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Managing Insecticide and Miticide Resistance in Florida Landscapes[1]

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Landscape managers in Florida are becoming more aware of pesticide resistance development in key turfgrass and ornamental plant pests. Pesticide resistance is no longer just a greenhouse or agricultural problem. Southern chinch bugs (*Blissus insularis*) became resistant to chlordane used in St. Augustinegrass in 1953, and have since become resistant to other chlorinated hydrocarbon, and organophosphate, carbamate, and pyrethroid insecticides (Cherry and Nagata 2005). The leafminer *Liriomyza trifolii* caused significant damage to annual bedding plants in the 1970s and early 1980s, which resulted in considerable insecticide use on infested plants, and subsequent resistance development to several chemical classes (Leibee 1981). With the limited development of new cost-effective pesticide chemistries, landscape managers need to be good stewards of existing products to try to mitigate or delay further resistance development.

A perceived product failure or poor pesticide performance does not always indicate pest resistance. Poor control may be the result of several factors, including pesticide degradation in storage, hydrolysis in acid or alkaline preparations, applications against an incorrect life stage, poor coverage or equipment calibration, or other inadequate application procedure. Consider which formulation is most appropriate for each pest and/or plant situation. For example, a granular insecticide used during a drought and watering restrictions may not work until enough moisture is present to release the toxicant from the carrier and move it into the soil. On the other hand, if a product is sprayed just before a rain storm, it could easily be washed out of the target zone before eliminating the pests.

Definitions

Resistance involves inherited (genetic) physiological and/or behavioral adaptations that confer a selective advantage in the presence of a pesticide, and that lead to control failures. **Cross-resistance** occurs when resistance to one insecticide confers resistance to another insecticide, even where the insect has not been exposed to the latter product. **Tolerance** is when physiological and/or behavioral adaptations lead to increased survivorship relative to some toxicity baseline (not genetic). **Mode of action** is the specific physiological activity of a toxin that results in the death of a pest.

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Resistance Development

Resistance development is affected by the frequency of application rate or dose of pesticide, and certain pest characteristics. Some arthropods are more likely to develop resistance to pesticides than others. Arthropods like mites, aphids, whiteflies, and thrips have similar traits that contribute to resistance development, such as having many generations per year, exposure of multiple generations to a pesticide, having a lot of offspring, limited dispersal, and exposure to sublethal (less than optimal) pesticide doses.

The pests within a population often vary in their level of susceptibility to a pesticide. But, before exposure to a new pesticide, resistant individuals are rare. After an application, the more susceptible pests die and the less susceptible ones survive, mate with other survivors, and reproduce. Most of their offspring then inherit the parental trait that allowed them to survive the pesticide application. Further applications kill the most susceptible individuals, so the survivors mate and produce more similar offspring. Continued applications within one chemical class or mode of action further select the population until the resistant genotype is the most abundant or dominant. Pure resistance in a population is probably not present before product failures begin.

Functionally, pest populations may become insensitive to formerly effective pesticides through one or more means. For example, resistant pests may deactivate (break down), sequester (safely store within their bodies), avoid or excrete the toxin from their bodies more effectively, have an altered target site in the nervous system that will not respond to the toxin, or reduce the permeability of their exoskeletons (“shells”) to the toxin.

Resistance Management

The best solution to pesticide resistance development is to diversify your plant protection techniques and not rely solely on pesticides. Integrated pest management (combining cultural, mechanical, physical, biological, and chemical controls) is good long-term philosophy and set of practices (Pedigo 2002, Scherer et al. 2006). For example, practice good sanitation. Completely remove all plant debris from a flower bed before installing new plants. Exclude pests by inspecting new plants and only buy pest-free plants. Use plant species and varieties that are resistant to key pests. Rotate plant species in annual flower beds. Conserve natural enemies by spot treating and leaving untreated refuges for them to live in. Most plants can tolerate minor pest damage for a while, before pesticidal intervention may be needed. Periodically scout landscapes and use pesticides only when pest densities approach economic or aesthetic injury levels.

To maximize product efficacy, follow the label instructions and consider these tips. Use fresh, fully potent pesticides that are prepared and applied according to label directions. Aqueous pesticidal solutions should be adjusted to near neutral pH (pH 7.0) or as specified by the label. Sprayer/spreader calibration, nozzle condition and pressure, and treatment placement must be correct. Applications also should be timed and directed to contact the most susceptible life stage of the pest.

We try to delay or reverse resistance by avoiding use of the pesticide, mode of action, or chemical class for some time. The hope is that the resistant pest populations may lose their resistance traits and become susceptible in the absence of repeated exposure. However, if those pesticides are used again, resistance may return. The market life of key pesticides may be extended using several strategies, which include mixtures, rotations, and mosaics (Hoy 1999).

Mixtures

Applying mixtures of products exposes pests simultaneously to more than one toxicant. This strategy depends on several assumptions, including that resistance to each product is “monogenic” (only has one gene), that no cross-resistance occurs between both products, that resistant individuals are rare and the resistance gene is recessive, the products have similar residuals, and that some of the population remains untreated (Tabashnik 1990). Synergists, such as piperonyl butoxide (PBO), are often added to pyrethroids or pyrethrins to boost their efficacy. Examples of registered mixtures include

Allectus (bifenthrin plus imidacloprid) for use in turfgrass, and Discus (cyfluthrin plus imidacloprid) in ornamentals. However, pesticide applicators could make their own mixtures if the pesticides are compatible and legal/label restrictions don't prohibit mixtures.

Rotations

The object is to alternate pesticides with different modes of action or chemical classes over time so each pest generation is exposed to only one product, but the population experiences more than one product over time. This strategy assumes that “negative cross-resistance” occurs, such that the number of individuals that are resistant to one product (e.g., a pyrethroid) will decline when exposed to a different product (e.g., an organophosphate). This may reduce the selection pressure as compared to repeatedly using the same product, mode of action, or chemical class. If multiple applications are required, use a different mode of action each time before returning to a previously-used one. An example of a rotation could be: Talstar (pyrethroid), Sevin (carbamate), Merit (neonicotinoid), and Malathion (organophosphate). Rotation does not mean using different products in sequence (e.g., pyrethroids: Talstar/Onyx, Tempo, DeltaGard, Astro, Scimitar).

A list of modes of action can be found at the Insecticide Resistance Action Committee Website: http://www.irac-online.org/documents/IRAC_MoA_Classification_v5.2.pdf. Tables 1-3 present a mode of action summary for insecticides and miticides intended for Florida landscape maintenance. Use pesticides with different IRAC numbers in a rotation - these numbers are listed on many new pesticide labels so you might not have to remember the different chemical class names or other specifics. The use of certain unique products with general modes of action (such as soaps and oils) is not expected to result in pest resistance, so no IRAC codes have been assigned and rotation of these products for resistance management is unnecessary.

Mosaics

Different locations within an area (e.g., lawns within a city) are treated with different pesticides to create a mosiac pattern in an area. This strategy may already occur in the landscape, given the variety of pest management companies and homeowners who treat plant pests differently in time and space. However, when only one mode of action or chemical class is used against a pest (e.g., pyrethroids against southern chinch bug) in both the homeowner and professional markets, and multiple pest control companies use the same products, then no real mosaic potential exists. A cooperative, area-wide pest management program would be necessary to truly implement this strategy.

Conclusions

Cases of pest resistance to popular pesticides increase control costs, the frequency of pesticide applications, the desire to use “fringe” or illegal methods of control, exposure of people and animals to toxins, and likely the amount of regulation needed to keep the environment safe. Implementing resistance management (e.g., integrated pest management) practices into the landscape maintenance industry will help keep current products on the market longer and allow pest managers to keep landscapes looking great.

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Table 1. Mode of action of insecticides and miticides registered for use in maintenance of Florida's landscape ornamentals (presented by active ingredient). (Insecticide Resistance Action Committee mode of action classification codes version 5.1).

Active Ingredient (common name)	Trade Name Examples	Mode of Action Code
abamectin	Avid Lucid Varsity Fire Ant Bait	6
acephate	Orthene Pinpoint	1B
acetamiprid	TriStar	4A
azadirachtin	Azatin Azatrol Ornazin	18B
Bacillus thuringiensis aizawai	Xentari	11B1
Bacillus thuringiensis kurstaki	Dipel Javelin	11B2
Beauveria bassiana	Botanigard Naturalis	
bifenazate	Floramite	25
bifenthrin	Talstar Onyx	3
buprofezin	Talus	16
carbaryl	Sevin	1A
carbofuran	Furadan	1A
chlorpyrifos	Duraguard Dursban	1B
clarified hydrophobic extract of neem oil	Triact	
clothianidin	Arena Celero	4A
cryolite	Kryocide Prokil Cyrolite	9A
cyfluthrin	Decathlon Tempo	3

Table 1. Mode of action of insecticides and miticides registered for use in maintenance of Florida's landscape ornamentals (presented by active ingredient). (Insecticide Resistance Action Committee mode of action classification codes version 5.1).

Active Ingredient (common name)	Trade Name Examples	Mode of Action Code
cypermethrin	Cynoff Demon	3
cyromazine	Citation	17
deltamethrin	DeltaGard	3
diazinon	Diazinon	1B
dicofol	Kelthane	Unknown Mode
diflubenzuron	Dimilin	15
dimethoate	Dimethoate	1B
dinotefuran	Safari	4A
etoxazole	Tetrasan	10B
fenoxycarb	Award Fire Ant Bait	7B
fenpropathrin	Tame	3
fipronil	Chipco Choice Top Choice	2B
halofenozide	Mach 2	18A
hexythiazox	Hexygon	10A
hydramethylnon	Amdro	20A
imidacloprid	Marathon Merit	4A
imidacloprid & bifenthrin	Allectus	4A & 3
iron phosphate	Sluggo	
lambda-cyhalothrin	Battle Demand	3
malathion	Malathion	1B
metaldehyde	Deadline Prozap	
methiocarb	Mesurol	1A
oxydemeton-methyl	Metasystox-R	1B
permethrin	Ambush Astro	3
phosmet	Imidan	1B
piperonyl butoxide	Diatect Pyrenone Pyreth-It	27A
potassium salts of fatty acids	AllPro Insecticidal Soap M-Pede	
pymetrozine	Endeavor	9B
pyrethrin	Diatect Pyrenone Pyreth-It PyGanic	3

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Active Ingredient (common name)	Trade Name Examples	Mode of Action Code
pyriproxyfen	Distance	7C
refined petroleum distillate	Ultra-fine Oil	
s-methoprene	Extinguish	7A
spinosad	Conserve Justice	5
spiromesifen	Forbid	23
tau-fluvalinate	Mavrik Yardex	3
tebufenozide	Mimic	18A
thiamethoxam	Flagship Meridian	4A
trichlorfon	Dylox	1B

Table 2. Mode of action of insecticides and miticides registered for use in maintenance of Florida's landscape ornamentals (presented by mode of action code). (Insecticide Resistance Action Committee mode of action classification codes version 5.2).

Mode of Action Code	Active Ingredient (common name)	Trade Name Examples
	Beauveria bassiana	Botanigard Naturalis
	clarified hydrophobic extract of neem oil	Triact
	iron phosphate	Sluggo
	metaldehyde	Deadline Prozap
	potassium salts of fatty acids	AllPro Insecticidal Soap M-Pede
	refined petroleum distillate	Ultra-fine Oil
1A	carbaryl	Sevin
	carbofuran	Furadan
	methiocarb	Mesurol
1B	acephate	Orthene Pinpoint
	chlorpyrifos	Duraguard Dursban
	diazinon	Diazinon
	dimethoate	Dimethoate
	oxydemeton-methyl	Metasystox-R
	malathion	Malathion
	trichlorfon	Dylox
	phosmet	Imidan

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Mode of Action Code	Active Ingredient (common name)	Trade Name Examples
2B	fipronil	Chipco Choice Top Choice
3	bifenthrin	Talstar Onyx
	cyfluthrin	Decathlon Tempo
	cypermethrin	Cynoff Demon
	fenpropathrin	Tame
	deltamethrin	DeltaGard
	lambda-cyhalothrin	Battle Demand
	permethrin	Ambush Astro
	pyrethrins	Diatect Pyrenone Pyreth-It PyGanic
	tau-fluvalinate	Mavrik Yardex
4A	acetamiprid	TriStar
	clothianidin	Arena Celero
	dinotefuran	Safari
	imidacloprid	Marathon Merit
	thiamethoxam	Flagship Meridian
4A & 3	imidacloprid & bifenthrin	Allectus
5	spinosad	Conserve Justice
6	abamectin	Avid Lucid Varsity Fire Ant Bait
7A	s-methoprene	Extinguish
7B	fenoxycarb	Award Fire Ant Bait
7C	pyriproxyfen	Distance
9A	cyrolite	Kryocide Prokil Cryolite
9B	pymetrozine	Endeavor
10A	hexythiazox	Hexygon
10B	etoxazole	Tetrasan
11B1	*Bacillus thuringiensis aizawai*	Xentari

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Mode of Action Code	Active Ingredient (common name)	Trade Name Examples
11B2	*Bacillus thuringiensis kurstaki*	Dipel Javelin
15	diflubenzuron	Dimilin
16	buprofezin	Talus
17	cyromazine	Citation
18A	halofenozide	Mach 2
	tebufenozide	Mimic
18B	azadirachtin	Azatin Azatrol Ornazin
20A	hydramethylnon	Amdro
23	spiromesifen	Forbid
25	bifenazate	Floramite
27A	piperonyl butoxide	Diatect Pyrenone Pyreth-It
Unknown Mode	dicofol	Kelthane

Table 3. Mode of action of insecticides and miticides registered for use in maintenance of Florida's landscape ornamentals (presented by trade name). (Insecticide Resistance Action Committee mode of action classification codes version 5.1).

Trade Name Examples	Active Ingredient (common name)	Mode of Action Code
Allectus	imidacloprid & bifenthrin	4A & 3
AllPro Insecticidal Soap	potassium salts of fatty acids	
Ambush	permethrin	3
Amdro	hydramethylnon	20A
Arena	clothianidin	4A
Astro	permethrin	3
Avid	abamectin	6
Award Fire Ant Bait	fenoxycarb	7B
Azatin	azadirachtin	18B
Azatrol	azadirachtin	18B
Battle	lambda-cyhalothrin	3
Botanigard	*Beauveria bassiana*	
Celero	clothianidin	4A
Chipco Choice	fipronil	2B
Citation	cyromazine	17

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Trade Name Examples	Active Ingredient (common name)	Mode of Action Code
Conserve	spinosad	5
Cynoff	cypermethrin	3
Deadline	metaldehyde	
Decathlon	cyfluthrin	3
DeltaGard	deltamethrin	3
Demand	lambda cyhalothrin	3
Demon	cypermethrin	3
Diatect	pyrethrin + piperonyl butoxide	3 & 27A
Diazinon	diazinon	1B
Dimethoate	dimethoate	1B
Dimilin	diflubenzuron	15
Dipel	*Bacillus thuringiensis kurstaki*	11B2
Distance	pyriproxyfen	7C
Duraguard	chlorpyrifos	1B
Dursban	chlorpyrifos	1B
Dylox	trichlorfon	1B
Endeavor	pymetrozine	9B
Extinguish	s-methoprene	7A
Flagship	thiamethoxam	4A
Floramite	bifenazate	25
Forbid	spiromesifen	23
Furadan	carbofuran	1A
Hexygon	hexythiazox	10A
Imidan	phosmet	1B
Javelin	*Bacillus thuringiensis kurstaki*	11B2
Justice	spinosad	5
Kelthane	dicofol	Unknown Mode
Kryocide	cryolite	9A
Lucid	abamectin	6
M-Pede	potassium salts of fatty acids	
Mach 2	halofenozide	18A
Malathion	malathion	1B
Marathon	imidacloprid	4A

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Trade Name Examples	Active Ingredient (common name)	Mode of Action Code
Mavrik	tau-fluvalinate	3
Meridian	thiamethoxam	4A
Merit	imidacloprid	4A
Mesurol	methiocarb	1A
Metasystox-R	oxydemeton-methyl	1B
Mimic	tebufenozide	18A
Naturalis	*Beauveria bassina*	
Ornazin	azadirachtin	18B
Orthene	acephate	1B
Onyx	bifenthrin	3
Pinpoint	acephate	1B
Prokil Cryolite	cryolite	9A
Prozap	metaldehyde	
PyGanic	pyrethrin	3
Pyrenone	pyrethrin + piperonyl butoxide	3 & 27A
Pyreth-It	pyrethrin + piperonyl butoxide	3 & 27A
Safari	dinotefuran	4A
Sevin	carbaryl	1A
Sluggo	iron phosphate	
Talstar	bifenthrin	3
Talus	buprofezin	16
Tame	fenpropathrin	3
Tempo	cyfluthrin	3
Tetrasan	etoxazole	10B
Top Choice	Fipronil	2B
Triact	clarified hydrophobic extract of neem oil	
TriStar	acetamiprid	4A
Ultra-Fine Oil	refined petroleum distillate	
Varsity Fire Ant Bait	abamectin	6
Xentari	*Bacillus thuringiensis aizawai*	11B1
Yardex	tau-fluvalinate	3