Understanding Insecticides and Selecting the Best Options

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How insecticides are used

- **Soil-applied insecticides**
  - For residual control
  - For systemic uptake
  - Soil fumigants

- **Seed-treatment insecticides**
  - For control of seed pests
  - For systemic uptake

- **Foliar insecticides**
  - For residual control
  - For systemic uptake/movement
  - For knockdown

- **Parallels in other settings**
  - Residual insecticides for residential pest control
  - Aerosol insecticides for residential pest control
  - Residual insecticides and fumigants in stored grains
  - Fumigants for grains and commodities
  - Residual and systemic insecticides for use on animals
Soil-applied residual insecticides

- Soil-applied for extended control:
  - Applied to kill insects in treated soil at time of application and for a period up to several weeks later; incorporated (at least lightly) or injected to mix with soil
    - Applied at planting for control of rootworms, cutworms, wireworms, grubs, seed and root maggots, etc. in field crops, vegetables, small fruits, gardens
    - Applied as soil treatments for termite control around houses, other buildings
  - Examples:
    - Organophosphates: Lorsban, Counter, Diazinon
    - Pyrethroids: Force, Fortress
  - Band applications instead of broadcast applications are most common in crops
Soil-applied insecticides

- Soil-applied residual insecticides
  - Typically have half-lives of (very roughly) 30 to 90 days
  - Typically are low to very low in water solubility (so that they do not leach out of the treatment zone in spring rainfall)
  - Are not bound too tightly to soil particles as to be unavailable in contact with insects
  - Historic problems have included too-great persistence (aldrin, dieldrin, heptachlor, chlordane, and other organochlorines) and too-great solubility and too little persistence (enhanced degradation of carbofuran / Furadan)
Seed-treatment insecticides

- Seed-applied residual insecticides
  - Insecticides applied to seed at seed company facility or as a planter-box mixture
  - Kill insects that feed directly on seeds and below-ground portions of seedlings
  - Common seed protectants have included diazinon, Lorsban, lindane, and permethrin
  - Targets: seedcorn maggot, other seed and root maggots, wireworms, white grubs, seedcorn beetles, and symphylans
  - IF effective, seed treatments are appealing because they use a lot less insecticide than band or broadcast applications
Soil-applied systemic insecticides

- Soil-applied for systemic uptake
  - Applied at planting or transplanting or as a side-dress
  - Historically in IL: Furadan and Thimet in corn, cucurbits, and/or potatoes for control of flea beetles, cucumber beetles, Colorado potato beetle, or aphids feeding on foliage
  - Elsewhere: Temik and Di-Syston in potatoes, (citrus), and wheat ... problems with leaching into groundwater
  - Currently: Neonicotinoids such as Admire (imidacloprid) and Platinum (thiamethoxam) in similar crops against similar pests
  - Control usually begins a few days after application and persists 2 to 4 weeks; somewhat dependent on precipitation
Some soil-applied systemics can be applied in irrigation water

- **Neonicotinoids**
  - Admire, Platinum, Venom, Scorpion
    - Effective against Colorado potato beetle, leafhoppers, aphids, cucumber beetles/flea beetles

- **Diamides**
  - Coragen
    - Effective against Colorado potato beetle, Lepidopteran larvae
  - Synapse/Belt

- **Combinations**
  - Durivo
    - Range of target pests susceptible to either active ingredient
Seed-treatment systemic insecticides

Seed-applied for systemic uptake
- Old O-Ps and carbamates that are systemic were not used as seed treatments because they were phytotoxic (poisonous to the seeds)
- Current systemic seed treatments are sold under the trade names Cruiser, Gaucho, and Poncho – all are neoniconitoids
  - On field crops, vegetables, and some ornamental plants
  - Targets include corn flea beetle, cucumber beetles, leafhoppers, and aphids for 1 – 3 weeks after seedling emergence
Soil fumigants

- Primary fumigant against insects, pathogens, and weeds in the soil is methyl bromide
  - Applications usually made to raised beds tarped with plastic (for specialty crops)
  - Fumigant gas kills organisms present at the time of fumigation; dissipates in a few days
  - Cost = several hundred dollars to $2,000 per acre
  - In IL, crops are “plasticulture” strawberries; some peppers and tomatoes
  - Soil fumigation is rare in IL, but in FL, TX, and CA (and a few other areas), fumigating before planting high-value fruits and vegetables is common.
  - Phase-out of methyl bromide because of its ozone-depleting effects presents a major challenge
Foliar-applied insecticides

- Foliar “knock-down” insecticides (with little or no residual control intended)
  - Very few insecticides are applied with the intent that they NOT last at least a few days, but insecticides that kill only the insects that are present at the time of application or persist for only a short time include: dormant oils, soaps, pyrethrins, and malathion.
  - Most insecticides that break down rapidly have short preharvest intervals; this can be especially important in fruits and vegetables where control may be necessary right up to the time the crop is picked.
Foliar-applied insecticides

- Foliar residual insecticides ... Most applications of insecticides to plant foliage, by aerial or ground sprayers, are intended to last for a few to several days as residues on plant foliage
  - Most last from 3 to 10 days as effective residues
  - Treatments remain effective if sprays dry before rainfall of up to 1 inch
  - In general, most foliar residual sprays are effective as contact poisons ... insects that crawl across treated surfaces are killed when insecticides are absorbed through the insect’s cuticle
Animal insecticides

- Insecticides are applied directly to animals for control of lice, flies, grubs, ticks, mites, mosquitoes, etc.

  - Application methods for residual insecticides include:
    - Self-treatment devices such as back rubbers and dust bags
    - Controlled-release devices such as ear tags and flea collars
    - High-pressure sprays and mists
    - Pour-on on spot-on treatments that distribute in the coat

  - Application methods for systemic insecticides include:
    - Pour-ons and spot-ons
    - Feed additives
    - Injections
Surface residual sprays

- Surfaces may be barn walls, bin walls, baseboards, wall voids, carpets, and more
  - Sprays applied to barn walls, wooden fences, etc. for fly control
  - Empty-bin sprays applied to grain bin walls for control of weevils, “bran bugs,” Indianmeal moth, etc.
  - Baseboard sprays and wall void treatments for cockroach control
  - Foundation and crawl-space sprays to control crickets, other “invaders”
Aerosol space sprays

- Examples include “bombs” for flea control, mists for fly control in livestock buildings, aerosols in food processing plants – often pyrethrins or pyrethroids with short residual and low toxicity

- These are not fumigants … the active ingredient is dispersed in very small droplets of liquid that float through the air and deposit on exposed surfaces (including insects’ cuticles). They do not move as a gas into closed spaces such as cabinets, drawers, etc.
Space and Commodity Fumigants

- Examples: methyl bromide, phosphine, chloropicrin, sulfuryl fluoride, and even carbon dioxide.
- In agriculture, used to disinfest stored grains, flour, flour mills and other food processing plants, and ripe fruits and vegetables (Mediterranean fruit fly and similar pests).
- In general, fumigants are EXTREMELY toxic and require special training and equipment for safe handling.
- The application of residual insecticides (Actellic, Storcid, Diacon) to stored grains (admixtures or surface sprays) is NOT fumigation.
So … choosing soil and foliar insecticides for vegetables

- Insecticides for vegetables
- What’s effective against what?
- Available references
Insecticides for use on vegetables

- **Organochlorines**
  - endosulfan (Thiodan, Endosulfan, Thionex) *(Group 2A)*
    - Phase-out pending

- **Organophosphates** *(Group 1B)*
  - acephate (Orthene)
  - chlorpyrifos (Lorsban)
  - diazinon (Diazinon)
  - dimethoate (Cyon, Dimate, Dimethoate)
  - malathion
  - methyl parathion (Penncap-M)

- **Carbamates** *(Group 1A)*
  - carbaryl (Sevin)
  - carbofuran (Furadan)
  - methomyl (Lannate)
  - oxamyl (Vydate)
  - thiodicarb (Larvin)
Insecticides for use on vegetables

- **Pyrethroids** *(Group 3)*
  - bifenthrin *(Capture, Brigade, Bifentrin, Bifenture, Discipline, Fanfare, Sniper, Tundra)*
  - cyfluthrin *(Baythroid, Renounce, Tombstone)*
  - cypermethrin *(Ammo)*
  - esfenvalerate *(Asana, Adjourn)*
  - fenpropathrin *(Danitol)*
  - lambda-cyhalothrin *(Warrior, Silencer)* *(related, gamma cyhalothrin = Pro-axis)*
  - permethrin *(Ambush, Pounce, Arctic, Permethrin, Perm-UP, and more)*
  - zeta-cypermethrin *(Mustang Max)*
Insecticides for use on vegetables

- **Neonicotinoids (Group 4A)**
  - acetamiprid (Assail)
  - imidaclorpid (Admire, Provado, Couraze, Imida, Macho, Malice, Montana, Nuprid, Torrent, Widow)
  - dinotefuran (Venom)
  - flonicamid (Beleaf) (Group 9C)
  - thiamethoxam (Actara, Platinum)
Insecticides for use on vegetables

- **Spinosyns (Group 5)**
  - spinosad (SpinTor, Entrust)
  - spinetoram (Radiant)

- **Avermectins and similar compounds (Group 6)**
  - abamectin (Agri-Mek, Abba, Epi-Mek, Zoro)
  - emamectin benzoate (Proclaim)

- **Juvenile hormone analogs (Group 7)**
  - pyriproxyfen (Esteem)

- **Benzoylureas (Group 15)**
  - Novaluron (Rimon)
Insecticides for use on vegetables

- **Diacyl hydrazines** *(Group 18)*
  - methoxyfenozide *(Intrepid)*
  - tebufenozide *(Confirm)*
  - azadirachtin *(neem)*

- **Indoxacarb** *(Group 22)*
  - Indoxacarb *(Avaunt)*

- **Tetronic acid derivatives** *(Group 23)*
  - Spirotetramat *(Movento)*

- **Anthranilic diamides** *(Group 28)*
  - chlorantraniliprole *(Coragen)*
  - flubendiamide *(Belt/Synapse)*
Miticides for use on vegetables

- **Organochlorines**
  - dicofol (Kelthane, Dicofol) *(Group un)*

- **Avermectins** *(Group 6)*
  - abamectin (Agri-Mek, Abba, Epi-Mek, Zoro)

- **Tetronic acid derivatives** *(Group 23)*
  - spiromesifen (Oberon)

- **Neuronal inhibitors**
  - bifenazate (Acramite) *(Group 25)*
Various microbials, botanicals, and/or OMRI products for use on vegetables

- *Bacillus thuringiensis* ssp. *kurstaki* and *aizawai* (Group 11B1 and 11B2)
  - Dipel, Agree, Biobit, Crymax, Deliver, Javelin, Lepinox, Xentari
- azadirachtin (Group 18B)
  - Neem, Neemix, Aza-Direct
- rotenone (Group 21)
- pyrethrins (Group 3)
  - Pyganic, Pyrenone
- suffocating oils
- abrasives, surface films
  - diatomaceous earth
  - kaolin clay (Surround)
- soaps
  - (M-Pede)
Insecticide Modes of Action

- IRAC Mode of Action Classification
  - Insecticide Resistance Action Committee
  - 28+ modes of action and insecticide groups
  - On-line listing of classifications

http://www.irac-online.org/documents/IRAC%20MoA%20Classification%20v5_3.pdf
So why are chemical structures and modes of action important?

- Insecticides work if (1) they remain intact within an insect to reach a “target site” and (2) the target site is susceptible to their attachment and interference.

- Differences among species in “natural susceptibility” to an insecticide and evolution of resistance in populations of a given species result primarily from (1) increased metabolism or breakdown of insecticide molecules – related to their structure – and from (2) receptor sites that are not susceptible to insecticide attachment and interference.

- Repeated use of insecticides within the same structural family or mode of action group result in more rapid development of resistance.

- Rotating among structural families and modes of action – assuming there are alternatives that are effective – is recommended to maximize long-term effectiveness of insecticides and miticides.
So what is the range of target pests for the different groups?

- **Group 1A, carbamates, acetylcholinesterase inhibitors**
  - Furadan: few remaining labeled uses.
  - Orthene: effective against aphids and certain Leps (corn borer in peppers and snap beans).
  - Sevin: effective against many beetles; not great against most Leps; kills natural enemies of aphids and mites and triggers their outbreaks.
  - Larvin and Lannate … some Lep activity (generally not as effective as pyrethroids), some aphid activity. Lannate’s residual activity is very short.
Group 1B, organophosphates, acetylcholinesterase inhibitors

- Lorsban: **Soil and seed treatment uses** against root and seed maggots, ~corn rootworm larvae, wireworms, and white grubs
- Diazinon: **Soil and seed treatment uses** against rot and seed maggots, wireworms, white grubs
- Dimethoate: Moderately effective against **aphids and leafhoppers**.
- Malathion: Remains labeled on several vegetable crops but is rarely recommended, usually for aphids
- Pennycap-M: Few uses remain labeled; may be used against European corn borer in dry beans and sweet corn.
Group 2A, organochlorines, cyclodienes

- Endosulfan: still useful against aphids, plant bugs, stink bugs, and leafhoppers. Some control of beetles and Leps. (Not systemic)
- Phase-out is underway
Group 3, pyrethroids and natural pyrethrins, sodium channel modulators

- Pyrethroid products include Permethrin, Asana, Capture/Brigade, Baythroid/Renounce, Danitol, Warrior, Mustang Max. Natural pyrethrins include Pyganic, Pyrenone, etc.
- In general, all pyrethroids are good against a range of Leps and beetles, as well as grasshoppers, stink bugs, plant bugs, and some thrips.
- Most compounds in this group are ineffective against aphids and mites and trigger more severe infestations of these pests by killing their natural enemies.
- Natural pyrethrins are effective against several beetles but break down very rapidly. Using synergists (not OMRI-approved) and spraying at night increases effectiveness.
Group 4A, neonicotinoids, nicotinic acetylcholine receptor promoters and antagonists

- Products that are active primarily against aphids, leafhoppers, etc. (plus systemically against Colorado potato beetle, corn flea beetle, and cucumber beetle) include
  - Admire/Provado (and Gaucho seed treatments)
  - Actara/Platinum (thiamethoxam seed treatments)
- Assail: Effective against aphids and leafhoppers, also some Leps (though not corn borer or corn earworm; not recommended against key cabbage Leps in cole crops)

Group 5, spinosyns, nicotinic acetylcholine receptor promoters that differ from group 4A

- SpinTor, Entrust, and Radiant ... effective primarily against Lep larvae – earworm, corn borer, Leps in cole crops, etc. – and some thrips and leafminers
Effective primarily against Lepidopteran larvae…

- **Group 6**: Chloride channel activators
  - emamectin benzoate (Proclaim)

- **Group 11**: Microbial disruptors of insect midgut membranes:
  - *Bacillus thuringiensis* (with multiple subspecies) (and multiple trade names)

- **Group 15**: Chitin inhibitors
  - Novaluron (Rimon) (also effective against Colorado potato beetle)

- **Group 18**: Ecdysone (molting hormone) promoters / mimics & molting disruptors
  - 18A: tebufenozide (Confirm), methoxyfenozide (Intrepid)

- **Group 22**: Voltage-dependent sodium channel blockers
  - indoxacarb (Avaunt)

- **Group 28**: Ryanodine receptor modulators
  - chlorantraniliprole (Coragen)
  - flubendiamide (Belt/Synapse)
Effective primarily against aphid, whitefly, and similar sucking insects ...

- **Group 7: Juvenile hormone mimics**
  - pyriproxyfen (*Esteem*)

- **Group 9: Selective feeding blockers (unknown MOA)**
  - pymetrozine (*Fulfill*)
  - flonicamid (*Beleaf*)

- **Group 23: Lipid synthesis inhibitors**
  - spiromesifen (*Oberon*) … also a miticide
  - Spirotetramat (*Movento*)
Specific miticides ...

- **Group 6: Chloride channel activators**
  - abamectin (*Agri-Mek*)

- **Group 23: Lipid synthesis inhibitors**
  - spiromesifen (*Oberon*) (also effective against whiteflies)

- **Group 25: Neuronal inhibitors (unknown mode of action)**
  - bifenazate (*Acramite*)

- **Group un: Unknown mode of action**
  - dicofol (*Kelthane*)

Pyrethroids that have some miticidal action include Capture and Danitol, but these are not usually the best choices for mite control.
Resistance Management

Simple rules:

- Do not use insecticides in the same MOA group repeatedly in the same crop/field/season
- Rotate among MOAs at least across generations
- Where an insect pest is not controlled by application(s) of an insecticide in a given MOA group, do NOT switch to another insecticide within the same MOA group
- If the target pest migrates into the region from an area with known resistance to a particular MOA, do not rely on an insecticide from that MOA group for control at your site
Useful References

- 2011 Midwest Vegetable Production Guide
  - [http://btny.purdue.edu/Pubs/ID/ID-56/](http://btny.purdue.edu/Pubs/ID/ID-56/)

- IRAC Mode of Action Classifications
  - [http://www.irac-online.org/documents/IRAC%20MoA%20Classification%20v5_3.pdf](http://www.irac-online.org/documents/IRAC%20MoA%20Classification%20v5_3.pdf)

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