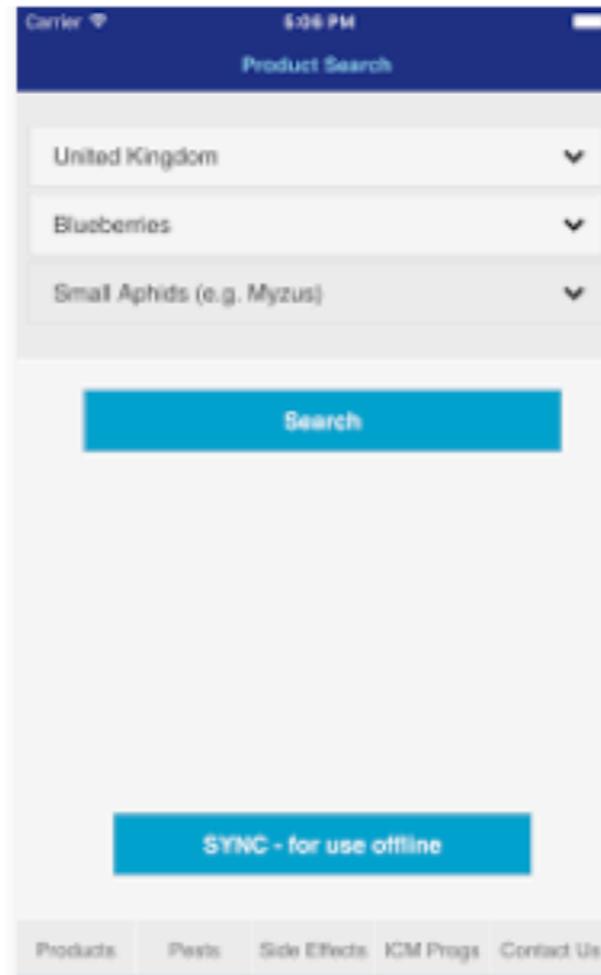
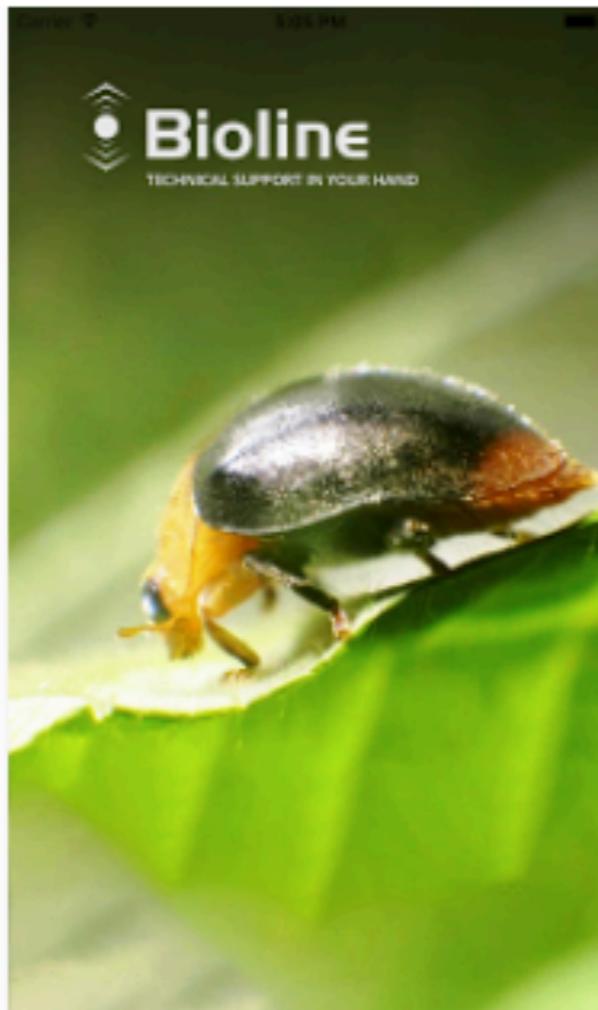
Digital Pie Ltd Business

★★★★★ 6 

 Everyone

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Installed



INTEGRATED CROP MANAGEMENT with Bioline™ Biological Control Agents

PEST CONTROLLED	ASSESSMENT	MAINTENANCE		CLEAN-UP		
FUNGUS GNATS 	Citation® insect growth regulator <ul style="list-style-type: none"> Initial insecticide treatment allows crop to start clean. If fungus gnat populations are low, it is possible to only use <i>Steinernema feltiae</i> and skip the Citation application. 	Exhibitline™ sf biological control agent <i>Steinernema feltiae</i> (insect pathogenic nematode) <ul style="list-style-type: none"> Preventive control: apply every 7-21 days. Curative control: apply every 7-14 days. 		Hypcline™ m biological control agent <i>Hypoaspis miles</i> (predatory mite) <ul style="list-style-type: none"> Preys on pupae. Apply Hypoline m evenly to the growing media. Sensitive to bifenthrin and lambda-cyhalothrin. 	Flagship® insecticide <ul style="list-style-type: none"> Use as drench for final clean-up application. Exhibitline sf <i>Steinernema feltiae</i> (insect pathogenic nematode) <ul style="list-style-type: none"> Apply 5-7 days before shipping. 	
SPIDER MITES 	Avid® miticide/insecticide <ul style="list-style-type: none"> Initial insecticide treatment allows crop to start clean. 	Phytoline™ p biological control agent <i>Phytoseiulus persimilis</i> (predatory mite) <ul style="list-style-type: none"> Release every 2 weeks. Voracious predator and fast establishment in crop. 	Anderline™ aa biological control agent <i>Amblyseius andersoni</i> (predatory mite) <ul style="list-style-type: none"> Release sachets preventively 4 weeks apart. Performs in a wide range of temperatures. 	Amblyline™ cal biological control agent <i>Amblyseius californicus</i> (predatory mite) <ul style="list-style-type: none"> Release every 7-14 days. Performs in hot and dry conditions. 	Avid miticide/insecticide <ul style="list-style-type: none"> Apply as needed for rescue or clean-up treatment. 	
LEAFMINERS 	Avid miticide/insecticide <ul style="list-style-type: none"> Initial insecticide treatment allows crop to start clean. Targets leafminer larvae. 	Digline™ i biological control agent <i>Diglyphus isaea</i> (predatory wasp) <ul style="list-style-type: none"> Release preventively at dawn or dusk. Release every 7 days. 		Citation insect growth regulator <ul style="list-style-type: none"> Apply every 7 days for the first 3 weeks of Digline i establishment. 	Flagship insecticide <ul style="list-style-type: none"> Apply as needed for rescue or clean-up treatment. 	
WHITEFLIES 	Endeavor® insecticide <ul style="list-style-type: none"> Make 1-2 applications at beginning of crop. Re-apply if needed as a rescue treatment. 	Swirskiline™ as biological control agent <i>Amblyseius swirskii</i> (predatory mite) <ul style="list-style-type: none"> Preventive control for eggs and smallest instar of whitefly species. 	Eretline™ e biological control agent <i>Eretmocerus eremicus</i> (parasitic wasp) <ul style="list-style-type: none"> Release every 7 days. Controls <i>Trialeurodes</i> (greenhouse whitefly) and <i>Bemisia</i> (silverleaf whitefly). 	Encarline™ f biological control agent <i>Encarsia formosa</i> (parasitic wasp) <ul style="list-style-type: none"> Release every 7 days. Controls <i>Trialeurodes</i> (greenhouse whitefly) only. 	Flagship insecticide <ul style="list-style-type: none"> Spray or drench for final clean-up application. 	
APHIDS 	Endeavor insecticide <ul style="list-style-type: none"> Apply every 7-14 days depending on pest pressure. 	Aphiline™ ce biological control agent mix <i>Aphidius colemani</i> + <i>Aphidius ervi</i> (parasitic wasps) <ul style="list-style-type: none"> Release preventively. Combination pack includes 50/50 mix that parasitizes large and small aphid species. 		Aphidoline™ a biological control agent <i>Aphidoletes aphidimyza</i> (gall-midge) <ul style="list-style-type: none"> Release every 7 days. Preys on multiple aphid species. 	Flagship insecticide <ul style="list-style-type: none"> Spray or drench for final clean-up application. 	
THRIPS 	Avid miticide/insecticide OR Flagship insecticide + Thripline™ pheromone <ul style="list-style-type: none"> Thripline brings adult thrips out of the flower and bud tissue. Initial insecticide treatment allows crop to start clean. Exhibitline st <i>Steinernema feltiae</i> (insect pathogenic nematode) <ul style="list-style-type: none"> Drench early to prevent pupae from emerging. Apply every 7-21 days. 	Amblyline cu <i>Amblyseius cucumbers</i> (predatory mite) <ul style="list-style-type: none"> Preys on first larval stage. Active at lower light levels. 	OR Swirskiline as <i>Amblyseius swirskii</i> (predatory mite) <ul style="list-style-type: none"> Prefers warm and humid conditions. Preys on first larval stage. 	Hypcline m <i>Hypoaspis miles</i> (predatory mite) <ul style="list-style-type: none"> Preys on pupae. Apply Hypoline m evenly to the growing media. Sensitive to bifenthrin and lambda-cyhalothrin. 	Oriline™ i biological control agent <i>Orius irsidiolosis</i> (predatory bug) <ul style="list-style-type: none"> Release once on blooming crops (must have pollen). Generalist predator that feeds on adults. 	Flagship insecticide <ul style="list-style-type: none"> Spray or drench for final clean-up application. Exhibitline sf <i>Steinernema feltiae</i> (insect pathogenic nematode) <ul style="list-style-type: none"> Drench 5 days before shipping.

K-State home » Entomology » People in Entomology » Faculty » Cloyd, Raymond A.

Department of Entomology

Home

Department Info

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Integrated Pest Management, Plant Protection, Horticultural and Ornamental Cropping Systems, **Biological Control, Insect-Plant Interactions, Pesticides**

Insecticide Efficacy?

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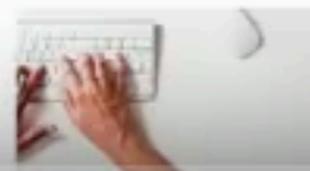
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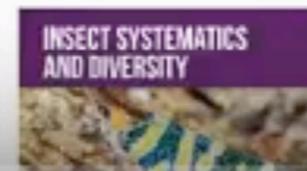
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Integrated Pest Management of Vegetables in Protected Culture

Thank you!

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