NebGuide

Nebraska Extension

Research-Based Information That You Can Use

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Insecticide Mode of Action Classification for Nebraska Field Crops

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Insecticides differ in their modes of action, or how they act against a target pest. This NebGuide discusses insect resistance management and provides modes of action for insecticides used for Nebraska field crops.

Insecticide resistance is becoming an increasing problem worldwide; over 500 insects are documented to be resistant to one or more insecticides. Although we often think of insecticide resistance as a problem in tropical areas, or in greenhouses where insects can produce many generations in a year, Nebraska also has had problems with insecticide resistance.

Western corn rootworms have developed resistance to insecticides twice: in the 1950s to persistent soil insecticides such as aldrin, dieldrin, and heptachlor and more recently, in the 1990s to foliar insecticides such as methyl parathion and carbaryl that were used to control adult corn rootworms in central Nebraska. Also, some greenbug populations are resistant to chlorpyrifos. We now have a greater diversity of types of insecticides labeled for use on Nebraska field crops than in the past. Understanding available modes of action of these insecticides and not repeatedly using products with the same mode of action can play an important role in reducing future problems with insecticide resistance.

Insecticide Resistance

Pesticide resistance may be defined as a decreased response of a population of animals or plants to a pesticide or control agent as a result of previous exposure to the pesticide. Resistance is different from "tolerance," which is the innate ability to survive a given toxicant dose without prior exposure and evolutionary change.

Insecticide resistance can be thought of as "accelerated evolution" or a population responding to an intense selective pressure and survival of those individuals that possess genes conferring resistance. Insecticide resistance occurs as a response to insect management practices over multiple years.

Resistance develops as a result of random mutations, producing a small number of individuals which possess traits that allow survival of normally lethal doses of insecticides. The insecticide itself does not produce a genetic change.

Insecticide Resistance Action Committee (IRAC)

IRAC is an international industry consortium providing a coordinated response to prevent or delay the development of resistance in insect and mite pests. Its website (www.irac-online.org) has a great deal of additional information. The following text from the IRAC website has been modified with permission.

Mode of Action, Target Site Resistance and Cross-Resistance

In most cases, not only does resistance render the selecting compound ineffective, it often also confers cross-resistance to other chemically related compounds. This is because compounds within a specific chemical group usually share a common target site within the pest, and thus share a common mode of action. For example, both carbamates such as Furadan® and Sevin® and organophosphates such as Lorsban® and Counter®, are acetylcholine inhibitors. Carbamates and organophosphates are subgroups with a similar mode of action.

It is common for resistance to develop based on a

Table I. Mode of action of insecticides

Main Group and Primary Site of Action	Chemical Subgroup or Exemplifying Active Ingredient	Active Ingredient (Representative Trade Names®)
1. Acetylcholine esterase inhibitors	1A Carbamates	Aldicarb (Temik®)
		Carbaryl (Sevin®, others)
		Carbofuran (Furadan®)
		Methomyl (Lannate®)
		Oxamyl (Vydate®)
		Thiodicarb (Larvin®)
	1B Organophosphates	Acephate (Orthene®)
		Chlorethoxyfos (Fortress®)
		Chlorpyrifos (Lorsban®, others)
		Dimethoate (Dimethoate, others)
		Ethoprop (Mocap®)
		Malathion (Fyfanon®, others)
		Methamidophos (Monitor®)
		Methidathion (Supracide®)
		Methyl parathion (Penncap-M®)
		Phorate (Thimet®)
		Phosmet (Imidan®)
		Tebupirimphos (Aztec®)
		Terbufos (Counter®)
2. GABA-gated chloride channel antagonists	2A Cyclodiene organochlorines	Endosulfan (Thionex®, others)
	2B Phenylpyrazoles (fiproles)	Fipronil (Regent®)
3. Sodium channel modulators	3A Pyrethroids Pyrethrins	Permethrin (Ambush®, Pounce®)
		Bifenthrin (Capture®, others)
		Beta-cyfluthrin (Baythroid®)
		Deltamethrin (Decis®)
		Esfenvalerate (Asana®)
		Zeta-cypermethrin (Mustang® MAX)
		Gamma-cyhalothrin (Proaxis™)
		Lambda-cyhalothrin (Warrior)
		Tefluthrin (Force®)
	3B DDT Methoxychlor	
4. Nicotinic acetylcholine receptor agonists	4A Neonicotinoids	Thiamethoxam (Cruiser®)
		Imidacloprid (Gaucho®)
		Clothianidin (Poncho™)
	4B Nicotine	
	4C Sulfoximes	Sulfoxaflor (Transform®)
	4D Butenolides	Flupyradifurone (Sivanto®)
5. Nicotinic acetylcholine receptor allosteric activators	Spinosyns	Spinosad (Entrust™, Success®, Tracer®)
		Spinetoram (Radiant®)
6. Chloride channel activators	Avermectins Milbemycins	
7. Juvenile hormone mimics	7A Juvenile hormone analogues	
	7B Fenoxycarb	
	7C Pyriproxyfen	
8. Miscellaneous nonspecific (multi-site) inhibitors		
9. Selective homopteran feeding blockers	9B Pymetrozine	Pymetrozine (Fulfill®)
	9C Flonicamid	

Main Group and Primary Site of Action	Chemical Subgroup or Exemplifying Active Ingredient	Active Ingredient (Representative Trade Names®)
10. Mite growth inhibitors	10A Clofentezine Hexythiazox (Onager®) 10B Etoxazole	Hexythiazox (Onager) Etoxazole (Zeal®)
11. Microbial disruptors of insect midgut membranes	Bacillus thuringiensis or Bacillus sphaericus and the insecticidal proteins they produce	Cry proteins used in Bt corn hybrids, Dipel®, and others
12. Inhibitors of mitochondrial ATP synthase	12A Diafenthiuron 12B Organotin miticides 12C Propargite 12D Tetradifon	 Propargite (Comite® II)
13. Uncouplers of oxidative phosphorylation via disruption of the proton gradient	Chlorfenapyr DNOC	
14. Nicotinic acetylcholine receptor channel blockers	Nereistoxin analogues	
15. Inhibitors of chitin biosynthesis, type 0, Lepidopteran	Benzoylureas	Diflubenzuron (Dimilin®)
16. Inhibitors of chitin biosynthesis, type 1, Homopteran	Buprofezin	
17. Moulting disruptor, Dipteran	Cyromazine	
18. Ecdysone receptor agonists	Diacylhydrazines	Methoxyfenozide (Intrepid®)
19. Octopamine receptor agonists	Amitraz	
20. Mitochondrial complex III electron transport inhibitors (Coupling site II)	20A Hydramethylnon 20B Acequinocyl 20C Fluacrypyrim	
21. Mitochondrial complex I electron transport inhibitors	21A METI acaricides 21B Rotenone	Fenpyroximate (Portal®)
22. Voltage-dependent sodium channel blockers	22A Indoxacarb 22B Metaflumizone	Indoxacarb (Steward®)
23. Inhibitors of acetyl CoA carboxylase	Tetronic and Tetramic acid derivatives	Spiromesifen (Oberon®)
24. Mitochondrial complex IV electron transport inhibitors	24A Phosphine 24B Cyanide	
25.		
26.		
27.		
28. Ryanodine receptor modulators	Diamides	Flubendiamide (Belt™) Rynaxypyr (Coragen®)
Un Compounds of unknown or uncertain mode of action	Azadirachtin Benzoximate Bifenazate Chinomethionat Cryolite Dicofol Pyridalyl	Azadirachtin (Azatin® XL Plus)

Based on information obtained from www.irac-online.org, IRAC (Insecticide Resistance Action Committee) Mode of Action Classification Version 8.1, issued April 2016.

genetic modification of this target site. When this happens, the selecting compound's interaction with its target site is impaired and the pesticide loses its pesticidal efficacy. Because all compounds within the chemical subgroup share a common mode of action, there is a high risk that the resistance that has developed will automatically confer cross-resistance to all the compounds in the same subgroup. It is this concept of cross-resistance within chemically related insecticides or acaricides that is the basis of the IRAC mode of action classification.

Effective IRM Strategies Use Alternations or Sequences of Different Modes of Action

The objective of successful Insecticide Resistance Management (IRM) is to prevent or delay the evolution of resistance to insecticides, or to help regain susceptibility in insect pest populations in which resistance has already arisen. Effective IRM is an important element in maintaining the efficacy of valuable insecticides. It is important to recognize that it is usually easier to proactively prevent resistance from occurring than it is to reactively regain susceptibility.

Experience has shown that all effective insecticide or acaricide resistance management strategies seek to minimize the selection for resistance from any one type of insecticide or acaricide. In practice, alternations, sequences, or rotations of compounds from different mode of action groups provide a sustainable and effective approach to IRM. This ensures that selection from compounds in any one mode of action group is minimized. The IRAC mode of action classification is provided as an aid to insecticide selection for these types of IRM strategies.

The following IRM principles are recommended and endorsed by IRAC:

Consider options for minimizing insecticide use by selecting early maturing or pest- tolerant varieties of crop plants.

Include effective cultural and biological control practices that work in harmony with effective IRM programs. Adopt all nonchemical techniques known to control or suppress pest populations, including biological sprays (Bts), resistant varieties, within-field refuges (untreated areas), and crop rotation.

Where possible, select insecticides and other pest management tools that preserve beneficial insects.

Use products at their full, recommended doses. Reduced (sublethal) doses quickly select populations with average levels of tolerance, while doses that are too high may impose excessive selection pressures.

Apply insecticides with appropriate, well-maintained equipment and use recommended water volumes, spray pressures, and optimal temperatures to obtain optimal coverage.

Where larval stages are being controlled, target younger larval instars where possible because these are usually much more susceptible and therefore much more effectively controlled by insecticides than older stages.

Use appropriate local economic thresholds and spray intervals.

Where there are multiple applications per year or growing season, use alternate products with different mode of action classes.

In the event of a control failure, do not reapply the same insecticide. Change the class of insecticide to one having a different mode of action and to which there is no locally known cross-resistance.

The Mode of Action Classification

This classification was developed and endorsed by IRAC and is based on the best available evidence of the mode of action of available insecticides. IRAC companies have agreed to the classification details and internationally recognized industrial and academic insect toxicologists and biochemists have approved the classification.

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