A Review of Insecticide Classes and Characteristics

Whitney Cranshaw
Colorado State University
Common Types of Pesticides

(Organisms Controlled)

- Herbicides – *Higher Plants*
- Algacides – *Algae*
- Fungicides – *Fungi*
- Bactericides – *Bacteria*
- Insecticides – *Insects*
- Acaricides/Miticicides
- Molluscsicides
Classification of Insecticides

Mode of Entry
Insecticides - Mode of Entry

- Contact (touch)
- Fumigant (spiracles)
- Stomach (ingestion)
PESTICIDES and the HUMAN BODY
Routes of Entry

DERMAL EXPOSURE

ORAL INGESTION

RESPIRATORY EXPOSURE
Classification of Insecticides

Systemic or Not Systemic?

Are they capable of moving within the plant?
Distribution of C$^{14}$ labeled Thiamethoxam™ 25WG after a foliar application to cucumber leaves

1 hour after application

8 hour after application

24 hour after application

Slide Credit: N. Rechcigl
Systemic insecticides applied to leaves

Some systemic insecticide can move into plants when sprayed onto leaves.

Some systemic insecticides can move into plant when applied to the roots.

Most systemic insecticides will appear in highest concentration in the new growth.
Systemic Insecticides

- **Capable of some translocation in plant**
- **Range exists in ability to move in plant**
  - Some limited to translaminar movement
  - Some broadly distribute in plant (usually to newer growth)
- **Systemic activity is limited to a small number of insecticides**
  - Most neonicotinoids
  - Diamides (limited)
  - Abamectin (translaminar only)
Systemic Insecticides

- **Capable of some translocation in plant**
- **Range exists in ability to move in plant**
  - Some limited to translaminar movement
  - Some broadly distribute in plant (usually to newer growth)

- **Systemic activity is limited to a small number of insecticides**
  - Some organophosphates
  - All neonicotinoids
  - Diamides (limited)
  - Avermectins (translaminar only)
Translaminar movement – Insecticide can move through a leaf (but not necessarily to another leaf)

Example: Foliar applications of abamectin (Avid)
Essentially all systemic insecticide move primarily in the xylem of the plant. Essentially all systemic insecticides primarily move upward.

Only one product moves both upwards and downwards - spirotetramat

This is labeled for greenhouse/nursery crops as Kontos and for fruits and vegetables as Movento
Common method of applying systemic insecticides – soil applications for root uptake

Soil injections

Soil drenches
Foliar sprays are often used when soil active systemic insecticides are not available.
Classification of Insecticides

Broad Spectrum or Selective Activity?
Selectivity of Insecticides Can Derive from…..

- Differences in inherent toxicity of the insecticide to different insects
- Persistence of the insecticide
- Formulation of the pesticide
- Time when the insecticide is applied
- Where the insecticide is applied
Pesticide that is Selective because it is *Inherent Toxicity of the Pesticide*

**What this means**

higher $L_{D_{50}}/L_{C_{50}}$ = less toxic

lower $L_{D_{50}}/L_{C_{50}}$ = more toxic

**LD50**: Lethal dose that will kill 50% of the test population
# Acute Toxicity of Neonicotinoids to Adult Honey Bees

(Oral LD50 – micrograms/bee)

<table>
<thead>
<tr>
<th>Chemical</th>
<th>LD50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetamiprid</td>
<td>14.53</td>
</tr>
<tr>
<td>Imidacloprid</td>
<td>0.005</td>
</tr>
<tr>
<td>Dinotefuran</td>
<td>0.056</td>
</tr>
<tr>
<td>Thiamethoxam</td>
<td>0.005</td>
</tr>
<tr>
<td>Chlothianidin</td>
<td>0.0003</td>
</tr>
</tbody>
</table>
Pesticide that is Selective in the *Time it is Applied*

Applications made during the dormant season
Insecticides and Pollinators: Bottom Line

Always avoid applications to plants that bees are visiting – *It is the law!*
Systemic Insecticides and Pollinators: Bottom Line?

Avoid applications to plants that bees visit that are in bloom – or soon will be in bloom
Spider Mite Control Products

- Least disruptive of natural enemies
  - Floramite (bifenazate)
  - TetraSan (extoxazole)
  - Hexygon (hexythiazox)
Pesticide that is Selective in the **Mode of Entry**

**Bacillus thuringiensis** example
Pesticide that is Selective because of its **Persistence of Activity**

- **Pyrethrins**
- **Insecticidal Soap**
Insecticide Persistence

• General measure – half life
• Factors affecting degradation
  – Sunlight/UV
  – Moisture
  – pH
  – Microbial degradation
Examples of insecticides that are very rapidly degraded upon exposure to sunlight

**Bacillus thuringiensis**

**Pyrethrins**
Pyrethrins

An example of an insecticide that very rapidly breaks down upon exposure to light

*Tancetum* (= *Chrysanthemum* *cinerariifolium*)
*Pyrethrum daisy* – source of pyrethrum
Pyrethroid Insecticides
(a.k.a., synthetic pyrethrins)

Many pyrethroid insecticides have ability to persist for weeks - months

Pyrethroid insecticides are based on the chemistry of natural pyrethrins
Pesticide that is Selective because of *Where the Pesticide is Applied*

- Spraying whole plant
- Soil application of systemic insecticide
Pesticide that is Selective because of the *Formulation of the Pesticide*

- **Baits**
- **vs.**
- **Sprays**
- **Dusts**
Selectivity of Insecticides Can Derive from.....

- Differences in inherent toxicity of the insecticide to different insects
- Persistence of the insecticide
- Time when the insecticide is applied
- Where the insecticide is applied
- Formulation of the pesticide
“Historical” Classes of Insecticides

Heavy metal/inorganic insecticides

Chlorinated hydrocarbon insecticides

Organophosphate Insecticides
Insect Control Products Available a Century Ago

- Lead Arsenate/Calcium Arsenate
- Sulfur/Lime Sulfur
- Dormant Oils
- Nicotine Sulfate
- Rotenone
- Pyrethrins
- Ryaania
Insect Control Products Available a Century Ago

- Lead Arsenate/Calcium Arsenate
- Sulfur/Lime Sulfur
- Dormant Oils
- Nicotine Sulfate
- Rotenone
- Pyrethrins
- Ryania
Aerial application of lead arsenate for gypsy moth control
What we used 35 years ago

- Dursban
- Malathion
- Methoxychlor
- Diazinon
- Carbaryl
- Cygon
- Orthene
- MetaSystox-R
- Furadan
Chlorinated Hydrocarbons

- First widely used class of synthetically produced insecticides
  - Post World War II
- Generally **broad spectrum of activity** against insects
- **Low to moderate acute toxicity to humans**
- **Very long persistence** – weeks to months, sometimes longer
  - Some soil applications lasting many years
When first introduced, originally to stop epidemic typhus during World War II, DDT and the new chlorinated hydrocarbons were considered nearly miraculous
Chlorinated Hydrocarbons

- Fat soluble
- Persistent in the environment
  - Concentrated in fat tissues
  - Biomagnification in ecosystems
  - Showed some hormonal effects at high concentrations (*estrogen mimics*)
The book that started a rethinking about insecticide use
Chlorinated hydrocarbons, such as DDT, are persistent and concentrate in fat.
Biomagnification of chlorinated hydrocarbon insecticides in food chains
Biomagnification of chlorinated hydrocarbon insecticides in food chains.

In high levels chlorinated hydrocarbons act as estrogen mimics.

Primary effect on top predators – egg shell thinning.
Paul Muller – Received 1948 Nobel Prize for Medicine/Physiology for his discovery of the insecticidal activity of DDT

Malaria mosquito
Chlorinated Hydrocarbons

- Fat soluble
- **Persistent in the environment**
  - Concentrated in fat tissues
  - **Biomagnification** in ecosystems
  - Showed some hormonal effects at high concentrations *(estrogen mimics)*

- **Current Status**
  - DDT banned 1972
  - Termiticide uses eliminated in 1990s
  - Methoxychlor used for bark beetles into the 1990s; all uses ended in 2002
Organophosphates

- Primary class used during 1960s through early 1990s
- Some have systemic activity
- Mode of Action: Inhibition of cholinesterase
  - Effects persist and can accumulate with repeated exposure
- Acute Toxicity (to humans): Moderate to very high
Organophosphates were originally developed in Nazi Germany as Chemical Warfare (Nerve Gas) Agents. G Class (Sarin, Tabun), VCX series.
Organophosphate Insecticides Historically Used for Landscape Pest Management

- Chlorpyrifos (Dursban)
- Diazinon
- Acephate (Orthene)
- Dimethoate (Cygon)
- Malathion
- Disulfoton (DiSyston)
- Oxydemetonmethyl (MetaSystox-R)
Organophosphates

- Non-target Effects:
  - Birds: Moderate to very high toxicity to birds
  - Fish: Moderately toxic

- Other: Many organophosphates have a strong associated odor

- Current Status
  - Steady reduction in registrations since late 1990s
Organophosphate Insecticides Presently Used in Landscape Care

- Acephate (Orthene, Lepitect)
- Malathion?
Hi-Yield 55% Malathion SPRAY

- For Outdoor Garden Use
- Controls Aphids, Bagworms and Many Other Listed Insects.
- For use on listed outdoor ornamental herbaceous plants, ornamental non-flowering plants, ornamental woody shrubs, vegetables, and fruit trees.
- 1 1/2 Teaspoons Makes 1 Gallon of Spray

KEEP OUT OF REACH OF CHILDREN

CAUTION

See Back/label Prior
For Adult Use
Precautionary Statements

NET CONTENTS ONE QUART (32 FL. OZ.)
There are over two dozen modes of action of insecticides and miticides.

**IRAC - Insecticide Mode of Action Classification**

Insecticide Resistance Action Committee  www.irac-online.org

**Introduction**
Insecticide Resistance Action Committee [IRAC] promotes the use of a Mode of Action (MoA) classification of insecticides as the basis for effective and sustainable insecticide resistance management (IRM). Insecticides are allocated to specific groups based on their target site. Revised and re-issued periodically, the IRAC MoA classification list provides farmers, growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of insecticides or acaricides in IRM programs. Effective IRM of this type preserves the utility and diversity of available insecticides and acaricides. Sample MoA groups are shown below.

**Effective IRM strategies: Sequences or alternations of MoA**
All effective insecticide resistance management (IRM) strategies seek to minimise the selection of resistance to any one type of insecticide. In practice, alternations, sequences or rotations of compounds from different MoA groups provide sustainable and effective IRM for pest Lepidoptera. This ensures that selection from compounds in the same MoA group is minimised, and resistance is less likely to evolve.

Applications are often arranged into MoA spray windows or blocks that are defined by the stage of crop development and the biology of the pest species of concern. Local expert advice should always be followed with regard to spray windows and timings. Several sprays may be possible within each spray window but it is generally essential to ensure that successive generations of the pest are not treated with compounds from the same MoA group. Metabolic resistance mechanisms may give cross-resistance between MoA groups, and where this is known to occur, the above advice must be modified accordingly. IRAC also provides general recommendations for resistance management tactics regarding specific MoA groups, e.g. neonicotinoids (Group 4A).

**Growth & Development targets**
Group 1  Juvenile hormone mimics
  1A  Juvenile hormone analogues (e.g. Methoprene)
  1B  Fenoxycarb, 7C Pyriproxyfen

Group 10  Mite growth inhibitors
  10A  Methidathion, Hexitoloxaol, 10B Etoxazole

Group 15  Inhibitors of chitin biosynthesis, Type 0
  15A  Benzoylureas (e.g. Flufenoxuron, Noveluron)

Group 16  Inhibitors of chitin biosynthesis, type 1 Buprofezin

Group 17  Moulting disruptor, Difetan Cyromazine

Group 18  Ecdysone agonists / moulting disruptors
  18A  Daclofluridzin (e.g. Methoxyfenozide, Tebufenozide)

**Nerve & Muscle Targets**
Group 1  Acetylcholinesterase (AChE) inhibitors
  1A  Carbamates (e.g. Thiocarb), 1B Organophosphates (e.g. Chloropyrifos)

Group 2  GABA-gated chloride channel antagonists
  2A  Cyclodiene Organochlorines (e.g. Endosulfan, 2B Phenylureas (e.g. Fipronil)

Group 3  Sodium channel modulators
  3A Pyrethrins, Pyrethroids (e.g. Cypermethrin, 3B Cyhalothrin)

Group 4  Acetylcholine receptor (nAChR) agonists
  4A  Neonicotinoids (e.g. Imidaclopid, Thiamethoxam)

Group 4  Sulfasafetil, 10F Flupyradiflorine

Group 5  Nicotinic acetylcholine receptor channel agonists (Allosteric)
  5A  Spinosyns (e.g. Spinosad, Spinetoram)

Group 8  Chloride channel activators Avermectins (e.g. Abamectin, Emamectin benzoate, Lepimectin)

Group 9  Modulators of Chordotonal Organs
  9A Pymetrozine, 9C Flonicamid

Group 14  Nicotinic acetylcholine receptor channel blockers Neurexin analogs (e.g. Cartap hydrochloride)

Group 19  Octopamine receptor agonists Amitraz

Group 22  Voltage dependent sodium channel blockers
  22A Indoxacarb, 12E Netafimazine

Group 28  Rydoneline receptor modulators
  28A Diamide (e.g. Flumetiamide, Chlorantraniliprole, Cyantianthrole)

**Respiration targets**
Group 12  Inhibitors of mitochondrial ATP synthesis
  12A Affenbuturon, 12B Organoin micides (e.g. Cypermethrin, 12C Propargite, 12D Tetrafluron

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

Group 20  Mitochondrial complex III electron transport inhibitors
  20A Hydramethylnon, 20B Acequinocyl,

Group 26  Mitochondrial complex I electron transport inhibitors
  26F Flucyctosyn

Group 27  Mitochondrial complex II electron transport inhibitors
  27A MET sciacides (e.g. Pyridaben, Tetufenpyrad)

Group 29  Inhibitors of proton (CoA carboxylase Tetracyclic & Tetronic acid derivatives (e.g. Spirodiclofen)

Group 35  Mitochondrial complex II electron transport inhibitors Cyantraniliprole, Cyfluthrin

**Midgut Targets**
Group 11  Microbial targets
  11A Bacillus thuringiensis

11B Bacillus sphaericus

**Unknown**
UN  Compounds of unknown or uncertain mode of action (e.g. Azadirachtin, Bifentrazone, Pyridofluid, Pyrifloza)
A great source of information on insecticide classes and their mode of action

IRAC – Insecticide Resistance Action Committee
How were most presently used insecticides discovered?

- Derived from microbes
- Derived from active ingredients found in plants
- Derived from hormones used in insect growth
Pyrethroid Insecticides  
(a.k.a., synthetic pyrethrins)

Pyrethrins are the active ingredient extracted from pyrethrum flowers.
Tanacetum (=Chrysanthemum) cinaeriofolium  Pyrethrum Daisy

Botanical source that lead to development of the pyrethroid insecticides

Extracts of pyrethrum flowers contain active ingredients known as pyrethrins
Dalmatian (Pyrethrum) Daisy

*Tanacetum (=Chrysanthemum) cinaeriafolium*

A Colorado *Plant*

*Select Selection*
Pyrethroid Insecticides
(a.k.a., synthetic pyrethrins)

Pyrethrins are the active ingredient extracted from pyrethrum flowers.
Some Presently Marketed Pyrethroid Insecticides

- Permethrin
- Cypermethrin
- Bifenthrin
- Resmethrin
- Sumithrin
- Tetramethrin
- Tralomethrin
- Deltamethrin

- Esfenvalerate
- Cyfluthrin
- Cyhalothrin
- Allethrin
Some Pyrethroid Insecticides

Pyrethrins
Pyrethroid Uses

- Non-systemic, attaches well to organic matter (high Koc)
- Persistence ranges widely
  - Bifenthrin, cypermethrin most persistent (days to a couple weeks)
  - Permethrin, cyhalothrin, cyfluthrin quite persistent (days)
  - Resmethrin, sumithrin, pyrethrins non-persistent (hours)
Pyrethroid Uses for Tree/Shrub Insect Control

- Generally broad spectrum
  - Standards for bark beetle and borer sprays
  - Strong on most beetles, caterpillars, sawflies, scale crawlers
  - OK on most Hemiptera (e.g., aphids, whiteflies, leafhoppers, bugs)
  - Fair to poor on spider mites
OTC Pyrethroids with Uses on Ornamental Plants

• **Bifenthrin/Cypermethrin (combination)**
  – Ortho Max Insect Killer for Lawns & Gardens

• **Cyfluthrin**
  – Bayer Advanced Rose & Flower Insect Killer, Bayer Advanced Vegetable & Garden Insect Spray

• **Gamma-cyhalothrin**
  – Spectracide Triazicide Insect Killer for Lawns & Landscapes

• **Permethrin**
  – Bonide Eight Insect Control Vegetable, Fruit & Flower; Bayer Advanced Complete Insect Dust for Gardens; Ace House & Garden Bug Killer2; probably many others
Primary Pyrethroid Insecticide Found on Nursery Shelves – That Can Be Used on Fruits/Vegetables

- Permethrin
A Pyrethroid Insecticide Found on Nursery Shelves – *That Can Be Used on Many Fruits/Vegetables*

Active Ingredient: Gamma-cyhalothrin
Active Ingredients of Wood Borer Insecticides (Trunk Sprays)

- Permethrin (Astro, Permethrin, etc.)
- Bifenthrin (Onyx)
Only One OTC product, containing permethrin, has a label and use rate that allows effective use against Borers and Bark Beetles!
Pyrethroids are non-selective

…and can be rough on insect natural enemies
Pyrethroids are highly toxic to bees.

Treated flowers may kill flower visitors for a couple of days after application.
My favorite/”go to” publication on this subject

Table 4. Active ingredients of commonly used pesticides and their effect on bees in California, Idaho, Oregon, and Washington

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Highly Toxic to Bees (RT)</th>
<th>Toxic to Bees (RT)</th>
<th>No Bee Precautionary Statement (PS) on Label</th>
<th>Common Product Names</th>
<th>Notes and Special Precautions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abamectin (Avermectin) Neemseed products (neem) effects sense and associate with pheromone application to bees</td>
<td>X</td>
<td>0.015 % or below 1-3 days RT, ≤ 0.002 in schools 6 hours RT [1]</td>
<td>No</td>
<td>Abate, Alar, Abate, Agri-Mek, Afric, Epi-Mek, Rapsar, Solara, Solasta, Temprano, Timectin, Zeta</td>
<td>ERT to honey bees [2], short RT to shifts lasting less than 6 hours and all bees at 0.002 RT in schools [1]</td>
</tr>
<tr>
<td>Acephate Organophosphate esters</td>
<td>X</td>
<td>&gt;3 days RT [1]</td>
<td>No</td>
<td>Bradicid, Orthene, Orthoxene</td>
<td>Incompatible with honey bees [2]; ERT to shifts lasting less than 3 days and all bees [1]</td>
</tr>
<tr>
<td>Acetamiprid Neonicotinoid insecticide (pyre group)</td>
<td></td>
<td></td>
<td>X</td>
<td>Karvanil, Shuttle</td>
<td></td>
</tr>
<tr>
<td>Assail, Triter, Transports</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Length of residual toxicity to honey bees is unknown. ERT to shifts lasting less than 3 days and all bees [2]; 3 day RT to honey bees [2]; Canto group neonicotinoids exhibit lower toxicity to bees than other group neonicotinoids [1]</td>
</tr>
</tbody>
</table>
Pyrethroids

- **Acute Toxicity to Humans:** Low to moderate

- **Non-target Effects:**
  - Birds: Low to very high acute toxicity
  - Fish: Extremely toxic

- **Current Status**
  - Broadly registered and available – *although under review*
Botanical source that led to development of neonicotinoid insecticides

Nicotine

Older nicotine sulfate insecticide
Neonicotinoids

• Insecticide class originally developed commercially in the late 1980s

• Mode of Action
  – Nicotinic acetylcholine receptor agonist
  – IRAC Mode of Action Group 7A
  – Nicotine mode of action similar
Neonicotinoids

• Insecticide class originally developed commercially in the late 1980s
• Mode of action - Nicotinic acetylcholine receptor agonist
  • IRAC Mode of Action Group 7A
  • Nicotine mode of action similar

• Emerged in early 1990s
  – First new class of insecticide with systemic activity in plants in 30+ years

• Low toxicity to vertebrates accelerated registration as “reduced risk” products
Primary Neonicotinoid Insecticides Used in Landscape Plant Care

- **Imidacloprid** (Merit, Marathon, Zenith, Mallet, etc.)
- **Dinotefuran** (Safari, Zylam, Transtect)
- **Acetamiprid** (Tristar)
Not all Neonicotinoids are alike:

- UV stability
- Water solubility
- Rate of uptake by plants
- Mobilization within plants
- Host range of susceptible insects
Comparison of UV Stability

Data obtained from published EPA registration documents

Slide Credit: R. Fletcher
UV Stability

Neonicotinoids are generally not UV stable. Foliar persistence can be shortened by this feature.

Acetamiprid is an exception.
Relative Water Solubility of Neonicotinoids:

Water Solubility (Active Ingredient)

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Solubility (mg/liter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clothianidin</td>
<td>327</td>
</tr>
<tr>
<td>Imidacloprid</td>
<td>500</td>
</tr>
<tr>
<td>Acetamiprid</td>
<td>2950</td>
</tr>
<tr>
<td>Thiamethoxam</td>
<td>4100</td>
</tr>
<tr>
<td>Dinotefuran</td>
<td>39830</td>
</tr>
</tbody>
</table>

Information sources
- Clothianidin (Celero), Acetamiprid (Tristar), Dinotefuran (Safari) – EPA Pesticide Fact Sheet
- Imidacloprid (Marathon), Thiamethoxam (Flagship) – MSDS for Products

Slide information courtesy J. Chamberlin
Water Solubility

There is a wide range of water solubility among the neonicticoides. Dinotefuran (Safari, Transtect, Zylam) is highly water soluble.
$K_{oc}$ Values of Neonicotinoids:

- Clothianidin: 16
- Imidacloprid: 440
- Acetamiprid: 267
- Thiamethoxam: 26
- Dinotefuran: 26

Source Data: EPA Pesticide Fact Sheets
Koc Value

There is wide range of Koc values (measure of adsorption to organic matter) among the neonicotinoids. This affects mobility within plants.

Dinotefuran (Safari, Transtect, Zylam) has a much lower Koc value than do other neonicotinoids.
Dinotefuran (Safari, Zylam, Transtect)
Not all Neonicotinoids are alike:

- UV stability
- Water solubility
- Rate of uptake by plants
- Mobilization within plants
- Host range of susceptible insects
Acute Toxicity of Neonicotinoids to Adult Honey Bees
(Dermal LD50 in micrograms/bee)

- Acetamiprid 8.09
- Imidacloprid 0.08
- Dinotefuran 0.022
- Thiamethoxam 0.024
- Chlothianidin 0.044
Acute Toxicity of Neonicotinoids to Adult Honey Bees
(Oral LD50 – micrograms/bee)

- Acetamiprid: 14.53 micrograms/bee
- Imidacloprid: 0.005 micrograms/bee
- Dinotefuran: 0.056 micrograms/bee
- Thiamethoxam: 0.005 micrograms/bee
- Chlothianidin: 0.0003 micrograms/bee
Neonicotinoids are effective against most phloem-feeding insects.
Aphids and soft scales suck sap from the phloem and excrete honeydew.
If the insect excretes honeydew, neonicotinoids will almost always work well for its control.
Most all neonictinoids have good activity against beetle larvae and sawfly larvae.
Armored scales – poor, with an exception

Spider mites – often terrible

Neonicotinoid host range, continued

Caterpillars/Lepidoptera – poor with some exceptions
Imidacloprid formulations
Over-the-Counter Imidacloprid Formulations
Some imidacloprid formulations sold to control parasites of pets

Active ingredient: imidacloprid

Active ingredients: imidacloprid, permethrin, pyriproxifen
Imidacloprid Characteristics and Niche

• **Advantages**
  – Good persistence with soil application
  – Easy to apply soil treatment
  – Inexpensive
Imidacloprid Characteristics and Niche

• Limitations
  – Poor on caterpillars
  – Weak on armored scales
  – Tends to make spider mite problems worse
  – High risk for pollinators
Imidacloprid
Control Range

Yes – Soft Scale

No – Armored Scale
Soft Scales

Families Coccidae, Eriococcidae

<table>
<thead>
<tr>
<th>Oak lecanium</th>
<th>European elm scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pine tortoise scale</td>
<td>Cottony maple scale</td>
</tr>
</tbody>
</table>
Soft Scales vs. Armored Scales

Feeding Site: Phloem
Soft scales produce honeydew

Feeding Site: Cells, often of the cambium
Armored scales do not produce honeydew
Systemic insecticides for wood borers?
Imidacloprid for Borers?

Yes.....but
Imidacloprid will not work well on borers that are the larval stage of moths.
Lilac/ash borer

Not effective
Peach tree borer larval tunneling in base of plant

Not effective
Zimmerman pine moth injury

Not effective
Imidacloprid will *not* work well if the borer spends much of its life in the heartwood of the plant.
Imidacloprid soil drenches may work well against flatheaded borer larvae (aka metallic wood borers)
Four common *Agrilus* species metallic wood borers

- Bronze cane borer / Rose stem girdler
- Bronze birch borer
- Twolined chestnut borer
- Honeylocust borer
Neonicotinoids for emerald ash borer (and other flatheaded borers)

Imidacloprid as a soil injection, soil drench

Dinotefuran as a bark spray
Commercial formulations for ornamentals

Retail formulation

Dinotefuran formulations
Dinotefuran Characteristics and Niche

**Advantages**
- Rapid uptake
- Mobile in plant
- Capable of trunk spray use

**Limitation**
- High risk for pollinators
Soil Systemic Insecticides and Scale Insects?

- Imidacloprid (Merit, Mallet, Zenith, etc.)
  - *Soft scales only*
- Dinotefuran (Safari, Zylam, Transtect)
  - *Soft scales and armored scales*
Dinotefuran
Control Range

Yes – Soft Scale

Yes – Armored Scale
Armored Scales  Family Diaspididae

- Pine needle scale
- Oystershell scale
- Poplar/willow scale
- Black pineleaf scale
Basal trunk spray with dinotefuran (Safari, Zylam)
Whole tree sprays produce surface residues on all foliage. Natural enemies are killed. Natural controls are wasted.

Treatment area limited to bark of lower trunk. Impacts on natural enemies are minimized.
Commercial formulation for ornamentals

Retail formulations

Acetamiprid products

Commercial formulation for fruits and vegetables
Acetamiprid Characteristics and Niche

• **Advantages**
  – Stable in UV
  – Good on caterpillars
  – Fairly mobile in plant
  – Low toxicity to honey bees

• **Limitation**
  – Not suitable for soil application
Acetamiprid can be used as a systemic insecticide to be sprayed.
Ryania speciosa

Botanical source that lead to development of the anthranilic diamides

Powdered stems are the source of the insecticide ryania.

Active ingredient: ryanodine
Anthranilic Diamides

• Based on chemistry of active compounds in ryania (ryanodines)
  – Effects ryanodine receptors associated with insect muscle

• Some systemic activity in plants
  • Extremely low toxicity to mammals (Category IV)
  • Recently registered products:
    – chlorantraniliprole (Acelepryn)
    – cyantraniliprole (Ference – \textit{turfgrass label only})
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Chlorantraniliprole
(Acelepryn, Grub-Ex)
HAZARDS TO HUMANS AND DOMESTIC ANIMALS
When used as directed this product does not present a hazard to humans or domestic animals.

Personal Protective Equipment
Applicators and other handlers must wear:
• Long-sleeved shirt and long pants.
• Shoes plus socks.

Applicator caution with chlorantraniliprole/Acelepryn

Class IV Toxicity – No Caution Label

No cautionary language for protection of bees
The original federal label just includes certain caterpillars as target pests.

### TABLE 3: Foliar Ornamental Application Rates

<table>
<thead>
<tr>
<th>Target Pests</th>
<th>Product (fl oz) per 100 Gallons</th>
<th>Lb Al per 100 Gallons</th>
<th>Percent Al (wt/vol)</th>
<th>Maximum Gallons per Acre per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf-feeding caterpillars (such as bagworms and tussock moth)</td>
<td>1</td>
<td>0.013</td>
<td>15.6</td>
<td>0.00156</td>
</tr>
<tr>
<td>Major caterpillars (including whitemarked tussock moth)</td>
<td>2</td>
<td>0.026</td>
<td>31.3</td>
<td>0.00313</td>
</tr>
<tr>
<td>For maximum residual control of the pests listed above</td>
<td>4</td>
<td>0.052</td>
<td>62.5</td>
<td>0.0625</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>0.104</td>
<td>125</td>
<td>0.0125</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.208</td>
<td>250</td>
<td>0.025</td>
</tr>
</tbody>
</table>

**Soil Applications:**

Acelepryn is a systemic product and will be translocated upward into the plant from root uptake. Soil treatment application rates are listed in Table 4. To assure optimum effectiveness, the product

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**Section 2(ee) Recommendation**

**Effective:** 07/10/2015  
**Expires:** 11/19/2018

AK1489002BC0715 Additional Pests of Ornamental Plants (Exterior Landscapes and Interior Plantscapes) in AK, AL, AR, AZ, CO, CT, DC, DE, FL, GA, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, OH, OK, PA, RI, SC, SD, TN, UT, VA, VT, WA, WI, WV and WY

**For Use Against:**  
Banded ash clearwing, Fall webworm, Gypsy moth caterpillars, Hemlock Wooly Adelgid, Japanese beetle (adult), Lesser peachtree borer, Magnolia scale, Rhododendron borer, Rhododendron lace bug, Sawfly, Viburnum borer, Zimmerman pine moth
Chlorantraniliprole Niche

- Very low hazard to vertebrates
- Very low hazard to bees
- Target pests include:
  - All leaf chewing caterpillars
  - Wood borers that are caterpillars
  - Leaf chewing beetles, including Japanese beetle
  - White grubs in lawns
Insect Growth Regulators (IGRs)

• Affect growth processes of arthropods/disrupt hormones

• Diverse chemistry, mode of action
  – Mimic/disrupt molting hormone (ecdysone)
  – Mimic/disrupt juvenile hormone
  – Prevent normal chitin synthesis
## Interaction of Ecdysone - JH in Regulating Growth and Metamorphosis

<table>
<thead>
<tr>
<th>Ecdysone</th>
<th>JH</th>
<th>Development</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>immature characters maintained during larval stages</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tissue differentiation during pupal stage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tissue differentiation completed</td>
</tr>
</tbody>
</table>

*Note: Diagram shows stages of development with corresponding ecdysone and JH levels.*
Potato beetles (top row) killed by IGR insecticide that prevented successful molting to pupal stage.
Insect Growth Regulators (IGRs)

- Acute Toxicity to Humans: Low
- Non-target Effects:
  - Birds: Low toxicity
  - Fish: Low toxicity
- Most are highly selective in effects on beneficial insects
Azadirachtin *indica* (Neem)

Neem seed extracts contain the active ingredient azadirachtin.
Azadirachtin affects the molting hormone ecdysone. This disrupts many things including ability to molt and to reproduce successfully.
Some target pests of azadirachtin

Leaf beetles

Caterpillars

Flatheaded borers

Soft scales
Neem

• Active Ingredients: *Azadirachtin* primarily, oil fractions have some uses.
• Disrupts the molting hormone (ecdysone) of susceptible insects
Examples of products that contain azadirachtin – but no neem oil
Examples of products that contain the oil fraction from neem seed extracts, but has had the azadirachtin removed
Horticultural oils may also be derived from cottonseed, soybean, neem seed, sesame, fish, and many other sources.
Methoprene

Altosid Pellets WSP

A juvenile hormone-derived insecticide
Mosquito Life Cycle

Adult (left)

Larvae/wrigglers (lower left)

Pupae/tumblers (below)
Pyriproxifen

Mimics juvenile hormone.
Target pests: Scale insects, whiteflies, aphids (suppression)

Special Colorado Niche: A selective insecticide for use on scale insects

Excellent against neonicotinoid-resistant European elm scale
Microbial Insecticides

• Microbes Used as Insecticides
  – Bacteria
  – Viruses
  – Fungi
    • Microsporidia

• Insecticides Derived from Microbes
Bacillus thuringiensis

- Derived from a widely distributed soil bacterium
- Active ingredient a toxic protein crystal that destroys cells of the midgut
- Used as a stomach poison
Treated Foliage Consumed
Feeding Inhibition (1 Hour)

- Toxin Crystals Dissolve in Gut.
- Larvae Stop Feeding.
- Growth Stops.
Death (2-5 Days)

- Starvation
- Gut Disruption
Bacillus thuringiensis var. kurstaki and B.t. var. aizawi

Used to control leaf feeding caterpillars
Bacillus thuringiensis var. israelensis

Used to control larvae of certain kinds of flies (e.g., mosquitoes, fungus gnats, black flies)
Bacillus thuringiensis var. galleriae

A newly developed strain of Bt that can control adult Japanese beetles - and can be used on plants in flower!
Key problem with control of Japanese beetle adults on many plants

Overlap of adult feeding on flowers – and use of those flowers by pollinators

Never apply persistent insecticides to plants that are in flower and attractive to pollinators!!
Treated with *Bacillus thuringiensis* var. *galleriae*

Water check
Bacillus thuringiensis va. galleriae for adult Japanese beetle?

Provides **good reduction in feeding** injury by Japanese beetle

Provides **fair mortality** of Japanese beetles and mortality is slow

Persistence of effects probably **a few days**
None. You can apply this product to plants in bloom when bees are visiting.
After application:

Are they dead?  
(probably not)
Are they still feeding?  
(probably not)
Controls Most Effective for Control of Japanese Beetle Adults……

- **Most pyrethroids** (e.g., cyfluthrin, permethrin, bifenthrin)
- Carbaryl
- Imidacloprid
- Acetamiprid
- Chlorantraniliprole
  - Acelepryn
- *Bacillus thuringiensis* var. *galleriae*
  - BeetleGON
  - BeetleJUS

….and can be used on plants in bloom!
Microbial Insecticides

- Microbes Used as Insecticides
  - Bacteria
  - Viruses
  - Fungi
    - Microsporidia

- Insecticides Derived from Microbes
Spinosad

• Microbial derived insecticide (spinosyns)
  – Secreted by a bacterium (Saccharopolyspora spinosa)

• Low mammalian toxicity
  – Low hazard to most beneficial insect
  – Some formulation allowed in Certified Organic production

• Target Species
  – Leaf chewers (caterpillars, beetles, sawflies)
  – Thrips
Some Spinosad Formulations

- Conserve® SC
- Entrust® SC
- Spintor
- Monterey Garden Insect Spray

Turfgrass, ornamentals, many fruits and vegetables

Agricultural label - Organic

One of many products sold through nurseries
Some insects that are well-controlled by spinosad
MAGIC®
PEST SCOURGE

- Kills everything
- Use on all plants
- Works instantly
- Completely safe

INSECTS
mites
WEEDS
DISEASES
IRIS AGENTS
RODENTS

"Works like a charm."

Try me!
There are over two dozen modes of action of insecticides and miticides.

IRAC - Insecticide Mode of Action Classification
Insecticide Resistance Action Committee  www.irac-online.org

Introduction
Insecticide Resistance Action Committee (IRAC) promotes the use of a Mode of Action (MoA) classification of insecticides as the basis for effective and sustainable insecticide resistance management (IRM). Insecticides are allocated to specific groups based on their target site. Reviewed and re-issued periodically, the IRAC MoA classification list provides farmers, growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of insecticides or acaricides in IRM programs. Effective IRM of this type preserves the utility and diversity of available insecticides and acaricides. Sample MoA groups are shown below.

Effective IRM strategies: Sequences or alternations of MoA
All effective insecticide resistance management (IRM) strategies seek to minimise the selection of resistance to any one type of insecticide. In practice, alternations, sequences or rotations of compounds from different MoA groups provide sustainable and effective IRM for pest Lepidoptera. This ensures that selection from compounds in the same MoA group is minimised, and resistance is less likely to evolve.
Applications are often arranged into MoA spray windows or blocks that are defined by the stage of crop development and the biology of the pest species of concern. Local expert advice should always be followed with regard to spray windows and timings. Several sprays may be possible within each spray window but it is generally essential to ensure that successive generations of the pest are not treated with compounds from the same MoA group. Metabolic resistance mechanisms may give cross-resistance between MoA groups, and where this is known to occur, the above advice must be modified accordingly. IRAC also provides general recommendations for resistance management tactics regarding specific MoA groups, e.g. neonicotinoids (Group 4A).

Growth & Development targets
Group 7 Juvenile hormone mimics
7A Juvenile hormone analogues (e.g. Methoprene)
7B Fenoxycarb, 7C Pyriproxifen
Group 10 Mitotic inhibitors
10A Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10B Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10C Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10D Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10E Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10F Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10G Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10H Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10I Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10J Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10K Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10L Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10M Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10N Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10O Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10P Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10Q Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10R Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10S Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10T Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10U Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10V Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10W Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10X Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10Y Clethodim, Clethodim, Clethodim, Clethodim, Clethodim
10Z Clethodim, Clethodim, Clethodim, Clethodim, Clethodim

Nerve & Muscle Targets
Group 1 Acetylcholinesterase (AChE) inhibitors
1A Carbamates (e.g. Methiocarb),
1B Organophosphates (e.g. Chlorpyrifos)
Group 2 GABA-gated chloride channel antagonists
2A Pentamethane Organophosphates (e.g. Endosulfan), Group 3 Sodium channel modulators
3A Pyrethroids, Pyrethroids (e.g. Cypermethrin, 3C-Semiothrin, 3B-Fenoxycarb),
Group 4 Acetylcholine receptor (mACHR) agonists
4A Neonicotinoids (e.g. Imidacloprid, Thiamethoxam),
4B Carbamate Nerve agents (e.g. Parathion-methyl, Parathion),
4C Pyrethroidic Nerve agents (e.g. Deltamethrin, Deltamethrin),
4D Pyrethroidic Nerve agents (e.g. Lambda-cyhalothrin, Lambda-cyhalothrin),
Group 8 Chloride channel activators Avermectins (e.g. Abamectin, Emamectin benzoate, Lepimectin),
Group 9 Chloride channel blockers Avermectins (e.g. Abamectin, Emamectin benzoate, Lepimectin),
Group 10 Modulators of Cholinergic Organs
10A Chlorpyrifos, 10B Pyrethroids, 10C Pyrethroids, 10D Pyrethroids, 10E Pyrethroids,
10F Pyrethroids, 10G Pyrethroids, 10H Pyrethroids, 10I Pyrethroids, 10J Pyrethroids,
10K Pyrethroids, 10L Pyrethroids, 10M Pyrethroids, 10N Pyrethroids, 10O Pyrethroids,
10P Pyrethroids, 10Q Pyrethroids, 10R Pyrethroids, 10S Pyrethroids, 10T Pyrethroids,
10U Pyrethroids, 10V Pyrethroids, 10W Pyrethroids, 10X Pyrethroids, 10Y Pyrethroids,
10Z Pyrethroids, 10A Pyrethroids, 10B Pyrethroids, 10C Pyrethroids, 10D Pyrethroids,
10E Pyrethroids, 10F Pyrethroids, 10G Pyrethroids, 10H Pyrethroids, 10I Pyrethroids,
10J Pyrethroids, 10K Pyrethroids, 10L Pyrethroids, 10M Pyrethroids, 10N Pyrethroids,
10O Pyrethroids, 10P Pyrethroids, 10Q Pyrethroids, 10R Pyrethroids, 10S Pyrethroids,
10T Pyrethroids, 10U Pyrethroids, 10V Pyrethroids, 10W Pyrethroids, 10X Pyrethroids,
10Y Pyrethroids, 10Z Pyrethroids, 10A Pyrethroids, 10B Pyrethroids, 10C Pyrethroids,
Insecticide Resistance Action Committee (IRAC) Web Site

http://www.irac-online.org/

Check the section on Mode of Action to learn of the various classes of insecticides that have been developed.
Presently there are 28 insecticide groups recognized with different modes of action.
This presentation will be posted at the Insect Information Website

- Housed at Department of Bioagricultural Sciences and Pest Management
  - Search “BSPM CSU”
- Within “Entomology”
- “Insect Information”
  - Extension presentations are posted at the bottom of the page, most recent at end
Insect Information

All materials needed in another accessible format can be made available upon request.

Arthropods of Colorado Fact Sheets
This is a listing of about 200 downloadable fact sheets related to insects and other "bugs" found in Colorado. It contains fact sheets that are written for the Colorado Arthropods of Interest series and the Extension fact sheets that are related to insects.

Some Entomology Hot Links:
- Colorado Hemp Insect Website
- Western Colorado Entomology Website
- IFM Images/bugwood (Cranehead)
- IFM Images/bugwood (Pears)
- Entomology Resources List
- Honey Bee Swarm Hotlines

Miscellaneous Insect Information
This contains a variety of downloadable fact sheets and pamphlets on diverse miscellaneous subjects, from "Bug Mugs" and "Life in a Colorado Water Garden" to "Mystery Bites and Itches" and "Commercially Available Sources of Biological Control Organisms: Sources and Uses in Colorado."

Hemp Insect Information
This links directly to the Hemp Insect Website, which includes information being developed to better recognize and manage insects associated with industrial hemp.

Master Gardener Information
This includes the handouts and PowerPoint presentations (as PDF) used in Master Gardener Entomology training. These will get updated annually at the end of the winter/spring training programs.

Recent Extension Presentations
This is a listing that provides the PowerPoint presentations (as PDF) of most Extension entomology programs conducted during the past 12 months.

Top of the Insect Information Website

Bottom of the Website page
Thank you!

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