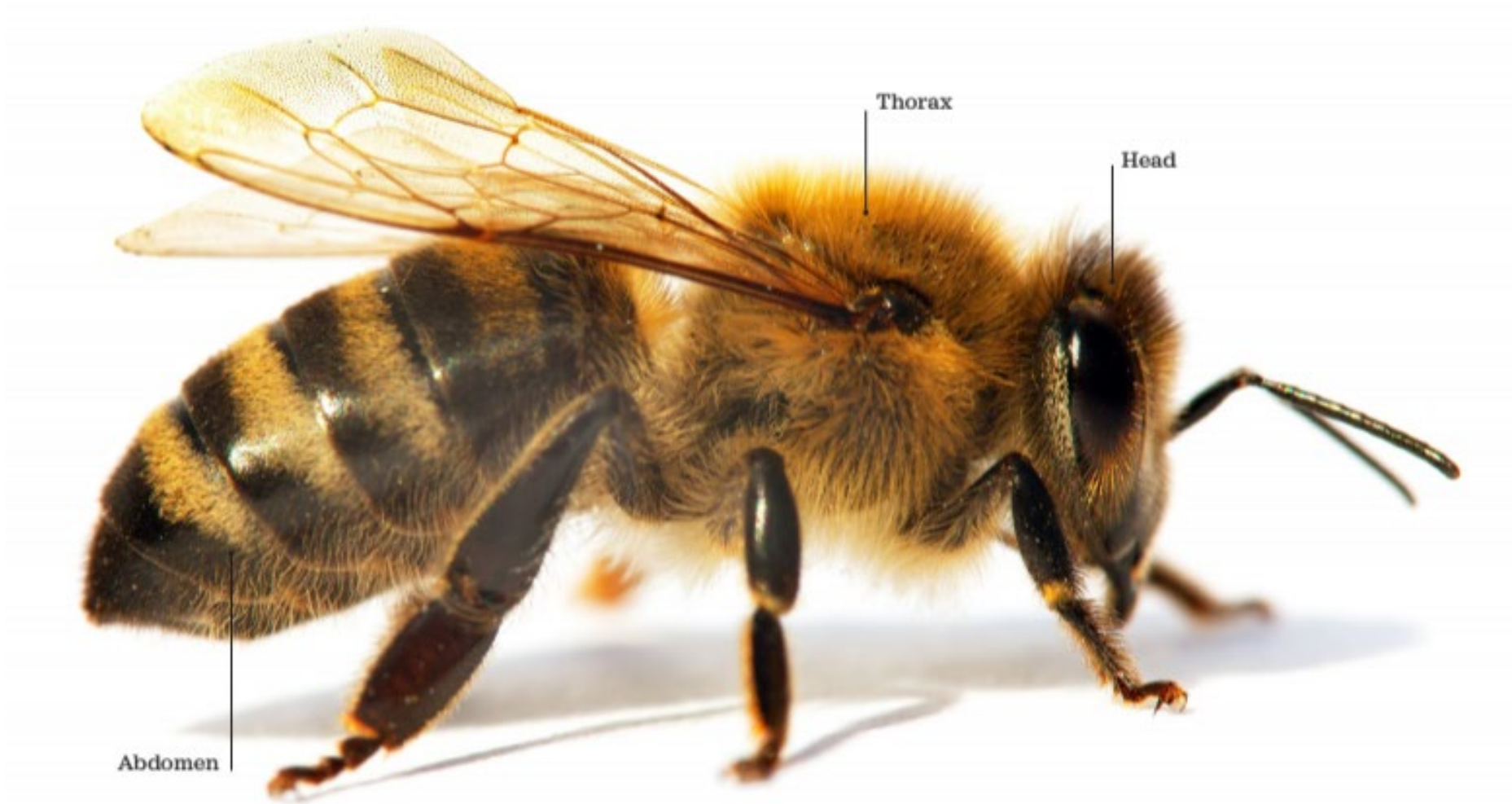




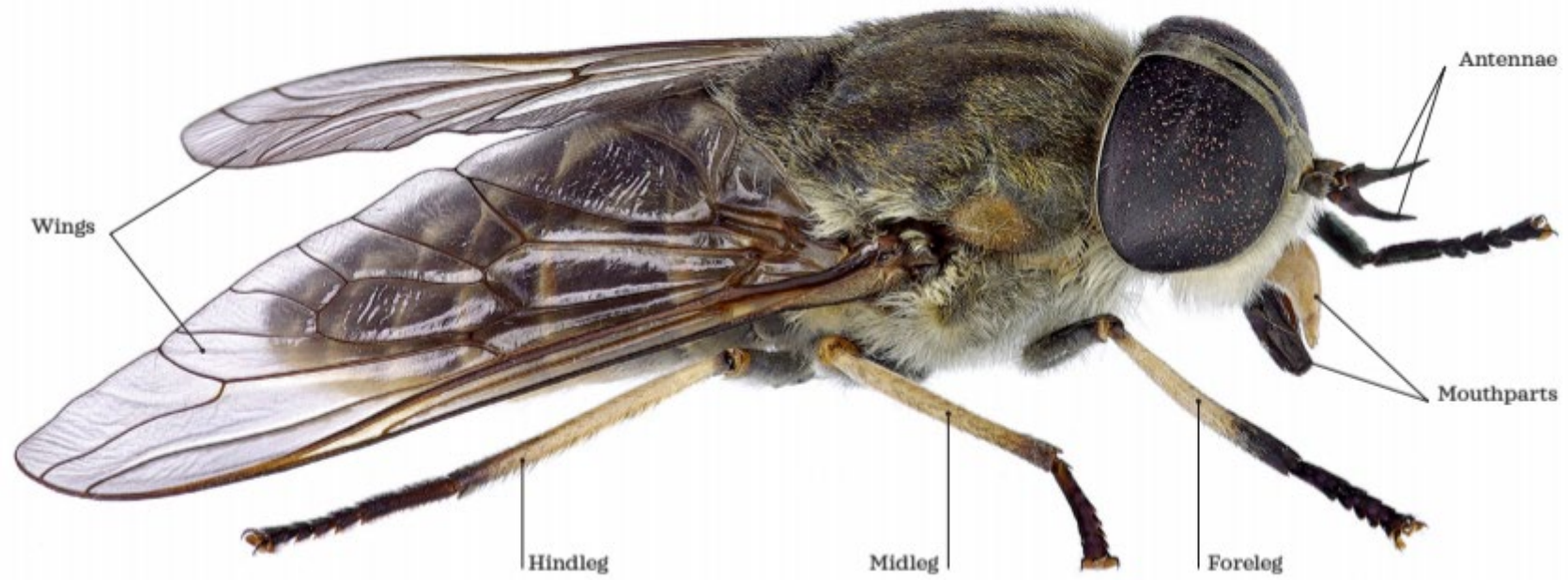
Entomology and Integrated Pest Management

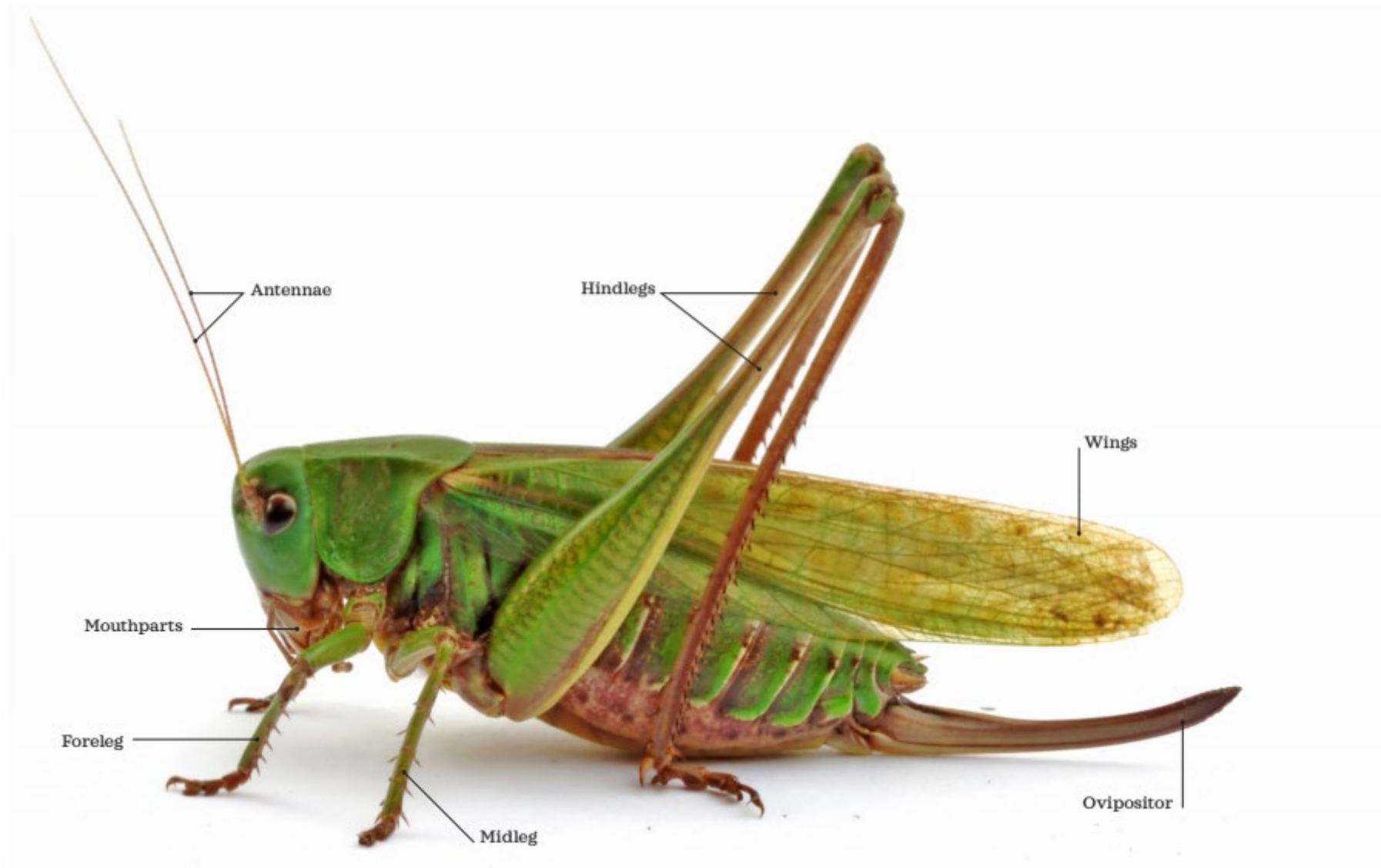
Eddie Kyle Slusher

Texas A&M University AgriLife Research
and Extension Center, Stephenville, TX



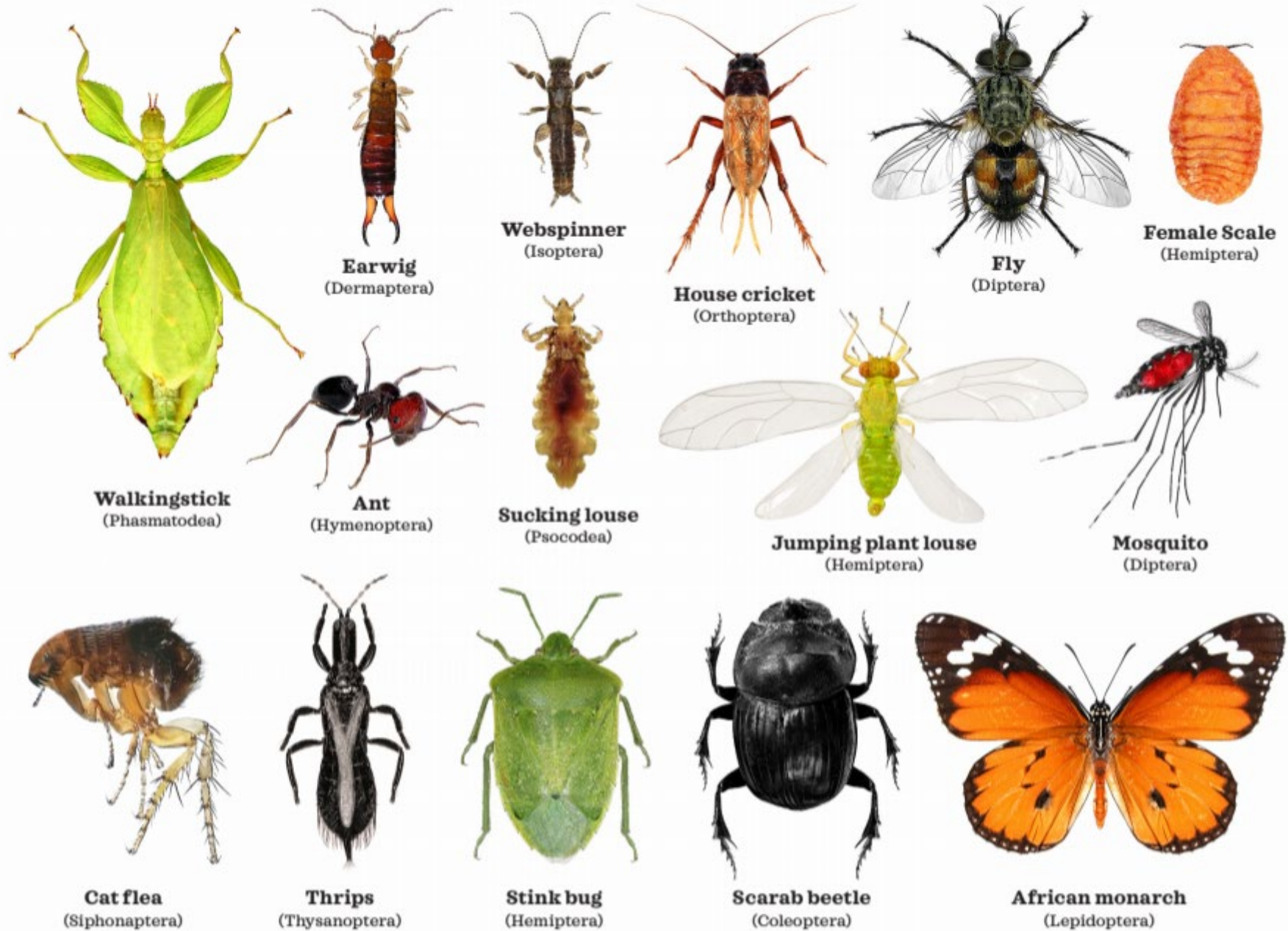
Marcouliana/Dreamstime;
Grimaldi, David A.. The Complete Insect: Anatomy, Physiology, Evolution, and Ecology (p.
367). Kindle Edition.





What percentage of insects are classified as pests?

~1 – 3% depending on the source

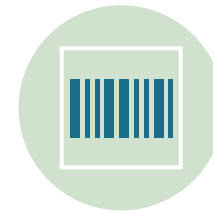


What is Integrated Pest Management?

- Reduce losses from pests in ways that are effective, economically sound, and ecologically compatible



Scouting/Monitoring



Identification



**Implement
Management
Strategies**



**Evaluation
Effectiveness**

Scouting and Monitoring

- Treat your farm like an ecosystem
- **Get a good scout or get good at scouting!**
- Who are my key pests?



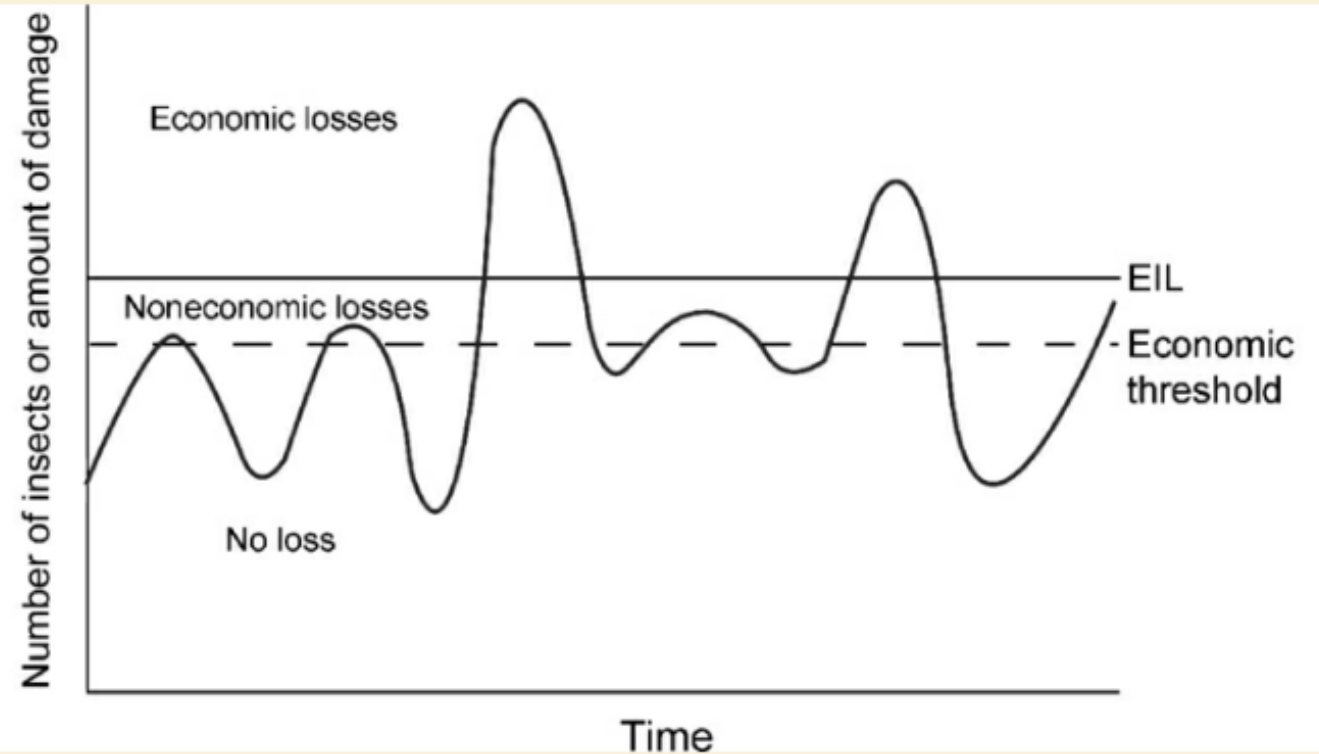
Scouting and Monitoring

- Understand pest biology.
- Foliage feeding insects can often be spotted by careful examination of plants during pest windows – Aphids, Mites
- Some insects require more specialized methods
 - Pheromone traps: PNC
 - Circle Traps: Pecan Weevil



Scouting/Monitoring

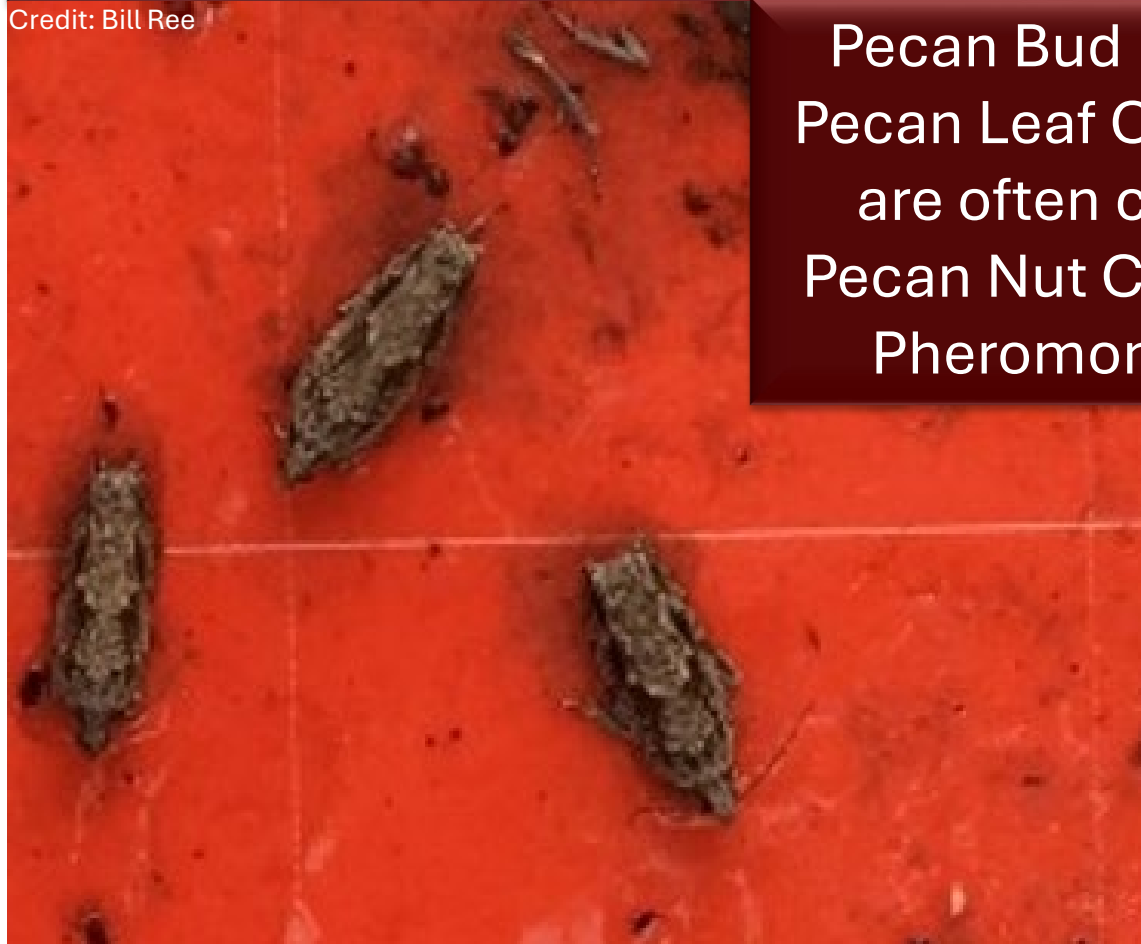
- Understanding Economic Thresholds
- Most pests have an established threshold, but this should be used more as guideline than as gospel.



From: Pedigo, L. P., Rice, M. E., & Krell, R. K. (2021). *Entomology and pest management*. Waveland Press.

Identification

Credit: Bill Ree



Pecan bud moth

Pecan Bud Moth and
Pecan Leaf Casebearer
are often caught in
Pecan Nut Casebearer
Pheromone Traps

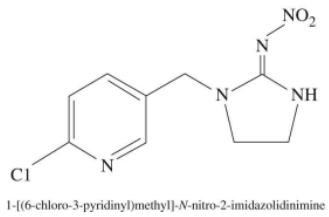
Credit: Bill Ree



Pecan nut casebearer

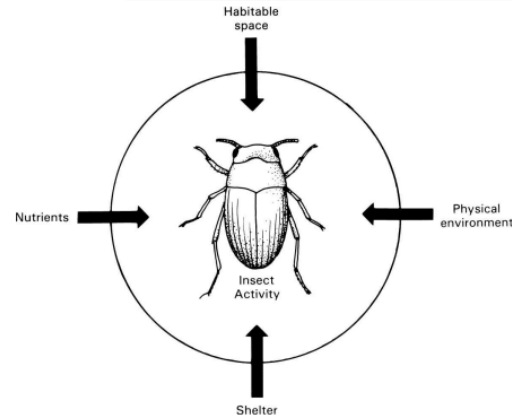
- So, now that we've determined our pest, and we've determined our population and thresholds. Now what?:
 1. Reduce Pest Population Numbers
 2. Reduce Crop Susceptibility
 3. Combine Steps 1+2

Chemical Management



Marlin E. Rice

Cultural Management



Iowa State University of Extension Service

Biological Management



Marlin E. Rice

Marlin E. Rice

Implement Management Tactics

In IPM, we focus on Biological, Cultural/Ecological, and Behavioral/Genetic Management first. We rely on Chemical management only when we have no other options.

Cultural/Ecological Management

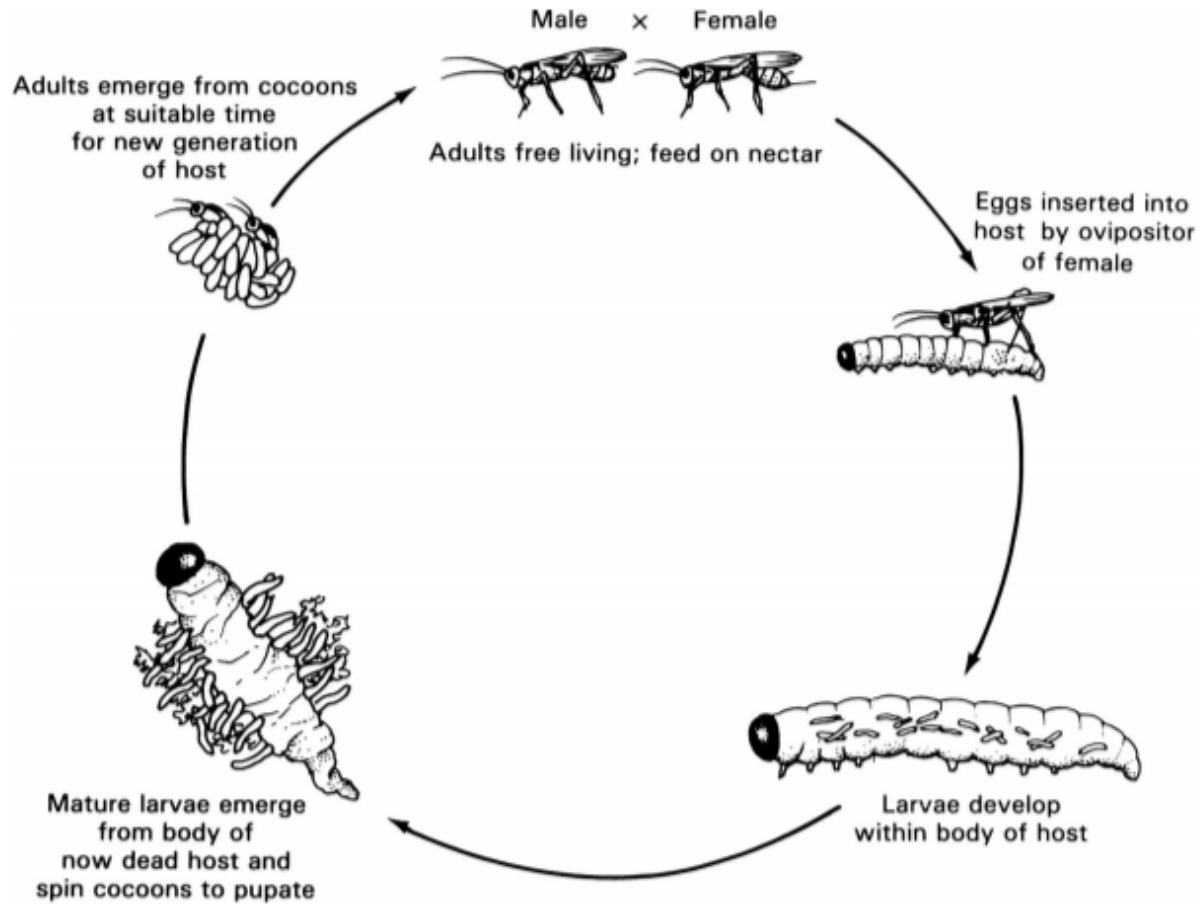
- **Site Selection and Variety Selection** are key.
- **Keep plants healthy** – pest are less apt to attack and overcome a healthy plant – Especially true for borers
- **Sanitation** – Crop residue removal (Hickory Shuckworm), Efficient storage and processing (Indian meal moth, red flour beetle)
- **Irrigation and Water Management**



Biological Control

- Purposeful natural enemy manipulation to reduce pest populations.
- Types of Biological Control Agents
 - Parasitoids
 - Entomopathogens
 - Predators

Parasitoids



Photos From: Pedigo, L. P., Rice, M. E., & Krell, R. K. (2021). Entomology and pest management. Waveland Press.

Parasitoid Wasp attacking a waxworm



Table 4
Common Parasitoids *

ORDER	FAMILY	HOST OR PREY	MODE OF ATTACK
Diptera (true flies)	Tachinidae	Beetles, butterflies, moths	internal
	Nemestrinidae	Locusts, beetles	internal
	Phoridae	Ants, caterpillars, termites, flies, others	internal
	Cryptochaetidae	Scale insects	internal
Hymenoptera (ants, bees and wasps)	Chalcididae	Flies and butterflies (larvae and pupae)	Internal or external
	Encyrtidae	Aphids, scales, mealybugs, whiteflies	internal
	Eulophidae	Aphids, gall midges, sawflies, mealybugs	Internal or external
	Pteromalidae	Flies, including houseflies and stable flies	internal
	Pteromalidae	Boll weevils	External
	Aphelinidae	Whiteflies, scales, mealybugs, aphids	Internal or external
	Trichogrammatidae	Moth eggs	internal
	Mymaridae	True bugs, flies, beetles, leafhopper eggs	internal
	Scelionidae	Eggs of true bugs and moths	internal
	Ichneumonidae	Larvae or pupae of beetles, caterpillars, wasps	Internal or external
	Braconidae	Larvae of beetles, caterpillars, sawflies	Internal (mostly)

From: Altieri, M.A., Nicholls, C.I., Fritz, M.A. Manage Insects on Your Farm: A guide to Ecological Strategies. SARE Handbook Series Book 7.

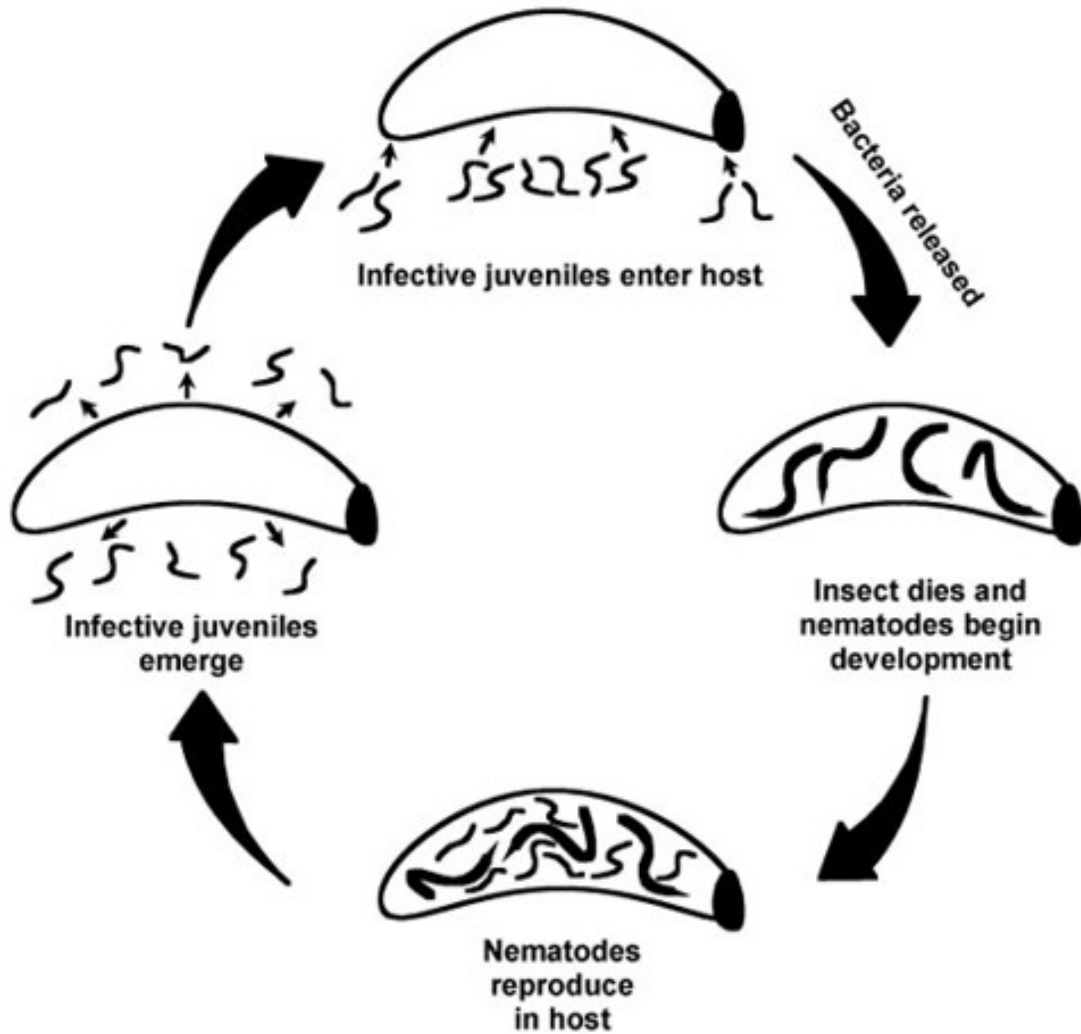
Stephen Bonk/Shutterstock;
Grimaldi, David A.. *The Complete Insect: Anatomy, Physiology, Evolution, and Ecology* (p. 367). Kindle Edition.



Eileen Kumpf/ Shutterstock;
Grimaldi, David A.. The Complete Insect: Anatomy, Physiology, Evolution, and Ecology (p.
367). Kindle Edition.



Entomopathogens



<u>Pest, Common name</u>	<u>Pest, Scientific name</u>	<u>Nemas</u>
Artichoke plume moth	<i>Platyptilia carduidactyla</i>	Sc
Banana moth	<i>Opogona sachari</i>	Hb, Sc
Banana root borer	<i>Cosmopolites sordidus</i>	Sc, Sf, Sg
Black cutworm	<i>Agrotis ipsilon</i>	Sc
Black vine weevil	<i>Otiiorhynchus sulcatus</i>	Hb, Hm
Borers	<i>Synanthedon</i> spp.	Hb, Sc, Sf
Codling moth	<i>Cydia pomonella</i>	Sc
Corn earworm	<i>Helicoverpa zea</i>	Sr
Diamondback moth	<i>Plutella xylostella</i>	Sc
Fungus gnats	Diptera: Sciaridae	Sf, Hb
Japanese beetle	<i>Popillia japonica</i>	Hb, Sg
Leafminers	<i>Liriomyza</i> spp.	Sc
Mole crickets	<i>Scapteriscus</i> spp.	Sc, Sr, Ss
Plum curculio	<i>Conotrachelus nenuphar</i>	Sr



Entomopathogenic nematodes

J. Ogrodnick; Vittum et al., 1999).
Hajek, Ann E.; Eilenberg, Jørgen. Natural
Enemies: An Introduction to Biological
Control (p. 192). Cambridge University
Press. Kindle Edition.



(McCoy et al., 2007)
Hajek, Ann E.; Eilenberg,
Jørgen. Natural Enemies: An
Introduction to Biological
Control (p. 192). Cambridge
University Press. Kindle
Edition.



Entomopathogens



Weevil infected with *B. bassiana*



BotaniGard, a commercial version of *B. bassiana*

Table 12.1 Selected Registered Microbial Insecticides

Organism	Trade Name	Manufacturer	Target Pest
<i>Bacteria</i>			
<i>Bacillus popilliae</i>	Milky Spore	St. Gabriel Organics	Japanese beetle
<i>B. thuringiensis</i> var. <i>kurstaki</i>	Dipel	Valent	Several moths
	Biobit	Valent	
	Thuricide	Valent	
	Condor	Certis	
<i>B. thuringiensis</i> var. <i>kurstaki</i> plus beta-exotoxin	Javelin	Certis	Armyworm and other moths
<i>B. thuringiensis</i> var. <i>aizawai</i>	Agree	Certis	Wax moth
<i>B. thuringiensis</i> var. <i>tenebrionis</i>	Novodor	Valent	Colorado potato beetle
<i>B. thuringiensis</i> var. <i>israelensis</i>	VectoBac	Valent	Mosquitoes, black flies
<i>Fungi</i>			
<i>Beauveria bassiana</i>	Naturalis	Troy Biosciences	Whiteflies, scales, aphids
	Mycotrol	BioWorks for Mycotrol	
<i>Viruses</i>			
<i>Spodoptera exigua</i> NPV	Spod-X	Certis	Beet armyworm
<i>Helicoverpa</i> NPV	Gemstar	Certis	Corn earworm, tobacco budworm
<i>Cydia pomonella</i> GV	ViroSoft	Biotepp	Codling moth
<i>Microsporidian</i>			
<i>Nosema locustae</i>	Nolo Bait	M&R Durango, Inc.	Grasshopper nymphs, Mormon crickets

From: Pedigo, L. P., Rice, M. E., & Krell, R. K. (2021). Entomology and pest management. Waveland Press.

Predators

TABLE 3
Common Predators*

COMMON NAME	ORDER	FAMILY	HOST OR PREY
Praying mantids	Orthoptera	Mantidae	Large and small insects
Earwigs	Dermoptera	Labiduridae	Caterpillars, many others
Predaceous thrips	Thysanoptera	Aleoarthridae	Spider mite eggs
Minute pirate bugs	Hemiptera	Anthracorhinae	Insect eggs, soft-bodied insects, small insects
Big-eyed bugs		Lygaeidae	Insect eggs, soft-bodied insects, small insects
Plant bugs		Miridae	Insect eggs, soft-bodied insects, small insects
Damsel bugs		Nabidae	Insect eggs, small insects
Assassin bugs		Reduviidae	Small insects, caterpillars
Predaceous stink bugs		Pentatomidae	Small caterpillars
Lacewings	Neuroptera	Chrysopidae	Aphids, soft-bodied insects
Lady beetles	Coleoptera	Coccinellidae	Aphids, soft-bodied insects, insect eggs
Ground beetles		Carabidae	Insect eggs, soft-bodied insects, caterpillars
Rove beetles		Staphylinidae	Small insects
Soft-winged flower beetles		Melyridae	Insect eggs, soft-bodied insects, small caterpillars
Predaceous midges	Diptera	Cecidomyiidae	Aphids
Syrphid/hover flies		Syrphidae	Aphids, soft-bodied insects
Ants	Hymenoptera	Formicidae	Insect eggs, soft-bodied insects, small insects
Hornets, yellow jackets		Vespidae	Caterpillars, small insects
Digger wasps, mud daubers		Sphecidae	Caterpillars, small insects

From Entomology and Pest Management



Marlin E. Rice

Crab Spider



Bradley Higbee

Lacewing Larva

Agustiar/Dreamstime;
Grimaldi, David A.. The Complete Insect: Anatomy, Physiology, Evolution, and Ecology (p.
367). Kindle Edition.



Musat/istockphoto;
Grimaldi, David A.. The Complete Insect: Anatomy, Physiology, Evolution, and Ecology (p.
367). Kindle Edition.



Types of Biological Control

- Classical – Identify a natural enemy from a host's origin and introduce it into a new location.



Evie Adriani

Anagyrus lopezi parasitizing a mealy bug



USDA/ARS

Vedalia Beetle attacking a cushion scale

Types of Biological Control

- Augmentative – Any activity that increases natural enemy numbers or effectiveness.

From Entomology and Pest Management



Trichocaps



Commercial Lacewing eggs



Commercial Beneficial Nematodes

Types of Biological Control

- Conservation – Protect and maintain natural populations using habitat management.

© Lorraine Seymour:

The Xerces Society. Farming with Native Beneficial Insects:
Ecological Pest Control Solutions (p. 650). Storey Publishing, LLC.
Kindle Edition.



Jessa Cruz, The Xerces Society:

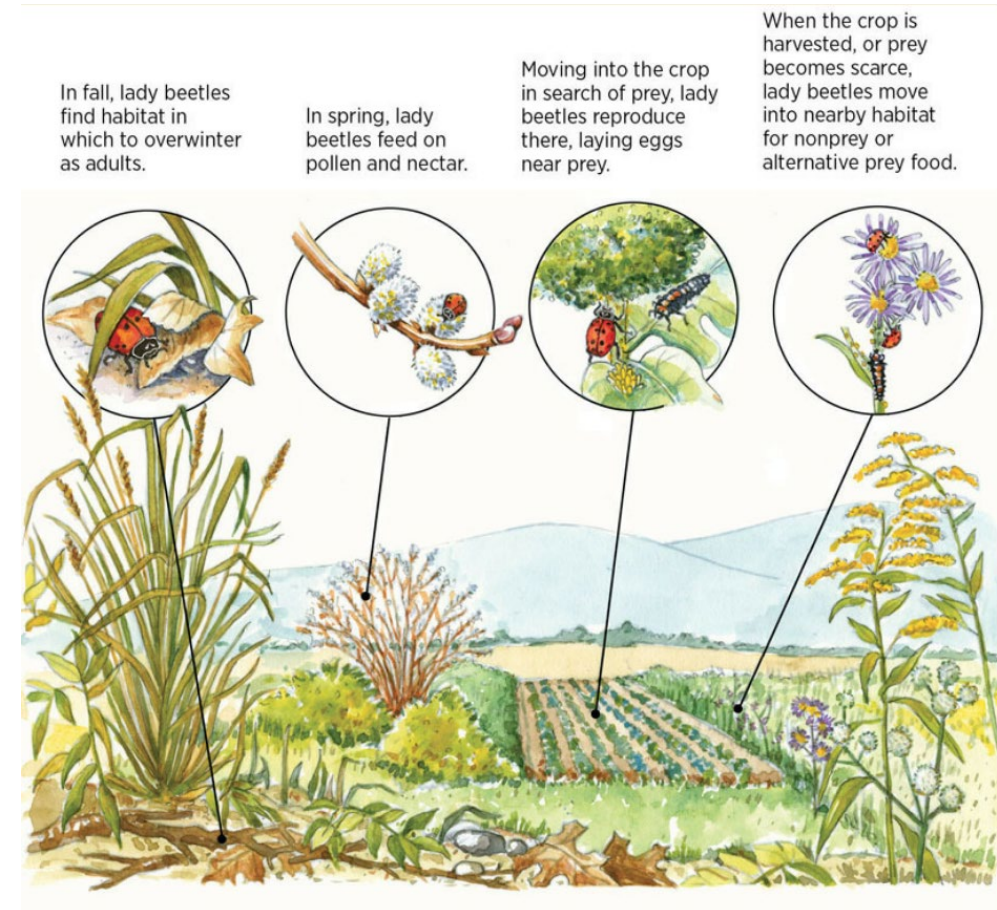
The Xerces Society. Farming with Native Beneficial Insects: Ecological Pest
Control Solutions (p. 649). Storey Publishing, LLC. Kindle Edition.



From Farming with Beneficial Insects

Managing Beneficials

- Supplementation of nectar and pollen (flowering borders, intercropping, cover crops)
- Provide overwintering habitat (beetle banks, leaf litter, rock piles, brush piles)
- Minimize broad-spectrum insecticides.



From Farming with Beneficial Insects.

Common Natural Enemies

Lady beetle

Eggs



Photo: Scott Bauer, USDA Agricultural Research Service, Bugwood.org

Larva



Photo: Whitney Cranshaw, Colorado State University, Bugwood.org

Pupa



Photo: Susan Ellis, Bugwood.org

Adult



Photo: R.L. Croissant, Bugwood.org

Stink bug

Predatory



Photo: Hanna Royals, Museum Collections: Heteroptera, USDA APHIS PPQ, Bugwood.org

Plant-feeding



Photo: Lindsey Seastone, Museum Collections: Heteroptera, USDA APHIS PPQ, Bugwood.org

Spined soldier bug

Nymph

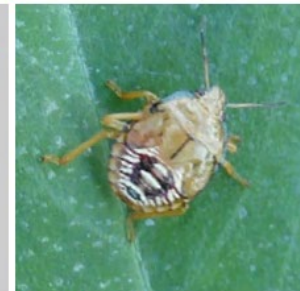


Photo: Andrew Sawyer, UGA

Adult



Photo: Andrew Sawyer, UGA

Lacewing

Eggs



Photo: Whitney Cranshaw, Colorado State University, Bugwood.org

Larva



Photo: Joseph Berger, Bugwood.org

Pupa



Photo: Whitney Cranshaw, Colorado State University, Bugwood.org

Adult



Photo: Whitney Cranshaw, Colorado State University, Bugwood.org

Assassin Bug



UGA5082092

Parasitoid Wasp





ADMIRE[®] PRO[™]

SYSTEMIC PROTECTANT

Net Contents:

1 GAL. 12 OZ. (140 FL. OZ.)

GROUP 4A INSECTICIDE

For uses in pest management and maintenance of plant health.

ACTIVE INGREDIENT:

Imidacloprid, 1-[[6-Chloro-3-pyridinyl)methyl]-
N-nitro-2-imidazolidinimine 42.8%

OTHER INGREDIENTS: 57.2%

TOTAL: 100.0%

EPA Reg. No. 264-827

Contains 4.6 pounds of active ingredient per gallon or 550 grams AI/liter.

SHAKE WELL BEFORE USING

**STOP - Read the label before use
KEEP OUT OF REACH
OF CHILDREN
CAUTION**

See Back Panel for First Aid Instructions and Booklet for Complete Precautionary Statements and Directions for Use.

For **MEDICAL** And **TRANSPORTATION** Emergencies

ONLY Call 24 Hours A Day 1-800-334-7577

For **PRODUCT USE** Information Call

1-866-99BAYER (1-866-992-2937)

Produced for
Bayer CropScience LP
800 N. Lindbergh Blvd.
St. Louis, MO 63167

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TREE NUTS – SOIL

Crops of Crop Group 14 except Almond including: Beechnut, Brazil nut, Butternut, Cashew, Chestnut, Chinquapin, Filbert, Hickory nut, Macadamia nut, Pecan, Walnut [black and English]

Pests Controlled	Rate fluid ounces/Acre
Aphids	7.0 – 14.0
Leafhoppers/Sharpshooters	
Mealybugs	
Spittlebugs	7.0 – 14.0
Termites	
Whiteflies	
Pests / Diseases Suppressed	
Pecan scab (from reduction in honeydew deposition)	7.0 – 14.0
Thrips (foliage-feeding thrips only)	14.0

Tree Nuts – Soil Applications

Apply specified dosage prior to or at onset of pest infestation in one of the following methods:

1. Chemigation into root-zone through low-pressure drip, trickle, micro-sprinkler or equivalent irrigation equipment. Pre-wet soil prior to applications of ADMIRE PRO SYSTEMIC PROTECTANT and allow soil to dry following application and prior to subsequent irrigation;
2. Emitter or spot application in a minimum of 4 fluid ounces of mixture per emitter site;
3. Shank or subsurface side-dress, injected to a depth just above or just within the root zone and between the trunk and drip line of the tree canopy. Apply product in a minimum of 10 gallons per acre using multiple shanks on both sides of trees. Ensure product placement is below sod or orchard floor debris. Irrigation covering entire treated area should follow within 48 hours to promote uptake by root system.
4. For control of termites, apply specified dosage to slightly moist soil as a high-volume drench to the basal portion of the tree trunk and surrounding soil in the immediate vicinity of the tree trunk. Utilize sufficient carrier volume to penetrate the soil to a depth of 18 – 24 inches to obtain optimum control. Allow soil to dry following treatment and prior to applying any irrigation.

Tree Nuts – Soil Application Restrictions

Pre-Harvest Interval (PHI): **7 days**

Maximum ADMIRE PRO SYSTEMIC PROTECTANT allowed per year: **14.0 fluid ounces/Acre** (0.5 lb AI/Acre)

Do not apply pre-bloom or during bloom or when bees are foraging.

Tree Nuts – Soil Application Remarks

Use the higher rate within the specified rate range when applied by shank or subsurface sidedress, used on larger trees, soils with high clay content, for high plant populations, and/or where extended control is desired. Under some conditions, control may not occur for 14 or more days or until two (2) irrigations have been made. Applications made later in the season may result in reduced efficacy.



ADMIRE[®] PRO

SYSTEMIC PROTECTANT

Net Contents:

1 GAL. 12 OZ. (140 FL. OZ.)

For uses in pest management and maintenance of plant health.

ACTIVE INGREDIENT:

Imidacloprid, 1-[[6-Chloro-3-pyridinyl)methyl]-
N-nitro-2-imidazolidinimine 42.8%

OTHER INGREDIENTS: 57.2%

TOTAL: 100.0%

EPA Reg. No. 264-827

Contains 4.6 pounds of active ingredient per gallon or 550 grams AI/liter.

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STOP - Read

KEEP O

OF O

CAUTION

See Back Panel for First Aid Instructions and Booklet for Complete Precautionary Statements and Directions for Use.

For **MEDICAL** And **TRANSPORTATION** Emergencies

ONLY Call 24 Hours A Day 1-800-334-7577

For **PRODUCT USE** Information Call

1-866-99BAYER (1-866-992-2937)

- The label is the law!
- Important Information to consider
 - Re-entry (REI)
 - Pre-Harvest (PHI)
 - M.O.A
 - Pest Listed
 - Amount per season

mond including: Beechnut, Brazil nut, Butternut, Cashew, Chestnut, Damiana nut, Pecan, Walnut [black and English]

	Rate fluid ounces/Acre
Stem-borers	7.0 – 14.0
Leaf-miners	
Leaf-tyers	
Unassisted	
(dew deposition)	7.0 – 14.0
	14.0

Onset of pest infestation in one of the following methods:
 • High-pressure drip, trickle, micro-sprinkler or equivalent irrigation applications of ADMIRE PRO SYSTEMIC PROTECTANT and allow soil to dry prior to subsequent irrigation;
 • Minimum of 4 fluid ounces of mixture per emitter site;
 • Applied to a depth just above or just within the root zone and between the canopy. Apply product in a minimum of 10 gallons per acre using a hose-end sprayer. Ensure product placement is below sod or orchard floor debris. Irrigation should follow within 48 hours to promote uptake by root system.
 • Apply specified dosage to slightly moist soil as a high-volume drench to the soil and surrounding soil in the immediate vicinity of the tree trunk. Utilize

sufficient carrier volume to penetrate the soil to a depth of 18 – 24 inches to obtain optimum control. Allow soil to dry following treatment and prior to applying any irrigation.

Tree Nuts – Soil Application Restrictions

Pre-Harvest Interval (PHI): **7 days**

Maximum ADMIRE PRO SYSTEMIC PROTECTANT allowed per year: **14.0 fluid ounces/Acre** (0.5 lb AI/Acre)

Do not apply pre-bloom or during bloom or when bees are foraging.

Tree Nuts – Soil Application Remarks

Use the higher rate within the specified rate range when applied by shank or subsurface sidedress, used on larger trees, soils with high clay content, for high plant populations, and/or where extended control is desired. Under some conditions, control may not occur for 14 or more days or until two (2) irrigations have been made. Applications made later in the season may result in reduced efficacy.

RESTRICTED USE PESTICIDE
DUE TO TOXICITY TO FISH AND AQUATIC ORGANISMS
FOR RETAIL SALE TO AND USE ONLY BY CERTIFIED APPLICATORS,
OR PERSONS UNDER THEIR DIRECT SUPERVISION, AND ONLY FOR
THOSE USES COVERED BY THE CERTIFIED APPLICATOR'S CERTIFICATION.

GROUP 3 INSECTICIDE

 **Warrior**
with Zeon Technology[®]

Insecticide

Active Ingredient:

Lambda-cyhalothrin¹
[1 α (S*),3 α (Z)]-(\pm)-cyano-(3-phenoxyphenyl)methyl-
3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2-
dimethylcyclopropanecarboxylate 11.4%

Other Ingredients: 88.6%

Total: 100.0%

Warrior Insecticide with Zeon Technology contains 1 lb. of active ingredient per gal. and is a capsule suspension.

¹Synthetic pyrethroid

KEEP OUT OF REACH OF CHILDREN.
WARNING/AVISO

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand the label, find someone to explain it to you in detail.)

See additional precautionary statements and directions for use in booklet.

PULL HERE TO OPEN ►

RESTRICTED USE PESTICIDE
DUE TO TOXICITY TO FISH AND AQUATIC ORGANISMS
FOR RETAIL SALE TO AND USE ONLY BY CERTIFIED APPLICATORS, OR PERSONS UNDER THEIR DIRECT
SUPERVISION, AND ONLY FOR THOSE USES COVERED BY THE CERTIFIED APPLICATOR'S CERTIFICATION.

GROUP 3 INSECTICIDE

 **Karate**[®]

Insecticide

For Use to Control Certain Insects on Selected Crops

Active Ingredient:

Lambda-cyhalothrin¹
[1 α (S*),3 α (Z)]-(\pm)-cyano-(3-phenoxyphenyl)methyl-3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2-
dimethylcyclopropanecarboxylate 13.1%

Other Ingredients²: 86.9%

Total: 100.0%

Karate[®] Insecticide contains 1 pound of active ingredient per gallon and is an emulsifiable concentrate.

¹Synthetic pyrethroid

²Contains petroleum distillates.

KEEP OUT OF REACH OF CHILDREN.
WARNING / AVISO

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand the label, find someone to explain it to you in detail.)

EPA Reg. No. 100-1086 EPA Est. No. 39578-TX-1

Product of the United Kingdom

Formulated in the USA

SCP 1086B-L1A 1209
311387

1 gallon
Net Contents

 **syngenta**[®]

PULL HERE TO OPEN

RESTRICTED USE PESTICIDE

DUE TO TOXICITY TO FISH AND AQUATIC ORGANISMS

FOR RETAIL SALE TO AND USE ONLY BY CERTIFIED APPLICATORS, OR PERSONS UNDER THEIR DIRECT SUPERVISION, AND ONLY FOR THOSE USES COVERED BY THE CERTIFIED APPLICATOR'S CERTIFICATION.

Sale, use and distribution of this product in Nassau and Suffolk counties in the state of New York is prohibited.

GROUP 3A | 4A INSECTICIDES



syngenta.

Insecticide

For control of listed pest infesting specified crops.

Active Ingredient:

Lambda-cyhalothrin ^{1,2}	9.48%
Thiamethoxam ³	12.60%
Other Ingredients:	77.92%
Total:	100.00%

Endigo ZC contains 1.18 pounds thiamethoxam and 0.88 pounds lambda-cyhalothrin per gallon.

¹Synthetic pyrethroid

²CAS No. 91465-08-6

³CAS No. 153719-23-4

KEEP OUT OF REACH OF CHILDREN. WARNING / AVISO

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand the label, find someone to explain it to you in detail.)

See additional precautionary statements and directions for use in booklet.

EPA Reg. No. 100-1276

EPA Est. 100-NE-001

SCP 1276A-L1F 0611 343398

1 gallon Net Contents



Key to Targeted Physiology

- Nerve & Muscle
- Growth & Development
- Respiration
- Midgut
- Protein Suppressor
- Unknown or Non-specific

Group 1: Acetylcholinesterase (AChE) inhibitors
(Only representative actives of the group are shown)

1A Carbamates
1B Organophosphates

Group 2: GABA-gated chloride channel antagonists

2A Cyclohexenyl Organochlorines
2B Phenylpyrazoles (Fluorals)

IRAC
Insecticide Resistance Action Committee
Mode of Action Classification

Group 21: Mitochondrial complex I electron transport inhibitors

21A METI acaricides and insecticides
21B Rotenone

Group 22: Voltage-dependent sodium channel blockers

22A Coadjuvants
22B Semicarbazones

Group 3: Sodium channel modulators (Only representative actives of group 3A are shown)

3A Pyrethroids
3B DDT, Methoxychlor

Group 9: Chordotonal organ TRPV channel modulators

9B Pyridine azarothione derivatives
9D Pyripenes

Group 18: Mite growth inhibitors affecting CHS1

18A Colferatazins
18B Ethoxazole

Group 23: Inhibitors of acetyl-CoA carboxylase

23 Tetrone & Tetranoic acid derivatives

Group 24: Mitochondrial complex IV electron transport inhibitors

24A Phosphites
24B Cyanides

Group 4: Nicotinic acetylcholine receptor (nAChR) competitive modulators

4B Nicotine
4C Sulfoxonines
4D Butenolides
4F Pyridylidene
4E Mesocitric

Group 11: Microbial disruptors of insect midgut membranes

11A *Bacillus thuringiensis*
11B *Bacillus sphaericus*

Group 25: Mitochondrial complex II electron transport inhibitors

25A Dato-Ketolidide derivatives
25B Carboxanilides

Group 28: Ryanodine receptor modulators

28 Clamides
28B Telonitride

Group 29: Chordotonal organ nicotinamide inhibitors

29 Flonicamid

Group 5: Nicotinic acetylcholine receptor (nAChR) allosteric modulators sites I

5 Spiroayres

Group 6: Glutamate-gated chloride channel (GluCl) allosteric modulators

6Avermectins & Milbemycins

Group 12: Inhibitors of mitochondrial ATP synthase

12A Difenflufenuron
12B Organotin imides
12C Propargyle
12D Tetradifon

Group 30: GABA-gated chloride channel allosteric modulators

30 Isoxazolines & Meta-diazides
30B Fluoropyridone

Group 31: Baculoviruses

31 Granuloviruses & Nucleopolyhedroviruses

Group 32: Nicotinic Acetylcholine receptor (nAChR) allosteric modulators sites II

32 GG-omega-kappa HXTX-Hv1a peptide

Group 7: Juvenile hormone receptor modulators

7A Juvenile hormone analogues
7B Fenoxycarb
7C Pyriproxyfen
7D Pyriproxyfen

Group 13: Uncouplers of oxidative phosphorylation via disruption of proton gradient

13 Pyrimoles, Dithiopyrimidol, Sulfoxonine, DNCC

Group 14: Nicotinic acetylcholine receptor (nAChR) channel blockers

14 Nematostil analogues
14B Carbonyl hydroxamate
14C Thiopyridin
14D Thiopyridin

Group 33: Calcium-activated potassium channel (KCa2) modulators

33 Acynonyl

Group 34: Mitochondrial complex II electron transport inhibitors - Qi site

34 Flometoquin

Group 35: RNA interference mediated target suppressors

35 Ledprona

Group 36: Chordotonal organ modulators - undefined target site

36 Dempropyridaz

Group 8: Miscellaneous non-specific (multi-site) inhibitors

8A Alkyl halides
8B Chlorophen
8C Fluorides
8D Borates
8E Tartar emetic
8F Methyl isothiocyanate generators
8G Methyl isothiocyanate generators
8H Methyl isothiocyanate generators

Group 15: Inhibitors of chitin biosynthesis affecting CHS1 (Only representative actives of group are shown)

15 Senexolones

Group 16: Inhibitors of chitin biosynthesis, type 1

16 Buprofezin

Group 18: Ecdysone receptor agonists

18 Dicyclopyridines

UN: Unknown or uncertain mode of action

UNF Fungal agents
UNB Bacterial agents (non-BI)
UNM Non-specific mechanical and physical disruptors
UNE Botanical essence including synthetic, extracts and refined oils

Group 19: Octopamine receptor agonists

19 Ambiaz

Group 28: Mitochondrial complex II electron transport inhibitors - Qi site

28A Hydramethylnon
28B Azaquinoyl
28C Flacrypyrim
28D Bifenazate

Use of Sub-Groups:

- Alterations, sequences or rotations of compounds between MOA groups reduce selection for target site resistance
- Applications are arranged into MOA spray windows defined by crop growth stage and pest biology. Several sprays of a compound may be possible within each spray window, but successive generations of a pest should not be treated with compounds from the same MOA group. Local expert advice on spray windows and timings should always be followed.
- Groups in the classification whose members do not act at a common target site are exempt from the prescription against rotation within the group (Group 8, 13 and all UN groups: UN, UNB, UNF, UNM, UNP & UNV).

Use of Sub-Groups:

- Sub-groups represent distinct structural classes which are believed to have the same mode of action.
- Sub-groups provide differentiation between compounds that may bind at the same target site but are structurally different enough that risk of metabolic cross-resistance is lower than for close chemical analogs.
- Cross-resistance potential between sub-groups is higher than between groups, so rotation between sub-groups should be considered only when there are no alternatives, and only if cross-resistance does not exist, following consultation with local expert advice. These exceptions are not sustainable, and alternative options should be sought.

Disclaimer: While CropLife International and IRAC make every effort to present accurate and reliable information, they do not guarantee the accuracy, completeness, efficacy, timeliness, or correct sequencing of such information. Inclusion of active ingredients on the IRAC Code List is based on scientific evaluation of their modes of action; it does not provide any kind of testimony for the use of a product or a judgment on efficacy. CropLife International and IRAC are not responsible for, and expressly disclaim all liability for, damages of any kind arising out of use, reliance on, or reliance on information provided. Listing of chemical classes or modes of action must not be interpreted as approval for use of a compound in a given country. Prior to implementation, each user must determine the current registration status in the country of use and strictly adhere to the uses and instructions approved in that country.

Poster Notes:

- Sub-group 38: DDT is no longer used in agriculture and therefore this is only applicable for the control of insect vectors of human disease, such as mosquitoes, because of a lack of alternatives.
- Sub-group 18A: Hirsutoxazole is grouped with Colferatazins because they exhibit cross-resistance even though they are structurally distinct. Diflovidazin has been added to this group because it is a close analogue of Colferatazins and is expected to have the same mode of action.
- Group 20: While there is strong evidence that Bifenazate acts on the Qi site of Mitochondrial Complex II and some Bifenazate resistance mutations confer cross-resistance to Acetquinyl, the sites of action of Flacrypyrim and Hydramethylnon have not been determined.
- Groups 26 & 27 are unassigned.
- In some cases, only representative actives are shown.
- Because of documented cross-resistance between Dicoib, Bromopropylate and Abamectin, these active ingredients should not be rotated after each other in an IRM program.

Mode of Action Classification | Insecticide Resistance Management | IRAC

37 Groups + Several Compounds with Unknown MOAs

Using IRAC Groups

Pesticide	MOA
Acetamiprid (Assail)	4A
Afidopyropen (Sefina)	9D
Clothianidin (Belay)	4A
Flonicamid (Beleaf, Carbine)	9C
Flupyradifurone (Sivanto 200 SL)	4D
Imidacloprid	4A
Pesticide	MOA
Pymetrozine (Fulfill)	9B
Pyridaben (Nexter)	21
Pyrifluquinazon (PQZ)	9B
Sulfoxaflor (Closer, Transform)	4C
Thiamethoxam (Centric)	4A
Tolfenpyrad (Apta)	21A



**Imidacloprid
(4A)**

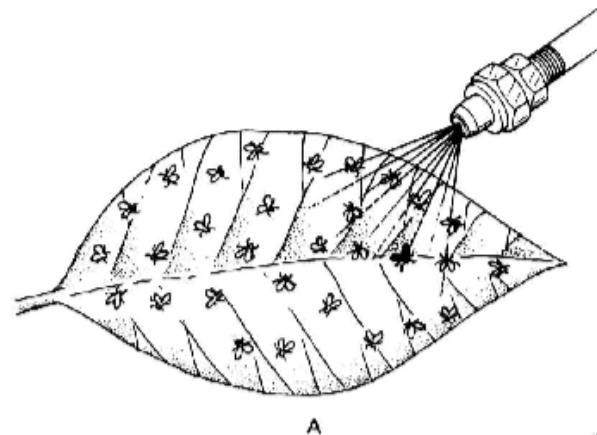


**Apta
(21A)**

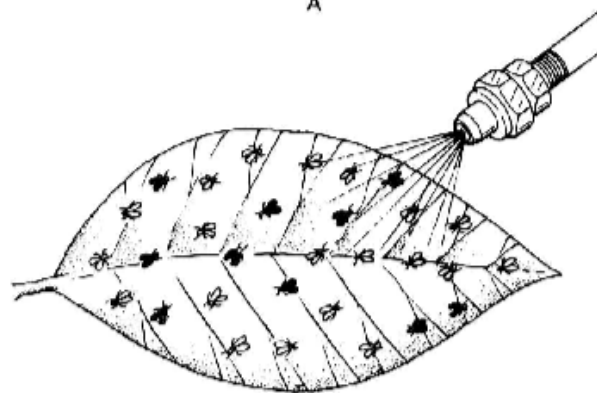


**Sefina
(9D)**

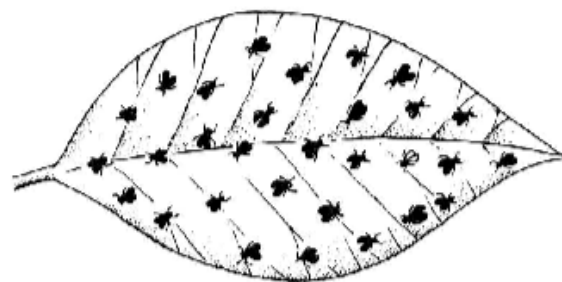
- Pecan Aphid resistance to Imidacloprid has been observed in some parts of the state.
- When we are spraying, we want to make sure we are targeting different generations with different insecticides.
- Some pest, such as pecan weevil, don't require as much rotation, as they only produce 1 generation a year.





A



B

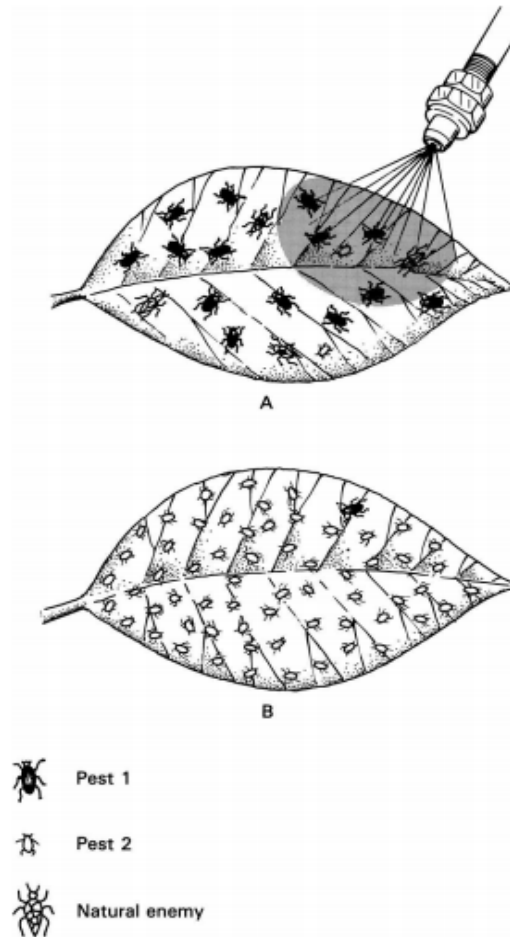
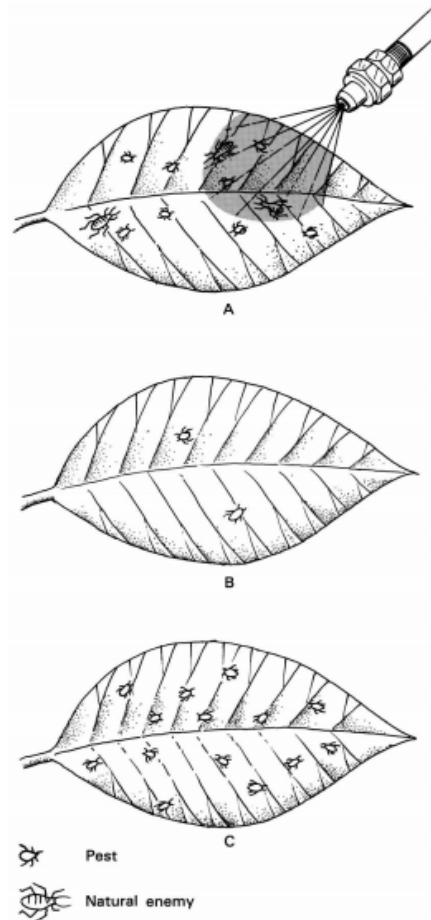


C

-  Susceptible individual
-  Resistant individual

Insecticide Resistance

Pest Resurgence



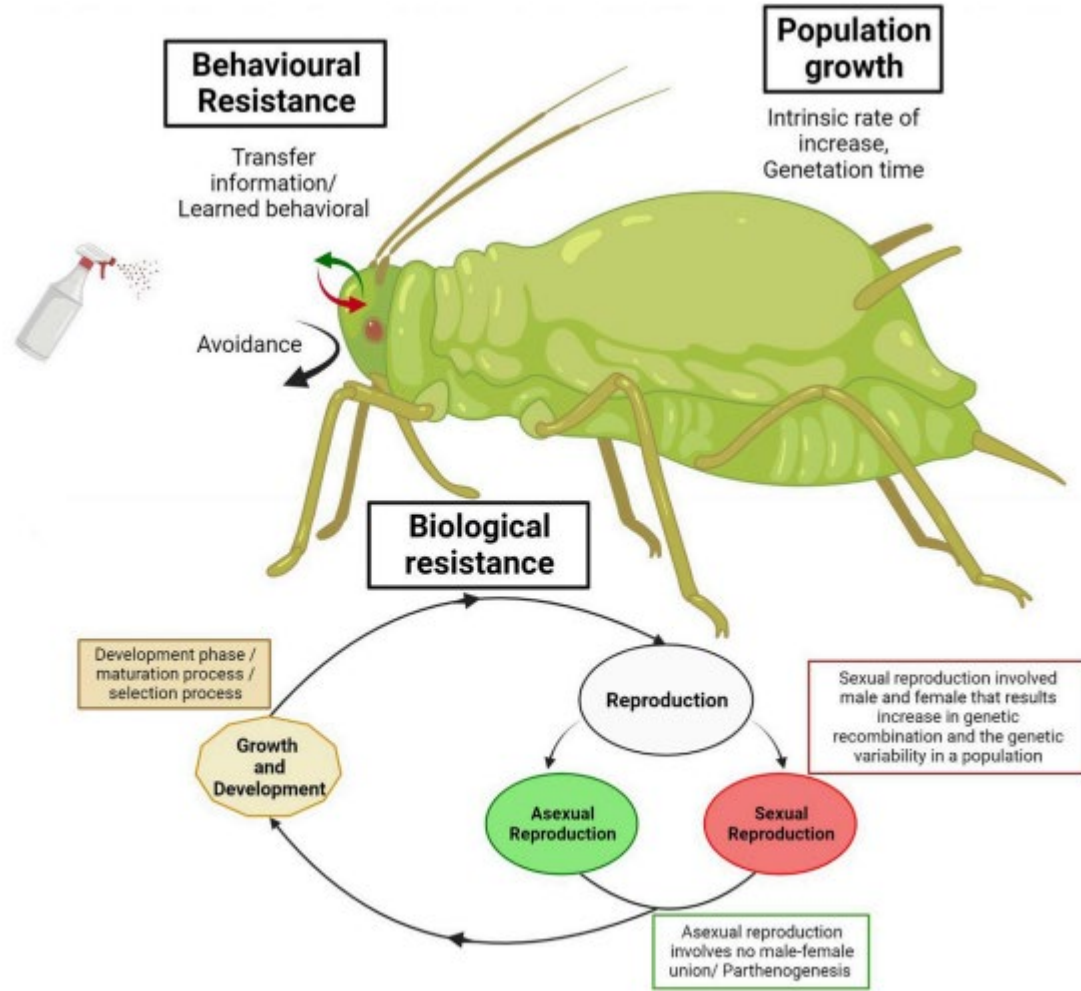


FIGURE 1
Schematic diagram of the biological and behavioral mechanisms of insecticide resistance in invasive insects.

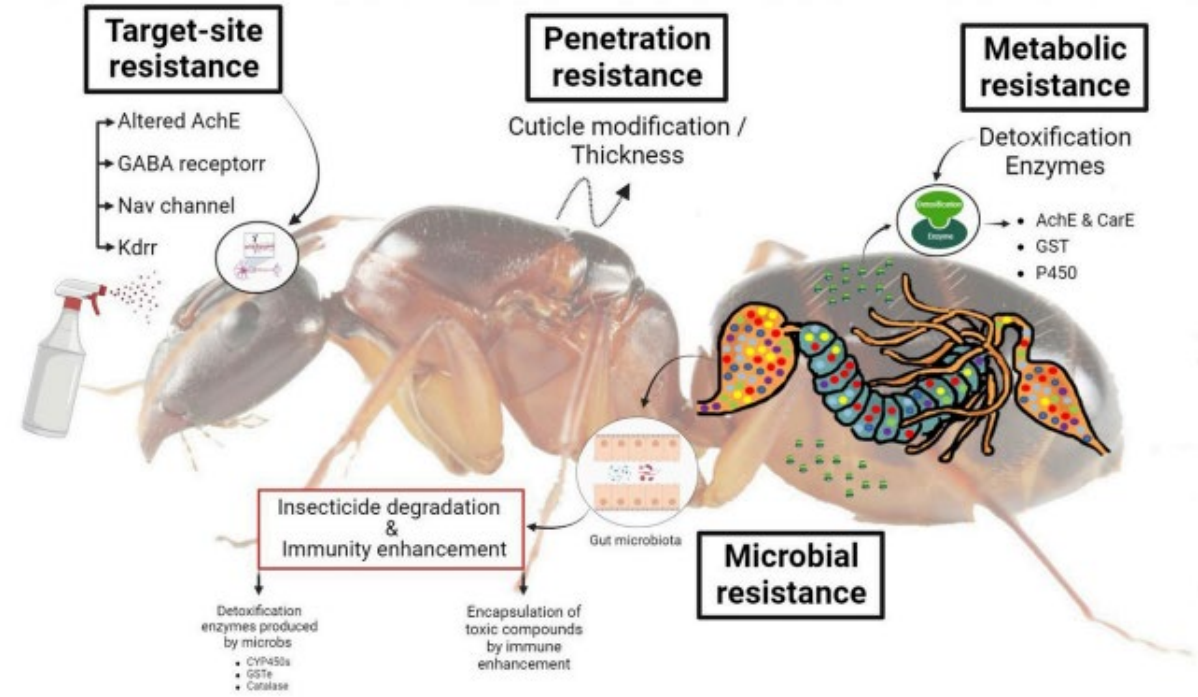


FIGURE 2
A schematic diagram represents the role of enzymes and gut microbiota in pesticide detoxification in invasive ants.

Cross-Resistance

Table 17.2 Critical Instances of Cross Resistance in the United States.

Pest	Organo-phosphates OP	Carbamates C	Pyrethroids P	Other (includes microbials)
Twospotted spider mite (<i>Tetranychus urticae</i>)	X	X	X	X
Colorado potato beetle (<i>Leptinotarsa decemlineata</i>)	X	X	X	X
Southern house mosquito (<i>Culex quinquefasciatus</i>)	X	X	X	X
Little house fly (<i>Fannia canicularis</i>)	X		X	X
Sweetpotato whitefly (<i>Bemisia tabaci</i>)	X	X	X	
Greenhouse whitefly (<i>Trialeurodes vaporariorum</i>)	X	X	X	
Cotton aphid (<i>Aphis gossypii</i>)	X	X	X	
Pear psylla (<i>Cacopsylla pyricola</i>)	X	X	X	
Tobacco budworm (<i>Heliothis virescens</i>)	X	X	X	
Soybean looper (<i>Chrysodeixis includens</i>)	X	X	X	
Beet armyworm (<i>Spodoptera exigua</i>)	X	X	X	
Fall armyworm (<i>Spodoptera frugiperda</i>)	X	X	X	
Diamondback moth (<i>Plutella xylostella</i>)	X	X	X	X
German cockroach (<i>Blattella germanica</i>)	X	X	X	X
Cat flea (<i>Ctenocephalides felis</i>)	X	X	X	X

SOURCE: *Biologically Based Technologies for Pest Control*. 1995. U.S. Congress, Office of Technology Assessment.

From: *Entomology and pest management*

- Where an insect becomes resistant to multiple insecticides through resistance to one.
- Usually occurs **within** a class of insecticides
 - DDT and Methoxychlor (Chemform, Moxie) (Both IRAC Class 3B).
- However, **between** class resistance also occurs.
 - Carbamates (Carbaryl, Sevin) and Organophosphates (Chlroyrifos) (IRAC Class 1A and 1B).
 - Carbamates (1A), Organophosphates (1B), Pyrethroids (3A) (All three target nerves and muscles).

4. Evaluate Effectiveness



Did what I apply work? - Monitoring



YES!



NO! Start from Step 1

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