Mode of Activity and Rotation: A Breakdown


Aphid. (Photo courtesy of Ray Cloyd)

Find out here — with these new research results — if your insecticide/miticide program is effective.

By Ray Cloyd

Mode of action or mode of activity refers to how a pesticide — in this case, an insecticide or miticide — affects the metabolic and physiological processes in an insect or mite. Greenhouse producers, in order to sustain successful integrated pest management programs and preserve the longevity of currently available insecticides/miticides, need to practice rotating insecticides/miticides to reduce the likelihood that plant-feeding insects and mites in greenhouses will develop resistance.

First of all, it is important to understand what resistance is. Resistance is the genetic ability of some individuals in a pest population to survive a pesticide application. In other words, the pesticide no longer effectively kills the target pest, which may be an insect, mite or fungal pathogen (if discussing fungicides). This is primarily due to the intensive mortality placed on insect/mite populations from frequent applications of insecticides/miticides, resulting in the amplification of already-existing genetic traits and/or potential genetic changes that lead to mutations in the remaining individuals. Due to the selection of individuals in insect and mite populations to overcome this burden, insect and mite populations are then able to tolerate applications of insecticides and/or miticides. The rate at which insects and mites may develop resistance to insecticides or miticides is influenced by a variety of factors:

- length of exposure to a single pesticide,
- level of mortality (high v. low),
- presence or absence of refuge sites or hiding places,
- relatedness of one pesticide to another,
- generation time (short v. long),
- number of young or offspring produced per generation, and
- mobility of individuals.

It is often argued that insect and mite populations will develop resistance faster to pesticides that are used in greenhouses than when these same materials are used outdoors. The primary reason for this mind-set is that the material will "hang around" or persist longer in greenhouses than outdoors, whereas pesticides used outdoors will generally break down from exposure to ultraviolet light or rainfall, which may reduce the amount of selection pressure placed on a pest population.

ROTATION

In order to reduce the possibility of insect and mite pests from developing resistance it is important to design a rotation program that involves insecticides and/or miticides with different modes of activity — not chemical classes. The reason for this is that some chemical classes have similar modes of activity.

For example, organophosphates and carbamates, despite being different chemical classes, both have identical modes of activity. Both chemical classes block the action of acetylcholinesterace (AChE), an enzyme that deactivates acetylcholine (ACh) thus allowing nerve signals to stop, which results in the total loss of nerve functions. So, using acephate (Orthene, Valent USA) for two spray applications during a generation and then switching to methiocarb (Mesurol, Gowan Company) does ➧

Figure 1. Mode of action of insecticides and miticides used in greenhouse production systems.

Mode of Action Group	Trade Name (Common Name, Manufacturer)	Mode of Activity
Acetycholine Esterase Inhibitors	Carzol (Formetanate, Gowan) DuraGuard (Chlorpyrifos, Whitmire Micro-Gen) Mesurol (Methiocarb, Gowan) Orthene (Acephate, Valent)	Inhibit the enzyme cholinesterase (ChE) from clearing the acetylcholine (ACh) transmitter. This prevents termination of nerve impulse transmission and results in an accumulation of acetylcholine leading to hyperactivity, respiratory failure, exhaustion of metabolic energy and death.
GABA-Gated Chloride Channel Blockers	Thiodan (Endosulfan, Bayer CropScience)	Act on the gamma-aminobutyric acid (GABA) receptor by binding to the chloride channels, thus preventing chloride ions from entering neurons. This disrupts GABA activity, which leads to hyperexcitation, paralysis and death.
Sodium Channel Blockers	Astro (Permethrin, FMC) Decathlon (Cyfluthrin, Olympic) Mavrik (Fluvalinate, Wellmark) Scimitar (Lambda-cyhalothrin, Syngenta) Talstar (Bifenthrin, FMC) Tame (Fenpropathrin, Valent)	Destabilize nerve cell membranes by working on the sodium channels in the peripheral and central nervous system, slowing down or preventing closure. This results in stimulating nerve cells to produce repetitive discharges, eventually leading to paralysis and death. ➧

not constitute a proper rotation scheme. Similarly, although pyridaben (Sanmite, Scotts Company) and fenpyroximate (Akari, SePRO Corp.) are in different chemical classes — pyridazinone and phenoxypyrazole, respectively — they both work on the mitochondria electron transport system (responsible for energy production), so these materials should not be used in succession.

The chemical class, neonicotinoid (also referred to as chloronicotinyl) is relatively new and contains a number of systemic insecticides that are registered for use in commercial greenhouses including imidacloprid (Marathon, Olympic Horticultural Products), thiamethoxam (Flagship, Syngenta) and acetamiprid (Tristar, Cleary Chemical Corp.). Another neonicotinoid, dinotefuran (Safari, Valent USA) will eventually be registered, which means there will be four neonicotinoid insecticides available. Because all neonicotinoids have similar modes of activity it is important to not use them in succession, as this will increase the selection pressure on the target pest population and may potentially enhance the development of insecticide resistance. Use an insecticide with a different mode of activity either before or after using a neonicotinoid-based insecticide.

Mode of Action Group	Trade Name (Common Name, Manufacturer)	Mode of Activity
Nicotinic Acetylcholine Receptor Disruptors	Flagship (Thiamethoxam, Syngenta) Marathon (Imidacloprid, Olympic) Safari (Dinotefuran, Valent) Tristar (Acetamiprid, Cleary Chemical)	Act on the central nervous system, causing irreversible blockage of the post-synaptic nicotinergic acetylcholine receptors, leading to disruption of nerve transmission and uncontrolled firing of nerves. This results in rapid pulses from a steady influx of sodium (Na+), leading to hyperexitation, convulsions, paralysis and death.
Nicotinic Acetylcholine Receptor Agonist	Conserve (Spinosad, Dow AgroSciences)	Disrupt binding of acetylcholine at nicotinic acetylcholine receptors located at the post-synaptic cell junctures and negatively affect the gamma-amino butyric acid (GABA) gated ion channels.
GABA Chloride Channel Activators	Avid (Abamectin, Syngenta) Ultiflora (Milbemectin, Gowan)	Affect gamma-amino butyric acid (GABA) dependent chloride ion (Cl-) channels by increasing membrane permeability to chloride ions, leading to inhibition of nerve transmission, paralysis and death.
Juvenile Hormone Mimics	Distance (Pyriproxyfen, Valent) Enstar II (Kinoprene, Wellmark) Preclude (Fenoxycarb, Whitmire Micro-Gen)	Arrest development by causing insects to remain in a young or immature stage, primarily by inhibiting metamorphosis (=change in form). As a result, insects are unable to complete their life cycle.
Chitin Synthesis Inhibitors	Adept (Diflubenzuron, Crompton/Uniroyal) Pedestal (Novaluron, Crompton/Uniroyal) Talus (Buprofezin, SePRO) TetraSan (Etoxazole, Valent)	Prevent the formation of chitin, which is an essential component of an insect's exoskeleton, causing the insect's cuticle to become thin and brittle. As a result, insects (and mites in the case of etoxazole) die while attempting to molt from one stage to the next.
Growth and Embryogenesis Inhibitors	Hexygon (Hexythiazox, Gowan) Ovation (Clofentezine, Scotts)	Disrupt the formation of the embryo during development or inhibit larval maturation. However, the specific mode of action and target site of activity are still not known.
Selective Feeding Blockers	Aria (Flonicamid, FMC) Endeavor (Pymetrozine, Syngenta)	Inhibit feeding behavior of insects by interfering with neural regulation of fluid intake in the mouthparts.
Disruptors of Insect Midgut Membranes	Dipel and Deliver (*Bacillus thuringiensis* var. *kurstaki*, Valent and Certis USA) Gnatrol (*Bacillus thuringiensis* var. *israelensis*, Valent)	Bind to specific receptor sites on the gut epithelium, resulting in degradation of the gut lining and eventual starvation of the insect. Crystals release protein toxins (endotoxins) that bind to the mid-gut membrane receptor sites, creating pores or channels. This paralyzes the digestive system and ruptures the midgut cell walls, allowing ions to flow through the pores and disrupt potassium (K+) and pH balances. As a result, the alkaline contents of the gut spill into the blood resulting in gut paralysis and death.
Oxidative Phosphorylation Uncoupler	Pylon (Chlorfenapyr, Olympic)	Uncouple oxidative phosphorylation, which is a major energy-producing step in cells, by disrupting the H+ gradient, which prevents the formation of adenosine tri-phosphate (ATP).
Ecdysone Antagonist	Citation (Cyromazine, Syngenta) Confirm (Tebufenozide, Dow AgroSciences) Azatin and Ornazin (Azadirachtin, Olympic and SePRO)[1]	Disrupt the molting process by inhibiting biosynthesis or metabolism of the molting hormone — ecdysone.
Mitochondria Electron Transport Inhibitors	Akari (Fenpyroximate, SePRO) Sanmite (Pyridaben, Scotts)	Inhibit site 1 electron transport or act on the NADH-CoQ reductase site in the mitochondria, reducing energy production by preventing the synthesis of adenosine triphosphate (ATP).
Desiccation or Membrane Disruptors	Triact (Neem oil, Olympic) SunSpray UltraFine Oil (Paraffinic oil, Whitmire Micro-Gen) Insecticidal Soap (IPotassium salts of fatty acids)	Damage the waxy layer of the exoskeleton of soft-bodied insects and mites by altering the chitin so it cannot hold fluids, resulting in desiccation (drying up) or smothering insects by covering the breathing pores (spiracles).
GABA-Gated Antagonist	Floramite (Bifenazate, Crompton/Uniroyal)	Blocks or closes gamma-amino butyric acid (GABA) activated chloride (Cl-) channels in the peripheral nervous system.

[1]*In addition to acting as an insect growth regulator, azadirachtin acts as a feeding deterrent/inhibitor, oviposition inhibitor, repellent, egg-laying deterrent, sterilant and/or direct toxin.*

Another essential strategy is to rotate insecticides and miticides with non-specific or broad modes of activity — such as insect growth regulators, insecticidal soap, feeding inhibitors, horticultural oil and beneficial fungi and bacteria — with materials having specific modes of activity. This will alleviate the possibility of insects and mites developing resistance.

It is important to rotate common names (active ingredient) not trade names. For example, both Azatin (Olympic Horticultural Products) and Ornazin (SePRO Corp.), despite having different trade names, contain the same active ingredient — azadirachtin. In general, rotate different modes of activity every 2-3 weeks or every 2-3 insect/mite generations. The actual length of rotation will depend on the time of year, as temperature and season influence the duration of the life cycle. For example, high temperatures that typically occur in greenhouses during the summer months shorten the developmental time (egg to adult) of most of the major greenhouse insect and mite pests, including aphids, thrips, two-spotted spider mites and whiteflies. This often leads to overlapping generations with variable age structures (eggs, larvae, pupae and/or adults) present at the same time. As a result, more frequent applications of insecticides or miticides are needed, and they must be rotated more often. In contrast, during the winter months, the developmental time of most greenhouse insect and mite pests is extended (due to the cooler temperatures and shorter daylengths), which means that insecticides and miticides may not need to be rotated as frequently.

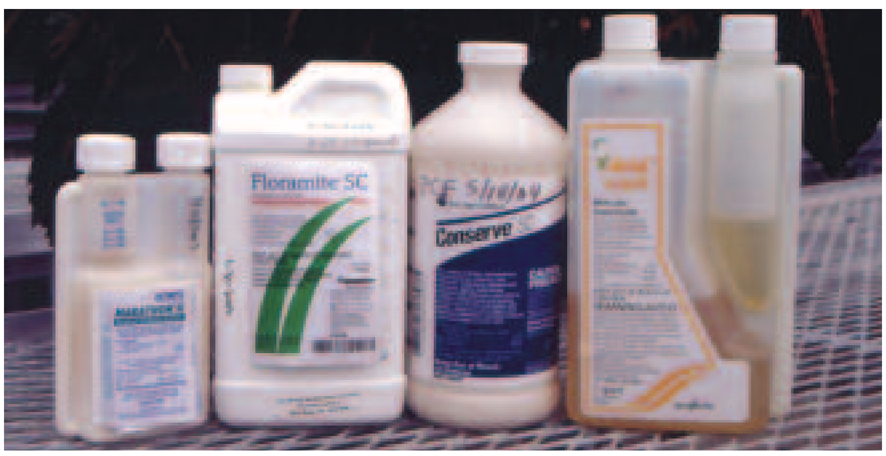
Below are examples of insecticides or miticides that have dis-similar modes of activity and may be used in rotation schemes for aphids, thrips, two-spotted spider mites and whiteflies:

• Aphids: Endeavor (Syngenta), Marathon (spray application), Ultrafine Oil (Whitmire Micro-Gen), Orthene and Insecticidal Soap

• Thrips: Conserve (Dow AgroSciences), Avid (Syngenta), Mesurol (Gowan), Orthene and Pedestal (Crompton/Uniroyal)

• Two-spotted Spider Mite: Floramite (Crompton/Uniroyal), Pylon (Olympic), Avid, Akari or Sanmite (Scotts) and TetraSan (Valent)

• Whiteflies: Marathon (spray application), Endeavor, Distance (Valent), Talstar (FMC) and Orthene



Tank mix pesticides.

One of the continual problems that greenhouse producers contend with is that the insecticide or miticide label does not state the mode of activity, so it may be difficult to access this information unless you directly contact the manufacturer. Olympic Horticultural Products has produced a useful brochure (Chemical Class Chart) that briefly describes the mode of action of insecticides, miticides, fungicides, herbicides and plant growth regulators used in greenhouses. This information has also recently been posted to the USDA Web site at www.usda.gov. In Figure 1, page 68, I present a listing of the major modes of activity, concentrating on insecticides and miticides, with detailed descriptions for each along with the insecticides and miticides (common name and trade name) that may be categorized under each specific mode of activity. This information can be used to develop sound rotation programs that will help deal with insect and mite pests more effectively. GPN

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