10. Managing Pest Resistance

Pest Resistance to Fungicides, Insecticides and Miticides

Random natural mutation may result in a small proportion of a population that is resistant to a particular chemical or group of chemicals with similar modes of action. When a population is exposed to a pesticide, the resistant individuals survive and the susceptible individuals are killed. The resistant survivors then multiply and pass their resistant traits on to the next generation. When the same pesticide is applied again, the proportion of resistant individuals increases, replacing the susceptible ones in the population. Once the resistant population dominates, the pesticide has lost efficacy. A pest population is considered resistant when it is able to survive exposure to rates of a pesticide that previously controlled it.

Resistance to one pesticide can result in resistance to a different pesticide or a group of pesticides, where pesticides have similar action sites. This is called **cross-resistance**. It develops when exposure to one pesticide causes selection for resistance in other related ones and is the result of a single mechanism or genetic mutation.

Multiple resistance involves two or more mechanisms acquired independently through exposure to pesticides with different action sites. Pests with multiple resistance are resistant to pesticides from two or more groups at the same time.

Multiple resistance and cross-resistance create serious challenges to the success of integrated resistance management strategies.

Pest control failures are not necessarily caused by resistance. Factors such as product selection, timing, rate, spray coverage, spray water pH and weather conditions also affect the success or failure of a pesticide application.

Assessing resistance risk

The development of resistance depends on characteristics of both the pest and the group of pesticides involved, as well as the way in which pesticides are used. Table 10–1. *Factors Favouring the Development of Resistance*, on this page, describes situations where resistance is most likely to occur.

Resistance can develop very quickly for some pesticides. If a product is prone to resistance, do not use the product repeatedly unless it is used in rotation or combination with products from a different group.

Resistance Management Strategies

Resistance management strategies include rotating products from different groups and limiting the total number of applications from a single group within a growing season. Specific knowledge is required for growers to manage resistance effectively.

General resistance management strategies

- Follow an integrated pest management program that makes use of a variety of different pest control strategies, including monitoring, crop rotation and cultural, biological and chemical control options.
- Do not use pesticides at levels below label rates.
- Use adequate water volumes to deliver the pesticide to all tissues.
- Spray only when necessary. Use established thresholds where available.
- Spray at the best timing for the pest and the product you are using.

Table 10–1. Factors Favouring the Development of Resistance

Pests most likely to develop resistance	Pesticides or use patterns where resistance is likely to develop
• have a prolific life cycle, with many generations per year, produce lots of spores, or multiply very quickly	• are used repeatedly or have persistent residues, exposing many generations to these residues
• have a pre-existing resistance to other products in the same group	• are toxic to beneficial insects as well as the pest
• have a narrow host range, spending entire life cycle on one crop	• have a specific mode of action that works on a single site
• do not migrate between crops/regions, so gene pool is not diluted	• are used at deficient rates or improper times

- Make each spray application count. Be sure the sprayer is calibrated, the correct rate is applied and spray coverage is complete.

- Read the product label. New products include resistance management recommendations on the label.

- Know the active ingredient of a pesticide. Many chemicals with the same active ingredients are marketed under different brand names. For example, the insecticide permethrin is marketed under the brand names Pounce and Perm-Up.

- Know the product group. Choose products from different groups when possible in your spray rotation. For example, both Assail and Admire are in the same insecticide group. To use Assail after Admire is equivalent to using Assail after Assail, since resistance to both chemicals develops in the same way.

- For a list of groups and their modes of action, see Table 10–2. *Fungicide/Bactericide Groups*, page 303 and Table 10–3. *Insecticide/Miticide Groups*, page 307, or the "*Products used on*" tables at the end of each crop calendar.

In addition to these general resistance management strategies for all products, more specific strategies have been developed for fungicides, insecticides and miticides.

Managing resistance to fungicides

- Know the fungicide groups. Over a season, choose fungicides from different groups whenever possible.

- Limit the total number of applications, and the number of sequential applications, of a particular fungicide group per season. Look for specific resistance management strategies on the product label.

- Know which disease is targeted by which fungicide group. For combination products, know which fungicide component is controlling which disease. For example, Pristine is a combination of boscalid (Group 7) and pyraclostrobin (Group 11). Boscalid is strong against botrytis grey mould, and pyraclostrobin is effective against powdery mildew and anthracnose. Alternating Pristine with other fungicides in Group 7 is not effective for resistance management of botrytis.

- Apply fungicides before disease occurs. Applications of fungicides after the disease is established are more likely to select for resistant populations of the pathogen.

- Make use of Group M fungicides. These fungicides are known as multi-site inhibitors (Table 10–2. *Fungicide/Bactericide Groups*, page 303). They affect a wide range of metabolic processes in fungi and are not prone to the development of resistance. These products can be applied to fungal pathogens repeatedly, without rotation, with no significant risk of resistance development. Coppers are exceptions to this with respect to bacteria. For example, bacteria causing fire blight or blister spot can develop resistance to these products.

- Tank-mix products from different groups. Wherever possible, one of the tank-mix partners should be a fungicide from Group M, with a multi-site mode of action. (This is an accepted resistance management strategy for fungicides, although not recommended for insecticides.)

Resistance management strategies by fungicide group and disease for Ontario fruit crops

Resistance management strategies are important for diseases like botrytis, powdery mildew, downy mildew, anthracnose, brown rot and apple scab because these pathogens have characteristics which favour the development of resistance (see Table 10–1. *Factors Favouring the Development of Resistance*, page 299).

The suggested strategies for preventing fungicide resistance were developed using the recommendations of the Fungicide Resistance Action Committee (FRAC), which is a working group of Crop Life International. They were then adapted specifically for Ontario based on:

- the resistance risk of the pathogen to a particular fungicide group

- the number of rotation options registered for use at this time

Two components of a resistance management strategy for a fungicide group are limiting the number of consecutive applications before rotating to a different group and observing a maximum number of applications per season. These strategies reduce the risk for resistance development and may be more stringent than label guidelines.

- For high-risk pathogens with fungicide options from many groups, rotation to a different group is advisable after a single application of a resistance-prone fungicide, although this is not necessarily required by the label.

- For pathogens controlled by only a few registered fungicide groups, use no more than 2 consecutive applications of a resistance-prone fungicide and then alternate to a different fungicide group.

When a product contains active ingredients from more than one group, each application counts as a use for each group.

In some cases, a single fungicide group can control more than one pathogen. In this case, the maximum number of consecutive and total applications per season should be based on the pathogen with the highest risk of developing resistance.

Solo products have one active ingredient. Combination products have more than one active ingredient and are indicated with an asterisk (*).

Group 3: Bumper, Fullback, Funginex, Indar, Inspire Super*, Jade, Mettle, Nova, Nustar, Proline, Tilt, Quash, Quilt

- **Apple** — For apple scab, use no more than 2 consecutive applications then rotate to a different fungicide group. Use fungicides from this group no more than 4 times per season as a solo or mixture product. Resistance to Nova and Nustar has recently been confirmed in apple scab populations in Ontario. Avoid using these products in orchards with resistance.

- **Berry crops** — For powdery mildew, use no more than 2 consecutive applications then rotate to a different fungicide group. Use fungicides from this group no more than 4 times per season.

For mummy berry, use no more than 2 consecutive applications and consider tank-mixing with a Group M fungicide such as Captan or Maestro.

- **Grape** — For powdery mildew, use once then rotate to a different fungicide group. Use fungicides from this group no more than 2 times per season.

- **Stone fruit** — For brown rot, use once then rotate to a different fungicide group. Use fungicides from this group no more than 2 times per season.

Group 5: Priwen

- **Grape** — For powdery mildew, use once then rotate to a different fungicide group. Use fungicides from this group no more than 2 times per season.

Group 7: Aprovia, Cantus, Fontelis, Kenja, Luna Tranquility*, Pristine*, Sercadis

- **Apple** — Avoid using Pristine in apple orchards with documented resistance to Group 11 fungicides.

- **Berry crops** — For botrytis grey mould, use once then rotate to a different fungicide group. No more than 30% of total fungicides applied per season should include a solo or mixture product from this group. See Group 11 for recommendations for Pristine use.

- **Grape** — For powdery mildew, use once then rotate to a different fungicide group. Use fungicides from this group no more than 2 times per season as a solo or mixture product.

- **Stone fruit** — For brown rot, use once then rotate to a different fungicide group. Use fungicides from this group no more than 2 times per season as a solo or mixture product.

Group 9: Inspire Super*, Luna Tranquility*, Scala, Switch*

- **Apple and pear** — For scab, use once then rotate to a different fungicide group. Use fungicides from this group prebloom only and no more than 2 times per season.

- **Berry crops** — For botrytis grey mould, use once then rotate to a different fungicide group. No more than 30% of total fungicides applied per season should include a solo or mixture product from this group.

- **Grape** — For botrytis bunch rot, use once then rotate to a different fungicide group. Use fungicides from this group no more than 2 times per season.

- **Stone fruit** — For brown rot, use once then rotate to a different fungicide group. Use solo fungicides (Scala) from this group no more than 2 times per season and co-formulations (Inspire Super, Luna Tranquility, Switch) no more than 3 times per season.

Group 11: Cabrio, Flint, Pristine*, Quadris, Quilt*, Sovran, Tanos*

Resistance to Flint and Sovran has recently been confirmed in apple scab populations in Ontario. Avoid using these products in orchards with resistance.

- **Apple and pear** — For scab, use no more than 2 consecutive applications then rotate to a different fungicide group. Use fungicides from this group no more than 3 times per season as a solo or mixture product.

- **Berry crops** — For botrytis grey mould, use once then rotate to a different fungicide group. No more than 30% of total fungicides applied per season should include a solo product from this group or no more than 50% of total fungicides applied per season if using combination products.

For anthracnose fruit rot, do not make consecutive applications of Group 11 products. Consider tank mixing with group M (Captan or Maestro) to expand the spectrum of disease control.

- **Grape** — For powdery mildew, use once then rotate to a different fungicide group. Use fungicides from this group no more than 2 times per season as a solo or mixture product.

- **Stone fruit** — For brown rot, use once then rotate to a different fungicide group. Use fungicides from this group no more than 2 times per season as a solo or mixture product.

Group 12: Scholar, Switch*

- **Apple and pear** — For storage rots, do not make more than 1 postharvest application of Scholar.

- **Berry crops** — For botrytis grey mould, use no more than 2 consecutive applications of Switch then rotate to a different fungicide group. No more than 50% of total fungicides applied per season should include a product from this group.

- **Grape** — For botrytis bunch rot, use once then rotate to a different fungicide group. Use fungicides from this group no more than 2 times per season.

Group 13: Quintec

- **Strawberry** — For powdery mildew, use no more than 2 consecutive applications then rotate to a different fungicide group. No more than 50% of total fungicides applied per season should include a product from this group.

- **Grape** — For powdery mildew, use once then rotate to a different fungicide group. Use no more than 2 times per season.

- **Stone fruit** — For powdery mildew, use once then rotate to a different fungicide group. Use no more than 2 times per season.

Group 17: Elevate

- **Berry crops** — For botrytis grey mould, use once then rotate to a different fungicide group. Use no more than 2 times per season.

- **Grape** — For botrytis bunch rot, use once then rotate to a different fungicide group. Use no more than 2 times per season.

- **Stone fruit** — For brown rot, use once then rotate to a different fungicide group. Use no more than 2 times per season.

Group 33: Aliette, Confine Extra, Phostrol, Rampart

- **Grape** — For downy mildew, use once then rotate to a different fungicide group. Use fungicides from this group no more than 3 times per season.

Group 40: Acrobat, Revus, Zampro*

- **Grape** — For downy mildew, use once then rotate to a different fungicide group. Use Revus or Acrobat no more than 2 times per season and Zampro no more than 3 times per season.

Group 43: Presidio

- **Grape** — For downy mildew, tank-mix with a labelled rate of another fungicide registered for this disease, but with a different mode of action. Use once then rotate to a different fungicide group. Use no more than 2 times per season.

Group 45: Zampro*

- **Grape** — For downy mildew, use once then rotate to a different fungicide group. Use no more than 3 times per season.

Group U8: Vivando

- **Grape** — For powdery mildew, use once then rotate to a different fungicide group. Use no more than 2 times per season.

Table 10–2. Fungicide/Bactericide Groups

Group	Chemical Group	Product Name	Active Ingredient*
1	MBC (methyl benzimidazole carbamates)	Mertect SC	thiabendazole
		Senator 70 WP	thiophanate-methyl
2	Dicarboximides	Rovral	iprodione
3	DMI (demethylation inhibitors) Note: sometimes loosely known as sterol inhibitors (SI)	Bumper 418 EC	propiconazole
		Fullback 125 SC	flutriafol
		Funginex DC	triforine
		Indar	fenbuconazole
		Inspire Super	difenoconazole* + cyprodinil
		Jade	propiconazole
		Mettle 125 ME	tetraconazole
		Nova	myclobutanil
		Nustar	flusilazole
		Proline 480 SC	prothioconazole
		Quash	metconazole
		Quilt	propiconazole *+ azoxystrobin
		Tilt 250 E	propiconazole
4	PA (phenylamides)	Ridomil Gold MZ 68 WG	metalaxyl* + mancozeb
		Ridomil Gold 480 SL	metalaxyl
5	Amines (morpholines)	Priwen	spiroxamine
7	SDHI (succinate dehydrogenase inhibitors)	Aprovia	benzovindiflupyr
		Cantus WDG	boscalid
		Fontelis	penthiopyrad
		Kenja 400 SC	isofetamid
		Luna Tranquility	fluopyram* + pyrimethanil
		Pristine WG	boscalid* + pyraclostrobin
		Sercadis	fluxapyroxad
9	AP (anilinopyrimidines)	Inspire Super	difenoconazole + cyprodinil*
		Luna Tranquility	fluopyram + pyrimethanil*
		Scala SC	pyrimethanil
		Switch 62.5 WG	cyprodinil* + fludioxonil
11	QoI (quinone outside inhibitors) Note: strobilurins belong in this group, but not all QoI are strobilurins	Cabrio EG	pyraclostrobin
		Flint	trifloxystrobin
		Pristine WG	boscalid + pyraclostrobin*
		Quadris Flowable	azoxystrobin
		Quilt	propiconazole+azoxystrobin*
		Sovran	kresoxim-methyl
		Tanos 50 DF	cymoxanil + famoxadone*
12	PP (phenylpyrroles)	Scholar 230 SC	fludioxonil
		Switch 62.5 WG	cyprodinil + fludioxonil*
13	Aza naphthalenes	Quintec	quinoxyfen
17	Hydroxyanilide	Elevate 50 WDG	fenhexamid
22	B3 Benzamide	Gavel 75 DF	mancozeb + zoxamide*
24	Antibiotic	Kasumin 2 L	kasugamycin
25**	Antibiotic	Streptomycin 17	streptomycin

M = Multi-site fungicides. NC = Not classified by FRAC, or group not indicated on product label. P = Plant extract. U = Mode of action has not been determined.

* Indicates the active ingredient (a.i.) that puts it in this group.
** Recently renamed, formerly Group 18.

Table 10–2. Fungicide/Bactericide Groups (cont'd)

Group	Chemical Group	Product Name	Active Ingredient*
27	Cyanoacetamide oxime	Tanos 50 DF	cymoxanil* + famoxadone
29	2,6-dinitroaniline	Allegro 500 F	fluazinam
33	Phosphonate	Aliette WDG	fosetyl al
		Confine Extra	mono- and dipotassium salts of phosphorous acid
		Phostrol	mono- and dibasic sodium, potassium and ammonium phosphites
		Rampart	mono- and dipotassium salts of phosphorous acid
40	CAA (carboxylic acid amides)	Acrobat 50 WP	dimethomorph
		Revus	mandipropamid
		Zampro	dimethomorph* + ametoctradin
43	B5 Benzamide	Presidio	fluopicolide
44	Microbial	Double Nickel 55	*Bacillus amyloliquefaciens* strain D-747
		Serenade OPTI	*Bacillus subtilis* strain QST 713
45	QxI (quinone x inhibitor)	Zampro	dimethomorph + ametoctradin*
46	Cell membrane disruption	Timorex Gold	tea tree oil
M1	Inorganic	Copper 53 W	tri-basic copper sulphate
		Guardsman Copper Oxychloride 50	copper oxychloride
		Copper Spray	copper oxychloride
		Cueva	copper octanoate
		Kocide 2000	copper hydroxide
M2	Inorganic	Kumulus DF	sulphur
		Lime Sulphur	lime sulphur
		Microscopic Sulphur WP	sulphur
		Microthiol Disperss	sulphur
M3	Dithiocarbamate	Dithane Rainshield	mancozeb
		Ferbam WDG	ferbam
		Gavel 75 DF	mancozeb* + zoxamide
		Granuflo T	thiram
		Manzate Pro-Stick	mancozeb
		Penncozeb 75 DF Raincoat	mancozeb
		Polyram DF	metiram
		Ridomil Gold MZ 68 WG	metalaxyl + mancozeb*
		Thiram 75 WP	thiram
M4	Phthalimide	Supra Captan 80 WDG	captan
		Folpan 80 WDG	folpet
		Maestro 80 DF	captan
M5	Chloronitrile	Bravo ZN	chlorothalonil
		Echo 90 DF	chlorothalonil
NC	Biological	Actinovate SP	*Streptomyces lydicus*
		Bio-Save 10 LP	*Pseudomonas syringae*
		Bloomtime Biological FD	*Pantoea agglomerans*
		Blossom Protect	*Aureobasidium pullulans*

M = Multi-site fungicides. NC = Not classified by FRAC, or group not indicated on product label. P = Plant extract. U = Mode of action has not been determined.

* Indicates the active ingredient (a.i.) that puts it in this group.
** Recently renamed, formerly Group 18.

Table 10–2. Fungicide/Bactericide Groups (cont'd)

Group	Chemical Group	Product Name	Active Ingredient*
NC	Bicarbonate	MilStop	potassium bicarbonate
		Sirocco	potassium bicarbonate
NC	Oil	Purespray Green Spray Oil 13 E	mineral oil
NC	Not classified	Buran	garlic powder
		Fracture	BLAD polypeptide
		Tivano	citric acid + lactic acid
P5	Plant extract	Regalia Maxx	*Reynoutria sachalinensis* extract
U8	Benzophenone	Vivando SC	metrafenone
U12	Guanidines	Syllit 400 FL	dodine

M = Multi-site fungicides. NC = Not classified by FRAC, or group not indicated on product label. P = Plant extract. U = Mode of action has not been determined.

* Indicates the active ingredient (a.i.) that puts it in this group.
** Recently renamed, formerly Group 18.

Managing resistance to insecticides and miticides

- Know the insecticide groups. Rotate products from different groups. Avoid sequential applications of the same group or repeated use of any insecticide or group of insecticides.

- For insects with discrete generations (e.g., oriental fruit moth, codling moth, grape berry moth), manage each generation of an insect pest as separate units or "treatment windows". Use products from a single insecticide group to manage a given generation of a pest. If the pest emergence or activity of that generation is prolonged, apply a second application of the same product. This exposes each generation to only one group. Rotate to another insecticide group (or groups) for subsequent generations.

  For pests whose populations build quickly and with multiple, overlapping generations (e.g., aphids, mites), rotate between products in different insecticide groups for each spray.

- Avoid unnecessary or repeated applications of miticides and rotate between products in different groups. Many labels limit the number of applications of a product to one per season. Consider a multi-year rotation of miticides, so that mites are not exposed to products with a similar mode of action more frequently than once every 3–4 years.

- Consider annual delayed dormant oil or summer oils to suppress mite or aphid populations and reduce the need for miticides when numbers exceed the treatment threshold(s).

- Time sprays to contact the most susceptible life stage of the pest.

- Tank mixes and pre-formulated mixtures are pest management tools, not insecticide resistance management tools. Mixtures can provide a broader range of target pest control, however, their repeated use increases the probability that the target pest population(s) will develop multiple resistances. Alternating or rotating between products with one active ingredient, rather than mixing them, is the preferred strategy for insecticides and miticides in most situations.

- Consider area-wide resistance management programs such as mating disruption, especially for pests of more than one crop.

- Encourage biological control by choosing pesticides less harmful to beneficial insects and by landscaping to provide flowering plants and unsprayed habitat for these natural enemies. This may reduce the need for insecticides or miticides, particularly those targeting indirect pests such as aphids and mites.

Resistance management strategies by insecticide group for Ontario fruit crops

Solo products have one active ingredient. Combination products have more than one active ingredient and are indicated with an asterisk (*).

Group 1A, 1B & 2A

Resistance to these older, broad-spectrum insecticides has occurred in various fruit pest populations in Ontario. Documented cases include resistance to organophosphates in spotted tentiform leafminer and codling moth on apples, obliquebanded leafroller on apples and pears, pear psylla on pears, and oriental fruit moth on peaches, nectarines, pears and apples.

Group 3: Ambush, Concept*, Decis, Mako, Matador, Perm-Up, Pounce, Pyganic, Silencer, Up-Cyde

Present status of spotted tentiform leafminer and pear psylla resistance is unknown given that resistance in these pests has not been monitored since the early 1990s. Previous studies demonstrate that spotted tentiform leafminer adults became resistant to all pyrethroids in many orchards in Ontario when exposed to repeated applications of these chemicals. Pear psylla resistance to pyrethroids has been documented in western North America and some pear orchards in the Niagara peninsula. Resistance may occur in other parts of the province. Documented cases of resistance in populations of obliquebanded leafroller on apples have been found.

The repeated use of pyrethroid insecticides (more than once per season) is discouraged because of the potential for further resistance development and because pyrethroids are toxic to beneficial insects and mites.

Group 4: Actara, Admire, Alias, Calypso, Closer, Clutch, Concept*, TwinGuard*

Documented cases of resistance to Calypso have been found in some codling moth populations in Ontario and Quebec.

Group 5: Delegate, Entrust, GF-120, Success, TwinGuard*

Resistance in western flower thrips to this group is known in greenhouse crops and could also be present in outdoor crops.

Group 11: Bioprotec, Dipel, Foray

There are no documented cases of resistance in Ontario for fruit crops. Use the basic principles of resistance management to ensure that insecticides in these groups work well in the future.

Group 15: Rimon

There are no documented cases of resistance in Ontario for fruit crops. Use the basic principles of resistance management to ensure that insecticides in these groups work well in the future.

Group 18: Confirm, Intrepid

Documented cross-resistance between organophospate insecticides and the growth regulators, Confirm and Intrepid, has been found in some obliquebanded leafroller and codling moth populations, respectively, in Ontario. Where resistance is suspected for obliquebanded leafroller or codling moth, do not use Group 18, 1A or 1B. Always use one group of insecticides within the generation and rotate insecticide groups between generations. Consult the apple calendar for the appropriate timing of these products.

Group 28: Altacor, Exirel

There are no documented cases of resistance in Ontario for fruit crops. Use the basic principles of resistance management to ensure that insecticides in these groups work well in the future.

Resistance management strategies by miticide group for Ontario fruit crops

Group 6: Agri-Mek

There are no documented cases of resistant mite populations in Ontario to this group. Use resistance management principles. Apply this product early before threshold numbers are reached.

Group 10: Apollo

Isolated cases of mite resistance to Apollo have been found in Ontario. Resistance has occurred where Apollo has been applied repeatedly in one season, or applied too late in the season. To delay resistance to Apollo, do not use Apollo every year. Apply Apollo when the mite population is synchronous and in the first summer-generation egg stage.

Group 20B, 21 & 25: Kanemite, Nexter Nealta

There are no documented cases of resistant mite populations in Ontario. Use resistance management principles.

Group 23: Envidor, Movento, Oberon

There are no documented cases of resistant mite populations in Ontario. Use resistance management principles. These products work slowly, so patient and careful monitoring is needed to assess the results.

Group UN: Acramite

There are no documented cases of resistant mite populations in Ontario. Use resistance management principles.

Table 10–3. Insecticide/Miticide Groups

Group	Type of Action	Chemical Sub-group or Exemplifying Active Ingredient	Product Name	Active Ingredient
1	Nerve	1A[1] Carbamates	Lannate Toss-N-Go	methomyl
			Sevin XLR	carbaryl
			Vydate L	oxamyl
		1B[1] Organophosphates	Cygon 480-AG	dimethoate
			Diazinon 50 WSP	diazinon
			Diazinon 500 E	diazinon
			Imidan 70-WP Instapak	phosmet
			Lagon 480 E	dimethoate
			Lorsban 50 W	chlorpyrifos
			Malathion 25 W	malathion
			Malathion 85 E	malathion
			Orthene 75% SP	acephate
			Pyrinex 480 EC	chlorpyrifos
			Warhawk 480 EC	chlorpyrifos
2	Nerve	2A[2] Cyclodiene organochlorines	Thionex 50 W WSP	endosulfan
3	Nerve	3A Pyrethroids Pyrethrins	Ambush 500 EC	permethrin
			Capture 240 EC	bifenthrin
			Concept	imidaclorpid + deltamethrin*
			Decis 5 EC	deltamethrin
			Mako	cypermethrin
			Matador 120 EC	lambda-cyhalothrin
			Perm-Up EC	permethrin
			Pounce 384 EC	permethrin
			Pyganic EC 1.4 II	pyrethrins
			Silencer 120 EC	lambda-cyhalothrin
			Up-Cyde 2.5 EC	cypermethrin
4	Nerve	4A[3] Neonicotinoids	Actara 25 WG	thiamethoxam
			Admire 240 Flowable	imidacloprid
			Alias 240 SC	imidacloprid
			Assail 70 WP	acetamiprid
			Calypso 480 SC	thiacloprid
			Clutch 50 WDG	clothianidin
			Concept	imidacloprid* + deltamethrin
		4C[3] Sulfoxaflor	Closer	sulfoxaflor
			TwinGuard	sulfoxaflor*+spinetroam

NC = Not classified by IRAC, or group not indicated on product label. UN = Mode of action has not been determined.

* Indicates the active ingredient (a.i.) that puts it in this group.

[1] All members of Group 1 may not be cross-resistant, although they share the same primary target site and mode of action. For this reason, Group 1 is divided into sub-groups Group 1A and 1B, each with different mechanisms of resistance. Assume that cross-resistance exists between pesticides in each sub-group, but that rotation of pesticides between sub-groups is an acceptable part of a resistance management program.

[2] Other resistance mechanisms that are not linked to site of action (i.e., enhanced metabolism) are common for this group of chemicals.

[3] Although compounds in Groups 4A and 4C are thought to have the same target site, current evidence suggests the risk of metabolic cross-resistance between Groups 4A and 4C is low. If there are no other alternatives, then compounds from Groups 4A and 4C may be rotated.

Table 10–3. Insecticide/Miticide Groups (cont'd)

Group	Type of Action	Chemical Sub-group or Exemplifying Active Ingredient	Product Name	Active Ingredient
5	Nerve	Spinosyns	Delegate	spinetoram
			Entrust	spinosad
			GF-120 Fruit Fly Bait	spinosad
			Success	spinosad
			TwinGuard	sulfoxaflor+spinetroam*
6	Nerve and muscle	Avermectins	Agri-Mek SC	abamectin
9	Nerve-feeding blockers	9C Flonicamid	Beleaf 50 SG	flonicamid
10	Growth regulation	10A Clofentezine	Apollo SC	clofentezine
11	Disrupt midgut membrane	11A B.t. microbial (and the insecticidal proteins they produce)	Bioprotec CAF	*Bacillus thuringiensis* var. *kurstaki*
			Dipel 2X DF	*Bacillus thuringiensis* var. *kurstaki*
			Foray 48 BA	*Bacillus thuringiensis* var. *kurstaki*
15	Growth regulation	Benzoylureas	Rimon 10 EC	novaluron
18	Growth regulation	Diacylhydrazine	Confirm 240 F	tebufenozide
			Intrepid 240 F	methoxyfenozide
20	Energy metabolism	20B Acequinocyl	Kanemite 15 SC	acequinocyl
21	Energy metabolism	21A Mitochondrial complex I electron transport inhibitors (METI)	Nexter	pyridaben
23	Lipid synthesis, growth regulation	Tetronic and tetramic acid derivatives	Envidor 240 SC	spirodiclofen
			Movento 240 SC	spirotetramat
			Oberon Flowable	spiromesefin
25	Energy metabolism	Beta-ketonitrile derivatives	Nealta	cyflumetofen
28	Nerve and muscle	Diamides	Altacor	chlorantraniliprole
			Exirel	cyantraniliprole
NC	Disrupt gut and other insect tissues	Granulosis virus	CYD-X	*Cydia pomonella* granulovirus
			Virosoft CP 4	*Cydia pomonella* granulovirus
UN	Unknown	Bifenazate	Acramite 50 WS	bifenazate

NC = Not classified by IRAC, or group not indicated on product label. UN = Mode of action has not been determined.

* Indicates the active ingredient (a.i.) that puts it in this group.

[1] All members of Group 1 may not be cross-resistant, although they share the same primary target site and mode of action. For this reason, Group 1 is divided into sub-groups Group 1A and 1B, each with different mechanisms of resistance. Assume that cross-resistance exists between pesticides in each sub-group, but that rotation of pesticides between sub-groups is an acceptable part of a resistance management program.

[2] Other resistance mechanisms that are not linked to site of action (i.e., enhanced metabolism) are common for this group of chemicals.

[3] Although compounds in Groups 4A and 4C are thought to have the same target site, current evidence suggests the risk of metabolic cross-resistance between Groups 4A and 4C is low. If there are no other alternatives, then compounds from Groups 4A and 4C may be rotated.