Garden insect pest management using chemical tactics:
advanced training for Master Gardeners

Celeste Welty
Ohio State University
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Chemical Control

• History

• Classification of insecticides available for garden food crops
  – By origin
    • Natural
    • Synthetics
  – By mode of action

• The OMRI list

• Data on efficacy against common pests
History of insecticides

- **Sulfur**, Homer 1000 BC
- **Arsenic**, China AD 900
- **Mineral oil** for camel mange, 1300
- **Tobacco decoction** on pears, 1690
- **Pyrethrum** for fleas <1800
- **Paris Green** (copper aceto-arsenite), 1867
- **Kerosene + soap**, 1874
- **Lead arsenate**, 1892
- **DDT**, 1939
Insecticides, by Origin

- Minerals & elementals
- Oils & soaps
- Botanicals (plants)
- Diatomaceous earth
- Microbials
- Compounds derived from microbes
- Mimics of natural insect hormones
- Petroleum-based synthetic chemicals
Insecticides, by Mode of Action

- Nerve poisons
- Respiration disruptors
- Gut disruptors
- Insect growth regulators
- Suffocation agents
- Cuticle disruptors
Minerals & Elementals

• sulfur
• lime-sulfur
• kaolin (‘Surround At Home’)
• iron phosphate (slug baits)
• boric acid (for indoor pests only)
sulfur & lime-sulfur

• sulfur
  — Mostly for disease control
  — Kills some mites & thrips

• lime-sulfur
  — Mostly for disease control on tree fruit
  — Kills some scale insects
iron phosphate: slug bait
‘Surround’ on pumpkin
‘Surround’ on apple
Smothering agents

- Petroleum oil
- Soap (potassium salts of fatty acids)
Diatomaceous earth

- Silicon dioxide
- For indoor pests: sold alone
- For food crops: sold only in mix with pyrethrins + PBO
Insecticides from plants (botanicals)

- pyrethrum, from chrysanthemum
- azadirachtin, from neem tree
- rotenone, from cubé root
- capsaicin, from hot pepper
- garlic extract
Insecticides from plants (botanicals)

• **limonene**
  – from citrus peels
  – for indoor pests
• **nicotine**
  – from tobacco
• **sabadilla**
  – from seeds of tropical lily
  – cancelled
• **ryania**
  – from stems of So. American shrub
  – cancelled
neem:
azadirachtin
& neem seed oil →
(7 brands)
Rotenone

• Dust, or mix with water to spray
• More effective as dust
• Very low toxicity to bees
Repellents from plants:
capsaicin & garlic
Oils from plants

example: ‘Mite-X’ is cottonseed oil + clove oil + garlic oil
• Pyrethrins

• = Pyrethrum?

• = Pyrethroids?
- **Pyrethrum**: the raw natural product from dried flowers
  - Dalmatian Chrysanthemum (*Chrysanthemum cinerariaefolium*)
  - Persian Chrysanthemum (*Chrysanthemum coccineum*)

- **Pyrethrins**: the extracted active ingredients from pyrethrum
  - pyrethrin I
  - pyrethrin II
  - cinerin I
  - cinerin II
  - jasmolin I
  - jasmolin II

- **Pyrethroids**: synthetic mimics of pyrethrins
Pyrethrins + PBO*

*PBO= piperonyl butoxide, a synergist
What’s PBO?

• PBO = piperonyl butoxide
• A synergist
• When mixed with some insecticides, makes them more active
  — Most common with pyrethrins
  — Also used with pyrethroids, rotenone, & carbamates
• Prevents enzymes from detoxifying the a.i. before it acts on target site
Status of Pyrethrin Products

- **Pyrethrins + PBO** (piperonyl butoxide)
  - Many brands through 2005
  - Far fewer brands starting in 2006
- **Pyrethrins + oil**
  - Common in shops in 2006
- **Pyrethrins + soap**
  - Common in shops in 2006
- **Pyrethrins (alone)**
  - Sold in larger packages
  - For larger farms
Examples of pyrethrin products available

• Pyrethrins + PBO
  – FoxFarm ‘Don’t Bug Me’
  – Spectracide ‘Bug Stop For Gardens’

• Pyrethrins + oil
  – Garden Safe ‘Fruit & Vegetable Insect Spray’
  – Garden Safe ‘Houseplant & Garden Insect Spray’

• Pyrethrins + soap
  – Safer ‘Tomato & Vegetable Insect Killer’
  – Safer ‘Yard & Garden Insect Killer’

• Pyrethrins (alone)
• MGK’s ‘PyGanic 1.4 EC’
Microbial Insecticides

• **Micro-organisms** that cause disease in insects
  — *B.t.* (bacterium)
  — *Beauveria* (fungus)
  — *Nosema* (protozoan)
  — Viruses
  — Nematodes

• **Derived from micro-organisms**
  — spinosad (from actinomycete)
What is B.t.?

• A natural soil-borne bacterium
• Species: *Bacillus thuringiensis*
• produces crystal-like proteins that kill certain insects
• Produced by fermentation methods
• Discovered 1915; used since 1957
How does B.t. work?

• B.t. must be eaten by target insect
• B.t. contains toxins that are activated by insect’s gut enzymes
• toxins paralyze insect’s digestive tract
• feeding stops within 2 hours
• death takes 1 - 5 days
Bacteria for Insect Control

• B.T. = *Bacillus thuringiensis*
  - *B.t. kurstaki* (caterpillars)
  - *B.t. aizawai* (caterpillars)
  - *B.t. tenebrionis* (certain beetle larvae)
  - *B.t. israelensis* (mosquito larvae)
• *Bacillus popillae* (Milky Spore)
B.t. products

• Sprayable or dusts
  — For caterpillars:
    • DiPel, Thuricide
  — For Colorado potato beetle:
    • Potato Beetle Beater

• Transgenic crops
  — ‘Attribute’ sweet corn (5 acre minimum)
Sprayable B.t.: performance

• Sometimes erratic due to:
  – Breakdown in U.V. light
  – Reduced toxicity to older larvae
  – Incomplete spray coverage
  – Too long a spray interval

• Best if:
  – Target young larvae
  – Apply at 3-4 day intervals
  – Get thorough coverage (lot of water)
**Spinosad:** more brands

- Dow: Entrust
- Fertilome: Borer, Bagworm, Leafminer & Tent Caterpillar spray
- GreenLight: Lawn & Garden Spray Spinosad Concentrate
- Monterey: Garden Insect Spray
- Gardens Alive: Bulls-Eye Bioinsecticide
Insecticides, by **Mode of Action**

- Suffocation agents *(oils, soaps)*
- Cuticle disruptors *(diatomaceous earth)*
- Respiration disruptors *(rotenone)*
- Gut disruptors *(B.t.)*
- Insect growth regulators *(neem)*
- Nerve poisons
Insect growth regulators

• Mimics of insect growth hormones
  – juvenile hormone (neem)
  – molting hormone
  – chitin biosynthesis

• For control of caterpillars & other immature insects
Conventional petroleum-based synthetic insecticides: Nerve poisons

• 3 old classes: shrinking
  – Organo-chlorines (2 a.i.s)
  – Carbamates (1 a.i.)
  – Organo-phosphates (3 a.i.s)

• 1 class: growing
  – Pyrethroids (5 a.i.s)

• Other new classes:
  – Neonicotinoids: 1 a.i. OK for commercial food crops & home ornamentals, but not yet for garden food crops
Organochlorines

endosulfan (Thiodan)
dicofol (Kelthane): concentrates
Carbamate

carbaryl (Sevin)

concentrate  RTU
Organo-phosphates

- **malathion**
  - For use on many crops
- **disulfoton (Di-Syston)**
  - For only a few veg crops
- **dimethoate (Cygon)**
  - For only a few veg crops
- **diazinon**
  - Not sold since 2001
Pyrethroids: 5 for food crops

- permethrin
- cyfluthrin
- esfenvalerate
- lambda-cyhalothrin
- bifenthrin
Beware of similar names

esfenvalerate  
bifenthrin
<table>
<thead>
<tr>
<th>Crop</th>
<th>esfenvalerate</th>
<th>bifenthrin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broccoli, cabbage, cauliflower</td>
<td>Yes, 3 d PHI</td>
<td>Yes, 7 d PHI</td>
</tr>
<tr>
<td>Cuke, squash, pumpkin</td>
<td>Yes, 3 d PHI</td>
<td>Yes, 3 d PHI</td>
</tr>
<tr>
<td>Pepper, eggplant</td>
<td>Yes, 7 d PHI</td>
<td>Yes, 7 d PHI</td>
</tr>
<tr>
<td>Tomato</td>
<td>Yes, 1 d PHI</td>
<td>Yes, 1 d PHI</td>
</tr>
<tr>
<td>Sweet corn</td>
<td>Yes, 1 d PHI</td>
<td>Yes, 1 d PHI</td>
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<tr>
<td>Snap beans, green peas</td>
<td>Yes, 3 d PHI</td>
<td>Yes, 3 d PHI</td>
</tr>
<tr>
<td>Dry beans, dry peas</td>
<td>Yes, 21 d PHI</td>
<td>No</td>
</tr>
<tr>
<td>Potato</td>
<td>Yes, 7 d PHI</td>
<td>No</td>
</tr>
<tr>
<td>Radish, Carrot</td>
<td>Yes, 7 d PHI</td>
<td>No</td>
</tr>
<tr>
<td>Collards</td>
<td>Yes, 7 d PHI</td>
<td>No</td>
</tr>
<tr>
<td>Head lettuce</td>
<td>No</td>
<td>Yes, 7 d PHI</td>
</tr>
<tr>
<td>Lima beans</td>
<td>No</td>
<td>Yes, 3 d PHI</td>
</tr>
</tbody>
</table>
‘Biorational’
insect control products

- Microbials that are host-specific
- Pheromones (for mating disruption)
- Insect growth regulators
OMRI: The Organic Materials Review Institute

• Used by certified organic growers
• List of products applied to crops
  — Fertilizers
  — Pesticides
• Two categories:
  — ‘Allowed’
  — ‘Restricted’
Insect control products on the OMRI List

- **Behavioral control**
  - pheromone mating disruption

- **Microbial control**
  - viruses
  - B.t. (DiPel)

- **Smothering agents**
  - soaps
  - oils

- **Nerve poisons**
  - spinosad (Entrust)
  - pyrethrins (PyGanic)

- **Repellents**
  - kaolin (Surround)
  - neem
  - garlic
Bioassays

• Basic set-up
  – 8 oz deli dish
  – Leaf sprayed both sides
  – 24 & 48-hr mortality evaluation
  – Damage quantified for chewing pests

• Residual tests
  – Pests added after residue dry

• Direct tests
  – Pests added before spray
Bioassays to test efficacy of garden insecticides

• % Mortality, for all pests
• Damage, for chewing pests
• Importance:
  — #1: Prevention of damage
  — #2: Death of pest
Bioassays

• 2005
  – 10 pests
  – 16 chemicals

• 2006
  – 6 pests (4 repeats, 2 new)
  – 2 more chemicals
  – 3 more pyrethrins +/- PBO

• 2007
  – 4 pests (2 repeats, 2 new)
  – 1 more chemical
## Conventional Products Tested

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Brand</th>
</tr>
</thead>
<tbody>
<tr>
<td>bifenthrin</td>
<td>Ortho Bug-B-Gon Max Lawn &amp; Garden</td>
</tr>
<tr>
<td>carbaryl</td>
<td>Garden Tech Sevin Bug Killer</td>
</tr>
<tr>
<td>cyfluthrin</td>
<td>Bayer Advanced Garden Power Force</td>
</tr>
<tr>
<td>dicofol</td>
<td>Hi-Yield Kelthane Spray</td>
</tr>
<tr>
<td>endosulfan</td>
<td>Hi-Yield Thiodan</td>
</tr>
<tr>
<td>esfenvalerate</td>
<td>Ortho Bug-B-Gon Max Garden &amp; Landscape</td>
</tr>
<tr>
<td>lambda-cyhalothrin</td>
<td>Spectracide Triazicide</td>
</tr>
<tr>
<td>malathion</td>
<td>Bonide Malathion Insect Control</td>
</tr>
<tr>
<td>methoxyfenozide</td>
<td>Dow Intrepid</td>
</tr>
<tr>
<td>permethrin</td>
<td>Bonide Eight Garden &amp; Home</td>
</tr>
<tr>
<td>Ingredient</td>
<td>Brand</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td>azadirachtin</td>
<td>Safer BioNeem</td>
</tr>
<tr>
<td>B.T.</td>
<td>Bonide Thuricide BT; GreenLight Dipel Dust</td>
</tr>
<tr>
<td>capsaicin</td>
<td>Bonide Hot Pepper Wax</td>
</tr>
<tr>
<td>garlic extract</td>
<td>Garlic Barrier</td>
</tr>
<tr>
<td>neem seed oil</td>
<td>Garden Safe Fungicide-3</td>
</tr>
<tr>
<td>oil (cottonseed + clove + garlic)</td>
<td>Bonide Mite-X</td>
</tr>
<tr>
<td>pyrethrins + PBO</td>
<td>Schultz F&amp;V Spray; Spectracide BugStop</td>
</tr>
<tr>
<td>pyrethrins + oil</td>
<td>GardenSafe Fruit &amp; Veg. Insect Spray</td>
</tr>
<tr>
<td>pyrethrins + soap</td>
<td>Safer Tomato &amp; Vegetable Insect Killer</td>
</tr>
<tr>
<td>rotenone</td>
<td>Bonide Rotenone Insect Control</td>
</tr>
<tr>
<td>soap</td>
<td>Garden Safe Insecticidal Soap</td>
</tr>
<tr>
<td>spinosad</td>
<td>Fertilome Borer, Bagworm, …. Spray</td>
</tr>
</tbody>
</table>
Chewing pests
Sample of results

Most effective products at top of graph

Least effective products at bottom of graph

Common for the most effective products to have both **LOW damage** & **HIGH mortality**
Striped cucumber beetle tested on pumpkin leaves, 7/5/05; 4 replicates/treatment, 5 beetles/replicate
Striped Cucumber Beetle
tested on pumpkin leaves, 6/30/2006
5 replicates/treatment, 5 beetles/replicate
Striped Cucumber Beetle
tested on pumpkin leaves, 9/25/2006
3 replicates/treatment, 3 beetles/replicate
Spotted cucumber beetle
tested on pumpkin cotyledon & leaf, 8/22/05;
5 replicates/treatment, 5 beetles/replicate
Spotted cucumber beetle

2nd test with extra pyrethroids, tested on pumpkin leaves, 9/22/05;
5 replicates/treatment, 5 beetles/replicate
Spotted Cucumber Beetle tested on pumpkin leaves, 9/21/2006
3 replicates/treatment, 3 beetles/replicate

![Graph showing damage rating and percentage mortality after 48 hours for various treatments.](image-url)
Blister Beetle
tested on swiss chard leaves, 9/6/05
5 replicates/treatment; 2 beetles/replicate
Imported Cabbageworm

pyrethrins+PBO: D
BT dust: CD
spinosad: BCD
BT spray: ABCD
azadirachtin: ABC
carbaryl: ABC
methoxyfenozoide: AB
water: A

Broccoli leaf 7/24/07
P = 0.03

% Mortality
P = 0.25
Sucking pests
Two-spotted spider mite
tested on snap bean leaves, 10/26/05;
3 replicates/treatment, 30 mites/replicate

![Graph showing mean % mortality after 24 hours for different treatments.]

- **dicofol**: A
- **soap**: B
- **oil (Mite-X)**: B
- **pyrethrins+PBO**: BC
- **permethrin**: CD
- **water (control)**: D

Mean % Mortality after 24 hours
Melon Aphid
tested on pumpkin leaves, 10/5/05;
3 replicates/treatment, 10 aphids/replicate

Bar graph showing the mean % mortality of Melon Aphid after 24 hours:
- Pyrethrins + PBO: 100%
- Endosulfan: 100%
- Oil (Mite-X): 100%
- Esfenvalerate: 90%
- Carbaryl: 80%
- Soap: 70%
- Permethrin: 60%
- Neem oil: 50%
- Garlic: 40%
- Capsaicin: 30%
- Water (control): 20%
- Spinosad: 10%
- Azadirachtin: 0%

Legend:
- A: Highest mortality
- B: Lower than A, higher than BC
- C: Lower than BC, higher than CD
- D: Lower than CD
- MA: 10/5/05
Potato Aphid
tested on tomato leaves, 10/3/2006
3 replicates/treatment, 10 aphids/replicate
Potato Leafhopper, nymphs
tested on bean leaflet, 7/28/05;
3 replicates/treatment, 5 bugs/replicate
Squash bug, young nymphs
tested on zucchini leaf & petiole, 8/27/05
5 replicates/treatment, 5 bugs/replicate
Squash bug, adults
tested on zucchini leaf & petiole, 9/19/05;
5 replicates/treatment, 3 bugs/replicate

* Not registered for use on cucurbit crops
Squash bug

adult

nymph
Harlequin Bug (on kale)

3 replicates/treatment
3 bugs/replicate

nymph

adult
Natural Enemies
Lady Beetle

tested on broccoli leaves, 11/1/05;
3 replicates/treatment, 4 beetles/replicate
Efficacy of Pyrethrins

• Pyrethrins + PBO
  – Very effective in field & lab tests

• Pyrethrins + oil
  – Somewhat effective in lab tests

• Pyrethrins + soap
  – Not effective in lab tests

• Field data needed!!
Field trial on snap bean

- Late planting (seed late August)
- Heavy beetle pressure
- **Start sprays as soon as seedlings emerge**
- **Spray 10 times on 1- to 5-day schedule**
  - Azadirachtin
  - Capsaicin
  - Garlic
  - Neem seed oil
  - Pyrethrins
  - Rotenone
- **Spray 5 times on 5- to 8-day schedule**
  - Spinosad
- **Spray 4 times on 7- to 10-day schedule**
  - Carbaryl
  - Permethrin
  - Endosulfan
Field trial on snap beans
(bean leaf beetle + spotted cucumber beetle)

![Beetle Damage on Beans, 9/15/05]

- rotenone
- pyrethrins
- carbaryl
- permethrin
- azadirachtin
- capsaicin
- neem seed oil
- endosulfan
- spinosad
- garlic
- untreated check

Beetle damage rating

- D
- CD
- CD
- CD
- CD
- BC
- BC
- AB
- AB
- A
- A

$P = 0.0001$
## Trends in efficacy

<table>
<thead>
<tr>
<th>Spectrum</th>
<th>Exc./Good</th>
<th>Good/Fair</th>
<th>Fair/Poor</th>
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</thead>
<tbody>
<tr>
<td>Broad</td>
<td>pyrethrins + PBO carbaryl esfenvalerate</td>
<td>permethrin malathion</td>
<td>neem seed oil azadirachtin</td>
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<tr>
<td></td>
<td>lambda-cyhalothrin cyfluthrin bifenthrin</td>
<td>pyrethrins +oil</td>
<td>capsaicin garlic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>pyrethrins +soap</td>
</tr>
<tr>
<td>Less broad</td>
<td>spinosad</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>endosulfan rotenone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Narrow</td>
<td>dicofol soap oil</td>
<td>B.T.</td>
<td></td>
</tr>
</tbody>
</table>

*in red if on OMRI list*
### Conclusions: insecticide choices

<table>
<thead>
<tr>
<th>User’s general preference</th>
<th>Best bets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural products only (OMRI)*</td>
<td>1) spinosad</td>
</tr>
<tr>
<td></td>
<td>2) soap</td>
</tr>
<tr>
<td>Natural products only (non-OMRI)</td>
<td>1) pyrethrins+PBO</td>
</tr>
<tr>
<td></td>
<td>2) rotenone</td>
</tr>
<tr>
<td>Conventional products only</td>
<td>esfenvalerate (Bug-B-Gon Max)</td>
</tr>
<tr>
<td>Anything goes</td>
<td>pyrethrins+PBO</td>
</tr>
</tbody>
</table>

* *Note lack of effective beetle control product*
Info on vegetable pest management on web site

http://bugs.osu.edu/welty/