Insecticide Mode of Resistance
Utah Pests In-Service Training
Ryan Davis

Outline

1) Insect resistance
2) Insecticide Mode of Action (MoA)
3) Cover 9 common MoA’s
Insect Resi stance:

Insect resistance: occurs when a population of insects builds up a tolerance to a specific chemical, or group of chemicals with the same Mode of Action (MoA).
Importance/
Resistance
MoA Group 2
MoA Group 3
MoA Group 4
MoA Group 5

Finally
Done!

MoA Group 1
MoA Group 7

Quiz

Introduction

Insect Resistance
Stage 1
Insect Resistance
Stage 2

= aphid (susceptible)

= aphid (resistant)

= predator

Finally
Done!

Introduction
Insect Resistance
Stage 3

= aphid (susceptible)
= aphid (resistant)
= predator
Insect Resistance
Stage 4

= aphid (susceptible)

= aphid (resistant)

= predator

Finally Done!
How Can You Help Reduce Insect Resistance to Insecticides?

1) consult extension agent for spray recommendations

2) minimize insecticide use by using early-maturing or pest-tolerant crops

3) use non-chemical techniques first (eg. Biological sprays, crop rotation, etc.)

4) select insecticides and management tools which preserve natural enemies

5) use products at their full, recommended doses

6) use well-maintained equipment to achieve full and proper coverage

7) target younger, more susceptible insect stages
How Can You Help Reduce Insect Resistance to Insecticides?

8) use appropriate local economic thresholds and spray intervals

9) Follow label or extension recommendations on rotating different classes (MoA’s) of insecticides

10) When multiple applications per year are needed rotate different MoA’s

11) If control is not achieved do NOT spray the same insecticide, switch to one with a different MoA

12) Do NOT mix chemicals for use against one target pest

13) Withhold a chemical from use until the population once again becomes susceptible. Treat with a different MoA insecticide in the mean time.

14) Use insecticides that are specific to your target pest (eg. narrow spectrum)
MODE of ACTION (MoA)

What is Mode of Action?

-is the sum of anatomical, physiological and biochemical interactions and responses that result in toxic action of a chemical, as well as the physical (location) and molecular (degradation) fate of the chemical in the organism.
What?

MoA = how an insecticide kills!
### Levels of Classification

- **Main Group**
- **Chemical Sub-group**
- **Active Ingredients**
- **Product Name**

### Example

1. Acetylcholinesterase inhibitors

#### 1A. Carbamates
- **Carbaryl**
  - SEVIN
  - BONIDE
  - ROSE RX
  - ECO BRAN 2%
  - HI-YIELD 5%
  - GARDEN & PET DUST
  - 58 products

#### 1B. Organophosphates
- **Diazinon**
  - DIAZINON 50W
  - DIAZINON AG 500W
  - TERMINATOR II INSECTICIDE CATTLE EAR TAG
  - 9 products

- **28 MoA’s**
- **7 MoA’s are unknown**

*Physical toxicants are not listed: oils, soaps, dusts, etc.*
What to talk about?

*Surveyed 2008 PNW Insect Management Handbook

- Selected commonly recommended insecticides for ornamental and turf

- Chose insecticides based on use frequency and “coolness factor”

- http://pnwpest.org/pnw/insects

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Insecticide Class</th>
<th>O = Onram.</th>
<th>T = Turf</th>
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<tbody>
<tr>
<td>Bt</td>
<td>biological</td>
<td>O</td>
<td>T</td>
</tr>
<tr>
<td>nematodes</td>
<td>&quot; &quot;</td>
<td>O</td>
<td>T</td>
</tr>
<tr>
<td>azadirachtin</td>
<td>botanical*</td>
<td>O</td>
<td>-</td>
</tr>
<tr>
<td>carbaryl</td>
<td>carbamate</td>
<td>O</td>
<td>T</td>
</tr>
<tr>
<td>halofenozide</td>
<td>diacylhydrazines</td>
<td>-</td>
<td>T</td>
</tr>
<tr>
<td>insecticidal soap</td>
<td>fatty acid</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>hydramethylnon</td>
<td>hydramethylnon</td>
<td>-</td>
<td>T</td>
</tr>
<tr>
<td>imidacloprid</td>
<td>neonicitinoid</td>
<td>O</td>
<td>T</td>
</tr>
<tr>
<td>acephate</td>
<td>organophosphate</td>
<td>O</td>
<td>T</td>
</tr>
<tr>
<td>disulfoton</td>
<td>&quot; &quot;</td>
<td>O</td>
<td>-</td>
</tr>
<tr>
<td>malathion</td>
<td>&quot; &quot;</td>
<td>O</td>
<td>-</td>
</tr>
<tr>
<td>chlorpyrifos</td>
<td>&quot; &quot;</td>
<td>-</td>
<td>T</td>
</tr>
<tr>
<td>fenbutatin-oxide</td>
<td>organotin</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>horticultural oil</td>
<td>petroleum distillate</td>
<td>O</td>
<td>-</td>
</tr>
<tr>
<td>pyrethrins/pyrethrum</td>
<td>pyrethrin</td>
<td>O</td>
<td>-</td>
</tr>
<tr>
<td>bifenthrin</td>
<td>pyrethroid</td>
<td>O</td>
<td>T</td>
</tr>
<tr>
<td>esvenvalerate</td>
<td>&quot; &quot;</td>
<td>O</td>
<td>-</td>
</tr>
<tr>
<td>permethrin</td>
<td>&quot; &quot;</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>cyfluthrin</td>
<td>&quot; &quot;</td>
<td>-</td>
<td>T</td>
</tr>
<tr>
<td>lambda-cyhalothrin</td>
<td>&quot; &quot;</td>
<td>-</td>
<td>T</td>
</tr>
<tr>
<td>spinosad</td>
<td>spinosyn</td>
<td>O</td>
<td>T</td>
</tr>
</tbody>
</table>
Mode of Action (MoA) Outline

1. Carbamates and Organophosphates
2. Pyrethroids, Pyrethrins
3. Neonicitinoids
4. Spinosyns
5. Insect Growth Regulators (IGR): Juvenile Hormone
6. Oils
7. Entomopathogenic nematodes
8. Dusts
9. *Bacillus thuringiensis* (Bt)
General Nerve Overview

- Glands
- Senses
- Muscle
General Nerve Overview

-neuron
-axon
-neurotransmitter
-receptor
-synapse
-nerve impulse
MoA Group 1. Acetylcholinesterase Inhibitors: Carbamates, Organophosphates

MoA Group 1A and 1B Examples:

- 1A: SEVIN, FURADAN, MESUROL

- 1B: ACEPHATE, DURSBAN, DIAZINON, MALATHION
MoA Group 1. Acetylcholinesterase Inhibitors: Carbamates, Organophosphates
MoA Group 1. Acetylcholinesterase Inhibitors: Carbamates, Organophosphates

neurotransmitter = acetylcholine = neurotransmitter inhibitor = acetylcholinesterase = neurotransmitter inhibitor

insecticide = insecticide inhibitor

nerve impulse

post-synaptic cell
MoA Group 1. Acetylcholinesterase Inhibitors: Carbamates, Organophosphates

Rapid firing of nerve impulses: convulsion, paralysis, death (respiratory failure)
MoA Group 3: Sodium Channel Modulators
Pyrethroids, Pyrethrins, DDT, Methoxychlor

Group 3 Examples:

- 3A: TALSTAR, ALOFT, Bifenthrin, WARRIOR, ADJOURN, Permethrin, Pyrethroids, Pyrethrins

- 3B: DDT, Methoxychlor
MoA Group 3: Sodium Channel Modulators
Pyrethroids, Pyrethrins, DDT, Methoxychlor

Sodium ions = 🦢
Sodium channel blocker (agonist) = 🦢
Sodium ion channel = 🕺
MoA Group 3: Sodium Channel Modulators
Pyrethroids, Pyrethrins, DDT, Methoxychlor

Sodium ions = 🍈
Sodium ion channel = 📦
Insecticide = ✗
Sodium channel blocker (agonist) = 🐝

AXON

= 🐝
MoA Group 3: Sodium Channel Modulators
Pyrethroids, Pyrethrins, DDT, Methoxychlor

Side Effects: stimulate repetitive nerve discharges (twitching=“DDT Jitters”), leading to paralysis, and death.

Both Group 3A and 3B are more effective at colder temperatures
MoA Group 4: Nicotinic Acetylcholine Receptor Agonists
Neo-nicotinoids (merit), and Nicotine

Group 4 Examples:

- 4A: MERIT, SAFARI, BAYER ADVANCED 12-MONTH…

- 4B: FERTI-LOME DOG AND RABBIT RIDDER, FULEX NICOTINE FUMIGATOR
MoA Group 4: Nicotinic Acetylcholine Receptor Agonists
Neo-nicotinoids (merit), and Nicotine

neurotransmitter = acetylcholine = 🐛
nicotinic acetylcholine receptors = 🎆
sodium ion = 🥤

nerve impulse
MoA Group 4: Nicotinic Acetylcholine Receptor Agonists
Neo-nicotinoids (merit), and Nicotine

neurotransmitter = acetylcholine = 

nicotinic acetylcholine receptors = 

nicotine = 

sodium ion = 

nerve impulse
MoA Group 4: Nicotinic Acetylcholine Receptor Agonists
Neo-nicotinoids (merit), and Nicotine

Side Effects (neo-nicotinoids target insects, not mammals): increased or decreased heart rate, excitation, convulsions, paralysis, and death
MoA Group 5: Nicotinic Acetylcholine Receptor Allosteric Activators

Spinosyns

Group 5 Examples:

5: Spinosad, CONSERVE, ENTRUST, SUCCESS
MoA Group 5: Nicotinic Acetylcholine Receptor Allosteric Activators
Spinosyns

Where does Spinosad come from?

- Soil in an abandoned rum distillery on a Caribbean Island
- By-product of a bacterial fermentation of corn, cottonseed flour, soybean flour, glucose, methyl oleate, and calcium carbonate.
- Compatible with organic farming/gardening practices
MoA Group 5: Nicotinic Acetylcholine Receptor Allosteric Activators

Spinosyns

neurotransmitter = acetylcholine = 🍊
nicotinic acetylcholine receptors = 🩸
spinosyn = 🚤
sodium ion = 🌞

nerve impulse
MoA Group 5: Nicotinic Acetylcholine Receptor Allosteric Activators

Spinosyns

- Neurotransmitter = Acetylcholine
- Nicotinic acetylcholine receptors
- Spinosyn
- Sodium ion

Diagram:
- Nerve impulse
- Spinosyn binding to receptor
- Neuron activation
MoA Group 5: Nicotinic Acetylcholine Receptor Allosteric Activators

Spinosyns

Side Effects: increased or decreased heart rate, excitation, convulsions, paralysis, and death
MoA Group 7: Juvenile Hormone Mimics (IGR)

Group 7 Examples:

7A: GENTROL, ENSTAR II INSECT GROWTH REGULATOR,

7B: AWARD

7C: SENTRY, SERGEANTS GOLD (pet flea and tick products)
Juvenile Hormone Analogues, Fenoxycarb, and Pyriproxyfen

Juvenile Hormones (JH) regulate insect growth
MoA Group 7: Juvenile Hormone Mimics (IGR)

Amount of JH = [HI → LOW]

Normal

SPRAY APPLIED

egg instar 1 instar 2 instar 3 instar 4 extra instar no adult formed
MoA Group 7: Juvenile Hormone Mimics (IGR)

Other groups that affect insect growth:

MoA Group 10: Mite growth inhibitors

MoA Group 15: Inhibitors of chitin (exoskeletal) biosynthesis, type 0, Lepidopteran

MoA Group 16: Inhibitors of chitin biosynthesis, type 1, Homopteran

MoA Group 17: Molting disruption, Dipteran

MoA Group 18: Ecdysone receptor agonists (halofenozide)
MoA (Physical toxicant): Horticultural Oil

Best for: eggs, scales (adult and crawler), blister/rust mites, spider mites, thrips, whiteflies, psyllids, etc.

Product Names:
- Bonide
- Horticultural Oil Spray
- IFA Dormant Oil Spray
- Supreme Oil
Importance/Resistance
MoA Group 2
MoA Group 3
MoA Group 4
MoA Group 5

Finally Done!

MoA Nematode
MoA Group 7

Quiz

HORTICULTURAL OIL
Lateral view of abdominal segments

- thorax
- head
- abdomen
- tergite
- spiracle
- sternite
MoA (Biological: Microbial disruptors of insect midgut membranes): Entomopathogenic nematodes

## Common nematode families and preferred hosts:

<table>
<thead>
<tr>
<th>Steinernematidae</th>
<th>Heterorhabditidae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual bluegrass weevil</td>
<td>Black turfgrass ataenius</td>
</tr>
<tr>
<td>Bluegrass billbug</td>
<td>European chafer</td>
</tr>
<tr>
<td>Hunting billbug</td>
<td>Green June beetle</td>
</tr>
<tr>
<td>Black cutworm</td>
<td>Japanese beetle</td>
</tr>
<tr>
<td>Dog/cat flea larvae</td>
<td>May/June beetles</td>
</tr>
<tr>
<td>European crane fly</td>
<td>No. masked chafer</td>
</tr>
<tr>
<td>Armyworms</td>
<td>So. masked chafer</td>
</tr>
<tr>
<td>Sod webworms</td>
<td>SW. masked chafer</td>
</tr>
<tr>
<td></td>
<td>West. masked chafer</td>
</tr>
</tbody>
</table>

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Suppliers of beneficial organisms in North America:
[http://www.cdpr.ca.gov/docs/pestmgt/ipminov/ben_supp/contents.htm](http://www.cdpr.ca.gov/docs/pestmgt/ipminov/ben_supp/contents.htm)

*Dr. Parwinder Grewal, The Ohio State University. [http://www.oardc.ohio-state.edu/nematodes/turfgrass_pest_management.htm](http://www.oardc.ohio-state.edu/nematodes/turfgrass_pest_management.htm)*
Importance/Resistance

MoA Group 2

MoA Group 3

MoA Group 4

MoA Group 5

Finally Done!

MoA Group 7

Quiz

Introduction

Nematodes
Nematodes are not compatible with the following chemicals:

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Trade name</th>
<th>Chemical</th>
<th>Trade Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anilazine</td>
<td>Dyrene</td>
<td>Fipronil</td>
<td>Chipco Choice</td>
</tr>
<tr>
<td>Azadirachtin</td>
<td>Azatin</td>
<td>Insecticidal Soap</td>
<td>Various</td>
</tr>
<tr>
<td>Azinphosmethyl</td>
<td>Guthion</td>
<td>Isazophos</td>
<td>Triumph</td>
</tr>
<tr>
<td>Bendiocarb</td>
<td>Turcam</td>
<td>Methomyl</td>
<td>Lannate</td>
</tr>
<tr>
<td>Carbofuran</td>
<td>Furadon</td>
<td>Oxamyl</td>
<td>Vydate</td>
</tr>
<tr>
<td>Carbaryl</td>
<td>Sevin</td>
<td>2-4-D</td>
<td>Various</td>
</tr>
<tr>
<td>Chlorpyriphos</td>
<td>Dursban</td>
<td>Trichlorfon</td>
<td>Dylox</td>
</tr>
<tr>
<td>Ethoprop</td>
<td>Mocap</td>
<td>Triclorpyr</td>
<td>Turflon, Confront</td>
</tr>
<tr>
<td>Fenamiphos</td>
<td>Nemacur</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

http://www.oardc.ohio-state.edu/nematodes.htm
MoA (Physical Toxicant): Insecticidal Dust

Best against soft-bodied insects such as: aphids, caterpillars,

Types of dust:
- Boric acid
- Diatomaceous earth (DE)
- Silica gel/Aerosilica

The following slide is rated R for graphic insect violence and dust.
Insecticidal dust cuts through insect cuticle

Without cuticle insect looses water
MoA (Microbial disruptor of insect midgut membranes): *Bacillus Thuringiensis*

Best against: Fly, moth, and sawfly larvae (caterpillars)

Product Names: Bonide, Dipel, Thuricide (not in Kelly registry)

Species and subspecies:

- *Bacillus thuringiensis* subsp. *israelensis*
- *Bacillus sphaericus*
- *Bacillus thuringiensis* subsp. *aizawai*
- *Bacillus thuringiensis* subsp. *kurstaki*
- *Bacillus thuringiensis* subsp. *tenebrionis*
Bacillus thuringiensis
Importance/Resistance

MoA Group 2

MoA Group 3

MoA Group 4

MoA Group 5

Finally

Done!

MoA Nematode

Introduction Bt Cry toxin protein

Cry toxin protein

midgut cuticle

midgut epithelial cells
Importance/Resistance
MoA Group 2
MoA Group 3
MoA Group 4
MoA Group 5

Finally Done!

MoA Nematode
MoA Group 7

Quiz

Introduction Bt
Things to remember

1. Insect resistance is caused by using insecticides within the same group, sub-group, active ingredient, or product.

2. Rotate insecticides from different MoA main groups as part of your pest control program.

3. Tank mixing of chemicals for one target pest will result in resistance of two chemicals at once.

4. Contact county agent or UPPDL for spray recommendations.

5. Insecticides aren’t just “magical liquids…” they alter arthropod, mammalian, etc., bodily functions and can cause short- and long-term health problems. Always wear proper equipment when applying pesticides.
Thank You; Questions?

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Visit: utahpests.usu.edu

ID before you spray! Please send samples.
How Resistance Works

Genetics play the key role in resistance

<table>
<thead>
<tr>
<th>Expression</th>
<th>Formula</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p^2 \times p^2$</td>
<td>$S^A S^A S^B S^B$</td>
<td>about 100% of population</td>
</tr>
<tr>
<td>$2pq \times p^2$</td>
<td>$R^A S^A S^B S^B$</td>
<td>0.0002%</td>
</tr>
<tr>
<td>$p^2 \times 2pq$</td>
<td>$S^A S^A R^B S^B$</td>
<td>0.0002%</td>
</tr>
<tr>
<td>$4p^2q^2$</td>
<td>$S^A R^A S^B R^B$</td>
<td>0.00000002%</td>
</tr>
</tbody>
</table>

Richard Roush, The University of Melbourne, Melbourne, Victoria, Australia
Rotations, mixtures and managing cross-resistance  ESA, Nov. 2008
Group 2: GABA-gated chloride channel antagonists: cyclodiene, organochlorines, and phenylpyrazoles

Group 2 Examples:

- 2A: ENDOSULFAN, THIONEX

- 2B: FIPRONIL, TERMIDOR, MAXFORCE BAITS
Group 2: GABA-gated chloride channel antagonists: cyclodiene, organochlorines, and phenylpyrazoles
Group 2: GABA-gated chloride channel antagonists: cyclodiene, organochlorines, and phenylpyrazoles
Group 2: GABA-gated chloride channel antagonists: cyclodiene, organochlorines and phenylpyrazoles

Side Effects: Hyperactivity, tremors, convulsions, staggering, difficulty breathing, nausea, vomiting, diarrhea, lack of coordination, unconsciousness, paralysis, death