8. Pesticide Application, Toxicity and Activity

Pesticide Application Effectiveness

When pesticide control fails, resistance is often suspected. However, resistance is not the most common cause of control failure, and a number of other factors should also be considered:

- Ensure that pesticide rates are calculated correctly and the product is measured accurately.
- Good coverage is needed for good pest control. Simple changes such as walking at a slower pace through the crop when applying pesticides, or walking every aisle instead of every other one, can significantly improve performance.
- Maintain spray equipment in good condition, changing spray nozzles on a regular basis. Older nozzles become worn, which can alter spray pattern and droplet size.
- Consider using different application technologies. High-volume, low-volume and electrostatic-spray application all have appropriate uses in the greenhouse.
- The biggest improvement in pesticide application may come from timing and targeting sprays more effectively. To accomplish this, implement an IPM program that provides the required information to decide when, where and why a pesticide application is needed. Sprays can then be applied where needed most (e.g., as spot sprays), when they will provide optimal control, and directly at the appropriate pest at the correct life stage.
- Pesticide effectiveness will vary (often considerably) between greenhouses, depending on factors such as the usage history of a particular product, the method of application, the time of application and the water quality.

Water for pesticide application

It is very important to lower the pH of alkaline water before using it for pesticide spray-tank mixtures. Adjust water pH to 5.5–6.0. At pH greater than 7, the pesticide may degrade rapidly. The rate of degradation depends on the pesticide, the concentration of pesticide in the tank (dilution factor) and the temperature of the water. To avoid the potential for pesticide degradation at higher pH, neutralize alkaline water before adding any pesticides.

Water-soluble fertilizers are used occasionally with pesticides as a tank mixture. In this case, it is important to choose acidic fertilizers, which make the further acidification of the water unnecessary. Do not use alkaline fertilizers for this purpose as it will be more difficult to neutralize the water and pesticide degradation may increase.

If it is not possible to acidify the spray water, try to use pesticides diluted with alkaline water (pH >7) immediately.

Pesticide compatibility

The rates, efficacy and phytotoxicity information for pesticides listed in this publication are based on these products being applied alone as opposed to being applied in mixtures.

Before mixing pesticides, read the product labels carefully for compatibility statements or contact the supplier. Avoid mixing emulsifiable concentrate formulations. Herbicides should never be mixed with fungicides and insecticides. Herbicides should be applied with spray equipment reserved for herbicide use only.

Types of Pesticide Application

Spraying

Spraying is one of the most widely used and effective methods of applying pesticides. Clean and maintain nozzles to achieve a fine spray that will result in uniform coverage when the mixture is applied up to the point of runoff. Complete coverage is the objective. Spray both the lower and upper leaf surfaces thoroughly.

Soil drenches

Soil drenches are used for both disease and insect control and involve the application of the pesticide to the root zone. The amount of pesticide added varies depending on the pot size and volume of the growing medium. To thoroughly wet the growing medium in a 15-cm pot requires approximately 150–180 mL. For soil beds, apply 12 L of drench per m^2. Be aware that not all pesticides require that the medium be completely wet, so follow the label directions carefully.

For disease control, drenches should not replace a thorough greenhouse pasteurization program, but are useful for preventing recontamination or eliminating pathogens in the soil or the basal parts of the plant. Use a root inspection monitoring program as the first line of defence against root diseases.

Some drenches are taken up from the soil by plant roots and distributed throughout the plant. This is described as systemic action, and the whole plant is effectively treated against the pest or disease being targeted.

For insect control, drenches can be used for either soil-dwelling insects, such as fungus gnats and shoreflies, controlling them by contact action, or for foliar-feeding sucking insects, such as aphids and whiteflies, using systemically active products.

Thermal fogs

Thermal fogs are produced by several kinds of machines, all of which use heat from different sources to vaporize the pesticide. Fogging can be a very efficient method of pesticide application, but the machine must be well-maintained.

Granular application

Several types of applicators are available for applying granular pesticides. Be sure the applicator does not grind or fracture the granules.

Insecticidal smoke applications

Smokes are a very simple but effective means of pesticide application. DDVP is the only registered pesticide available in a smoke applicator. There is no equipment involved – containers are simply placed on the path and lit. Do not use smokes in very old, poorly sealed greenhouses or during high winds.

Ultra-low volume

There are several types of ultra-low volume (U.L.V.) applicators available. They atomize the pesticide solution to an extremely small particle size (7–20 microns) and distribute pesticide through the greenhouse by a forced-air fan system.

Electro-static sprayers

Electro-static sprayers (E.S.S.) add an electrical charge to the fine spray particles. This enhances plant coverage by the pesticide and reduces drift.

Seed treatments

Seed treatments are pesticides that coat the seed, providing protection against pests or diseases during germination and early growth stages of the plant. See precautions when using seed treatments in Chapter 2, *Safe Use of Pesticides* on page 11.

Wetting Agents

Wetting agents are classified as pesticides and must be registered as such. In the following paragraphs, the term "wetting agent" includes spreaders, stickers and surfactants, although these terms have slightly different technical meanings.

Water will not always spread evenly over a surface. Its high surface tension means that when sprayed on a leaf (hydrophobic) surface, it forms large droplets that easily roll (with the pesticides) off the leaf and onto the ground.

Adding a wetting agent reduces the water's surface tension and allows the water to make better contact with the leaves. Consequently, the pesticides spread more evenly over the leaf surface. Most pesticides are formulated with a wetting agent in them. However, in some cases (due to air or water temperature, water hardness, type of leaf surface, stage of plant growth and/or the type of formulation), the amount may not be adequate. Consult the pesticide label for specific recommendations.

A simple method to determine if there is a sufficient amount of wetting agent is to spray approximately 3 m of bed area. Examine both the upper and lower surfaces of the leaves at different growth stages for evidence of uniform wetting. If wetting is not uniform, add 125 mL of spreader/1,000 L of spray. Spray another 3 m of the bed and re-examine, continuing until wetting is satisfactory. Wetting agents help the spray solution wet powdery mildew mycelium, improving control. However, an excessive amount of wetting agent can cause plant damage and excessive foaming, which will cause pumping problems or runoff resulting in poor control.

Pesticide Toxicity and Classification

The toxicity, Restricted Entry Interval, chemical family, pesticide grouping and Ontario classification of pesticides included in this publication are listed in Table 8-1. *Insecticide and Miticide Toxicity and Classification* on page 104, Table 8-2. *Fungicide Toxicity and Classification* on page 106, Table 8-3. *Growth Regulator Toxicity and Classification* on page 108, and Table 8-4. *Herbicide Toxicity and Classification* on page 108. Products have been included in these tables if they are registered for use in greenhouse or outdoor ornamental crops. Read the product label for each pesticide being considered for use to ensure suitability for a particular crop and use pattern.

Pesticide groupings are listed in the tables below for insecticides, fungicides and herbicides. These groupings are used to differentiate the modes of action (MOA), i.e., how they work on the insect, disease or weed pest, based on classifications of the Insecticide Resistance Action Committee (IRAC), the Fungicide Resistance Action Committee (FRAC) and the Herbicide Resistance Action Committee (HRAC). The actual terminology that describes the MOA is complex and technical, so it is has been simplified by assigning numbers to the various MOAs in each group of pesticides. This information is important since resistance development in pests is often associated with a specific MOA. If resistance develops to a pesticide, the chances of cross-resistance occurring with other pesticides with the same MOA are very high. Therefore, rotating between pesticides with different MOAs is an important strategy in managing the development of resistance. It becomes much simpler to do this by just referring to the pesticide group number to ensure that there is not excessive use of pesticides in the same group. Tables 8-5. 8-6 and 8-7 list the MOAs and the groupings of insecticides, fungicides and herbicides based on IRAC, FRAC and HRAC classification. In addition, pesticide groups are also noted in Table 10-2. *Pesticide Registrations by Pest* on page 133. This allows for a quick check of the pesticide groups available for each pest, making it easier to develop a rotational program.

Table 8-1. Insecticide and Miticide Toxicity and Classification

Common Name	Trade Name	LD_{50} (mg product per kg body weight)[1] unless stated otherwise	REI (hours)[2]	Chemical Family	IRAC Insecticide Group[3]	Ontario Classification
Abamectin	Avid 1.9% EC	300	Dry	Avermectin	6	4
Acephate	Orthene 75 SP	1,494	12 24 (cut flowers)	Organophosphate	1B	3
Acequinocyl	Shuttle 15 SC	>5,000	12	Acequinocyl	20B	3
Acetamiprid	Tristar 70 WSP	1,064	12	Neonicotinoid	4A	3
Bacillus thuringiensis	Dipel 2X DF Dipel WP Thuricide BioProtec 3P BioProtec CAF Vectobac 600L	>5,050 >4,000 Not stated Not toxic Not toxic >5,000	12 12 12 12 12 12	Biological	11	4 4 4 4 3 3
Beauveria bassiana Strain GHA *Beauveria bassiana Strain* ANT-03	BotaniGard 22 WP BotaniGard ES BioCeres G WP	>5,000 >5,000	4 4 When dry	Biological Biological	Microbial products are not classified under IRAC	3
Bifenazate	Floramite SC	>5,000	12	Carbazate	Unknown	4
Carbaryl	Sevin T&O Sevin SL Chipco Sevin RP2	642 590 1,820	12 12 12	Carbamate	1A	3
Chlorfenapyr	Pylon	560–567	12	Pyrrole	13	2
Chlorpyrifos	Dursban Turf Dursban WSP Pyrate 480	135 382 409	48	Organophosphate	1B	3
Clofentezine	Apollo SC	>5,000	12	Tetrazine	10A	3
Cyromazine	Citation 75 WP	4,460	12	Triazine	17	3
Deltamethrin	DeltaGard SC	>15,000	12	Synthetic pyrethroid	3A	3
Dichlorvos	DDVP Smoke 20% EC	56 56	24	Organophosphate	1B	3
Diflubenzuron	Dimilin 25 WP	>10,000	12	Substituted benzoylurea	15	3
Dimethoate	Cygon 480 Lagon 480	425	12 12	Organophosphate	1B	3
[4]Endosulfan	Thiodan 4EC Thiodan 50 WP Thionex EC Thionex 50W	107 24 45 41	48 48 48 48	Organochlorine	2A	4
Fenbutatin oxide	Vendex 50W	>5,000	12	Organotin	12B	4
Flonicamid	Beleaf 50SG	>2,000	12	pyridinecarboximide	9C	4
Imidacloprid	Intercept 60 WP	1,858	12	Neonicotinoid	4A	4
Kinoprene-S	Enstar EW	3,129	12	Insect growth regulator	7A	4
Malathion	Malathion 25 W Malathion 500 E	1,375 1,375	12 12	Organophosphate	1B	4
Metarhizium anisopliae (Strain F52)	Met52	Value not stated. Listed as very low toxicity	0	Biological	Microbial products are not classified under under IRAC	4
Mineral oil	Landscape Oil	>15,000	12	Horticultural oil		3

Common Name	Trade Name	LD_{50} (mg product per kg body weight)[1] unless stated otherwise	REI (hours)[2]	Chemical Family	IRAC Insecticide Group[3]	Ontario Classification
Naled	Dibrom	92	48	Organophosphate	1B	3
Paecilomyces fumosoroseus	NoFly	>5,000	4	Biological	Microbial products are not classified under IRAC	3
Permethrin	Pounce 384 EC Ambush 50 EC	1,030 2,280	12 12	Synthetic pyrethroid	3A	4
Phosmet	Imidan 50 WP	275	72	Organophosphate	1B	3
Potassium salts of fatty acids	Safer's Insecticidal Soap Opal Insecticidal Soap	>5,000 >5,000	12 12	Insecticidal soap	Potassium salts of fatty acids are not classified under IRAC	4
Pymetrozine	Endeavor 50 WG	>5,000	12	Pymetrozine	9B	4
Pyridaben	Dyno-Mite 75 W	1,930	12	METI acaricides and insecticides	21A	4
Pyriproxifen	Distance	3,773	12	Juvenile hormone mimic	7C	3
Spinosad	Success 480 SC	>5,000	Dry	Spinosyn	5	3
Spiromesifen	Forbid 240 SC	>2,000	12	Tetronic acid	23	3
Spirotetramat	Kontos	>2,000	12	Tetramic acid	23	4
Tebufenozide	Confirm 240 F	>5,000	12	Insect growth regulator	18	3

[1] Figures obtained from the Material Safety Data Sheet (MSDS) for each product. Products with the same active ingredient can differ in LD_{50} because of differences in concentration of the active and toxicity of inert ingredients. Where the LD_{50} has been obtained using technical active ingredient instead of formulated product, this has been noted.

[2] REI is the Restricted Entry Interval as described in Chapter 1, *Using Pesticides in Ontario*. Where no REI is listed on the label, it is assumed to be 12 hours. "Dry" means the treated area is safe to enter when the spray has dried.

[3] Insecticide Resistance Action Committee.

[4] Endosulfan registration is being phased out. Registrants must cease production and sale of endosulfan pesticide products by Dec 31, 2014. Sale of endosulfan products by others is not permitted after Dec 31, 2015, and use by growers is not permitted after Dec 31, 2016.

Table 8-2. Fungicide Toxicity and Classification

Common Name	Trade Name	LD_{50} (mg product per kg body weight)[1] unless stated otherwise	REI (hours)[2]	Chemical Family	FRAC Fungicide Group[3]	Ontario Classification
Azoxystrobin	Heritage	>5,000	12	Strobilurin	11	3
Bacillus subtilis Strain QST 713	Rhapsody ASO Cease Biological Fungicide	>5,000 >5,000	12 12	Biological Biological	44 44	4 3
Bacillus subtilis Strain MBI 600	BioTak	None known	12	Biological	44	3
Bacillus subtilis var. amyloliquefaciens Strain FZB24	Taegro	Very low	0	Biological	44	3
Boscalid/pyraclostrobin	Pristine WG	1,490	12	Pyridine carboximide/ strobilurin	7/11	2
Captan	SupraCaptan 80 WDG Maestro 80 DF Captan 50 WP	>5,000 (Technical) >5,000	96 96 96	Phthalimide	M4	3
Chlorothalonil	Daconil 2787 Daconil Ultrex	4,200 >5,000	48	Chloronitrile	M5	4
Citric acid/Lactic acid, as fermentation products of *Lactobacillus casei* Strain LPT-111	Cyclone/Tivano	Not stated. Listed as “No known acute effects from swallowing”.	12	Biological	Not classified	4
Coniothyrium minitans	Contans	>2,500	12	Biological	Not classified	4
Copper	Phyton-27	Not stated	Dry	Inorganic	M1	4
Cyazofamid	Torrent 400SC	>5,000	12	Cyano-imadizole	21	4
Cyprodinil/fludioxinil	Switch 62.5 WG	>5,000	12	Anilino-pyrimidine/ phenyl pyrrole	9/12	3
Dazomet	Basamid Granular	519	See label	Diazine	27	3
Dicloran	Botran 75W	>4,640	12	Aromatic hydrocarbon	14	4
Dimethomorph	Acrobat 50 WP	2,939	12	Cinnamic acid amide	40	3
[4]Dodemorph acetate	Meltatox 40 EC	>2,000	12	Morpholine	5	4
Etridiazole	Truban 30 WP Truban 25 EC	1,077 2,404	12	Thiadiazole	14	4
Fenhexamid	Decree 50 WDG	>2,000	4	Hydroxyanilide	17	3
Fluopicolide	Presidio	>2,000	12	Benzamide	43	2
Folpet	Folpan 50 WP Folpan 80 WDG	>2,000 >5,000	12 24	Phthalimide	M4	4
Fosetyl-Al	Aliette T&O	2,860	12	Ethyl phosphonate	33	3
Gliocladium catenulatum	PreStop	>2,000	4	Biological	Not classified	3
Hydrogen peroxide	ZeroTol	330 (7% solution)	Dry	Not classified	Not classified	3
Iprodione	Rovral 50 WP Rovral WDG	>5,000	12	Dicarboximide	2	3
Mancozeb	Dithane M-45	>5,000	12	Dithiocarbamate	M3	4
Mandipropamid	Micora, Revus	>5,000	12	Mandelic acid amide	40	3
Metalaxyl	Subdue Maxx	2,965	24	Acylalanine	4	3
Mono- and di-potassium salts of phosphorous acid	Confine	>5,000	12	Phosphonates	33	4
Mono- and dibasic sodium, potassium and ammonium phosphites	Phostrol	>5000	12	Phosphonates	33	4

Common Name	Trade Name	LD_{50} (mg product per kg body weight)[1] unless stated otherwise	REI (hours)[2]	Chemical Family	FRAC Fungicide Group[3]	Ontario Classification
Myclobutanil	Nova 40 W	3,129 (Technical)	24	Triazole	3	3
Potassium bicarbonate	Milstop	2,700	4	Inorganic	Not classified	4
Propamocarb hydrochloride	Previcur N	>2,000	24	Carbamates	28	3
Quintozene	Quintozene 75 WP	>3,670	12	Aromatic hydrocarbon	14	4
Regalia Maxx	Extract of *Reynoutria sachalinensis*	>5,000	Dry	Botanical	P5	3
Streptomyces griseoviridis	Mycostop	>15,000	4	Biological	Not classified	4
Streptomyces lydicus	Actinovate SP	Non toxic	1	Biological	Not classified	4
Sulphur	GroTek Ascend Vapourized Sulphur	>3,000	24	Inorganic	M2	3
Thiophanate methyl	Senator 70 WP	>6,000	12	Thiophanate	1	4
Trichoderma harzianum	RootShield Drench RootShield Granules	Non toxic Non toxic	4	Biological	Not classified	4
Trifloxystrobin	Compass 50 WG	>5,050	12 (48 for cut flowers)	Strobilurin	11	3
Triforine	Funginex 190 EC	3,487	48	Piperazine	3	3

[1] Figures obtained from the Material Safety Data Sheet (MSDS) for each product. Products with the same active ingredient can differ in LD_{50} because of differences in concentration of the active and toxicity of inert ingredients. Where the LD_{50} has been obtained using technical active ingredient instead of formulated product, this has been noted.

[2] REI is the Restricted Entry Interval as described in Chapter 1, *Using Pesticides in Ontario*. Where no REI is listed on the label, it is assumed to be 12 hours. "Dry" means the treated area is safe to enter when the spray has dried.

[3] Fungicide Resistance Action Committee.

[4] Meltatox registration is being phased out. Sale of Meltatox by retailers is not permitted after Dec 31, 2015, and use by growers is not permitted after Dec 31, 2016.

Table 8-3. Growth Regulator Toxicity and Classification

Common Name	Trade Name	LD_{50} (mg product per kg body weight)[1] unless stated otherwise	REI (hours)[2]	Chemical Family	Ontario Classification
Ancymidol	A-Rest	>5,000	12	Pyrimidine	4
Benzyladenine + gibberellins A_4A_7	Fascination Fresco	>5,050 3,400	12	Cytokinin	4
6-benzylaminopurine	Configure	>2,000	12	Cytokinin	4
Chlormequat	Cycocel Extra	2,836	12	Quaternary ammonium	3
Daminozide	B-Nine WSG Dazide 85 WSG	>5,000 >5,000	24	Organic acid	3
Ethephon	Florel	>5,000	12	Ethylene regulator	4
1-Methylcyclopropene	EthylBloc Technology	>5,000	30 min. venting after end of treatment	Ethylene inhibitor	2
Paclobutrazol	Bonzi Piccolo	>5,346 >2,000	12	Triazole	3
Uniconazole	Sumagic	>5,000	12	Triazole	3

[1] Figures obtained from the Material Safety Data Sheet (MSDS) for each product. Products with the same active ingredient can differ in LD_{50} because of differences in concentration of the active and toxicity of inert ingredients.
[2] REI is the Restricted Entry Interval as described in Chapter 1, *Using Pesticides in Ontario*. Where no REI is listed on the label, it is assumed to be 12 hours. "Dry" means the treated area is safe to enter when the spray has dried.

Table 8-4. Herbicide Toxicity and Classification

Common Name	Trade Name	LD_{50} (mg product per kg body weight)[1] unless stated otherwise	REI (hours)[2]	Chemical Family	HRAC/WSSA Group[3]	Ontario Classification
Chlorthal dimethyl	Dacthal W75	>10,000	12	Phthalate	3	4
Dazomet	Basamid Granular	519	See label	Dithiocarbamate	Z (Unknown site of action)	3
Dimethenamid-P	Frontier Max	500–2,000	24	Amide	15	3
Fluazifop	Venture L	2,451	12	Aryloxyphenoxypropionate	1	2
Glyphosate	Roundup	5,400	12	Amino acid	9	4
Isoxaben	Gallery 75 DF	>5,000	12	Benzamide	21	3
Metam	Vapam	812	See label	Thiocarbamate	Z (Unknown site of action)	4
Metolachlor	Dual Magnum	3,425	12	Acetanilide	15	4
Napropamide	Devrinol 50 DF Devrinol 2G Devrinol 10G	>5,000 >5,000 >5,000	12 12 12	Amide	15	4
Pendimethalin	Prowl H_2O	>5,000	24	Dinitroaniline	3	3
Propyzamide	Kerb 50 WSP	>5,000	24	Amide	3	3
Simazine	Princep Nine-T Simadex Simazine 480	>5,000 15,380 >5,000	12 12 12	S-triazine	5	3
Trifluralin	Bonanza 480 Treflan EC Rival 500 EC	3,738 3,738 5,600	12 12 12	Dinitroaniline	3	4

[1] Figures obtained from the Material Safety Data Sheet (MSDS) for each product. Products with the same active ingredient can differ in LD_{50} because of differences in concentration of the active and toxicity of inert ingredients.
[2] REI is the Restricted Entry Interval as described in Chapter 1, *Using Pesticides in Ontario*. Where no REI is listed on the label, it is assumed to be 12 hours. "Dry" means the treated area is safe to enter when the spray has dried.
[3] Herbicide Resistance Action Committee/Weed Science Society of America.

Table 8-5. Insecticide Groups Based on Sites of Action

The classification scheme listed below is adapted from information developed by the Insecticide Resistance Action Committee Mode of Action Working Group. Products with the same group number have a similar mode of action. For details on this classification system, see *www.irac-online.org/*.

Group #	Primary Site of Action	Group Name	Product Name(s)
1A	Acetylcholinesterase inhibitor	Carbamate	Sevin
1B	Acetylcholinesterase inhibitor Nerve action	Organophosphate	DDVP, Diazinon, Dibrom, Malathion, Orthene, Dursban/Pyrate, Cygon/Lagon, Imidan
2A	GABA-gated chloride channel agonists Nerve action	Cyclodiene organochlorines	Thiodan/Thionex
3A	Sodium channel modulators Nerve action	Pyrethroids	Ambush/Pounce, Decis/DeltaGard
		Pyrethrins	
4A	Nicotinic acetylcholine receptor agonists Nerve action	Neonicotinoids	Intercept, Tristar
5	Nicotinic acetylcholine receptor (n AChR) allosteric activators	Spinosyns	Success
6	Chloride channel activators Nerve and muscle action	Avermectins	Avid
7A	Juvenile hormone mimics	Juvenile hormone analogues	Enstar EW
7C	Juvenile hormone mimics Growth regulation	Pyriproxyfen	Distance
9B	Modulator of chordotonal organs	Pymetrozine	Endeavor
9C	Modulator of chordotonal organs	Flonicamid	Beleaf 50SG
10A	Mite growth inhibitors	Clofentezine	Apollo
11	Microbial disruptors of insect midgut membranes	*Bacillus thuringiensis*	Bioprotec/Dipel/Thuricide/VectoBac
13	Uncouplers of oxidative phosphorylation via disruption of the proton gradient	Pyrroles	Pylon
12B	Inhibitors of mitochondrial ATP synthase Energy metabolism	Organotin miticides	Vendex
15	Inhibitors of chitin biosynthesis, type 0 Growth regulation	Benzoyl urea	Dimilin
17	Moulting disruptor Growth regulation	Cyromazine	Citation
18	Ecdysone receptor agonists	Diacylhydrazine	Confirm
20B	Mitochondrial complex III electron transport inhibitors	Acequinocyl	Shuttle
21A	Mitochondrial complex 1 electron transport inhibitors (METI) Energy metabolism	METI insecticides and acaricides	DynoMite
23	Inhibitors of acetyl CoA carboxylase Lipid synthesis, growth regulation	Tetronic and Tetramic acid derivatives	Forbid Kontos
Un	Compounds of unknown or uncertain mode of action[1]	Bifenazate	Floramite

[1] A compound with an unknown or controversial mode of action, or an unknown mode of toxicity, will be held in category 'Un' until evidence becomes available to enable that compound to be assigned to a more appropriate mode of action class.

Table 8-6. Fungicide Groups Based on Sites of Action

This classification scheme is adapted from information developed by the Fungicide Resistance Action Committee to distinguish fungicide groups according to their cross-resistance behaviour. M = multi-site inhibitor, U = unknown mode of action and unknown resistance risk, NC = not classified. For further details on this classification system, see *www.frac.info/frac/publication/anhang/FRAC_Code_List_2010.pdf.*

Group #	Primary Site of Action	Group Name	Product Name(s)	Risk of Developing Resistance
1	â-tubuline assembly in mitosis	Methyl benzimidazole carbamates	Senator	High
2	Affect cell division, DNA and RNA synthesis and metabolism	Dicarboximide	Rovral	Medium to high
3	C14 – demethylase in sterol biosynthesis	DMI (De-methylation Inhibitor) fungicides	Nova, Funginex	Medium
4	RNA synthesis	PA – fungicides (PhenylAmides)	Subdue Maxx	High
5	$Æ^{14}$– reductase and $Æ^{8}$–> $Æ^{7}$ isomerase in sterol biosynthesis	Morpholine	Meltatox	Low to medium
7	Complex II: succinate dehydrogenase	Pyridine carboximide	Pristine (boscalid component)	Medium to high
9	Methionine biosynthesis (proposed)	Anilino-pyrimidines	Switch (cyprodinil component)	Medium
11	Fungal respiration – complex III: cytochrome bc1	QoI-fungicides (Quinone outside Inhibitors)	Heritage, Compass, Pristine (pyraclostrobin component)	High risk
12	MAP/Histidine- Kinase in osmotic signal transduction	Phenylpyrroles	Switch (fludioxinil component)	Low to medium
14	Lipid peroxidation (proposed)	Aromatic hydrocarbon	Botran, Quintozene	Low to medium
		Heteroaromatic	Truban	Low to medium
17	3-keto reductase, C4 – de-methylation	Hydroxyanilide	Decree	Low to medium
21	Complex III: cytochrome bc1 (ubiquinone reductase) at Qi site	Cyano-imadizole	Torrent	Medium to high
28	Cell membrane permeability, fatty acids (proposed)	Carbamate	Previcur	Low to medium
33	Unknown	Phosphonate	Aliette, Confine, Phostrol	Low
40	Phospholipid biosynthesis and cell wall deposition (proposed)	Carboxylic acid amides	Acrobat (Cinnamic acid amide) Micora (mandelic acid amine)	Low to medium Low to medium
43	Delocalisation of spectrin-like proteins	Benzamides	Presidio	Resistance not known
44	Microbial disrupters of pathogen cell membranes	Microbial (*Bacillus* sp.)	Rhapsody, BioTak, Taegro	Low
M1	Multi-site contact activity	Inorganic	Phyton-27	Low
M2	Multi-site contact activity	Inorganic	Sulphur	Low
M3	Multi-site contact activity	Dithiocarbamates	Dithane M-45, Zineb	Low
M4	Multi-site contact activity	Phthalimide	Maestro, Supra Captan, Folpan	Low
M5	Multi-site contact activity	Chloronitrile	Daconil	Low
NC	Unknown	Diverse	MilStop, RootShield, Mycostop, Actinovate, PreStop, Contans	Unknown

Table 8-7. Herbicide Groups Based on Sites of Action

This classification scheme is adapted from information developed by the Herbicide Resistance Action Committee (HRAC) to distinguish herbicide groups according to their site of action in the plant and to assist growers with resistance management options. The classification was developed jointly by the HRAC and the Weed Science Society of America (WSSA). The HRAC grouping is alphabetical in the left-hand column and the WSSA grouping is numerical in the right-hand column. It is the WSSA number that is provided on the product label and most commonly used to distinguish between different herbicide groups.

HRAC Group	Site of Action	Chemical Name	Product Name(s)	WSSA Group Number
A	Inhibition of acetyl CoA carboxylase (ACCase)	Aryloxyphenoxy-propionate 'FOPs'	Venture L	1
K1	Microtubule assembly inhibition	Dinitroaniline Phthalate Amide	Rival/Treflan/Bonanza 480 Prowl H_2O Dacthal Kerb	3
C1	Inhibition of photosynthesis at photosystem II	S-triazine	Simazine 480/Princep Nine-T/Simanex 80W	5
G	Inhibition of EPSP synthase	Amino acid	Roundup	9
K3	Inhibition of VLCFAs (Inhibition of cell division)	Acetanilide Amide	Dual Magnum/ Dual II Magnum Devrinol Frontier Max	15
L	Inhibition of cell wall (cellulose) synthesis	Benzamide	Gallery	21
Z	Unknown site of action. Note: While the site of action of herbicides in Group Z is unknown, it is likely that they differ in site of action between themselves and from other groups.		Basamid Metam	

Pesticide Injury (Phytotoxicity) to Flower Crops

Although greenhouse pesticides have been selected and formulated to avoid plant injury, damage can still occur under some conditions. Consider these general rules before you apply pesticides:

- No product is safe on all plants under all conditions, although wettable powders are generally less injurious than liquid formulations.
- A material (e.g., smokes) may be safe when applied to dry foliage but can cause injury when used on wet foliage.
- Weather conditions at the time of application are important. Pesticides are more likely to be phytotoxic when applied during bright sunny weather than during dull, overcast conditions.
- Well-watered, unstressed plants are less likely to be damaged by pesticides.
- Low-volume applications are generally less likely to cause plant injury than high-volume applications.

Pesticide hazards

The following list of possible hazards was compiled from pesticide label warnings. This list is not comprehensive. When using a product for the first time on a new crop, always test it first on several different varieties and on a small area, and check for damage after 4–5 days.

Acrobat may show slight stunting or phytotoxic symptoms to African violet, dusty miller, sweet alyssum and snapdragon after repeated applications.

Avid has been observed to cause phytotoxicity on certain species of ferns (e.g., *Adiantum* spp.) and Shasta daisies. Therefore, Avid should not be used on ferns or Shasta daisies.

BotaniGard 22 WP at higher application rates may result in commercially unacceptable visible residues. **BotaniGard ES** has been observed to cause foliage damage in some varieties of plants (e.g., necrotic spots on leaves of some varieties of tomatoes).

Botran 75W in combination with miscible oil formulations of insecticides, particularly organophosphorus compounds, may cause plant injury.

Do not use **chlorpyrifos (Pyrate)** on azalea, camellia, coleus, geranium, oxalis, poinsettias, rose bushes or variegated ivy because of possible phytotoxicity injury to these plants. Do not use **chlorpyrifos (Lorsban 4E, Pro Dursban Turf, Dursban T)** on azaleas, camellias, poinsettias, rose bushes or variegated ivy because of possible injury to these plants. Do not use **chlorpyrifos (Dursban WSP)** on ornamental plants listed on the label, which include petunia, impatiens, a number of rose varieties and various foliage plants.

Compass may cause injury to petunia, violet and New Guinea impatiens. If applied to poinsettia after bract formation, it may cause injury to bracts.

Products such as **Confine Extra** containing mono- and di-potassium salts of phosphorous acid may increase the uptake of certain metals into plants. Care must be taken when using tank mixes containing pesticide products with a metal base (such as copper-based fungicides).

Daconil (2787 and Ultrex) has been noted to cause discolouration of blooms on certain varieties of azalea, rhododendron, hydrangea and petunia when applications are made during flowering.

DDVP (dichlorvos) may adversely affect some varieties of chrysanthemum (e.g., Shasta and Pink Champagne) and some varieties of snapdragon. Crop should be dry when dichlorvos is applied as a smoke.

When **using Dibrom,** avoid over-treatment and direct application to plants. Dibrom may cause injury to white butterfly roses, Golden rapture, Green wandering jew and Dutchman's pipe.

Dimilin if used at higher than label rates, volumes or number of applications can cause serious foliar injury to some crops. Do not apply Dimilin to poinsettia, hibiscus or Rieger begonia.

Distance has been observed to cause phytotoxicity on salvia, ghost plant *(Graptopetalum paraguayense)*, Boston fern, Schefflera, Gardenia and coral bells. Do not apply to poinsettia after bract formation.

Dyno-Mite may cause colour change in blossoms of petunia (cv. White Madness).

Enstar EW application on some varieties of roses can result in delayed damage.

Do not use **Forbid** on *Pelargonium* spp., Peperomia or on "Attache", "Vogue" or "Classy" rose varieties or on "Noblesse" *Rosa floribunda*. Forbid is not recommended for use on alstroemeria, Cordyline, Dracaena, croton, neanthebella palm, schefflera, cyclamen, orchids, hoya, fuchsia, fern, *Hedera,* hydrangea, stock *(Matthiola)* or primula. Transient injury to flowers of Shasta daisy, begonia, snapdragon and Mexican heather has been observed. Transient bleaching has been observed on some varieties of gerbera daisy. Do not apply more than once per crop to phlox, Shasta daisy, snapdragon, verbena, roses, gerbera daisy or marigolds.

Do not use **insecticidal soap** on sweet pea, nasturtium or delicate ferns. Do not spray when plants are under stress or during full sun. Do not apply to poinsettias after colouring of bracts has begun.

Kontos is not recommended for use on the following plant species, varieties and cultivars: geraniums (Pelargonium spp.), orchids, Hoya, Dracaena, Cordyline, Schefflera, Neanthebella palm and ferns. Do not make more than one application per season to Hydrangea, Impatiens spp., crotons (Codieum spp.), Fuschia hybrids, Peperomia, stock or cyclamen.

Malathion may cause injury to African violet, Boston fern, crassula, Ilex, juniper, maidenhair fern, petunia, pteris fern and young plants.

Do not spray **Meltatox** under hot, sunny and low-humidity conditions.

Rates of **Phyton 27** above 125 mL/100 L may damage tender, open blooms.

Pristine should be used with caution on impatiens and petunia during flowering as discolouration may occur.

Pylon is likely to cause phytotoxicity to some varieties of carnation, dianthus, kalanchoe, poinsettia, roses, salvia and zinnia.

Rovral application may result in petal scorch on flowers of African violet.

Sevin (**carbaryl**) should not be used on Boston ivy, Virginia creeper or maidenhair fern.

Before using **Shuttle** on miniature roses and impatiens, test them for sensitivity on a limited scale before widespread use.

Subdue Maxx may cause phytotoxicity on gloxinia when used as a drench at transplanting.

Sulphur is not recommended for vapourization on cucurbits, spinach or Boston ferns due to phytotoxicity.

Endosulfan (**Thionex**) should not be used on geraniums or Bonnafon chrysanthemums in the greenhouse or chrysanthemum cuttings within one month of planting.

Vendex should only be applied up until the tight bud stage of chrysanthemum and the pre-bract stage of poinsettias. Do not spray when plants are under stress or when the temperature of the greenhouse is greater than 32°C.

Agribrom

Agribrom is registered for use as a water treatment to control algae. To be effective, it must be constantly present at a low level in the irrigation water. If irrigation water is being recirculated and Agribrom is added every time the water is reused, monitor chloride levels and suspend use if chloride levels are high. Treating reservoir water may also elevate chloride levels, so it is advisable to inject Agribrom just as the water is applied to the crop. Follow label directions carefully.

Pressure-treated lumber

Wolmanized® lumber is safe for greenhouse use.

Copper napthanate has caused some crop injury to poinsettia.

Wood treated with other preservatives should not be used. Check with a greenhouse floriculture specialist.

Prevent Bee Poisoning

While protection of bees is not relevant to most greenhouse flower growers, it is an important consideration for growers of outdoor flowers. Honeybees, as well as other bees and insects, are important pollinators of crops. Many crops also offer bees important sources of nectar for honey production. For more information on the prevention of bee poisoning see *Bee Poisoning* on page 5 of Chapter 1, *Using Pesticides in Ontario.* Most organophosphate and carbamate insecticides are highly toxic to bees. Examples of insecticides used in greenhouse and outdoor ornamental crop production that are toxic to bees are listed in Table 8-8. *Relative Toxicity of Pesticides to Honeybees* on page 114.

Table 8-8. Relative Toxicity of Pesticides to Honeybees

Source: PMRA Environmental Assessment Division. For more detailed information on the toxicity of specific pesticides to honeybees, refer to the pesticide label.

Trade Name	Active Ingredient
Group 1 – Highly toxic. Severe losses may be expected if the following materials are used when bees are present at treatment time or within a few days thereafter.	
Avid 1.9%EC	abamectin
Cygon 480, Lagon 480	dimethoate
DeltaGard	deltamethrin
Diazinon	diazinon
Dursban WDG, Dursban T, Pyrate 480	chlorpyrifos
Dyno-Mite 75 W	pyridaben
Imidan 50 WP	phosmet
Intercept 60 WP	imidacloprid
Kontos	spirotetramat
Malathion	malathion
Orthene 75 SP	acephate
Pounce 384 EC, Ambush 50 EC	permethrin
Pylon	chlorfenapyr
Sevin	carbaryl
Success 480 SC	spinosad
Group 2 – Moderately toxic. These can be used around bees if dosage, timing, and method of application are correct, but do not apply them directly on bees, in the field or at the colonies.	
BotaniGard 22WP, BotaniGard ES	*Beauveria bassiana* Strain GHA
Bio-Ceres G WP, Bio-Ceres G WB	*Beauveria bassiana* Strain ANT-03
Floramite SC	bifenazate
Supra Captan 80 WDG, Maestro 80 DF	captan
Thionex EC, Thionex 50 W	endosulfan
Tristar 70 WSP	acetamiprid

Trade Name	Active Ingredient
Group 3 – Pesticides relatively non-toxic to bees	
Actinovate SP	*Streptomyces lydicus*
Aliette T&O	fosetyl-Al
Apollo SC	clofentezine
Beleaf 50SG	flonicamid
BioProtec CAF, Dipel 2X DF	*Bacillus thuringiensis*
Botran 75 W	dicloran
Bravo 500, Daconil 2787, Daconil Ultrex	chlorothalonil
Confine	mono- and di-potassium salts of phosphorous acid
Confirm 240F	tebufenozide
Decree 50 WDG, Elevate	fenhexamid
Folpan 50 WP, Folpan 80 WDG	folpet
Forbid 240 SC	spiromesifen
Funginex DC	triforine
Insecticidal soap	potassium salts of fatty acids
Micora	mandipropamid
MilStop	potassium bicarbonate
Nova 40 W	myclobutanil
Phostrol	mono- and dibasic sodium, potassium and ammonium phosphites
Pristine WG	Boscalid + pyraclostrobin
Rhapsody ASO, Serenade, Cease, BioTak, Taegro	*Bacillus subtilis*
Rovral 50 WP	iprodione
Senator 70 WP	thiophanate-methyl
Shuttle 15 SC	acequinocyl
Subdue Maxx	metalaxyl
Torrent	cyazofamid

Read each pesticide label for specific precautions regarding bees.